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Research Article

Application of a framework for product-service systems characterization

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Abstract

Paper aims: Apply a framework for characterizing a product-service system (PSS) from a life cycle and sustainability perspective.

Originality: Although the literature on the topic has evolved, there is still limited practical guidance on how to characterize a PSS. The paper contributes by applying a framework in PSS types.

Research method: A proposed conceptual framework was applied to characterize a PSS. This framework was assessed by experts, from which responses were statistically analyzed. Then, it was applied in three PSS types (bike sharing, water purifier rental, and car sharing).

Main findings: The initial result is the consolidation of the framework through statistical analysis. Then, its application in the three PSS types was able to spot the stages of the life cycle that each PSS focuses on most. Specifically for the water purifier, the most focused steps were 'development' and 'implementation', demonstrating efficient strategic planning and a commitment to meeting customer needs.

Implications for theory and practice: This study contributes to calls for more research and guidance into the PSS application. From a practical perspective, it may support product and systems designers by shedding light on the conceptual elements of PSS offerings.

Keywords

Product-service systems. PSS application. PSS characterization. Sustainability.

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1. Introduction

Amidst environmental pressures for sustainable development and the problem of impending resource scarcity, society demands systemic alternatives (Nunes et al., 2021) capable of reconciling environmental, social, and economic benefits. Furthermore, as industrial requirements change rapidly due to technological advances, there is a need to stimulate alternative systems for more efficient design, in line with the digitalization context resulting from Industry 4.0 (Mourtzis, 2020).

Product-service systems consist of a system that combines marketable products and services to meet customer demands (Goedkoop et al., 1999). In fact, they are proposals that shift the focus from selling products as commodities to offering solutions to meet customer needs in order to provide added value (Henriques et al., 2023). In this sense, there is a contribution towards resource efficiency, becoming a strategy for merging economic and environmental development (Henriques et al., 2023).

As a system, the design of a PSS requires a holistic perspective, considering all stages of the solution's life cycle (Beuren et al., 2013). Therefore, the design of a PSS as a sustainable solution should be approached from a system's perspective considering all elements of the system in an integrated way. As identified earlier (Morelli, 2006), there is still a need to develop a broad understanding of the process of introduction and diffusion of a PSS. Thus, circular business proposals can contribute to all phases of a product (Neligan et al., 2022).

Some research looking at the development of PSS as sustainable and integrated solutions has been emerging in the literature, but most existing studies so far tend to focus on individual system elements. Joore & Brezet (2015), for instance, is one of the limited studies that has proposed the development of a framework that supports the sustainable design process of PSS solutions. Most of the frameworks in the existing literature have focused on the development of products or services (traditional offerings) and are usually, mostly conceptual, without testing the proposed frameworks (Joore & Brezet, 2015; Fernandes et al., 2020). Indeed, the design of PSS value propositions, taking a systemic approach and with a circular-oriented focus is still limited in the literature (Fernandes et al., 2020). Models that characterize product-service systems are still missing in the literature and recent research such as Wahyudi et al. (2022) cite the urgent need to investigate the components of a PSS throughout its life cycle. Furthermore, the design and evaluation of PSS is a difficult task due to the complexity and multidimensionality of product-service systems (Mourtzis et al., 2018), so a characterization of PSS solutions from a lifecycle perspective can be useful to support design and evaluation. Thus, the objective of this paper is to apply a framework for characterizing a product-service system from a life cycle and sustainability perspective.

A literature review was conducted to identify the conceptual elements that characterize a PSS and develop the conceptual framework. The conceptual elements identified are verified by experts and based on feedback, the framework is improved. Then, the framework is applied to the conceptualization of existing PSS solutions. By proposing and demonstrating the applicability of the characterization framework, the paper contributes to existing literature and calls for more research on the practical design of integrated product-service offerings with a sustainable and circular potential (Fernandes et al., 2020).

The remaining of this paper is structured as follows. Section 2 describes the research design, section 3 presents the results and discussions. Finally, section 4 draws conclusion of this work.

2. Research design

2.1. Literature review

This research was carried out in 7 stages, as depicted in Figure 1.

Firstly, a systematic literature review was conducted to identify conceptual elements for characterizing a PSS. The databases Scopus, Web of Science (WoS), Science Direct, and Springer Link were used for identifying publications. The search was based on Beuren et al. (2017) paper, aiming to further the search conducted by the authors. This work has deepened the research from Beuren et al. (2017), when a PSS life cycle framework was developed.

A search for the terms *product-service system*, *servitization*, and *productization*, was performed in combination with other keywords used by previous PSS reviews (e.g. Baines et al., 2007; Beuren et al., 2017) as shown in Table 1.

