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Product-Service Systems across Life Cycle

Comparing PSS design models based on content analysis

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Abstract

The combination of products and services in an integrated offer that delivers value through the provision of a required function is recognized as an important strategy for competitiveness and environmental perspectives. Despite its benefits, the design of a Product-Service System (PSS) is considered more challenging than the design of pure products and services. There are proposals of generic models of PSS design processes to support companies when creating their specific models. This paper presents a comparative analysis of the five most cited generic process models, addressing a level of granularity based on process activities, meanwhile other studies have mostly stopped at the phase level. It employed a content analysis approach to perform the comparative analysis. The results show that the analyzed process models prioritize activities related to "Conceptualization" and "Technical Development (Product, Service and Software, Integration)" categories of the PSS design. They also focus on different parts of these categories, being complementary to each other. Thus, this study suggests that companies should not choose only one of them as a reference to create its own PSS design process, but they should look for elements of different models that fit to their purposes and characteristics. At the end, perspectives for future research are discussed.

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Keywords: Product-Service System; PSS design model; Content analysis.

1. Introduction

Companies are seeking to better satisfy their clients' needs through offerings that combines product and services [1,2]. In a Product-Service System (PSS), the value is not only embedded in a physical asset, nor delivered via an ownership transfer, but in a provision of a required function based on a bundle of products and services [3–6]. For example, a PSS provider can sell clean clothes, warm and mobility instead of a washing machine, a heater or a car [4]. This new way of doing business introduces potential benefits to the PSS provider, its customers and the environment [1,6–11].

In the development of a PSS, traditional manufacturers systematically develop "tangible" components as well as create the "intangible" part of the system without the same rigor [12]. The service design process is performed detached from product design process, which leads to insufficient consideration of the interrelationship between products and services during PSS design [13].

The presence of a formal process is accepted as a best practice for product development [12–14]. This is also true for PSS design [15,16]. There is already a set of generic PSS design process models proposed in the literature as can be seen at the reviews conducted by Tukker and Tischner [17], Clayton et al. [18] and Vasantha et al. [19].

It can be noticed by analyzing these models that they have their own particularities. Moreover, they have different focus, comprehend different lifecycle phases and were proposed to be applied on different industries. Then a comparison of the existing models is helpful to support future PSS implementations.

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Tukker and Tischner [17], Clayton et al. [18] and Vasantha et al. [19] had already compared generic PSS design process models. However, their analyses were conducted at the phase level of the process models.

This paper aims at comparing the five most cited PSS generic models, allowing for the understanding of their similarities, differences and gaps. As a result, contributions are expected for both academics and practitioners seeking to advance their knowledge in the PSS design process.

The subsequent sections of this paper are: section 2 presents concepts of process modeling and a short description of the process models analyzed; section 3 explains the methodology; section 4 shows the main results of the analysis; and section 5 discusses the conclusions.

2. PSS design process

A company may be understood as a collection of processes, in which some of them are known as business processes [20]. They can be represented by process models using different formalisms (graphical, textual, symbolic, etc.), including its constituent elements and relationships [21]

The process models have many purposes, such as being the basis for planning and control [21]. To satisfy this purpose, they are usually structured in phases, gates and activities (see this structure in Fig. 1). The phases are the highest level of abstraction in a process model and are separated by moments of evaluation and decision-making, called gates. At last, each phase is represented in detail by its activities.

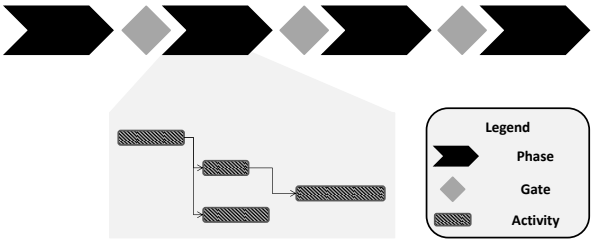

Fig. 1. Schema of generic process elements.

The process structure has been used by review articles that aim at analyzing PSS design models [17-19]. Mendes et al. [22] conducted a systematic literature review of PSS design process models adopting the process approach. Using bibliometric analysis, the authors identified the five most cited papers (models) dealing with PSS process models, presented in Table 1.

Aurich et al. [15] present the "**Integrated product and service design processes"** model for the development of technical services, organized in two dimensions: one related to product design and other to service design. Their model 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 between product development and service activities.

The process model proposed by Alonso-Rasgado and Thompson [9] is focused on the development of functional products (Total Care Products). Particularly, the "**Fast-track design process**" highlights the iterative design process conducted by the PSS provider and the client. Great emphasis is put on the development of a business proposal [22].

Table 1. The five most cited PSS design process models.

Process model	Author
Integrated product and service design processes – PM1	Aurich et al. [15]
Fast-track design process – PM2	Alonso-Rasgado and Thompson [9]
Service Model – PM3	Sakao e Shimomura [23]
Methodology for Product-Service System (MEPSS) – PM4	Van Halen et al. [16]
The Design Process for the Development of an Integrated Solution – PM5	Morelli [24]

The "**Service Model**" has its origin on the Service Engineering community [22]. Sakao and Shimomura [23] present a process model in which four sub-models (the flow model, the view model, the scope model, the scenario model) are necessary to design PSS.

