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PSS design process models: are they sustainability-oriented?

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Abstract

Sustainable growth demands focus not only on the product and production processes, but also in promoting shifts in consumption patterns and lifestyles towards a circular economy. The adoption of Product-Service Systems (PSS) strategies appears as a promising solution. However, practical application of PSS sustainable approaches is still limited. This may be associated to the fact that a PSS does not guarantee environmental improvements if it is not specifically designed with this purpose. PSS design process models can play a relevant role in supporting companies in designing sustainable PSS when they incorporate activities, methods and tools to approach the sustainability dimensions. Not only the process models, but also the intentions of practitioners and their awareness towards sustainability during the design of a PSS influence the dissemination of sustainable PSS. The objective of this work is to investigate whether the existent PSS design process models support the design of sustainable PSS and whether practitioners employ sustainability-related activities when designing PSS. Nine process models were analyzed and the perspective of practitioners about considering sustainability issues when designing PSS were captured. The collected data shows that only few of the analyzed process models actually propose activities, methods or tools to support a sustainable PSS design. This suggests an existing gap between literature and the practitioners' expectations of PSS design process models. Moreover, those activities, methods and tools are mainly focused on eco-efficiency and the social dimension is generally not covered.

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Keywords: PSS; Eco-PSS; Sustainability; Circular economy; Process model.

1. Introduction

Sustainable development has become a recurrent issue in academic, civil society, business and government fields. Recent researches recognize that the dominant neoclassical linear industrial model, which is oriented to obtaining profit from the efficient allocation of resources in the market without necessarily regarding their exhaustible nature, is reaching its limits [1–4]. The approaches being used by society in the last decades to reach sustainability such as end-of-pipe solutions, cleaner production, eco-design, and product Life Cycle Management are mainly environmental oriented and focused on production processes [3]. This sustainability strategy - limited to the micro perspective of individual organizations and still very associated to neoclassical economics - is not enough if the projection of three billion middle class consumers joining the global market by 2030 is taken into account [1,3]. The migration towards a circular economy (CE) is seen as a solution for this future scenario and a more adequate strategy for achieving sustainable development [1,3,4].

The core of CE consists of closing the loop of material and energy flows in order to promote a regenerative industrial system [1,4,5]. CE operates around the linear logic regulating the economic model in light of nature's limitations [4]. Differently from previous sustainability approaches oriented to resource management, CE proposes a radical innovation that surpasses production processes shifting the whole economic logic, lifestyles and consumption patterns [3,4]. Moreover, it affects different scales of society reaching single organizations and consumers (micro level), eco-industrial

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parks (meso level) and even cities, provinces and nations (macro-level) [4,5].

CE implementation involves different initiatives such as applying restoration (reuse, recycle, remanufacture) of materials instead of disposal in the end-of-life; promoting the use of renewable energy; eliminating the use of toxic materials; and reducing waste by improving the design of products, disseminating new technologies (e.g.: 3D printers) and proposing new business models that rethink linear concepts of selling and owning physical products [1,4,5]. These innovative business models are oriented to provide value to customers through utility or solutions of integrated bundles of services and products without the necessity of transferring the property of the physical product to the customer. Such offers are called Product-Service Systems (PSS) [6]. PSS concept emerged within the linear economy. From the business perspective, manufacturing companies started migrating to PSS business models as a way of obtaining price differentiation - which was not possible anymore with only selling products - and enhancing their competitiveness [2]. So, after starting selling spare parts and additional services, they evolved to offering integrated solutions and experiences, which nowadays are optimized with new technologies such as Internet of Things and Big Data. Besides the economic benefits, PSS business models may also contribute to improving environmental and social aspects [7,8].

Due to the economic, social and environmental potentials, the number of researches in PSS field has considerably increased in the last years [2,6,9]. However, despite all the knowledge accumulated in literature, practical application of this concept is still limited [2,6,9,10]. This limitation is even greater regarding sustainable PSS cases [2,9]. According to [9], this occurs because PSS are radical innovations, demanding huge challenges in different aspects of society, such as current customer habits, organizations' capabilities, and regulatory systems. Regarding the aspect of organizations' capabilities, this gap related to sustainable PSS may be associated to the fact that the PSS approach does not guarantee environmental improvements if it is not specifically designed with this purpose [2,3,8,9,11]. In other words, PSS is not a panacea for sustainability issues and is not necessarily more "circular" than product offers [2].