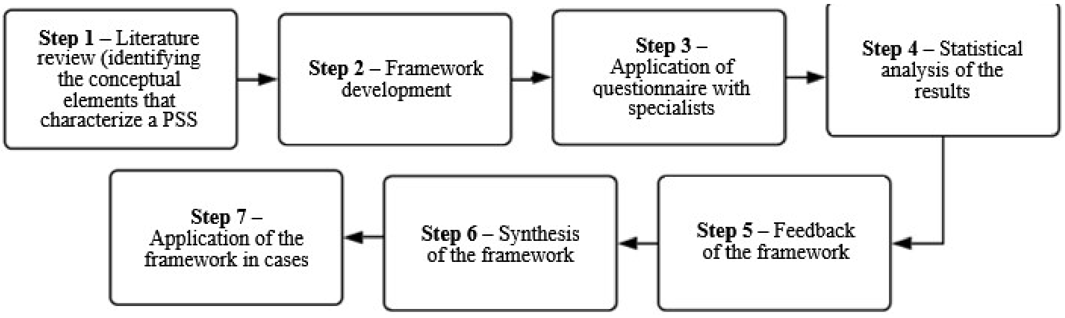

Figure 1. Methodological procedures.

After removing the duplicates, the search identified 729 publications. The selected publications were analyzed following the screening criteria presented in Table 2, aiming to select publications that could lead to the identification of elements along a PSS lifecycle for its characterization from a circular and sustainability perspectives. Then, 435 papers were selected for further analysis, which provided the basis for the development of the conceptual framework, as elaborated next.

2.2. Development of a framework for PSS characterization

Since a PSS is systemic (Morelli, 2006), a holistic perspective in their development process should be considered, and the entire life cycle was considered for the development of the framework to classify the conceptual elements into the stages (Beuren et al., 2017): (i) requirements definition, (ii) development, (iii) deployment, (iv) monitoring, and (v) post-use disposition.

The literature led to the identification of elements that characterize each stage of the PSS life cycle so that 34 elements were identified for the requirements definition stage, 37 for the development stage, 12 for deployment, 28 for monitoring, and 21 for post-use disposal, resulting in the identification of 132 conceptual elements that should be considered from a lifecycle perspective and in the construction of the framework (stage 2).

Next, a questionnaire was applied with PSS specialists (stage 3) to validate the conceptual elements identified in the literature review. A five-point Likert scale was adopted in the questionnaire composed of multiple questions to measure the respondents' degree of agreement with each element. The Statistical Package for the Social Sciences (SPSS)® software was employed to statistically analyze each conceptual element (stage 4) and assess respondents' degree of agreement.

The results of the framework analysis by PSS specialists provided feedback to improve the conceptual framework (stage 5); based on the responses, 15 conceptual elements were eliminated and 14 were further grouped. To verify the internal consistency of the questions and test the reliability of the data collection instrument, Cronbach's alpha coefficient was used, obtained from the variance of the individual questions and the variance of the sum of the questions, seeking to investigate possible relationships between the elements (Cronbach, 1951).

Thus, the new version of the framework, after feedback from the specialists, resulted in 103 conceptual elements arranged along the life cycle of a PSS. Finally, the framework was synthesized (stage 6) and coded so that the life cycle steps were represented as follows: (A) PSS requirement definition; (B) PSS development; (C) PSS deployment; (D) PSS monitoring; (E) PSS post-use disposal. The coding of each life cycle stage follows the example of the Requirement Definition in stage A, where the elements are represented as A1, A2, [...], and A34. The other life cycle stages follow the same representation.

The steps to propose the framework are shown in Figure 2.

Table 1. Keyword combinations (Beuren et al., 2017).

Keywords	Scopus	WoS	Science Direct	Springer Link
"Product-service systems"	358	275	276	40
"Servitization"	102	89	49	65
"Productization"	36	14	3	37
"product-service systems" and "life cycle" or "lifecycle"	69	51	55	25
("product-service systems") and ("sustainability" or "remanufacturing" or "service design" or "service economy" or "product substituting service" or "dematerialization" or "system solution" or "functional economy")	109	90	76	40

Table 2. Screening criteria (Beuren et al., 2017).

i)	Does the paper address the life cycle phases of PSS, both in modeling frameworks and in life cycle assessment studies?
ii)	Does the paper discuss the structure of the PSS business model?
iii)	Does the paper focus on PSS design methodologies, frameworks, and tools for developing a PSS?
iv)	Does the paper focus on case studies of different PSS categories, as these articles usually address elements that should be considered in a specific PSS offering?

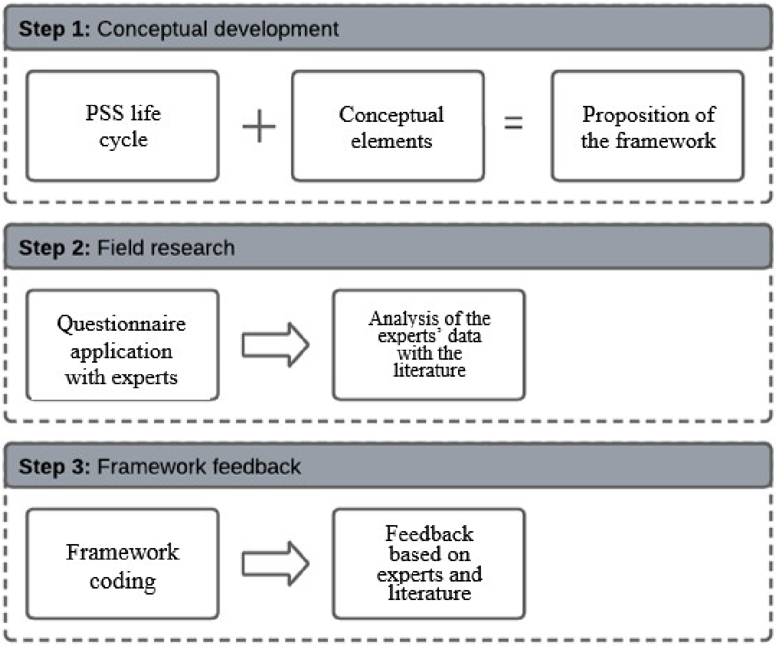

Figure 2. Steps for framework development.

