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GUIDELINES AND FACILITATORS FOR MINIMIZING BARRIERS IN THE IMPLEMENTATION OF PRODUCT-SERVICE SYSTEMS: A FRAMEWORK FOCUSED ON CIRCULAR ECONOMY

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ABSTRACT

The transition to a circular economy is gaining notoriety as society demands alternative forms of production and consumption. In this context, Product-Service Systems have the potential to reconcile economic and socio-environmental development. However, the implementation of Product-Service Systems has limitations, such as poor understanding of the system, difficulties in monitoring and establishing relationships with stakeholders. In order to guarantee guarantee a successful implementation of Product-Service Systems, there is a need to understand these organizational challenges and to present opportunities to mitigate these barriers. The goal of this paper is to identify facilitators and construct guidelines, capable of minimizing barriers in the implementation of a Product-Service System. To achieve this goal, a systematic literature review was conducted, contemplating bibliometric and content analysis

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(57 papers were read in full). The results of the bibliometric analysis point to the need to expand business proposals to different economic and cultural contexts, since they are mainly concentrated in developed countries. The content analysis presented a framework with guidelines, subguidelines, and facilitators, classified according to the PSS dimensions: provider, offer, and consumer. Thus, 111 facilitators were identified, and 26 subguidelines and 11 guidelines were built, demonstrating the contribution of the Circular Economy for the minimization of barriers in the implementation of the Product-Service System. The research highlights that approximately 73% of the facilitators correspond to the provider dimension, emphasizing the need to promote organizational changes and to adapt business proposals, adding value to the solution or to the results. However, the research highlights the need for the involvement of all stakeholders, where the customer must also promote changes in habits and an awareness of sustainable development. Finally, it is emphasized that this research provides a theoretical basis for the development of empirical studies, applying and expanding the knowledge of the interrelationship between Circular Economy and Product-Service Systems.

***Keywords**: Circular Economy; Product-Service Systems; Framework; Guidelines; Facilitators*

1. INTRODUCTION

Given population growth and increased material consumption, pressure arises for strategies capable of leading society towards sustainable development (Julianelli et al., 2020; Van Loon, Diener & Harris, 2021). In order to adopt a systemic approach, capable of generating a balance between environmental, social and economic spheres (Annarelli, Battistella & Nonino, 2016; Sousa-Zomer & Cauchick-Miguel, 2019), some strategies are pointed out: collaborative consumption, dematerialization, Product-Service Systems (PSS) and Circular Economy (CE) practices (Geissdoerfer et al., 2017; Goedkoop et al., 1999; Retamal, 2019).

The Circular Economy aims to replace the end-of-life concept by using renewable energy, eliminating waste, and designing products to facilitate disassembly and reuse (Ellen Macarthur Foundation, 2013). Circular actions range from designing for long life, component maintenance, to remanufacturing and changes in material flows (Bag, Gupta & Foropon, 2019; Geissdoerfer et al., 2017; Vence & Pereira, 2019). In this context, Product-Service Systems are mentioned as a model capable of leading society to a circular economy (Halstenberg, Lindow & Stark, 2019; Pieroni, Mcaloone & Pigosso, 2019a), benefiting both provider and consumer

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(Sakao & Lindahl, 2009). PSS proposes a revolution in resource utilization , by delivering functionality rather than ownership to the customer (Bocken et al., 2016; Tukker, 2015).

However, companies face difficulties in developing and deploying Product-Service Systems, such as low system reliability, poor understanding about PSS, difficulties in monitoring (Camacho-Otero et al., 2018; Matschewsky, Kambanou & Sakao, 2018; Retamal, 2019), strategic alignment, and establishing relationships with stakeholders (Battaglia, Borchardt & Pereira, 2019; Kjaer et al., 2018a). In this context, a need arises to understand organizational challenges and to present opportunities to mitigate these difficulties – treated in this paper as barriers for PSS implementation (Matschewsky, Kambanou & Sakao, 2018).

In view of this, the following research question is established: How does Circular Economy contribute to minimizing barriers in the implementation of a Product-Service System? Aiming to answer this question, the goal of this paper is to identify facilitators and build guidelines capable of minimizing the barriers for the implementation of a PSS.

The rest of this research is organized as follows: section 2 presents the methodology used in this research. In section 3, a bibliometric analysis is performed, followed by a content analysis of the articles, highlighting the facilitators and guidelines capable of minimizing the PSS barriers. Section 4 presents the discussions of the bibliometric and content analysis, and proposes a framework to synthesize and discourse on the results obtained. Finally, section 6 concludes this paper and provides perspectives for future studies, suggesting to take a practical approach to expand the contributions of the interrelationship between Circular Economy and Product-Service Systems.

2. METHODOLOGY

This research has a bibliographic character, since the method selected was a systematic review of the literature (qualitative and quantitative approach), described in section 2.1. In this way, it was possible to identify facilitators and build guidelines, aiming at minimizing barriers for the implementation of a PSS (section 2.2).

2.1. Systematic literature review

A systematic review was performed in order to provide information that allowed to understand the state of the art of the interrelationship between Product-Service Systems and Circular Economy. This method was selected because it allows capturing the development and

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diversity of literature (Alcayaga, Wiener & Hansen, 2019), since it recovers, synthesizes and evaluates knowledge on a given subject (Møller & Myles, 2016).

The report for systematic reviews and meta-analysis (PRISMA) (Pacheco et al., 2019; Moher et al., 2015) was used to structure the literature review in four stages: I - Identification of articles, II - Screening of articles, III - Eligibility and IV - Inclusion of studies (Moher et al., 2009); as shown in Figure 1.