PSS design process models might play a relevant role by supporting companies in designing sustainable PSS. These models use different formalisms (such as graphical, textual, symbolic), elements and relationships to represent the PSS design process. They may be applied for different purposes such as planning and controlling the development of PSS offers [12]. The limitation of sustainable PSS diffusion may be related to gaps in the existent PSS design process models - such as possible lack of proper activities, methods or tools to guide the practitioners in designing a PSS with a sustainable approach - or in the practitioners' awareness of sustainability when applying those process models to develop PSS.

In this context, two research questions arose: "Are the existent PSS design process models able to support the design of sustainable PSS?" and "Do practitioners consider sustainability activities when developing PSS"? Therefore, this study has two objectives: (i) investigating whether process models recognize the sustainability potential and suggest activities, methods or tools to cover sustainability dimensions (economic, environmental and social perspectives [13]), (ii) and whether practitioners consider sustainability activities when developing PSS.

The research methodology is described in the second section of this paper. The third section presents the PSS design process models considered in the assessment. The fourth section discusses the outcomes of this research. Finally, the fifth section presents concluding remarks and insights for future researches.

2. Research methodology

Initially, a theoretical analysis of the PSS design process models focusing on the sustainability dimensions (economic, environmental and social) was performed. Then, similar PSS activities among the process models were identified as a preparation for the empirical analysis. Finally, an empirical analysis by means of focus group was conducted with practitioners in order to understand what they expect from process models concerning the sustainability perspective.

2.1. Theoretical analysis of the PSS design process models

At first, nine PSS design process models were selected from literature as depicted in Table 1.

Table 1. Selected PSS design process models.

Process model	Author
Fast-track design process – PM01	Alonso-Rasgado and Thompson [14]
Integrated product and service design processes – PM02	Aurich et al. [15]
Design of eco-efficient services methodology – PM03	Brezet et al. [16]
APSIT method – PM04	Kar [17]
The Kathalys method – PM05	Luiten et al. [18]
The Design Process for the Development of an Integrated Solution – PM06	Morelli [19]
Detailed IPS² development process – PM07	Nguyen et al. [20]
Service Model – PM08	Sakao e Shimomura [21]
Methodology for Product-Service System (MEPSS) – PM09	Van Halen et al. [22]

This selection was based on previous literature works from Clayton et al. [23] and Vasantha et al. [24], whose reviews approach the assessment of process models to design and implement PSS. Those two works were considered as foundations for this research because they were recently published in reference journals. Besides that, they used strict selection criteria for the assessed methodologies, such as: models should be complete and approach all phases of a PSS development process [23]; and models should focus in the PSS field, be detailed, previously applied in practical cases, published in referred journals with adequate citation, and applicable in complex development business to business

environments [24]. Three process models referenced by Vasantha et al. [24] (Komoto [25]; Maussang et al. [26]; Welp et al. [27]) and one by Clayton et al. [23] (Engelhardt et al. [28]) were not considered in this article due to restrictions in obtaining the original works. The work of Tan [29] was removed because the author actually proposes a methodology to conceptualize a PSS and not a PSS design process model. Nevertheless, one more methodology (Nguyen et al. [20]) published after [23] was considered in the final sample, since it fits to the criterion used by [23].

After the selection, the works were individually analyzed with the support of mind-mapping techniques to cluster information according to three guiding questions: (a) Does the author relate PSS to possible sustainability improvements or reduced environmental impacts? (b) If the previous question is true, does the author understand environmental or sustainability benefits as mandatory in a PSS? (c) Does the model propose, in fact, activities, methods or tools to promote reduced environmental impacts or improve sustainability?

For each PSS design process model, the answer to question "a" was considered as "yes" when the authors explicitly mentioned sustainability improvements. For question "b", the answer was considered as "yes" for the models whose authors stated that sustainability gains were mandatory in PSS or if their PSS definition mentioned sustainability benefits. Finally, question "c" was judged as "yes" when the analyzed process model comprised activities, methods or tools related to sustainability.

2.2. Identification of similar PSS design activities among process models

Previously to the conduction of the empirical analysis, the aforementioned PSS design process models presented in Table 1 were divided into activities. Then, they were compared by means of linguistics techniques that enabled systematically identifying similar activities among those process models, resulting in 253 activities.