2.3. Application of the framework

Aiming to check the proposed framework, its application in practical cases was carried out (stage 7). PSS solutions considered that: (i) has widely discussed in the literature and for which all systems' elements are clear; (ii) could be classified according to the different PSS types proposed by Tukker (2004) (*i.e.*, product-oriented PSS, use-oriented PSS, or result-oriented PSS); and (iii) have a sustainable focus by identifying and selecting PSS candidates to apply the proposed framework.

Three PSS were selected: a bicycle-sharing system, a water purifier rental model, and a car-sharing system. To identify the conceptual elements in each PSS practical situation, a questionnaire was applied to managers of the companies, leading to the identification of whether the case studies are properly classified as PSS business models. Since the water purifier rental model presented the highest number of conceptual elements, details of this solution are presented next and discussed further as an illustration of the validation of the proposed framework.

2.4. Brief description of the water purifier PSS system

The water purifier system is a use-oriented PSS solution [considering Tukker's (2004) proposed categorization] that a leading company in Latin America (Brazil) leases for filtering drinking water. There is a market opportunity associated with drinking water solutions given variability in the quality of tap water in different regions of the country. To enhance its commitment to environmental issues, the company decided to focus on the development of products with a high level of energy efficiency, the management of materials, and waste, and the reduction of greenhouse gas emissions (Sousa-Zomer & Cauchick-Miguel, 2019). A new PSS business model with sustainable and circular potentials was thus developed and introduced in the market.

The water purification system has been in operation since the early 2000. The company has complete control over the product life cycle. The company leases the water purifier (in a monthly payment fee scheme) and provides a range of services that include installation, preventive maintenance, repair, and product end-of-life management. At product end-of-life, the company collects the product and its components through a reverse logistics process. The manufacturer assumes the responsibility for recycling the appliance components that need to be replaced (e.g. that need update) or discontinued. The offer is available in both business-to-consumer (B2C) and business-to-business (B2B) markets.

3. Results and discussions

3.1. Conceptual elements of PSS value propositions

When defining requirements for a product-service system, the conceptual elements should be different for each PSS orientation. Therefore, a statistical analysis was carried out, taking into account the Cronbach's Alpha. In this sense, this enabled to check the internal consistency index of the items and the stage as a whole.

The conceptual elements of the PSS 'requirements definition' stage was classified as follows: elements A1 to A10 refer to a product-oriented PSS, A11 to A24 are related to a use-oriented PSS, and A25 to A34 refer to a result-oriented PSS. However, following the suggestions of the interviewees and by analyzing the reliability of the elements for each PSS category through the statistical analysis performed (Cronbach's alpha), some elements were grouped (elements A12, A23, A32, and A34), while others were excluded from the model (A1, A6, A19, and A30). The resulting elements are presented in Table 3, and the rationale for the exclusion is presented next.

Cronbach's alpha analysis highlighted a low value for a product-oriented PSS (0.615); to be acceptable, it should reach a minimum value of 0.7 (Cronbach, 1951). Questions A1 to A10 (product-oriented PSS) are not homogeneous, i.e., they do not measure the same scale consistently for which they were designed. Thus, the questions should be analyzed to improve the reliability of the data in this cycle stage, in which the elimination of some conceptual elements was analyzed to ensure the reliability of the data included in the model.

Table 3. Conceptual elements - definition of requirements of a PSS.

Requirement definition classification	Conceptual elements	Sources
Product-oriented PSS	A2/A12.Plan to increase the intensity of product use	Jabbour et al. (2019)
	A3.Provide replenishments of consumables	Tukker (2004)
	A4.Plan the payment for services offered	Tukker (2004); UN Environment Programme (2004)
	A5.Offer maintenance services	Jabbour et al. (2019)
	A7.Serve the consumer with personalized services	Besch (2005); Jabbour et al. (2019)
	A8/A23/A34.Result in economy of scale	Wu & Gao (2010)
	A9.Offer on-site services	UN Environment Programme (2004)
	A10.Guide effective use of the product	Tukker (2004)
Use-oriented PSS	A11.Plan the use of the customized products and services	Alaei et al. (2019); Jabbour et al. (2019)
	A13.Plan individual product access	Tukker (2004)
	A14.Plan product sharing by different users	Tukker (2004)
	A15.Plan simultaneous use of the product by different users	Guzzo et al. (2019); Tukker (2004)
	A16.Plan the payment according to the time used	Tukker (2004); UN Environment Programme (2004)
	A17.Plan leasing, sharing, or simultaneous use for high-value products	Guzzo et al. (2019); Tukker (2004)
	A18.Plan lease contract	Besch (2005)
	A20/A32.Plan for product ownership to belong to service providers	Alix & Zacharewicz (2012); Tukker (2004)
	A21.Educate the consumer on effective product use, hygiene, and environmental, social, and economic benefits	Alaei et al. (2019)
	A22.Provide the consumer with personalized services without purchasing the product	Alaei et al. (2019); Besch (2005); Jabbour et al. (2019)
	A24.Offer on-site or consumer pick-up services	UN Environment Programme (2004)
Result-oriented PSS	A25.Plan the acquisition of services that customize products	Tukker (2004)
	A26.Outsource an activity to the consumer, who manages and takes over the activities	Gao et al. (2011); Tukker (2004)
	A27.Outsource a service where the company takes over the activities and the consumer manages them	Gao et al. (2011)
	A28.Outsource a service where the provider delivers a result	Besch (2005); Gao et al. (2011)
	A29.Plan the payment related to an outsourced activity	Tukker (2004); UN Environment Programme (2004)
	A31.Offering results, the consumer hires customization	Chen (2018)
	A33.Serve the consumer by offering a personalized result without purchasing the product	Chen (2018)