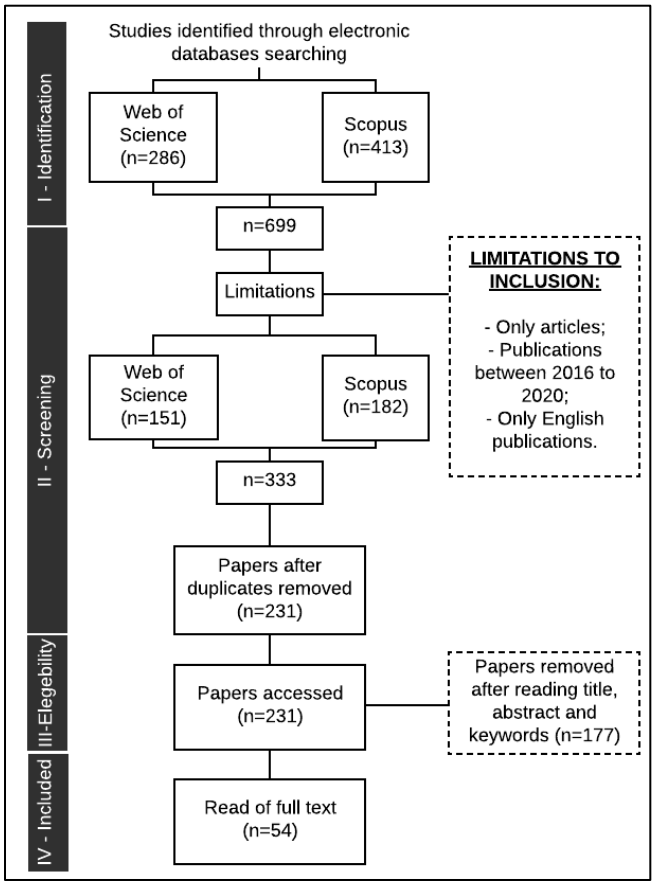

Figure 1: PRISMA method - Search parameters

For the selection of scientific articles (step I), Scopus and Web of Science databases were used, considered the most comprehensive ones (Chadegani et al., 2013). The combination of keywords presented in Table 1 was used to compose the initial sample of 699 papers.

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Table 1: Combinations of keywords

"product service system*"	AND	"circular"	AND	"sustainab*"	AND	"facilitator*"
"servitization"		"circular economy"				
"dematerialization"		"circle economy"		"triple bottom line" OR "TBL"		"improvement*"
"service design"		"closed loop*"				"positive point*"
"service economy"				"environmental"		"positive aspect*"
"system solution"		"circularity"				"guideline*"
"functional economy"				"social"		"strategies"
"product substituting service"		"circle"				"innovation"
"remanufacturing"				"economic"		

As presented in Table 1, keywords that characterize the Product-Service System (based on the work of Beuren et al., 2013) and the Circular Economy (based on the work of Pieroni et al., 2019b), were combined with Triple Bottom Line (environmental, social and economic spheres) and the facilitators, capable of minimizing the barriers for the PSS.

For further refinement of the results obtained in the previous stage, a bibliographic search was performed using filters (phase II), limiting the search to scientific articles, published between 2016 and 2020 (Maroli, Narwane & Gardas, 2021; Mrugalska & Ahmed, 2021) and written in English. Thus, 333 articles were identified and, excluding duplicates, 231 works were selected, which composed the sample for bibliometric analyses (quantitative approach), presented in section 3.1.

Tools provided by VOSviewer® and Excel® softwares were used to perform the following bibliometric analyses: time trend of publications, main journals, geographic distribution of publications and author co-citation. VOSviewer® was used to analyze the geographic distribution of publications and author co-citation. This software was selected because it corresponds to a free tool that allows the creation of graphs to visualize bibliometric data (Wong, 2018). However, VOSviewer® limits the use of only one database, so Scopus was used as it returned a higher number of results (Benachio, Freitas & Tavares, 2020).

In stages III and IV, title, abstract and keywords of the articles were analyzed. Thus, 57 papers (Appendix A) were selected to compose the analysis of content (qualitative approach), identify the facilitators and give theoretical basis for the construction of guidelines (presented in section 3.2).

2.2. Identification of facilitators and construction of subguidelines and guidelines

The systematic literature review pointed out several barriers for the implementation of a PSS. Low consumer acceptance (tunn et al., 2019), little understanding about the PSS (Sousa-Zomer & Cauchick-Miguel, 2019), organizational inertia (Battaglia, Borchardt & Pereira,

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2019), low reliability in the product (Wuest et al., 2018) and in the system (Camacho-Otero, Boks & Pettersen, 2018a) are some of the main ones.

In view of this, the literature inter-relating Product-Service Systems and Circular Economy has been analyzed in order to identify facilitators, capable of minimizing barriers for the implementation of PSS (presented in section 3.2). The PSS categorization in provider, offer and consumer dimensions, proposed by Sakao and Lindahl (2009), was used to classify the 111 facilitators identified. Thus, seven were classified in the consumer dimension, 23 in the offer, and 81 in the provider dimension.

In order to organize and synthesize the information obtained in the literature, subguidelines (presented in section 3.2) were constructed, providing a grouping of facilitators according to their characteristics and specificities. And finally, the subguidelines were classified into 11 guidelines. Thus, it was possible to analyze the contribution of Circular Economy in the implementation of a PSS, presented in the discussion section (4.2).

To organize the obtained information, a coding system was developed and applied to each PSS dimension: provider, offer and consumer (Sakao & Lindahl, 2009). The guidelines were thus presented as follows: C1 and C2 represent the consumer guidelines, O1, O2 and O3 correspond to the offer dimension guidelines, and P1 to P6 present the provider guidelines. In the sequence, the codification of subguidelines was carried out, following the example of the C1 guideline, which presents two subguidelines: C1.1 and C1.2. The other subguidelines follow the same representation. Finally, the facilitators were coded, following the example of subguideline C1.1, which presents three facilitators, represented as follows: FC1, FC2 and FC3. The other facilitators follow the same representation.

3. RESULTS

Section 3.2 presents the content analysis, where facilitators are identified, and subguidelines and guidelines are built.

3.1. Bibliometric analysis

In order to carry out the time trend analysis, the bibliographic portfolio has been expanded to include articles published in the last ten full years (2011 and 2020). Figure 2 shows the annual evolution of publications, highlighting the progressive increase of works.

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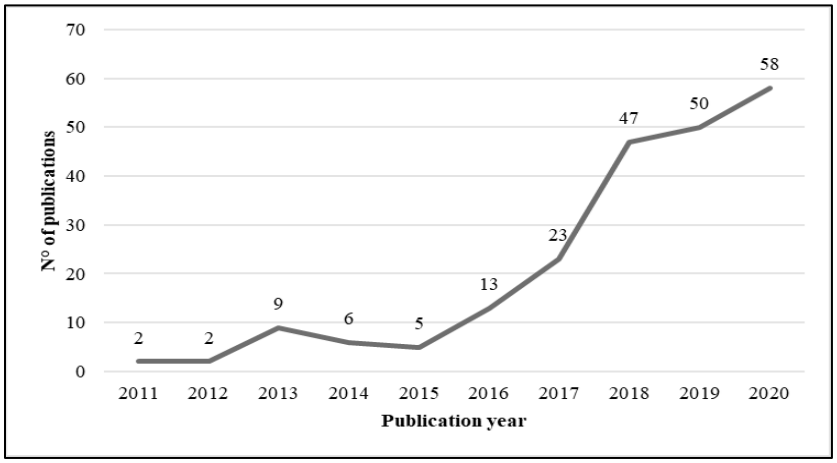

Figure 2: Temporal trend of publications

Figure 2 shows that publications in the last three years represent 72% of the total amount. This fact can be justified due to the special issues involving PSS and, especially, Circular Economy, launched by the Journal of Cleaner Production and Sustainability, considered the main journals, i.e., those with the largest number of publications (Figure 3).