From the 253 activities, the ones comprised in the conceptual phase were analyzed by a group of seven PSS academic experts. Their objective was to assure that the activities were not repeated (regarding its meaning) and add activities that they thought were missing. This resulted in 24 activities comprised in the conceptual phase, which were the ones analyzed by the group of practitioners. The practitioners analyzed only the conceptual phase due to time limitation (two hours). The conceptual phase was selected so the awareness of practitioners towards sustainability could be assessed since the beginning of the PSS development.

2.3. Empirical analysis with practitioners

A focus group session was performed with thirty participants from thirteen companies and two universities. Three of the participants were academicians and PSS researchers. The other twenty-seven participants were practitioners from companies that already offer PSS on the market or that are interested in developing a PSS. Their profiles are shown in Table 2.

Table 2. Profile of companies involved in the focus group session.

Company code	Sector
A, C, L	Automotive parts and systems
B, G	Healthcare and medical equipment
D	Agribusiness machinery and solutions
E	Compressors
F	Aeronautics
H	Sugar and energy
I	Plastic transformation machinery
J	Cosmetics
K	Cutting machinery
M	Biodegradable packaging

The participants were organized into eight groups. They had to select which activities from the conceptual phase they would like to perform when designing a particular PSS offering. These participants should discuss to each other and vote in order to select the activities (see Fig. 1). From the 24 activities related to the conceptual phase, only two were directly related to sustainability: "Evaluate sustainability" and "Define end-of-life strategies". This last activity was not originally comprised in the process models, but the PSS academic experts added it. In this paper we were interested in assessing the practitioners' choice regarding those last two aforementioned activities. Although the process models present other activities related to sustainability, they were not considered in the focus group because they were comprised in other phases of the design.

At the end of the workshop, a comparison was made between the practitioners' expectations about the PSS design process models and what they offer in terms of sustainability.

Fig. 1. Focus group with PSS practitioners

3. PSS design process models

The following paragraphs present an overview of each PSS design process model previously mentioned in Table 1.

Alonso-Rasgado and Thompson [14] propose a design process model to support the development of Total Care Products, which has a meaning quite similar to PSS. The "**Fast-track design process**" is structured in five stages that

prioritize the involvement of the client from the beginning in order to build a customized PSS offering.

Aurich et al. [15] present the "**Technical service design process**" which is organized in two categories: product design and technical service design. Each category is subdivided into six stages. The development of technical services is focused on B2B, as in industrial product-service systems (IPS²).

Brezet et al. [16] use the term "Eco-efficient Services (ES)" as a synonym for a PSS with clear environmental considerations. They proposed the "**Design of eco-efficient services methodology**" which is also structured in six stages.

The "**Analysis, Preparation, Synthesis, Implementation and Test (APSIT) method**" described by Kar [17] focuses on the development of mobile information services. The APSIT method emphasizes the involvement of users and has its activities organized in three categories (organizational network, technological architecture and service concept) distributed in its five stages.

Luiten et al. [18] present "**The Kathalys method**", which regards especial attention to environmental issues as in Brezet et al. [16]. The method is organized in five stages to guide the development of sustainable product-service systems. The deliverables of each stage are classified in five categories.

Morelli [19] proposes "**The Design Process for the Development of an Integrated Solution**". It is structured in seven stages and subdivided in two categories: the solution space, which comprises four stages; and the problem space, which comprises three stages.

Nguyen et al. [20] adopt a visualization approach similar to Kar [17] and Luiten et al. [18] to represent the "**Detailed IPS² development process**". The activities of the process model are distributed in seven categories organized in five stages. Likewise Aurich et al. [15], this process model is focused on the development of an IPS² and prioritizes technical activities.

The "**Service Model**" proposed by Sakao and Shimomura [21] is based on the concepts of the Service Engineering community. This process model has an iterative characteristic reflected on its five stages. The authors explain that it is necessary to consider four sub-models (the flow model, the view model, the scope model, the scenario model) in the view of developing PSS.

Van Halen et al. [22] present the "**Methodology for Product-Service System (MEPSS)**". MEPSS, likewise Brezet et al. [16] and Luiten et al. [18], greatly highlights the importance of environmental issues for PSS design. The process model is structured in five stages with decision points between them characterizing a "phase-gate" approach.