Source: adapted from Beuren et al. (2017).

Hence, questions A1 and A6 were excluded because they presented low total correlations and Cronbach's alpha values, i.e., they did not contribute to the measurement scale of the first stage of the life cycle of a PSS. With the elimination of these elements, Cronbach's alpha became 0.750 and was thus acceptable for a data measurement scale.

The Cronbach's alpha value for a use-oriented PSS was 0.868, considered adequate in the correlation of the questions, i.e., the set of questions is homogeneous and measures the same scale. Nevertheless, we analyzed the possibility of excluding a question that presented a high Cronbach's alpha value and low correlation with the other questions. Given this analysis, element A19 was excluded from the measurement scale for showing a low correlation with the other questions. Thus, Cronbach's alpha for the use-oriented PSS increased to 0.881.

The analysis of the conceptual elements for the result-oriented PSS in the "PSS requirement definition" step had a Cronbach's alpha of 0.857, thus presenting homogeneous data. However, the possibility of excluding any question that did not present an adequate correlation with the other questions was analyzed. In view of this, element A30 presented a low correlation and was excluded from the model, so Cronbach's alpha for the result-oriented PSS increased to 0.892.

In Table 4, the conceptual elements for the PSS 'development stage' were analyzed and classified according to the PSS elements taking into consideration the environmental and circular potential of the solutions: product, service, stakeholders, and infrastructure (Mont, 2002).

Table 4. Conceptual elements – developing a PSS.

Development classification	Conceptual elements	Sources
Product	B35. Plan resources (raw material) with low environmental impact	Vezzoli & Sciama (2006)
	B36. Plan the life extension of resources used	Jabbour et al. (2019); Vezzoli (2007)
	B37.Plan the use of appropriate resources for product safety	Alix & Zacharewicz (2012)
	B38.Plan that the leased product has individual access and/or may be shared and/or used simultaneously by different users	Tukker (2004)
	B39.Plan to use local resources to strengthen and enhance the region	Vezzoli (2007)
	B40.Plan the reuse of parts (especially high-value parts)	Jabbour et al. (2019)
	B41.Plan the product evaluation for its final destination (post-use)	Mien et al. (2005)
	B42.Design the product assembly system in a reversible way	Besch (2005); Jabbour et al. (2019)
	B43.Designing the product for durability	Jabbour et al. (2019); Vezzoli (2007)
	B44.Design the modularity and standardization of parts	Song & Sakao (2017)
	B45.Design for easy access to components	Sundin (2009)
	B46.Design product disassembly to facilitate maintenance and post-use	Jabbour et al. (2019); Vezzoli (2007)
Service	B47.Plan services with low environmental impacts	Vezzoli (2007)
	B48.Plan services that ensure product safety	Bastl et al. (2012); Besch (2005)
	B49.Plan appropriate service networks to serve different types of PSS	Vogtländer et al. (2002)
	B50.Plan the use of local services to strengthen and enhance the region	Besch (2005); Vezzoli (2007)
	B51.Plan service facilities near consumers	Besch (2005)
	B52.Design the services together with the product(s)	Besch (2005)
Stakeholders	B54.Plan for suppliers to use resources with low environmental impacts	Vezzoli (2007)
	B55.Plan for suppliers to increase the interface among business stakeholders (joint engineering)	Bastl et al. (2012); Vezzoli (2007)
	B56.Plan for producers to be development partners	Mont (2002); UN Environment Programme (2004)
	B57.Plan for producers to take responsibility for product design, repair, and upgrade	Besch (2005)
	B58.Plan for technicians to remain close to consumers	Bastl et al. (2012); UN Environment Programme (2004)
	B59.Plan for technicians to be trained to serve the consumer	Abramovici et al. (2018); UN Environment Programme (2004)
	B60.Plan for technicians to take responsibility for repairing, upgrading, and recycling products and materials and for reverse logistics	Abramovici et al. (2018); Mont & Tukker (2006)
	B61.Plan for the "end of life" manager to verify post-use disposal	UN Environment Programme (2004)
	B63.Plan a PSS with government incentives	Mont & Lindhqvist (2003)
	B65.Design a PSS with consumer participation	UN Environment Programme (2004)
	B66.Design a PSS balancing the work among the involved parties	Vezzoli (2007)
Infrastructure	B67.Plan a communication system among the involved parties, including the consumer	Mien et al. (2005)
	B68.Plan the distribution chain (systems interaction)	Maxwell et al. (2006)
	B69.Plan the take-back system (correct destination of the product)	Mien et al. (2005)
	B70.Plan the economy and valorization of local culture	Vezzoli (2007)
	B71.Check the installation conditions of the environment where a PSS will be used and thus install a PSS safely	Vezzoli (2007)

Source: adapted from Beuren et al. (2017).