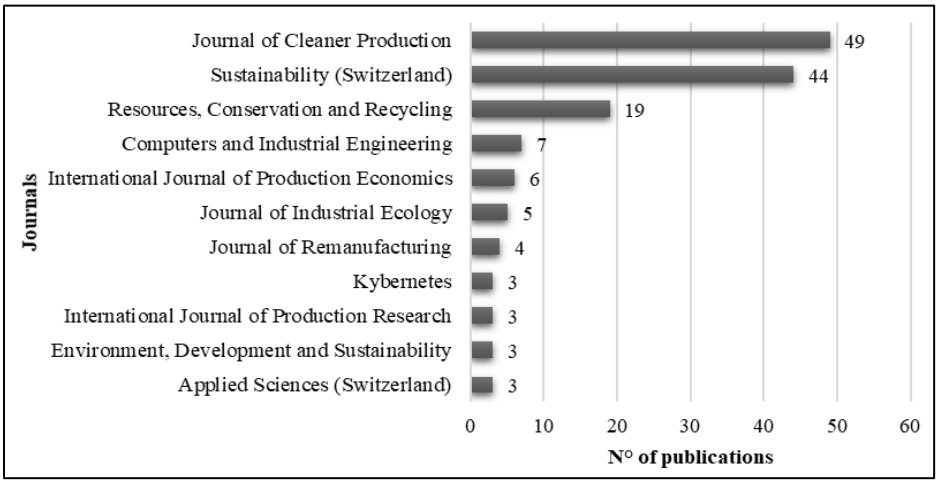

Figure 3: Main journals

Figure 3 highlights that about 43% of the papers were published in the journals Sustainability and Journal of Cleaner Production, which are among the scientific journals with the best reputation indicators, showing impact factor or Journal Citation Reports (JCR 2019) equal to 2.592 and 7.246, respectively. The articles were published in a total of 65 journals, most of them comprehending sustainable development in their scope.

The geographical distribution of the publications can be seen in Figure 4.

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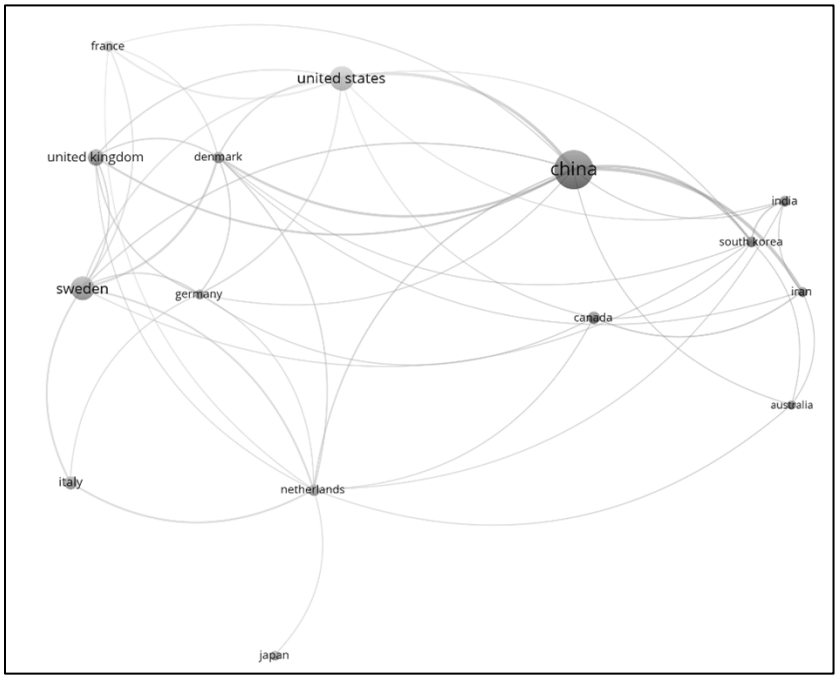

Figure 4: Geographical distribution of publications

Figure 4 allowed us to identify the countries with the largest number of publications, drawing attention to the United States (25 papers) and China (48 papers). This analysis highlighted that, although publications are spread globally - occurrence of publications in Europe, Asia, America and Oceania - they are concentrated in developed countries or countries that are under development.

To complement the bibliometric analysis, an author co-citation network is presented in Figure 5. The network presents three groups, highlighting a fragment where the strength of inter-relationship among authors is intensified, that is, where the greatest number of co-citations occur.

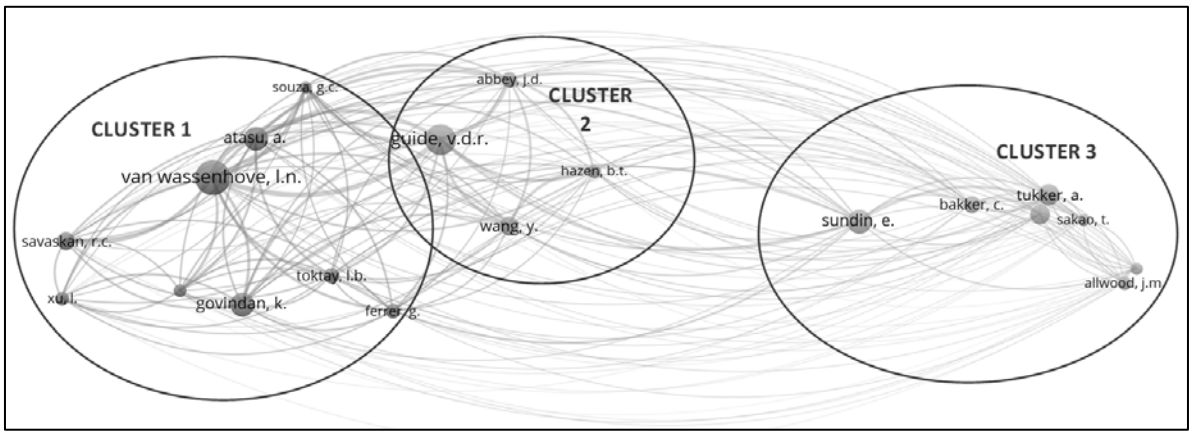

Figure 5: Co-citing authors

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Cluster 1 focuses on aspects related to Circular Economy (Van Loon & Van Wassenhove, 2020). Thus, the cluster addresses remanufacturing (Kovach, Atasu & Banerjee, 2018; Toktay & Wei, 2011), extended producer responsibility (Atasu, 2019), greenhouse gas emission reduction (Marchi et al., 2019) and other measures capable of promoting sustainable development (Atasu et al., 2020).