4. Results and discussion

From the selected PSS design process models, only six relate PSS concept to potential improvements in sustainability dimensions (Table 3). From those, four authors believe that the improvement in sustainability dimensions is mandatory to the PSS concept. Nevertheless, only three process models suggest sustainability-oriented activities or methods/tools. These numbers indicate that although the majority of the analyzed authors associate PSS to sustainability gains, only the minority of them addresses activities or methods/tools related to sustainability in their process models. This trend indicates a gap in existent PSS design process models in suggesting sustainability-oriented activities, methods or tools for designing a PSS, which corroborates what was previously pointed out in the introduction of this paper.

Table 3. Sustainability approach of PSS design process models (X= adherent to the criterion; "Year" = when the design process model was published).

Process model	Year	Sustainability improvements are related to PSS	Sustainability improvements are mandatory to PSS	Presents activities and methods/tools related to sustainability
PM01	2006	X		
PM02	2006	X	X	
PM03	2001	X	X	X
PM04	2010			
PM05	2001	X	X	X
PM06	2003			
PM07	2014			
PM08	2007	X		
PM09	2005	X	X	X

Moreover, the three process models that suggest sustainability-oriented activities or methods/tools (PM03, PM05, PM09) were published previously to 2006, being two of them published in 2001, when the basic foundations of PSS theory and concept were still being established [6]. An inference that may be extracted from that analysis is that sustainability issues seem to have their relevance decreased in the systematization of design process models as PSS concept evolved and its practical application was disseminated after 2006. Nevertheless, this claim is only a hypothesis that shall be further investigated and confirmed in future researches.

Those authors that link improvements in the sustainability dimensions to PSS associate these gains with two main reasons. The first is the increased resources efficiency, which concerns to less material and energy consumption, increased hardware efficiency and greater durability. This is a consequence of the provider, which now holds the property of the product, aiming to optimize costs of his operations with improved resource management. The second reason is greater users' awareness and improved consumption patterns.

The six PSS design process models that recognize the relation between improvements in sustainability dimensions and PSS are presented in Fig. 2 according to its sustainability orientation. Another remarkable finding is that the majority of publications focuses on the environmental and economic dimensions (eco-efficiency). Only Aurich et al. [15] explicitly indicate social improvements related to PSS, such as the increasing of jobs (for maintenance services, remanufacturing and reuse) and a balanced distribution of work as the service is in general delivered and consumed at the same geographical location using local work force [15]. Those authors also highlight other economic gains of PSS such as increased margin, new market potentials for PSS providers, and higher productivity and economic efficiency for B2B clients [15].

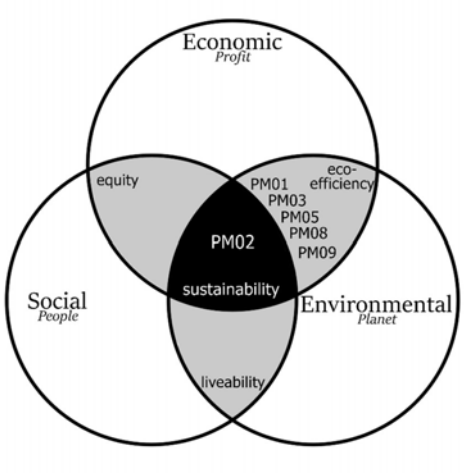

Fig. 2. PSS design process models (PM) and their sustainability orientation.

When it comes to suggesting activities or tools, the analyzed models comprise only an eco-efficiency approach (Table 4 and Table 5). Social dimension is not explicitly presented in the activities, methods or tools of any of the models, even though the author of PM02 highlighted its importance when discussing the benefits of sustainable PSS (Fig. 2). The three process models that incorporate activities or methods/tools related to sustainability in the PSS development, focus mainly in the environmental dimension.

Another finding is that the sustainability-oriented activities suggested in the process models (Table 4) are mainly concentrated in the development phase of the PSS. The majority of activities are applied in the phases of idea generation and conceptualization of the PSS. The presence of such activities in these early phases is fundamental for supporting the practitioners in keeping a sustainability mindset since the beginning. Nevertheless, the models are limited in supporting a life-cycle perspective of sustainability especially regarding the implementation or the monitoring of sustainability results after the PSS is in operation. Only the model PM03 presents one activity ("Measure the environmental impact of the new system and compare with the old system") comprised in the operation phase of the PSS.