The Cronbach's alpha values were high for the product (0.954), the service (0.884), the network of actors (0.819), and the infrastructure (0.895), so the conceptual elements of this stage of the cycle may be considered homogeneous, i.e., the measurement scale presents the reliability of the instrument. However, the correlation of the data was analyzed, and no elements were eliminated for the "product" and "infrastructure" dimensions since this could harm the measurement scale, rendering it redundant or heterogeneous.

For the "service" dimension, question B53 was eliminated since it presented a low correlation with the other elements, increasing Cronbach's alpha to 0.904. For the "infrastructure" dimension, questions B62 and B64 did not show correlations with some elements, so the analysis was performed excluding these questions to increase Cronbach's alpha to 0.899, improving the reliability of the data presented.

Table 5 presents the conceptual elements for the PSS 'implementation stage', classified as follows: delivery, installation, and payment.

Questions C72 and C81 do not have adequate correlation, making them elements to be eliminated to improve the reliability of the measurement scale or instrument. With the elimination of these elements, Cronbach's alpha went from 0.908 to 0.931, thus increasing the reliability of the data to be included in the model.

Table 6 presents the conceptual elements for the PSS 'monitoring stage', classified according to the following classification: product-oriented PSS (Cronbach's alpha equal to 0.892), use-oriented PSS (Cronbach's alpha equal to 0.941), and result-oriented PSS (Cronbach's alpha of 0.912). Table 6 highlights a clustering of elements D98, D99, D100, D102, D108, D109, D101, D106, D110, and D111, and the rationale for excluding elements D84, D92, and D93 is discussed next.

When analyzing the correlation between the conceptual elements of the product-oriented PSS, it was observed that the lowest value was presented in question D84, i.e., this element does not present reliability in the instrument's data. Thus, this question was eliminated to improve the measurement scale, obtaining a Cronbach's alpha of 0.932.

In the "use-oriented PSS" dimension, questions D92 and D93 were excluded from the analysis because SPSS automatically eliminated them for presenting zero variance among questions. Thus, we decided to exclude these elements since the variance cannot be zero for a question to have reliability because it presents redundancy in the data (George & Mallery, 2003). The "result-oriented PSS" dimension showed high reliability, given that there were high correlation indices among the elements. Thus, no question was eliminated in this dimension.

Finally, Table 7 presents the conceptual elements for the 'PSS post-use disposal stage', classified as follows: reuse, service renewal, repair, upgrade, recycling, termination of a PSS contract, and collection of lessons learned.

The correlation matrix of the PSS post-use disposal stage highlighted that questions E127 and E129 had very low correlations of 0.076 and 0.021, respectively. Hence, both were eliminated along with question E128, which was automatically excluded by SPSS. After eliminating questions E127, E128, and E129, Cronbach's alpha went from 0.956 to 0.967, and, with these results, the reliability of the data on the measurement scale was obtained.

Table 5. Conceptual elements - implementing a PSS.

Implementation classification	Conceptual elements	Sources
Delivery	C73.Identify the technician responsible for testing and simulating the product	Abramovici et al. (2018)
	C74.Guide on hygiene	Morelli (2003); UN Environment Programme (2004)
	C75.Identify the technician responsible for the periodic cleaning of the product	Morelli (2003)
	C76.Guide effective use	Morelli (2003)
	C77.Identify the technician responsible for guiding the use	Abramovici et al. (2018); Morelli (2003)
Installation	C78.Check whether the infrastructure meets the PSS specifications	Martinez et al. (2010)
	C79.Install the product and/or offer the service at the predetermined point	Aurich et al. (2006); UN Environment Programme (2004)
	C80.Identify the technician responsible for installing the product and/or offering a service at the point established by the consumer	Aurich et al. (2006); UN Environment Programme (2004)
Payment	C82.Plan payment for using a PSS	Tukker (2004)
	C83.Identify the technician responsible for payment	Tukker (2004)

Source: adapted from Beuren et al. (2017).

Table 6. Conceptual elements - monitoring a PSS.