Van Halen et al. [16] proposed the Methodology for Product-Service System (MEPSS). Among the process models presented in Table 1, "**MEPSS**" is the one which most emphasizes the environmental issues in PSS design [22]. The model is organized in phases, which are structured in steps representing a series of processes. The model also encompasses gates among their phases.

At last, Morelli [24] presents his process model through a case study. The activities of the "**The Design Process for the Development of an Integrated Solution**" are conducted in an iterative manner in two dimensions: the problem space and the solution space [22]. The design of PSS consists of proposing a set of products, activities, and cultural values directly to the customers.

3. Methodology

This paper aims to perform a comparative analysis of the five most cited PSS design process models showed in Table 1 and identified by Mendes et al. [22].

The Content Analysis (CA) was employed to support a systematic analysis of the selected models. CA comprises a set of techniques for analyzing communication/information. Moreover, with this methodology, qualitative data is used for discovering new meanings or concepts contained in written texts [26]. As the five models are described in scientific papers, the code is "written" and the channel is "mass communication", according to the Bardin's [25] classification.

The CA technique employed was the Categorization analysis, which consists of a data reduction technique by means of coding and thematic organization [26]. The following steps were performed:

1. Each process model was decomposed into activities, which represent the unit of analysis;
2. The explanation offered by the authors for each activity was recorded (codes);

3. The activities were grouped in categories by similarity according to their names and contents. According to Bardin [25], the categorization can be made with categories previously defined or with new categories emerging from the data analysis. The last one approach was adopted in this paper. The categories were constituted in order to group similar activities and to avoid that an activity could be classified in more than one category. And the names given to the emerged categories represent knowledge areas considered important by the authors of the PSS design process models;
4. The activities grouped in each category were organized in a list of activities. The intention was to create a complete list of activities for each category. Redundant activities (similar activities in more than one model) were counted and considered just once. The result was a Synthesis of activities (a single model composed by the activities from the analyzed models), which can be considered a more detailed process model for PSS design. Due the length limitation of this paper, the activities will not be presented;
5. To prevent bias on this step, the Synthesis was evaluated and confirmed through a panel of specialists;
6. At last, radar graphics were used to represent the results obtained for each process model. They show how each model emphasizes the PSS categories proposed. To build the graphics, the activities of the models were plotted together with the activities of the Synthesis. The next section presents insights that were drawn from these results.

4. Evaluation of PSS design process

As mentioned at the previous section, the list of activities that synthesizes the five process models is not presented in this paper, however in the column "Synthesis" of Table 2 is presented the number of activities classified at each category. It also presents the categories that emerged from the categorization phase. Therefore, the "Synthesis" model has twelve categories and 99 activities. As aforementioned, it can be considered a detailed reference model for developing PSS.

It can be noticed that "Conceptualization" and "Technical Development (divided in "Product", "Service and Software" and "Integration")" are the more emphasized categories, while "Technology and Marketing Analysis", "Environmental Analysis", "Strategy" and "Stakeholder Analysis" are not deeply approached.

On the right side of Table 2, we have the five most cited PSS design process models according to Mendes et al. [22]. In the columns PM1 to PM5 are presented the number of activities of each process model in each category. The decomposition of the process models resulted in: 40 activities from "Integrated product and service design processes (PM1)"; 36 activities from "Fast-track design process (PM2)"; 10 from "Service Model (PM3)"; 32 from "MEPSS (PM4)" and 12 activities from "The design process for the development of an integrated solution (PM5)".

These data shows activities per PSS design process model in each category. Therefore, it is possible to identity their particularities and emphasis in covering categories of PSS design process.

Although the five models recognize the complexity of PSS design, they do not properly cover all categories in PSS design. By analyzing Table 2, it can be seen that none process model contains activities of all categories. The most complete model, considering the number of categories covered, is the "MEPSS [16]".

Table 2. Number of process models activities grouped in each category.

	Process model					
Category	**Synthesis**	**PM1**	**PM2**	**PM3**	**PM4**	**PM5**
Strategy	4	0	2	0	2	0
Technology and marketing analysis	3	1	0	0	2	1
Project management	7	1	3	0	4	0
Stakeholder analysis	4	0	0	2	4	0
Requirement definition	7	4	3	4	3	4
Conceptualization	26	11	12	3	10	0
Financial evaluation	7	1	6	0	0	0
Technical development (Product)	9	9	0	0	0	0
Technical development (Service and Software)	9	7	2	0	0	1
Technical development (Integration)	11	0	6	1	3	6
Environmental analysis	3	0	0	0	3	0
Launch and Implementation	9	6	2	0	1	0
Total	**99**	**40**	**36**	**10**	**32**	**12**

The particularities of each process design model can be better visualized from Fig. 2 to Fig. 6, in which the radar axes represent the twelve categories presented in Table 2. To facilitate the interpretation, the scale of axes was normalized from 0% to 100%. Finally, the dots plotted represent the percentage of activities in a category covered by a particular process model.