Cluster 2 predominantly addresses supply chain changes. Abbey, J. D. and Guide, V. D. R. have developed researches together, addressing the adoption of strategic remanufacturing operations (Abbey & Guide, 2018), modular design, multiple life cycle (Abbey, Guide & Souza, 2013), and the need for supply chains to work in a closed loop (Abbey & Guide, 2018). Furthermore, Hazen, B. T., highlights the incorporation of artificial intelligence (Hazen, Russo & Confente, 2020) and Big Data as ways to improve business proposition management (Hazen, Russo & Confente, 2020).

Cluster 3 focuses on servitization, highlighting Product-Service Systems as a promising business opportunity that can lead society to a circular economy (Bech et al., 2019; Kjaer et al., 2018a; Pieroni, Mcaloone & Pigosso, 2019a; Tukker, 2015). Bocken N.M.P. comments on the potential of the sharing economy (Bocken et al., 2020; Konietzko, Bocken & Hultink, 2020), as pay-per-use is generally related to better environmental performance (Bocken et al., 2018). In this cluster, the research published by Tukker, A. in 2004 is highlighted as one of the precursors in studies on Product-Service Systems (Tukker, 2004), where the author proposes the classification of PSS into product oriented, use oriented and results oriented.

3.2. Content Analysis: Identification of facilitators and construction of subguidelines and guidelines

Vence and Pereira (2019) highlight that the Circular Economy corresponds to a promising approach for a sustainable transition from the linear economy. To this end, the authors point out that this change is systemic, involving new knowledge, technologies, regulations, and consumption patterns. In this context, numerous challenges emerge (Vence & Pereira, 2019), where difficulties related to dematerialization stand out (Ewijk & Stegemann, 2016). Chamberlin e Boks (2018) comment that the academic literature on Circular Economy is still incipient, especially in relation to the consumer perspective. Therefore, an expansion in the scope of CE is proposed by the authors, encompassing remanufacturing, reuse and Product-Service Systems (Chamberlin & Boks, 2018).

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To evaluate the environmental performance of a PSS, the work of Kjaer et al. (2018b) proposes guidelines based on the Life Cycle Analysis (LCA) methodology. The authors used interviews and case study applications to validate these guidelines, which are able to support organizations, consultants, and company employees conducting an environmental assessment of the PSS. Guzzo et al. (2019), through the foundation of a systematic literature review, developed a framework with strategies to facilitate decision making in PSS circular innovation. The authors highlight measures to enable circular strategies, presented through an adaptation of the Business Model Canvas tool. Thus, the work highlights how and with which resources business proposals should work.

The bibliometric and content analysis highlighted the potential of adopting an approach that integrates Product-Service Systems and the Circular Economy, but there are limitations in both areas (e.g. Annarelli et al., 2018; Beuren et al., 2013; Camacho-Otero et al., 2018; Grafström & Aasma, 2021; Peillon et al., 2016). In view of this, the following sections present facilitators, subguidelines and guidelines, based on the Circular Economy literature (analysis of 57 papers), capable of mitigating the effects of barriers in PSS implementation, classified according to their dimensions: provider, offer and consumer (SAKAO; LINDAHL, 2009). Table 2 presents the results obtained for the provider dimension.

Table 2: Facilitators and (sub)guidelines - provider dimension

IND	GUIDELINES	IND	SUB-GUIDELINES	FACILITATORS
P1	**Use technological resources and tools of ecodesign or service design**	**P1.1**	**Use of life cycle management tools**	**FP1** - Life Cycle Assessment (LCA); **FP2** - Life Cycle Costing (LCC); **FP3** - Social Life Cycle Assessment (S-LCA); **FP4** - Life Cycle Sustainability Assessment (LCSA); **FP5** - Input-Output Model; **FP6** - EoL strategy selection algorithm
		P1.2	**Implementation of Industry 4.0 technologies**	**FP7** - Internet of Things (IoT); **FP8** - Virtual and augmented Reality; **FP9** - 3D printing; **FP10** - Big Data; **FP11** - Virtual modeling and simulation
		P1.3	**Use of tools and strategies for requirements definition, ideation, and business proposal development**	**FP12** - CAD tool; **FP13** - Check list and guidelines; **FP14** - Business Model Canvas; **FP15** - IDEF0; **FP16** - Repro2; **FP17** - Material Flow Analysis (MFA); **FP18** - Analytic Hierarchy Process (AHP); **FP19** - Quality Function Deployment (QFD); **FP20** - SWOT analysis; **FP21** - BPMN; **FP22** - Empathy map; **FP23** - Service ecology mapping; **FP24** - Stakeholder motivation matrices; **FP25** - Diagram tools; **FP26** - Service Blueprinting; **FP27** - Cost Benefit Analysis (CBA); **FP28** - Data Envelopment Analysis (DEA); **FP29** - Key Performance Indicator (KPI); **FP30** - TOPSIS

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P2	**Develop a holistic understanding of the worked context**	**P2.1**	**Customer and stakeholder involvement in the business proposal**	**FP31 -** Synergies among circular strategies; **FP32** - Cannibalization and Upcycling; **FP33** - Partnerships; **FP34** - Networking and collaboration among companies; **FP35** - Stakeholder engagement; FP36 - Industrial symbiosis; **FP37** - Informing the relevant role of the customer in the CE system; **FP38** - Joint analysis
		P2.2	**Adopt management measures or strategies in order to gain a broad understanding of the business proposition**	**FP39** - Portfolio Management; **FP40 -** Research and Development (R&D); **FP41** - Quality Management; **FP42 -** Consulting or auditing
P3	**Manage life cycle stages with eco-efficiency**	**P3.1**	**Organizational restructuring and adaptability to market demands**	**FP43 -** Redesign, remodel or re-project products or technologies; **FP44** - Lean and sustainable manufacturing, cleaner production (P+L); **FP45** - Eco-industrial parks; **FP46** - Biomimetics; **FP47** - Modularity; **FP48**- Industry 4.0; FP49- Bioeconomic; **FP50 -** Kaizen; **FP51** - Lean Six Sigma; **FP52** - Green infrastructure
		P3.2	**Adverse events in the production process**	**FP53** - Mitigation of rebound effects
		P3.3	**Promoting maximum use of the products**	**FP54** - Collection of used products; **FP55** - Redistribution of the processed product
P4	**Promote organizational cultural change**	**P4.1**	**Designing products and services aiming at longevity**	**FP56 -** Design for ease of disassembly; **FP57** - Standardization of parts, interchangeability
		P4.2	**Adapt the production process based on sustainable development**	**FP58 -** Development of technologies and services, innovative green products; **FP59** - Closed production and consumption cycle; **FP60** - Efficient use of resources and materials, cascading of components; **FP61** - Cradle to cradle logic
P5	**Adapt the proposals to the local context, considering the environmental, social, and economic spheres, taking advantage of local strengths**	**P5.1**	**Acting preventively against the emergence of possible failures during the life cycle of the product and service**	**FP62** - Understanding the regulatory landscape; **FP63** - Providing or facilitating fault prediction, risk management; **FP64** - Benchmarks and competitor analysis; **FP65 -** Empowering service providers; **FP66 -** Localizing shareable products between stations to facilitate distribution
		P5.2	**Understanding of market demands**	**FP67** - Mapping customer and stakeholder needs
P6	**Implement End-of-Life (EoL) management strategies**	**P6.1**	**Adopt EoL measures from the early stages of the life cycle**	**FP68** - Rethink; **FP69** - Reduce
		P6.2	**Adopt measures based**	**FP70** - Reuse and repurposing; **FP71 -** Recycling; **FP72** - Remanufacturing; **FP73** - Repair; **FP74 -**