Monitoring classification	Conceptual elements	Sources
Product-oriented PSS	D85.Seek consumer feedback regarding PSS	Halstenberg et al. (2019); Vezzoli & Sciama (2006)
	D86.Identify the consumer problems and solutions during product use	De Coster (2011); Guzzo et al. (2019); Ingemarsdotter et al. (2019)
	D87/D99/D108.Identify the need to seek stakeholders to improve a PSS	Mien et al. (2005); UN Environment Programme (2004)
	D88/D98.Maintain contact during product use	Yang et al. (2010)
	D89/D100/D109.Guide the consumer on the effective use of the product and services	Alix & Zacharewicz (2012); Vezzoli & Sciama (2006)
	D90/D101/D110. Check the need to modify (extend) the infrastructure to meet the PSS specifications	Martinez et al. (2010)
	D91/D102/D111.Check the need to search for new infrastructure	Martinez et al. (2010)
Use-oriented PSS	D85.Seek consumer feedback regarding PSS	Ingemarsdotter et al. (2019); Vezzoli & Sciama (2006)
	D94.Identify with the consumer possible problems and solutions during the use of the product with individual access	Alix & Zacharewicz (2012); Halstenberg et al. (2019); Ingemarsdotter et al. (2019)
	D95.Identify with the consumer possible problems and solutions during the use of the product shared by different users	Halstenberg et al. (2019); Ingemarsdotter et al. (2019)
	D96.Identify with the consumer possible problems and solutions during the simultaneous use of the product by different users	Alix & Zacharewicz (2012); De Coster (2011); Halstenberg et al. (2019); Ingemarsdotter et al. (2019)
	D97/D106.Maintain contact with those involved in the business	Bastl et al. (2012)
Result-oriented PSS	D105.Identify with the consumer occasional problems and solutions observed during the outsourcing of the services	De Coster (2011)
	D107.Maintain contact while using the service	Yang et al. (2010)

Source: adapted from Beuren et al. (2017).

Table 7. Conceptual elements - post-use disposal of a PSS.

Post-use disposal classification	Conceptual elements	Sources
Reuse	E112.Reuse parts and materials, valuing and reintegrating them	Jabbour et al. (2019); Vezzoli (2007)
	E113.Send a technician to assist the consumer in the reuse of parts and materials	Vezzoli (2007)
Service renewal	E114.Renew the services to personalize the service	Jabbour et al. (2019); Vezzoli (2007)
	E115.Send a technician to serve the consumer at service renewal	Sundin et al. (2010)
	E116.Renew the contract for the use of a PSS	Sundin et al. (2010)
	E117.Send a technician responsible for renewing the contract with the consumer	Sundin et al. (2010)
Repair	E118.Repair damaged parts in the product	Vezzoli (2007)
	E119.Send a technician to repair damaged parts in the product	Alix & Zacharewicz (2012); Besch (2005); Vezzoli (2007)
	E120.Use the necessary infrastructure for possible repairs to the product	Besch (2005); Vezzoli (2007); Wu & Gao (2010)
Update	E121.Update damaged parts in the product with new, current parts	Jabbour et al. (2019); Vezzoli (2007)
	E122.Send a technician responsible for updating damaged parts in the product	Alix & Zacharewicz (2012); Vezzoli (2007)
	E123.Use the necessary infrastructure for possible product upgrades	Alix & Zacharewicz (2012); Besch (2005); Vezzoli (2007)
Recycling	E124.Recycle parts and materials no longer reused by using them in new products	Alix & Zacharewicz (2012); Jabbour et al. (2019).
	E125.Send a technician to recycle parts and materials to be used in other products	Alix & Zacharewicz (2012); Vezzoli (2007)
	E126.Use the necessary infrastructure for product recycling	Vezzoli (2007)
Termination of a PSS contract and collection of lessons learned	E130.Record lessons learned for improvements in a PSS	De Coster (2011)
	E131. Send a technician responsible for talking to the customer about the use of the PSS, seeking customer loyalty and continuous improvement	Besch (2005); De Coster (2011)
	E132.Use the necessary infrastructure to return the product to the service provider to dispose of it correctly	Besch (2005); De Coster (2011)

Source: adapted from Beuren et al. (2017).

3.2. PSS framework development

The framework presented in Figure 3 highlights that the conceptual elements are the same for the three PSS categories in stages B, C, and E (development, implementation, and disposal), and different for the three categories in stages A and D (definition of requirements and monitoring). In other words, depending on the value proposition, the definition of the requirements and monitoring of the solution will be different, while the development, implementation, and disposal have similarities in terms of the activities involved.

For the full development of a PSS and to properly characterize a business proposal as a PSS, the conceptual elements should be mutually considered. Thus, the information obtained in the output of one stage of the life cycle must be used as an input for the subsequent stage. In such a way, the information acquired throughout the life cycle is used to improve the business proposal continuously.

3.3. Framework application

Figure 4 shows that the water purifier presented the largest number of conceptual elements in all stages of the PSS life cycle. Therefore, the following subsections detail the business proposal for each stage of the PSS life cycle (water purifier), highlighting the main conceptual elements.

Table 8 summarizes the conceptual elements that characterize the water purifier business proposition.

