PRODUCT-SERVICE SYSTEM (PSS) DESIGN PROCESS METHODOLOGIES: A SYSTEMATIC LITERATURE REVIEW

Mendes, Glauco H. S. (1); Oliveira, Maicon Gouvea (2); Rozenfeld, Henrique (3); Marques, Caio Augusto Nunes (3); Costa, Janaina Mascarenhas Hornos (3)
1: Federal University of Sao Carlos, Brazil; 2: Federal University of Alfenas, Brazil; 3: University of São Paulo, Brazil

Abstract

Studies on Product-Service Systems (PSS) have risen significantly in the recent years driven by economic and sustainable benefits. In the PSS literature, the design of a PSS raises new issues since the service design and product design should be incorporated in the same design process. In this study a systematic literature review is conducted on PSS design process methodologies. The objective is to assess how five PSS design process methodologies support the integration between product and service design activities. Based on an analysis of 246 articles from Scopus database, some bibliometric indicators (number of papers published per year, the most important journals and the most cited papers) were provided. Considering this sample of articles, five PSS design process methodologies were analysed. The main characteristics of these methodologies were identified. More specifically, research findings were accumulated about the strategies used in each methodology for promoting the integration between product and service design activities.

Keywords: Product-service systems (PSS), Design methodology, Service design

Contact:
Prof. Glauco Henrique Mendes
Federal University of Sao Carlos
Production Engineering
Brazil
glauco@dep.ufscar.br

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1 INTRODUCTION

There is a tendency in the industry to seek new sources of value from the integrated offer of products and services. This tendency characterizes the shift from a product-dominant logic to a service-dominant logic (Vargo and Lusch, 2004; Baines et al., 2009; Baines et al., 2011). The term *servitization* was first used by Vandermerwe and Rada (1988), who define it as offering an integrated package (products, services, knowledge, and customer supporting) in order to add value to the core business of a customer. According to Baines et al. (2007), *product-service system* (PSS) is a special type of servitization. The term PSS originated in the 1990s in northern Europe, and it was associated with industrial ecology (Spring and Araujo, 2009). According to Goedkoop et al. (1999), PSS must be understood as a system that combines products and services, provides functionalities necessary to customers and contributes to reduce the environmental impact.

Different terms have been used when a company creates value by adding services in their products, such as *functional products* (Alonso-Rasgado et al., 2004) or *functional sales* (Lindahl and Ölundh, 2001). In industrial business (business-to-business), many authors have adopted the term *industrial PSS* (Meier et al., 2010). The term Product-Service System (PSS) will be used in this article.

The adoption of PSS can benefits providers, customers, the environment, and society (Baines et al., 2007; Cavalieri and Pezzota, 2012; Ceshin, 2013; Beuren et al., 2013). The advantages of PSS providers are primary related to economical and commercial aspects: facilitation of product sales, building of customer loyalty, creation of new revenue streams and maximization of profit margins (Baines et al. 2009). The benefits of customers are: customized offers, greater satisfaction and transfer of the product life cycle costs to PSS providers (Tukker, 2004; Tukker and Tischner, 2006; Cavalieri and Pezzotta, 2012; Beuren et al., 2013). There is also an argument that PSS is capable of minimizing environmental impacts decoupling economic value from material and energy consumption. At last, the society would benefit with these more efficient and sustainable development (Mont, 2002; Morelli, 2006).

The introduction of PSS may involve the development of a business model that changes the company's focus from designing and selling physical products to provide a system capable of meeting specific customer needs through the combination of products and services. The adoption of this model is complex and can leads to changes in organizational structure, processes and culture (Ceschin, 2013). According to Tan (2010), PSS design process is one of the most important changes. This fact is more evident in the use-oriented and result-oriented PSS types (Tukker, 2004), when product and service design should be integrated in the same design process. Furthermore, PSS design also encompasses the development of a new business model (Tan, 2010).