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	on Reverse Logistics, aiming at the reuse of components	Refurbishment; **FP75** - Reprocessing and remanufacturing; **FP76** - Renewal of components; **FP77** - Reconditioning; **FP78** - Recovery of materials and components; **FP79** - Reuse and second-hand sale; **FP80** - Waste management, reduction in the amount of waste

Table 3 presents the guidelines, subguidelines and the facilitators of the offer dimension of a PSS.

Table 3: Facilitators and (sub)guidelines - offer dimension

IND	GUIDELINES	IND	SUB-GUIDELINES	FACILITATORS
O1	**Add value to the business proposition by offering solutions or results to customers**	**O1.1**	**Functional Selling**	**FO1**- Pooling and pay-per-use; **FO2** - Sharing economy; **FO3** - Leasing; **FO4** - Servitization
		O1.2	**Provide assistance and instructions to customers**	**FO5** - Warranty, producer's extended responsibility, technical support; **FO6** - Upgrades; **FO7** - Maintenance; **FO8** - Spare or replacement parts
		O1.3	**Customer engaged and participative with the business proposal**	**FO9** - Personalized offers, customization
		O1.4	**Designing for durability**	**FO10** - Prevent or delay obsolescence; **FO11** - Extend useful life
O2	**Publicize the environmental, social and economic benefits of the proposal**	**O2.1**	**Announce the innovations and the differential of the proposal**	**FO12** - Marketing; **FO13** - Information and Communication Technologies (ICT), virtualization; **FO14** - Advertising
		O2.2	**Publicize the adoption of sustainable measures (environmental marketing)**	**FO15** - Energy efficiency; **FO16** - Renewable resources; **FO17** - Decrease in greenhouse gas emissions; **FO18** - Sustainable design; **FO19** - Sustainable entrepreneurship
O3	**Evaluate the performance of the proposal (monitor)**	**O3.1**	**Analyze the strengths and weaknesses, pointing out possible failures, opportunities for optimizations and changes in production patterns**	**FO20** - Remote monitoring; **FO21** - Track product activity; **FO22** - Provide feedback
		O3.2	**Use digital platforms to monitor products and services**	**FO23** - Online platform, sharing platform

Table 4 presents the guidelines, subguidelines and the facilitators of the consumer dimension of a PSS.

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Table 4: Facilitators and (sub)guidelines - consumer dimension

IND	GUIDELINES	IND	SUB- GUIDELINES	FACILITATORS
C1	**Environmental awareness**	**C1.1**	**Sustainable consumption**	**FC1** - Reduction in consumption, collaborative consumption; **FC2** - Sufficiency; **FC3** - Reduction of waste
		C1.2	**Acquire knowledge about sustainable development**	**FC4** - Eco-learning
C2	**Promote habit changes**	**C2.1**	**Choose systems that integrate products and services, such as renting and sharing**	**FC5** - Dematerialization
		C2.2	**Conscious and responsible consumption**	**FC6** - Efficiency in use; **FC7** - Collective or individual return.

4. DISCUSSIONS

Based on the results presented, section 4.1 consolidates the information from the literature review, while section 4.2 discusses and synthesizes the facilitators, guidelines, and subguidelines through a framework.

4.1. Bibliographic discussion

The bibliometric analysis highlights that, although research on the interrelationship between Circular Economy and Product-Service Systems is progressively evolving (Figure 2), there is a concentration of studies in developed or developing countries (Figure 4). The research by Retamal (2019) corroborates this finding, highlighting that the collaborative consumption of products and services have been studied and deployed in industrialized countries, in markets already saturated with products.

Thus, the relevance and timeliness of the concepts comprehended in this research (Figure 2) is observed, but it represents an area that requires studies with a holistic perspective in order to diffuse the principles of sustainable development in all countries, regardless of their degree of development. Therefore, it is essential to adapt business proposals to different economic and cultural contexts, since promising solutions in developed countries may not work in developing ones (Sousa-Zomer et al., 2018).

The bibliometric analysis also highlighted a large number of publications of theoretical studies, with emphasis on systematic literature reviews (e.g. Beuren et al., 2013; Camacho-Otero et al., 2018; Khan et al., 2018; Tukker, 2015). These publications are of great academic importance and are sources of theoretical background for the development of other works. However, a need was found to adopt a practical approach in order to mitigate the effects of

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barriers in the implementation of PSS, CE, and other scopes in order to promote sustainable development.

In this way, the literature review highlighted the need to adopt a multidisciplinary perspective (Atasu et al., 2020; Hazen, Russo & Confente, 2020; Peillon, Medini & Dubruc, 2016), bringing together contributions from different spheres of literature. Thus, this research highlights the benefits of the interrelationship between Circular Economy and Product-Service System. However, bibliometric and content analyses have highlighted barriers for the implementation of both approaches (e.g. Annarelli et al., 2018; Beuren et al., 2013; Camacho-Otero et al., 2018; Grafström & Aasma, 2021; Peillon et al., 2016). In order to mitigate the barriers in implementing a PSS, guidelines (Kjaer et al., 2018b) and facilitators (Guzzo et al., 2019) have been developed, and are analyzed further in the following section.

4.2. Facilitators, subguidelines and guidelines

In order to organize the information presented, Figure 6 shows a framework, consolidating the results from section 3.2. The coding system was used to synthesize the information. The proposed framework represents an opportunity to identify barriers or failures (phase a in Figure 6) in a business proposal and to minimize them through guidelines (phase b), subguidelines (phase c) and facilitators (phase d).