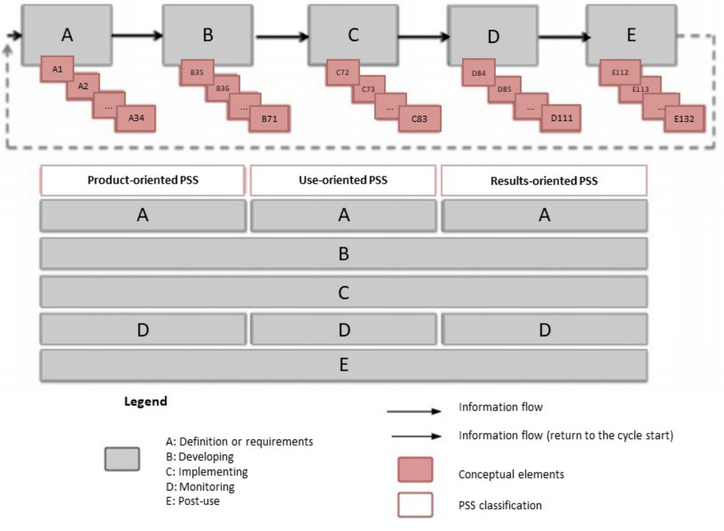

Figure 3. Framework - synthesis of the conceptual elements.

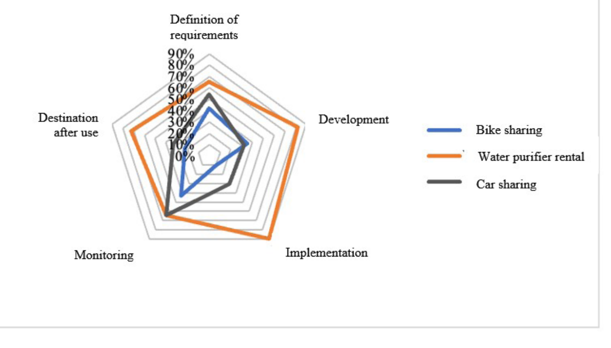

Figure 4. Application of the framework in three PSS.

Table 8. Conceptual elements of the water purifier.

PSS life cycle stages	Conceptual elements satisfied	Percentage of conceptual elements
Requirement definition	A2/A12, A3, A4, A5, A8/A23/A34, A9, A11, A13, A16, A18, A20/A32, A21, A22, A25, A27, A31, A33	65%
Development	B35, B36, B37, B39, B40, B41, B42, B43, B44, B45, B46, B47, B48, B49, B50, B51, B55, B56, B57, B58, B59, B61, B63, B65, B67, B68, B69, B71	82%
Implementation	C73, C74, C75, C76, C78, C79, C80, C82, C83	90%
Monitoring	D85, D86, D89/D100/D109, D90/D101/D110, D91/D102/D111, D94, D97/D106, D105	64%
Post-use disposal	E112, E114, E116, E119, E121, E122, E123, E124, E125, E126, E130, E131, E132	72%

3.3.1. Requirement definition

In the requirement definition step, the water purifier met 65% of the conceptual elements, so most of them correspond to the use-oriented PSS category (elements A2/A12, A8/A23/A34, A11, A13, A16, A18, A20/A32, A21, and A22) of the water purifier business proposition.

The elements A11, A25, A31, and A33 highlight the need to plan the customization of products and services. Beuren et al. (2012), in a previous study, have already identified that the great pressure variability of the public water supply network in Brazilian cities may be considered in the customization of the service. Thus, there is a need to measure the static pressure (in the same location pressures ranging from 0.2 kgf/cm^2 to 4.0 kgf/cm^2 can be found) and analyze the need to install a pressurizing pump (in case of low pressure) or pressure reducers (in case of high pressure).

Furthermore, the data obtained in the practical application highlight that, during the requirement definition stage, there is a concern with the raw material used in the product design, especially regarding safety and durability, to minimize the need for corrective maintenance. Hence, the company takes into consideration electrical safety requirements and the risks of failures that may lead to a leak of large proportions and analyzes the resistance to corrosion and degradation (usually in plastic parts) by the action of humidity and grease present in the installation sites. Thus, there is an extension in the use of the water purifier (element A2/A12) because there is an optimization of functionality (Jabbour et al., 2019).

Kuo et al. (2019) pointed out that the selection of raw materials should consider the stages of assembly and disassembly of parts. Thus, the business proposition selects materials and methods that facilitate the provision of maintenance services (conceptual element A5) such as changing filters or valves for internal cleaning or aesthetic or technological upgrades (Beuren et al., 2012).

3.3.2. Development

The water purifier met 82% of the conceptual elements concerning the development of a PSS, demonstrating that the business proposal has a broad mapping of the conception of products and services, as well as efficient strategic planning concerning the infrastructure and the network of actors necessary for the development of the business model. These data highlight that the case analyzed presents a systemic perspective since it adopts a holistic approach, considering all the elements of a PSS (França et al., 2017).

Conceptual elements B59 and B60 highlight the need to compose a qualified technical team to establish a close relationship with customers, providing versatile alternatives (Jabbour et al., 2019) that offer high availability and flexibility. Therefore, the technicians of the analyzed company check the quality of water filtration through chemical (chlorine removal) and visual (turbidity) tests. In addition, the water flow rate and the closing condition of the valves are tested to avoid leaks (Beuren et al., 2012) and to perform the product installation safely (elements B37, B48, and B71).

To make products' repair easier, the connections should be easy to assemble and disassemble which guarantees tightness and quick and precise assembly (Beuren et al., 2012). Thus, the design of a PSS product should incorporate services such as repair, refurbishment, warranty (Kanda et al., 2016), and upgrading (Jabbour et al., 2019), and the provider should take responsibility for all processes throughout the PSS life cycle (Igba et al., 2015), striving for minimal environmental degradation (element B47).