Several PSS design process methodologies have been described in the literature: Service Model (Sakao and Shimomura, 2007; Shimomura et al., 2008, 2009; Sakao et al., 2009), Methodology for Product-Service System - MePSS (Van Halen et al., 2005), Fast Track Total Care (Alonso-Rasgado et al., 2004; Alonso-Rasgado and Thompson, 2006), Integrated Product and Service Design Processes (Aurich et al., 2006). Although the interest for these methodologies has increased over the last years, they still require further empirical evidence and address partially the complexity of PSS design process (Hao et al., 2010; Meier et al., 2011; Cavalieri and Pezotta, 2012; Vasantha et al., 2012; Sakao and Mizuyama, 2014).

Based on these statements, the aim in this article is to conduct a systematic literature review of how PSS design process methodologies support the integration between product and service design activities in the same design process. In this sense, the most cited PSS design process methodologies were selected and analyzed. As a result, this article holds value for both academics and practitioners seeking to advance their knowledge about PSS design process.

The following section describes the research method followed in the article. Then, the results of the systematic literature review are presented and discussed. Finally, conclusions are drawn and opportunities for future research are suggested.

2 METHOD

Cook et al. (1997) argued that the systematic literature review employs research methods with greater scientific rigor. There are different strategies that can be considered in developing a systematic literature review. One of them is bibliometrics, which provides information about a research field through the investigation of its scientific production. Bibliometrics refers to the mathematical and

statistical analysis of the publication data; for example: the most referenced academic papers and the main authors and journals based on a citation analysis (Okubo, 1997). The systematic literature review can also include a content analysis, since it allows the identification of the most important research topics, approaches, and methods. In this article, bibliometric analysis and a content analysis were used to describe how the most cited PSS design process methodologies support the integration between product and service design activities.

The source of information chosen for this study was the Scopus database. This scientific database is one of the largest databases. It includes both major and minor publishers: Elsevier, Emerald, Springer, Wiley, among others. Because this database covers peer-reviewed multidisciplinary research studies, it was certain to find a large number of studies on PSS. The keywords selected to search the initial sample were "product-service system" and "servitization". In addition, the following criteria were considered: articles published until 2013 and articles published in scientific journals and written in English. Meanwhile, conference papers were not considered. The search resulted in 280 papers and the first scientific paper dealing with PSS indexed in Scopus database was published in 1988.

After the reading of abstracts, 34 articles were excluded from the initial sample, since they did not directly address topics related to PSS. Then, the final sample included 246 articles. Two researchers executed this filtering process. They read abstracts twice (double check process) to ensure that articles excluded in the first run did not meet the criteria for inclusion.

Next, a bibliometric analysis was performed using the VantagePoint (Search Technology, 2006), Ucinet and NetDraw (Borgatti, 2002) softwares. They were used to provide predefined analyses, which were carried out to explore the final sample: number of papers published per year, the most cited journals, the most used words in titles and keywords and the most cited references. At the end, a content analysis was employed to investigate PSS design process methodologies described in the most cited references.

3 BIBLIOMETRIC ANALYSIS

This article considered papers published between 1988 and 2013, which means a time span of 26 years. Figure 1 shows the histogram of papers throughout the years.