Also, in general, the use of eco-design tools for PSS development is not novel when compared to pure product development theory. Two works point to the use of environmental assessment tools that are already known and applied in the traditional product development such as Life Cycle Assessment (LCA), META Matrix and other eco-design methods (Table 5). Some of those tools are slightly adapted as PSS development differs from pure product development. Besides the environmental dimension, there are two models that focus in the eco-efficiency, as they suggest the use of Ecocosts Value Ratio (EVR) [16], Full lifecycle costing, and Screening profitability [22].

Concerning the practitioners' perspective, it seems that companies are giving more importance to sustainability issues. Focus groups' results show that the majority of participants selected activities related to sustainability to carry out a PSS design project. Respectively 93% and 90% of the 30 participants judged necessary to perform activities "evaluate sustainability" and "define end-of-life strategies". Although the selection was almost consensual, it occurred after some discussion in all groups since some participants hesitated to select the activities at first. The main reason stated by them to not select the activities revealed that they undermined the environmental and social dimensions when compared to the economic. Additionally, they faced difficulties in understanding the real meaning of each activity since they were in a very high level of abstraction. Some participants suggested that the process models should be more specific in describing the activities. They also suggested that the models and tools should be improved to better assess trade-offs and effects on economic aspects when trying to improve environmental and social aspects of the PSS.

Table 4. Activities related to sustainability in PSS design process models.

Process model	Activity
PM03	Assess the environmental load of the system
	Measure the environmental impact of the new system and compare with the old system
PM05	Generate sustainable ideas
	Evaluate environmental impact of the solution
PM09	Update sustainability aspects
	Prioritize sustainability guidelines
	Assess preliminary sustainability of PSS scenario
	Visualize sustainability aspects of PSS scenario
	Assess PSS idea for sustainability
	Visualize sustainability aspects of PSS idea
	Evaluate PSS sustainability
	Visualize sustainability aspects of developed PSS

Table 5. Methods/tools related to sustainability in PSS design process models.

Process model	Method/Tool
PM03	META matrix
	Life Cycle Assessment (LCA) tools
	Adapted eco-design tools
	Adapted LiDS-wheel
	Green options generation
	Ecocosts/value approach, EVR
	Eco-purchase
	LCA scenarios
	'Green' communication
	LCA Analysis
PM09	Inventory of sustainable indicators
	Screening LCA
	Sustainability Design-Orienting (SDO) Toolkit
	E2 vector (rebound effect)
	Environmental/socio/economic checklists/ radar diagrams
	Simplified LCA
	Full lifecycle costing
	Screening profitability

5. Conclusions

The adoption of PSS strategies is a promising solution to support sustainable development within the circular economy. Practical application of sustainable PSS is still limited. To understand potential origins of such limitation, this paper analyzed nine PSS design process models to identify gaps related to sustainable dimensions (economic, environmental, and social). Additionally, eight focus groups were performed with thirty participants to assess whether they considered sustainability activities when instantiating process models.

Results showed that the minority of the analyzed process models suggests activities or methods/tools to support sustainable PSS design. Their focus is mainly on eco-efficiency and the development phase of PSS. This deficiency of adequate process models to support sustainable PSS design could be contributing to the limited amount of cases of successful sustainable PSS. Complementarily, the practitioners' perception indicates an existing gap between what they expect from a PSS design process model and what the majority of the existing process models offer to them in terms of sustainability-related activities, methods and tools.

The main contributions of this work are the consolidation of the sustainability approaches of PSS design process models and the identification of a gap between these approaches and the practitioners' expectations. Some limitations were the exclusion of four ([25–28]) process models reviewed by [23] and [24] due to access limitations and the use of a non-exhaustive literature review. In addition, the empirical analysis was conducted in a relatively small group of practitioners, and focused on assessing activities from the conceptual phase of the design process. Future research opportunities are to increase the sample of PSS design process models by extending the literature review besides 2012. There is an opportunity for creating PSS design process models that explore better the three dimensions of sustainability, their interrelationship and their connections to circular economy.

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