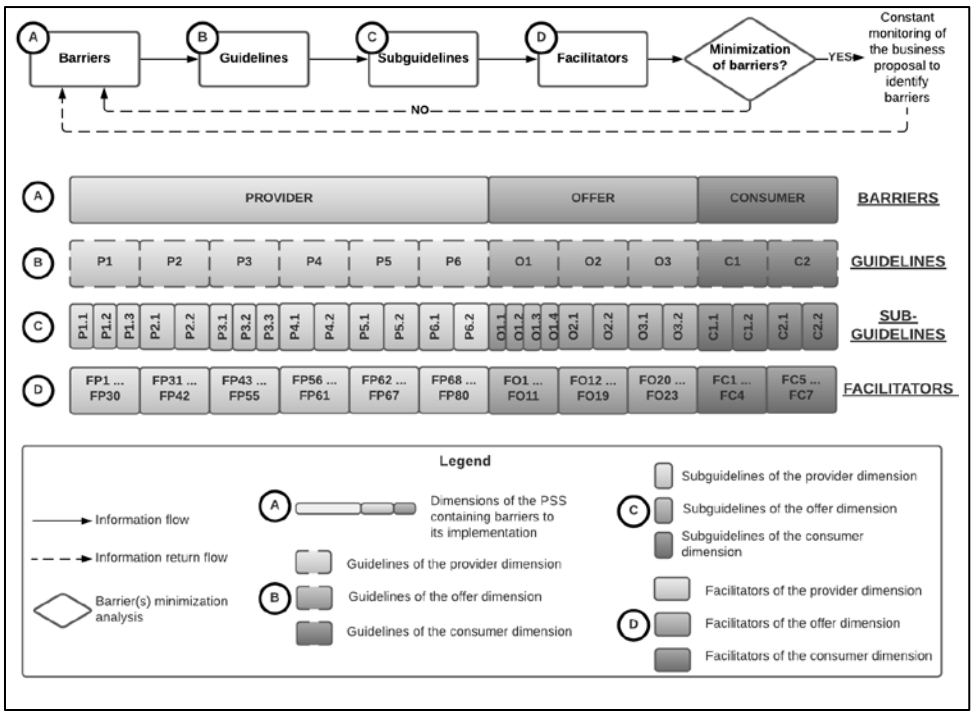

Figure 6: Framework for minimizing PSS barriers

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4.2.1. Provider

Figure 6 highlights the construction of six guidelines in the provider dimension: Use technological resources and tools of ecodesign or service design (P1); Develop a holistic understanding of the worked context (P2); Manage life cycle stages with eco-efficiency (P3); Promote organizational cultural change (P4); Adapt the proposals to the local context, considering the environmental, social, and economic spheres, taking advantage of local strengths (P5) as well as deploying End of Life (EoL) management strategies (P6).

Guideline P1 shows the importance of using technological resources and ecodesign or service design tools. Subguideline P1.1 stands out, where Life Cycle Analysis (LCA) has been widely cited in the literature (e.g. Bradley et al., 2018; Halstenberg et al., 2019; Jensen et al., 2019; Jiang et al., 2019; Kjaer et al., 2018b), as it corresponds to a systematic and standardized methodology to assess the environmental and social impacts of a product or service (Abyar, Younesi & Nowrouzi, 2020), from the extraction of raw materials to the final destination of all components (Omolayo et al., 2021).

In subguidelines P1.3, methods and tools are proposed for the strategic management of the entire life cycle (Bertoni, 2019; Beuren, Sousa-Zomer & Cauchick-Miguel, 2017; Tokarz et al., 2020), in order to propose their incorporation in the management and guidance of the PSS (Vezzoli & Kohtala, 2018). Among the enablers proposed by this subguidelines are Business Model Canvas (Guzzo et al., 2019), method Analytic Hierarchy Process (AHP) (Alamerew & Brissaud, 2019), IDEF0 (Halstenberg, Lindow & Stark, 2019), CAD tools (Sinclair et al., 2018) and Quality Function Deployment (QFD) (Bertoni, 2019).

Since supply chain professionals currently focus on implementing measures to conserve natural resources and reduce global warming (Bag, Gupta & Foropon, 2019), there is a need to meet guidelines P4 and P6. Subguidelines P4.1 and P4.2 emphasize the importance of business proposals to aim for longevity and adapt the production process based on sustainable development principles by adopting a closed production and consumption cycle (Alamerew & Brissaud, 2019; Bradley et al., 2018; Frishammar & Parida, 2019). Thus, efficient use of resources should be promoted (Charnley et al., 2019; Yang et al., 2018) and designed with an eye toward ease of disassembly of components (Pialot, Millet & Bisiaux, 2017; Vanegas et al., 2018; Vogtlander et al., 2017). The P6.2 subguidelines highlights measures based on Reverse Logistics, aiming at component reuse, such as recycling (Laurenti et al., 2016; Matschewsky, 2019), remanufacturing (Cherry & Pidgeon, 2018; Parida & Wincent, 2019), reconditioning

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(Alamerew & Brissaud, 2019), repair (Bressanelli et al., 2018), refurbishment (Bag, Gupta & Foropon, 2019), among others.

Thus, it is essential to develop a holistic understanding of the context to be worked (guideline P2), mapping the needs of customers and stakeholders (facilitator FP67), since it is essential to promote customer engagement with the business proposal (Pialot, Millet & Bisiaux, 2017). In this context, it is necessary to manage the stages of the life cycle with eco-efficiency (guideline P3), from the initial phases until the implementation of EoL strategies, mitigating the impacts in the environmental, social and economic spheres (Alamerew & Brissaud, 2019). Finally, the importance of adapting business proposals to the local context is highlighted (guideline P5). The bibliometric analysis corroborates this guideline, highlighting that business proposals should be adapted to countries with different levels of economic (Camacho-Otero, Boks & Pettersen, 2018b; Retamal, 2019) and cultural development (Sousa-Zomer et al., 2018).

4.2.2. Offer

In the offer dimension, guideline O1 emphasizes the importance of adding value to the business proposition by offering solutions or results to customers. Functional selling is pointed out as a subguideline (O1.1), where Vence and Pereira (2019) comment on the need to invest in eco-innovation and to restructure business propositions (Vence & Pereira, 2019), through servitization (Fleischmann, 2019) or the sharing economy (Ingemarsdotter et al., 2019). In this way, personalized offers (FO9) can be introduced to the market, making the customer engaged to the business proposition (O1.3).