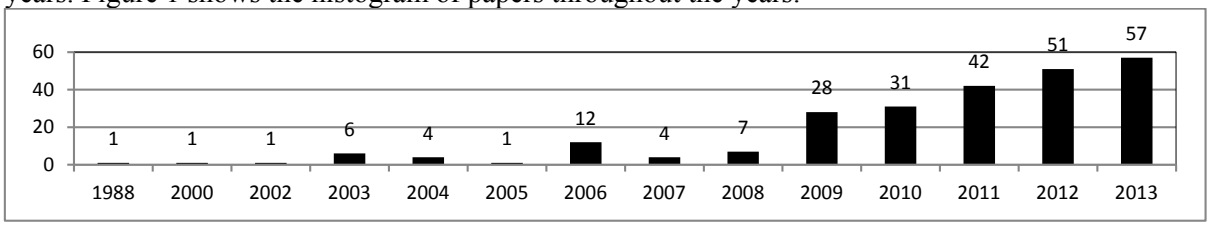

Figure 1. Frequency of articles

The histogram shows a strong growth of PSS publications after 2008. In the period between 2003 and 2008, the average was 5.6 articles per year, and there was a peak in 2006 due to the publication of a PSS special issue in the Journal of Cleaner Production. In the following interval (between 2009 and 2013), there was an expressive growth, which represents 85% of the total publications and an average of 41.8 articles per year. Given the growth in the number of publications on the PSS in recent years, the increased interest in this research field is evident.

The 246 articles were published in 88 journals. Table 1 shows the journals with at least five publications included in the final sample. The Journal of Cleaner Production is the dominant source of articles in the PSS literature, accounting for 33 of the 246 articles (13.7%). This fact reinforces that PSS is well-connected to sustainability. In addition, the Journal of Manufacturing Technology Management accounts for 18 articles, and the CIRP Journal of Manufacturing Science and Technology and the International Journal of Production Research account both for 14 articles each. It is clear that the PSS topics have spread around many different research areas: sustainability, operations, technology, services, business, design, product development, and others.

Table 1. Top journals with at least five publications included in the review.

Journal	Articles	Journal	Articles
Journal of Cleaner Production	33	CIRP Annals – Manuf. Technology	8
Journal of Manuf. Technology Management	18	Int. J. of Operations and Production Management	8
CIRP J. of Manuf. Science and Technology	14	Int. J. of Internet Manuf. and Services	6
International Journal of Production Research	14	Int. Journal of Product Development	6
Int. Journal of Adv. Manuf. Technology	13	Proceeding of the Institution of Mechanical Engineers, Part B.	6
Computers in Industry	10	Service Business	5

The keyword network (see Fig. 2) was created considering the keywords that had ten citations at least. This network intends to map the keywords most frequently used by the authors and to identify the main research subtopics in the PSS research field. The size of the node represents the centrality (most used keywords), and the ties show the keywords that have been mentioned together in the sample. The intensity of such relationships is given by the line thickness. Thicker lines represent stronger connections.

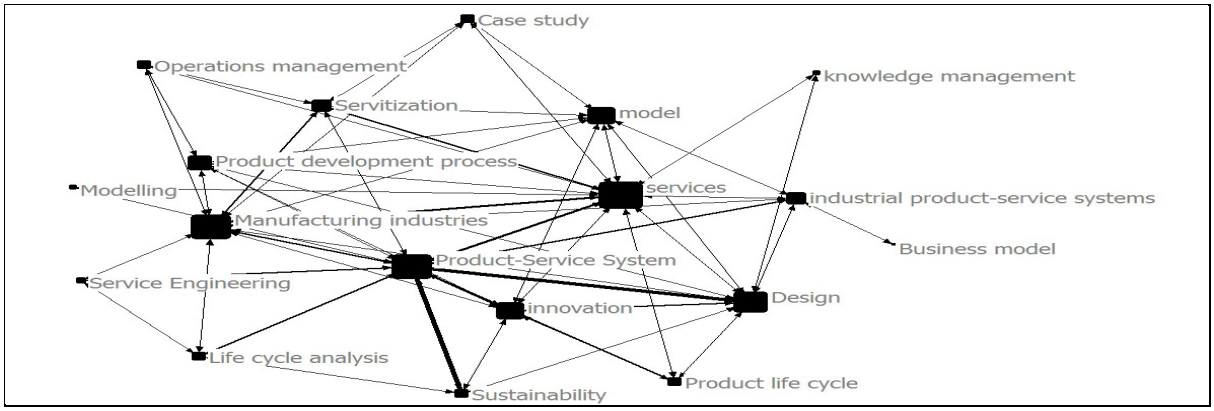

Figure 2. Keyword Network

The main connections revealed using this analysis are between product-service system and sustainability, product-service system and services, and product-service system and design. The PSS design has become a prominent topic mainly after 2009. PSS design process articles have been written dealing with the following topics: "PSS configuration," "PSS concept," "PSS design methodologies," "application of CAD system," "PSS requirements," "modelling," and others.