3.3.3. Implementation

In the PSS implementation stage, the water purifier met the highest number of conceptual elements of this analysis (90%), demonstrating the company's commitment to delivering and installing products and services that satisfy customer needs. This assertion may be justified with the guidance provided by the technical team, which guides the customer on efficient use (elements C76 and C80) and sanitization (C74), in addition to instructing them about possible product dysfunctionalities (Beuren et al., 2012; Igba et al., 2015).

Furthermore, the technicians offer agility in the service provided since components that need periodic replacement (such as filters) are strategically located in a region of easy access (conceptual element C79) (Beuren et al., 2012). Vence & Pereira (2019) highlighted that, through these support services, reliability in the business proposition and consumer satisfaction are increased (Vence & Pereira, 2019).

Since the customer is renting the product and relies on the services offered by the company, the payment scheme typically employed is an automatic debit or the issuing of a monthly bank slip (element C82) (Beuren et al., 2012).

3.3.4. Monitoring

In the monitoring stage, the water purifier met 64% of the conceptual elements, and it was observed that the company remains engaged with the customer by providing services such as guidance (element D89/D100/D109) and maintenance, which contribute to the extension of the product's life (Halstenberg et al., 2019) and the identification of opportunities for improvements in the business proposition (element D86), allowing to continuously satisfy customer needs (Khan et al., 2020).

According to data provided by the company, there is a growing interest in the business proposal and an increase in sales, which has been gaining popularity for its practicality since the customer is not in charge of services such as maintenance. Moreover, the scheduling of services occurs daily, and, to optimize the routing costs, it is possible to establish an optimized trajectory for each technician, minimizing travel expenses and increasing operational efficiency (Beuren et al., 2012).

The engagement with the customer (D94, D97/D106, and D105) allows analyzing their level of satisfaction with the products and services offered (D85) to make improvements (Kuo et al., 2019), i.e., check whether the value proposition needs adjustments regarding products, services, the network of actors, and the infrastructure adopted (elements D90/D101/D110 and D91/D102/D111).

3.3.5. Post-use disposal

The water purifier met 72% of the conceptual elements regarding the PSS post-use disposal stage, demonstrating that the analyzed company is committed to the reuse, service renewal, repair, upgrade, recycling, and termination of a PSS contract.

Thus, the need to adopt a "cradle to cradle" approach (Held et al., 2018), where reverse logistics represents a value-creation tool, is highlighted, given that it contributes to several practices guided by the circular economy, such as recycling, remanufacturing, and reconditioning. The principles of reverse logistics should be addressed since the conception of the business proposal to facilitate post-use disposal (Jabbour et al., 2019).

The takeback is approached by the company by subcontracting specialized companies to collect materials, which are then analyzed to ensure the optimization of the post-use destination process. Therefore, the use of the products follows a closed flow since the products go through upgrading, repair, and recycling mechanisms (Beuren et al., 2012).

4. Conclusions

This study highlighted that, despite the growth of publications referring to PSSs, there is still no consensus in the literature regarding the differentiation of a PSS business proposal from a traditional product and service offering. Thus, the paper aimed to develop a framework to characterize a PSS based on its life cycle. To meet this goal, conceptual elements were identified. It is demonstrated that to ensure the circularity of business proposals, there should be a reverse flow to promote the maximum use of products and services through reuse, renovation, repair of parts and materials, upgrading, and recycling.

For testing purposes, the proposed framework was analyzed by PSS experts and applied to three practical cases. The empirical study highlighted that the water purifier presented the highest number of conceptual elements in the development (82%) and implementation (90%) stages, demonstrating the commitment of the business proposal to stages such as planning, design, delivery, and installation of products and services. Moreover, the water purifier met a considerable number of conceptual elements in the post-use destination stage, such as reusing parts and materials, performing upgrades, and recycling components. Thus, the water purifier demonstrated its engagement with sustainable development by adopting measures based on circularity.

The life cycle stages with the lowest rate of conceptual elements also require analysis, given the possibility of improving the value proposition by incorporating them into the PSS solution. The water purifier presented the lowest number of conceptual elements in the requirement definition stage, possibly because it represents a business model already widespread in the market, so the strategic planning stages only need to be updated periodically. Some elements that were not met by the value proposition may be further incorporated, such as personalized customer service.

The contributions of the proposed framework are threefold: (i) it enables to check differentiation of traditional business proposals from PSS offerings, (ii) it provides guidance and strategic planning for the development of PSS offers, and (iii) it also enables the identification of improvements to the products and services provided (by an existing offering) through the recognition of conceptual elements that were not considered by the business model but that could be further considered. By providing more guidance into the development of a PSS with circular potential and by considering the entire lifecycle, this study contributes to calls for more research and guidance into the design of circular PSS offerings.

Future studies can focus on the systematization of the proposed framework, so it can be further developed into guidelines and/or tools to support the process of characterizing a PSS business proposition. Other practical applications related to the three PSS guidelines could be analytically explored. As every research suffers from limitations, this study poses that the framework presented may not be applied to all PSS from different sectors. Therefore, specific frameworks could be developed or the proposed framework could be to narrow down to investigate for PSS solutions in other industrial sectors.

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