It also highlights the importance of providing assistance and instructions to the customer (O1.2), where the ability to upgrade is widely cited in the literature. Khan et al. (2018) point out that besides adding value to the business proposition, upgradability contributes to sustainable development, since it reduces resource consumption, facilitating the implementation of a circular economy and the dissemination of PSS (Khan et al., 2018). In view of this, it is fundamental to design a business proposition aiming at component durability (O1.4), so designers should aim at preventing a product or service from becoming obsolete (Hollander et al., 2017), extending its useful life (Chamberlin & Boks, 2018; Halstenberg, Lindow & Stark, 2019).

Therefore, it is necessary to analyze the strengths and weaknesses of the business proposal, pointing out possible failures, opportunities for optimizations and changes in

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production patterns (O3.1). Thus, it is essential to consider processes throughout the life cycle of the PSS components (Beuren, Gomes Ferreira & Cauchick Miguel, 2013b), monitoring (Ingemarsdotter et al., 2019), tracking (Bressanelli et al., 2018) and providing feedbacks of the proposal (Chen, 2018). To facilitate these activities, the literature cites the use of digital platforms (O3.2) (Holtström, Bjellerup & Eriksson, 2019).

Through these platforms it is possible to announce the innovations and the differential of the business proposition (O2.1), since the environmental and economic spheres are benefited from the investment in marketing and advertising (Jena, Sarmah & Sarin, 2017), becoming a strategic measure (Vence & Pereira, 2019). Thus, the literature highlights the benefits of publicizing sustainable measures (environmental marketing) (O2.2), as supply chain professionals should focus on taking measures to conserve resources and reduce global warming (Bag, Gupta & Foropon, 2019). Thus, customers have been valuing companies that value sustainable development. The work of Laurenti et al. (2016) corroborates this information, as it comments that improvements in material and energy efficiency cause an increase in the company's profit.

4.2.3. Consumer

Vogtlander et al., 2017 point out that, to overcome the limitations in purchasing remanufactured products, there is a need to develop circular business models, such as the Product-Service System (Vogtlander et al., 2017). Other customer limitations can be noted, such as need for product ownership (Chamberlin & Boks, 2018) and low consumer acceptance for innovative business propositions (Annarelli et al., 2018). To overcome them, the literature proposes environmental awareness (C1), adopting sustainable consumption (C1.1) and acquiring knowledge about sustainable development (C1.2). Thus, the need to reduce consumerism (Guzzo et al., 2019) and wastage (Fleischmann, 2019), sufficiency (Vence & Pereira, 2019) and sustainable consumption is highlighted, emphasizing the relationship with SDG 12, which aims to ensure sustainable consumption and production patterns (Camacho-Otero et al., 2018; United Nations, 2015).

To this end, the need arises to promote a change of habits in the population (C2), in order to opt for systems that integrate products and services, such as renting (Kjaer et al., 2018a) and sharing (Kjaer et al., 2018b). Thus the concepts of green economy, aiming at sustainability, are strongly related to dematerialization and investment in business propositions

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based on servitization (Ewijk & Stegemann, 2016; Loiseau et al., 2016), capable of promoting conscious and responsible consumption (C2.2).

5. CONCLUSIONS AND RESEARCH PERSPECTIVES

Aiming to minimize barriers for the implementation of a Product-Service System, this work identified facilitators and built subguidelines and guidelines based on Circular Economy literature. The framework proposed in this research allowed the identification of CE's contribution with the minimization of PSS barriers. It highlights the importance of considering these approaches together, since they are able to overcome limitations and contribute to sustainable development.

The bibliometric and content analyses allowed the detailing of patterns for circular innovation in business proposals, providing a broad panorama for creating a resilient environment in the face of adversities in the development of products and services. Therefore, the proposed framework represents an opportunity to identify barriers or failures in a business proposal and to mitigate them through facilitators, subguidelines, and guidelines.

This research highlighted that approximately 73% of facilitators correspond to the provider dimension of a PSS. This data emphasizes the importance of promoting changes at organizational levels (guideline P4) and adapting business proposals (guideline P5), adding value by offering solutions or results to customers (guideline O1). The incorporation of technological resources and ecodesign or service design tools (guideline P1) has shown to contribute significantly to this context. However, in order to lead society to an environment with balance in the areas of sustainable development (environmental, social and economic), there is a need for mobilization of all stakeholders, where the customer must also present a change of habits (guideline C2) and an environmental awareness (guideline C1).

The bibliometric and content analysis pointed out that the publications on PSS and CE are concentrated in developed or developing countries. In this context, a research opportunity emerges, addressing how to disseminate the principles of sustainable development among all countries, regardless of their degree of economic development. However, it is necessary to analyze how to adapt business proposals to different contexts.

Based on the above, it is suggested to carry out the interrelationship between the barriers of the PSS and the guidelines, subguidelines and facilitators, presented in this work. Moreover, a research perspective emerges from the expansion of the scope of this investigation, in order

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to cover the Sustainable Development Goals (SDGs), mutually aiming to contribute to the minimization of barriers in the implementation of the PSS. It is also recommended to analyze the practical viability of the framework, performing analyses in PSS case studies, measuring the contribution of the guidelines, subguidelines and facilitators. Thus, these conclusions provide a theoretical basis for the development of research with practical approaches, that allow the expansion of knowledge and contributions of the inter-relationship between Circular Economy and Product-Service Systems.

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APPENDIX A - BIBLIOGRAPHIC PORTFOLIO

IND	TITLE	SOURCE	JOURNAL
1	"Upgradable PSS": Clarifying a new concept of sustainable consumption/production based on upgradability	Pialot, Millet and Bisiaux (2017)	Journal of Cleaner Production
2	A choice behavior experiment with circular business models using machine learning and simulation modeling	Lieder, Asif and Rashid (2020)	Journal of Cleaner Production
3	A conjoint analysis of circular economy value propositions for consumers: Using "washing machines in Stockholm" as a case study	Lieder et al. (2018)	Journal of Cleaner Production
4	A total life cycle cost model (TLCCM) for the circular economy and its application	Bradley et al. (2018)	Resources, Conservation and Recycling