After exploring the most used keywords, the most cited references were explored. They represent articles that had strong influence on the PSS authors. More than 5.900 references were cited for the sample's article. Table 2 shows a list of papers cited at least 30 times for others.

Table 2. Most cited references in the sample.

Most cited references	Citations	Most cited references	Citations
Baines et al. (2007)	117	Wise and Baumgartner (1999)	43
Mont (2002)	91	Morelli (2006)	40
Goedkoop (1999)	81	Alonso-Rasgado et al. (2004)*	37
Aurich et al. (2006)*	72	Neely (2007)	37
Tukker (2004)	71	Vargo and Lusch (2004)	34
Oliva and Kallenberg (2003)	62	Sakao and Shimomura (2007)*	33
Manzini and Vezzoli (2003)	54	Van Halen et al., (2005)*	32
Vandermerwe and Rada (1988)	51	Morelli (2003)*	31
Tukker and Tischner (2006a)	49	Cook et al. (2006)	30
Tukker and Tischner (2006b)	44		

* Articles related to PSS design process methodologies

There are three groups of articles that have influenced the PSS authors in Table 2. The first group is formed by articles that addressed the PSS in a more comprehensive perspective (Baines et al., 2007; Mont, 2002; Goedkoop, 1999; Manzini and Vezolli, 2003). They also can be assumed as classical papers in the PSS literature, which means that they had an important role in the introduction of PSS research field, presenting the main concepts, benefits, and barriers. It´s noteworthy the Manzini and Vezolli's paper that depicts Italian examples of eco-efficient PSS, but also highlights that new design activities (scenario building, service idea and service design) should be integrated with proper guidelines for sustainability. The second group is formed by papers that discuss the importance of creating and delivering services to manufacturers in general, a phenomenon known as servitization (Oliva and Kallenberg, 2003; Vargo and Lursch, 2004; Neely, 2007). At last, a group of papers and books that is strictly related to PSS design process methodologies (Aurich et al., 2006; Morelli, 2006; Alonso-Rasgado et al., 2004; Sakao and Shimomura, 2007; and Van Halen et al., 2005). These researchers have proposed design models for PSS, which will be explored in the next section.
In sum, this bibliometric analysis recognized the PSS design as an important topic in the PSS research field, which means that the scientific community has been trying to answer a challenge to design PSS projects with more suitable models, methods, and tools.

4 PSS DESIGN MODELS

Considering the bibliographic references in Table 2, five models have been selected for this article. The methodologies selected are supposed to be highly referred to within the PSS community and, therefore, they had an important role in influencing other authors. Table 3 summarizes main characteristics of the PSS methodologies discussed.
The first PSS design process methodology is **The Design Process for the Development of an Integrated Solution** proposed by Morelli (2002; 2003). For the author, PSS represents a new combination of technological artefacts on the basis of functional parameters and, consequently, the design of PSS consists of proposing a set of products, activities, and cultural values directly to the customers. This model consists of an interactive sequence of phases that happens in two dimensions of space: a problem space and design space. The phases in the problem space are: market analysis, use case development and test. The phases in the solution space are: value proposition, definition of product/service structure, prototype architecture and final definition. In PSS design should be given attention for the identification of actors involved in PSS and the simulation of possible PSS scenarios (Morelli, 2006).
The **Service Model (Service Explorer)** was proposed in the Service Engineering community (Sakao and Shimomura 2007, Shimomura et al., 2009; Sakao et al. 2009). The focus is on the development of service contents (material, energy, or information) and channels that are used for changing the receiver's state directly. The authors introduce four sub-models: (a) the flow model, (b) the view model, (c) the scope model and (d) the scenario model. A flow model represents a stream of a service, which may consist of contents and channels, among intermediate agents. A view model represents the mutual relationships among the service agents. A scope model represents a target area of a service, and the scenario model represents the behavior of the receivers during the service delivering. The authors have implemented these sub-models in a prototype software tool that is named service explorer, which combines Service CAD tools and service blueprint, and employs the Business Process Modeling Notation (BPMN).
The **Fast Track Total Care** is a methodology for designing functional products (total care products) to provide complete functional performance for the clients. It is an interactive process between customer and supplier developed in five stages (Alonso-Rasgado et al., 2004; Alonso-Rasgado and Thompson, 2006). The aim of this methodology is to develop a process of creation of functional products, but there is a great emphasis on the creation of the business proposal. For instance, the model starts with the first business contact with the customer and finishes with the contract commitment. A computational tool should be used for supporting the creation of the system architecture and business aspects of the total care product. Another function of this tool is to reduce the development time. However, this tool is not explained in detail by the authors. At last, no representation technique is mentioned.

The methodology proposed by Aurich et al. (2006), the **Integrated Product and Service Design Process**, has the aim of designing products integrated to technical services. The authors have stressed the potential of technical services for more sustainable production and consumption. For them, PSS is a solution formed by both physical (products with higher monetary value and importance) and nonphysical components (technical services) offered through a business-to-business relationship. The methodology is based on two central points: the systematization of the process for developing technical services and the application of a modularization strategy to promote the integration of product development and service activities. A life cycle perspective is included in this model and it is supported by a modular library (Aurich et al., 2006). Lastly, the authors use the unified modeling language (UML 2.0) for representing the designing of technical services.
The last methodology is the **Methodology for Product-Service System** (MePSS) proposed by Van Hallen et al. (2005) within the PSS research community with a focus on developing more sustainable product-services. It is a model to assist the creation of new PSS offerings. The MePSS is organized in a modular approach too. Each phase is structured in steps, and steps are described by a series of processes. The model also encompasses gates among their phases as decision points. The authors developed a Web tool in which they provide more information about the model, their phases, process and tools. Mind maps are used as representation technique.

Table 3. PSS design process methodology characteristics.

Methodology	Definition of PSS	Emphasis	Representation	Tool Support	Main References
The Design Process for the Development of an Integrated Solution	A systemic solution including products and services	Service Design	IDEF0 and blueprint	Not mentioned	Morelli (2002, 2003, 2006)
Service Model	A discipline seeking to increase the value of artefacts by focusing on service	Service Design	BPMN and Service Blueprint	Service CAD Service Explorer	Sakao and Shimomura (2007); Shimomura et al. (2008, 2009); Sakao et al. (2009)
Fast Track Total Care	An integrated systems comprising hardware and support services	PSS Business Proposal	No representation technique is mentioned	Supported by computational tool	Alonso-Rasgado et al. (2004); Alonso-Rasgado and Thompson (2006)
Integrated Product and Service Design Processes	Technical PSSs are interrelations between physical products and non-physical services	Service Design Systematization and Modularization	UML for designing technical services	Not mentioned	Aurich et al. (2004, 2006).
Methodology for Product-Service System – MePSS	An interconnected system of products and services	PSS Design Process	Mind maps	Web tool	Van Halen et al. (2005)