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	to post-recovery resource allocation		
5	Business model development for sustainable apparel consumption: The case of Houdini Sportswear	Holtström, Bjellerup and Eriksson (2019)	Journal of Strategy and Management
6	Circular Business Model Innovation: Inherent Uncertainties	Linder and Williander (2017)	Business Strategy and the Environment
7	Circular business model transformation: A roadmap for incumbent firms	Frishammar and Parida (2019)	California Management Review
8	Circular business models: Defining a concept and framing an emerging research field	Nußholz (2017)	Sustainability
9	Circular economy and consumer acceptance: An exploratory study in East and Southeast Asia	Kuah and Wang (2020)	Journal of Cleaner Production
10	Circular economy assessment tool for end-of-life product recovery strategies	Alamerew and Brissaud (2019)	Journal of Remanufacturing
11	Circular economy strategies for mitigating critical material supply issues	Gaustad et al. (2018)	Resources, Conservation and Recycling
12	Circular innovation framework: Verifying conceptual to practical decisions in sustainability-oriented product-service system cases	Guzzo et al. (2019)	Sustainability
13	Circular strategies enabled by the internet of things-a framework and analysis of current practice	Ingemarsdotter et al. (2019)	Sustainability
14	Combined analyses of costs, market value and eco-costs in circular business models: eco-efficient value creation in remanufacturing	Vogtlander et al. (2017)	Journal of Remanufacturing
15	Configuring new business models for circular economy through product-service systems	Pieroni, McAloone and Pigosso (2019a)	Sustainability
16	Consumer intervention mapping-A tool for designing future product strategies within circular product service systems	Sinclair et al. (2018)	Sustainability
17	Consumption in the circular economy: A literature review	Camacho-Otero, Boks and Pettersen (2018)	Sustainability

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18	Creating sustainable value through remanufacturing: Three industry cases	Jensen et al. (2019)	Journal of Cleaner Production
19	Data-driven ecological performance evaluation for remanufacturing process	Jiang et al. (2019)	Energy Conversion and Management
20	Dematerialization and the Circular Economy: Comparing Strategies to Reduce Material Impacts of the Consumer Electronic Product Ecosystem	Kasulaitis, Babbitt and Krock (2019)	Journal of Industrial Ecology
21	Design evolution and innovation for tropical livable cities: Towards a circular economy	Fleischmann (2018)	eTropic
22	Design-led innovation and Circular Economy practices in regional Queensland	Fleischmann (2019)	Local Economy
23	Dynamic cooperation strategies of the closed-loop supply chain involving the internet service platform	Xiang and Xu (2019)	Journal of Cleaner Production
24	Ease of disassembly of products to support circular economy strategies	Vanegas et al. (2018)	Resources, Conservation and Recycling
25	Eco-innovation and Circular Business Models as drivers for a circular economy	Vence and Pereira (2019)	Contaduria y Administracion
26	Enabling Circular Economy Through Product Stewardship	Jensen and Remmen (2017)	Procedia Manufacturing
27	Examining the role of dynamic remanufacturing capability on supply chain resilience in circular economy	Bag, Gupta and Foropon (2019)	Management decision
28	Exploring how usage-focused business models enable circular economy through digital technologies	Bressanelli et al. (2018)	Sustainability
29	Exploring the challenges for circular business implementation in manufacturing companies: An empirical investigation of a pay-per-use service provider	Sousa-Zomer et al. (2018)	Resources, Conservation and Recycling
30	Green economy and related concepts: An overview	Loiseau et al. (2016)	Journal of Cleaner Production
31	Guidance on the conceptual design of sustainable product-service systems	Chen (2018)	Sustainability
32	Guidelines for evaluating the environmental performance of	Kjaer et al. (2018b)	Journal of Cleaner Production

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	Product/Service-Systems through life cycle assessment		
33	Identifying ways of closing the metal flow loop in the global mobile phone product system: A system dynamics modeling approach	Sinha et al. (2016)	Resources, Conservation and Recycling
34	Integrated decision-making in reverse logistics: an optimization of interacting acquisition, grading and disposition processes	Lechner and Reimann (2019)	International Journal of Production Research
35	Integrated fades as a Product-Service System - Business process innovation to accelerate integral product implementation	Azcárate-Aguerre, Den Heijer and Klein (2018)	Journal of Facade Design and Engineering
36	Investment strategy in a closed loop supply chain: The case of a market with competition between two retailers	Yoon and Jeong (2017)	Sustainability
37	Joint-advertising for collection of returned products in a closed-loop supply chain under uncertain environment	Jena, Sarmah and Sarin (2017)	Computers and Industrial Engineering
38	Leveraging circular economy through a methodology for smart service systems engineering	Halstenberg, Lindow and Stark (2019)	Sustainability
39	Limitations of the waste hierarchy for achieving absolute reductions in material throughput	Ewijk and Stegemann (2016)	Journal of Cleaner Production
40	Marketing approaches for a circular economy: Using design frameworks to interpret online communications	Chamberlin and Boks (2018)	Sustainability
41	Multi-criteria decision making for sustainability and value assessment in early PSS design	Bertoni (2019)	Sustainability
42	Opportunities for industry 4.0 to support remanufacturing	Yang et al. (2018)	Applied Sciences
43	Orchestrating industrial ecosystem in circular economy: A two-stage transformation model for large manufacturing companies	Vinit Parida et al. (2019)	Journal of Business Research

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44	Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms	Hollander, Bakker and Hultink (2017)	Journal of Industrial Ecology
45	Product/Service-Systems for a Circular Economy: The Route to Decoupling Economic Growth from Resource Consumption?	Kjaer et al. (2019a)	Journal of Industrial Ecology
46	Product-service systems business models for circular supply chains	Yang et al. (2018)	Production Planning and Control
47	PSS Strategic alignment: Linking service transition strategy with PSS business model	Sholihah et al. (2019)	Sustainability
48	Review on upgradability – A product lifetime extension strategy in the context of product service systems	Khan et al. (2018)	Journal of Cleaner Production
49	Simulation to enable a data-driven circular economy	Charnley et al. (2019)	Sustainability
50	Skills and capabilities for a sustainable and circular economy: The changing role of design	De los Rios and Charnley (2017)	Journal of Cleaner Production
51	Towards circular business models: Identifying consumer needs based on the jobs-to-be-done theory	Hankammer et al. (2019)	Journal of Cleaner Production
52	Transition towards sustainable solutions: Product, service, technology, and business model	Nasiri et al. (2018)	Sustainability
53	Unintended circularity?-Assessing a product-service system for its potential contribution to a circular economy	Matschewsky (2019)	Sustainability
54	Unintended Environmental Consequences of Improvement Actions: A Qualitative Analysis of Systems' Structure and Behavior	Laurenti et al. (2016)	Systems Research and Behavioral Science
55	Using life cycle costing (LCC) to select circular measures: A discussion and practical approach	Kambanou and Sakao (2020)	Resources, Conservation and Recycling
56	Why and how to compete through sustainability: a review and outline of trends influencing firm and network-level transformation	Parida and Wincent (2019)	International Entrepreneurship and Management Journal

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57	Why is ownership an issue? Exploring factors that determine public acceptance of product-service systems	Cherry and Pidgeon (2018)	Sustainability