4.1 Discussing the integration

The potential benefits of PSS can only be achieved when the integration of products and services is reached. Tan et al. (2006) state that integration in the PSS development needs to be considered on three levels: strategic business level (planning the cooperation with networks and service partners), PSS development level (development of the product/service offer) and PSS delivery system level (the development of service channel). Companies must gain integration insights from these three levels in order to achieve the potentials of PSS. However, PSS literature is sparse on the management, coordination and integration of development activities of PSS design. Therefore, it is essential to understand how the integration of product design activities and service design activities is considered in the PSS design process methodologies listed in Table 2.
Table 4 shows the phases of the five PSS design process methodologies. Firstly, the PSS design process was divided into four groups of activities: PSS planning, PSS development, PSS test and PSS implementation. PSS planning includes all early activities for creating a PSS idea or a PSS business

model. PSS development includes the search for potential solutions and detailed development for each PSS element (product, service, system, etc.). PSS test covers the execution of tests and prototypes in order to identify potential failures or improvement in the PSS projects. Lastly, PSS implementation is equivalent to the start of production in manufacturing. Therefore, a start of PSS takes place at the end of this phase.
In general, the five analyzed models emphasize the early phases of the PSS design process. All of the models have activities regarding the planning and development of PSS. The phases covering the test and implementation of the PSS are not stressed in some models, and only general information is given. The phases addressing the end of product cycle life (use, repair, maintenance, and disposal) are not considered sufficiently in the PSS models.

Table 4. PSS design methodology phases

Methodology	Planning	Development	Test	Implementation
The Design Process for the Development of an Integrated Solution	Value proposition Market Analysis	Definition of product/service structure	Architecture and Test Final definition	
Service Model	Making a preliminary flow model Describing the target receiver	Describing the value Generating the realization structure Modifying the flow Model	(computational tool for simulation)	
Fast Track Total Care	Business ambitions of the client	Potential business Solutions Core definition of TCP + TCP options Enhanced definition of the potential TCP	Business case risk analysis and options Business case validation and evaluation of alternatives (ending with the contract formulation)	
Integrated Product and Service Design Processes	Customer demands identification Feasibility analysis	Concept development Service modelling Realization Planning	Service Testing	
Methodology for Product-Service System – MePSS	Strategic Analysis Exploring opportunities PSS idea development	PSS concept development	Development and Implementation	

The **Design Process for the Development of an Integrated Solution** methodology was based on the development of a telecentre case, which provides office space and facilities for work activities. According to the author (Morelli, 2002; 2003), a PSS project is originated in the space of interaction between the service designer and the customers. Therefore, its methodology tends to adopt service-oriented process rather than a traditional product development process, mainly because products are addressed as artefacts for service offerings. Products are not designed, but selected and combined to satisfy service cases and requirements. The design process, consisting in an iterative sequence of phases, is defined as the social construction of technological systems, which emphasis is given in the relational and organizational domains. To conclude, there is no clear integrated development of products and services in this methodology.
In the **Service Model** (Sakao and Shimomura, 2007, Shimomura et al., 2009; Sakao et al., 2009), the authors also present a model focused on the service development and on the analysis of those involved in the servicing (especially the receiver). This analysis supports the collection of client parameters, which are used to configure the service and the product (generating the realization structure). The authors state that the model seeks to perform parallel service and product development processes. However, it is noted that the emphasis is regarding the service and after the product. Despite this, the possibility of iteration in the phases of describing the value and generating the realization structure is also possible. Indeed, they mention the integration through the realization structure, in which products are treated as an input of the process. In conclusion, this process methodology follows service design

models, but with no evidence of integrated development of products and services. Actually, they propose that product design should be addressed in parallel to service design.
In the **Fast Track Total Care,** the authors (Alonso-Rasgado and Thompson, 2004; 2006) present a clear perspective based on the business development rather than product or service. In the creation of a total care product, the design of services and products are considered at the same time, and the effect of one on the other is considered. The integration is evidenced in different phases of the process. For example, in the business ambitions of the client phase, customer and supplier must decide on the most suitable combination of service and hardware in the offer. In the enhanced definition of the potential TCP phase, the hardware description and the service support system are defined in increasing detail. Although the authors mentioned that they worried about the integration between product and service support system in all phases of their model, they do this superficially, and the level of granularity in the methodology is not detailed.
In the **Integrated Product and Service Design Processes**, the authors (Aurich et al., 2006) argue that due to the interrelation between physical and nonphysical components, a good strategy would be adapting the already-existing product design processes to account for the special characteristics of technical services. Therefore, the service design activities should be implemented into the product design process. In order to link product and service, the concept of process modularization should be used. The idea is to build a library of building blocks for product and service design as well as the activities in the end of the life cycle. In the PSS design process, modules of traditional product and service design are linked, made parallel and integrated by means of matching corresponding inputs and outputs. A case example was given by the authors (Aurich et al., 2006).
The **Methodology for Product-Service System (MePSS)** provides active support during actual phase-by-phase execution of PSS innovation projects (Van Hallen et al., 2005). The MePSS is organized in a modular approach and it has five main phases: strategic analysis, exploring opportunities, PSS idea development, PSS development and implementation. The authors do not distinguish between product and service design activities, since they are focused on the development of PSS. For example, in phase 1 (strategic analysis), the idea is to create new PSS business concepts. At the end of phase 2 (PSS idea development), the aim is to formulate contrasting scenarios and related sustainable PSS ideas. In the next phase (PSS development), the most promised PSS idea is detailed in terms of system, offering, and interaction. In the last phase (PSS development and implementation), the company should consider commercialization options for the selected PSS. Although the authors have treated product and service as a single entity in all phases of MePSS and have offered some PSS tools combining product and service, the integration between product and service design activities is not so explored.

5 CONCLUSIONS

This article presents a systematic literature review on PSS design process methodologies. It aims at assessing how these methodologies support and promote the integration between product and service design activities. Several PSS design process methodologies have been proposed in the PSS literature. In this article, the five most cited methodologies were selected and reviewed. Some of them tend to be service-centric (Design Process for the Development of an Integrated Solution and Service Model). Others have emphasized a creation of a proposed business (Fast Track Total Care and MePSS). The Integrated Product and Service Design Processes (Aurich et al., 2006) tend to be product-centric, incorporating the service design activities into product design.
After presenting the results of this systematic literature review, it is possible to highlight some implications for the PSS design process research:

- Designing a PSS is different from designing only a service or a tangible product. New activities, new actors, new relationships among these actors, new technological artefacts, new cultural and social values, interactions and other elements should be considered in a holistic PSS design process. Although the five methodologies recognize the complexity of designing a PSS, they do not properly model these elements together. As mentioned before, they are focused on different elements and dimensions (business, technological, organizational or social).
- It is possible to note some common aspects among the five methodologies observed. First, the emphasis is given on the early stages of PSS design process. As consequence, the other life cycle

phases such as test and implementation are not sufficiently considered. Second, the service process is stressed by all authors. The service process is the base of the model (Service Model and The Design Process for the Development of an Integrated Solution) or the authors showed interested in providing a systematic service process in their work (The Fast Track Total Care and Integrated Product and Service Design Processes). In the MePSS methodology, services and tangible products are referred as PSS offering (single artefact) and there is no distinction about service design and product design.

- At last, it has been agreed that designing PSS is a co-creation process, but the involvement of client and other partners should be more appropriately addressed.
- PSS design process seems to be not sufficiently understood from a scientific standpoint. Concerning the integration of product and service design processes, process modularization has been identified as a promising approach for different PSS models (Integrated Product and Service Design Processes and Fast Track Total Care and MePSS). Moreover, how to integrate product and service in different levels (strategic business, process development and end of life cycle activities) should be further explored.

This article clarifies that the PSS design requires further investigation. There are research gaps concerning activities, representation, and PSS tools that, if explored, can contribute for improving the integration between product and service processes. To conclude, this article contributes to theory by providing a critical review of several PSS design process methodologies. Some limitation of this study could be addressed for future research. One limitation is the short number of methodologies considered, which could include more methodologies published in journals as well as in conferences' proceedings. Furthermore, other dimensions and variables of the PSS design process methodologies could be analysed.

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