In Fig. 2 is presented the radar of "**Integrated product and service design processes**" model proposed by Aurich et al. [13]. PM1 emphasizes "technical" aspects of PSS design. Consequently, activities involving physical product design (technical product development) as well as the design of non-physical services (technical service) are predominant in this model. Moreover, the service design activities should be implemented into the product design process and the modularization approach should be used for this goal. "Launch and Implementation" and "Requirement definition" are important as well due to life cycle perspective presented in this model. According to the authors, the allocation of service design tasks to decentralized services must be systematically

supported in order to flexibly meet changing customer requirements.

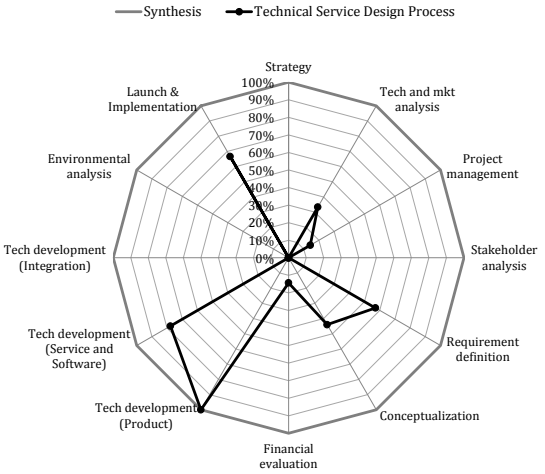

Fig. 2. Profile of "Technical Service Design Process (PM1)" related to the Synthesis.

The radar of "**Fast-Track Design Process (PM2)**" is shown in Fig. 3. The process model proposed by Alonso-Rasgado and Thompson [9] presents a clear perspective based on the business proposal rather than product or service technical development activities. In the creation of a total care product, it is necessary to run an iterative process between customer and supplier that occurs in all phases of this methodology. Although the design of services and products should be considered at the same time, no further information about how to get this integration is given by the authors.

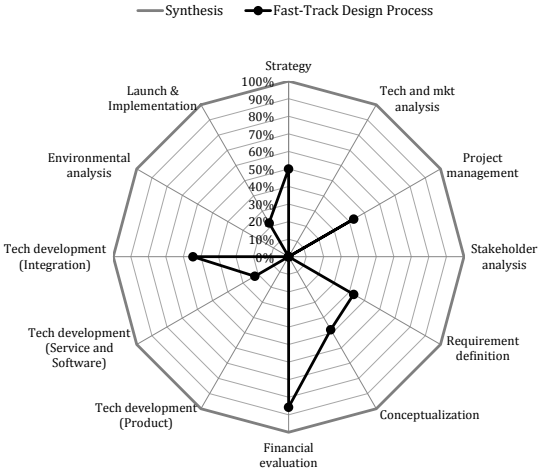

Fig. 3. Profile of "Fast-Track Design Process (PM2)" related to the Synthesis.

Besides the conceptualization category, the authors emphasize the customer requirement definitions and financial aspects of Total Care Product solution. For example, there are two phases (Business case risk analysis of options and Business case validation) dedicated to identify the risks involved in this offering, in particular the financial risks. After this, a contract should be assigned between customer and PSS provider, ending the Fast-Track Design Process.

The "**Service Model (PM3)**" focuses on the service development and on the analysis of those involved in the servicing (especially the receiver). The authors introduce four sub-models. The scope model identifies the parameters that should be attended in order to change the receiver state. A flow model represents the sequential chain of agents of a service. A view model represents the mutual relationships among the service agents. Finally, the scenario model represents the behavior of the receivers during the service delivering. A software tool supports the implementation of these four sub-models.

Due to the high level of granularity in the presentation of the Service Model, the identification of specific activities among the four sub-models was difficult. This fact can be interpreted as a weakness of this model since it fails to support practitioners that desire to follow it to implement PSS. A possible explanation is the emphasis on Service Engineering, which characterizes the work of these authors. As a result, the activities of this model were classified only into three categories. The emphasis is on "Requirement Definition", "Stakeholder analysis", "Conceptualization" and "Technical Development (Integration)". However, in this last category, the authors do not provide detailed evidences. In conclusion, this PSS design process models follows a service design emphasis.

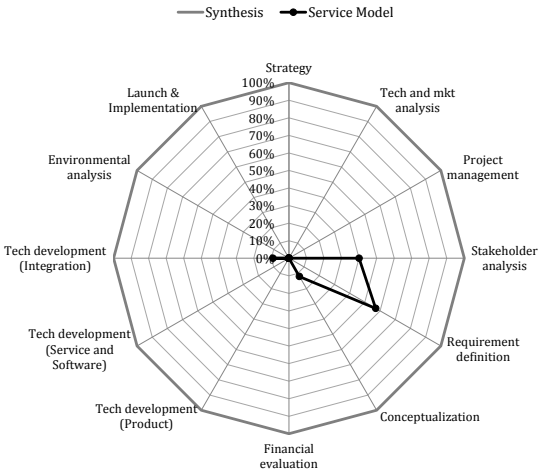

Fig. 4. Profile of "Service Model (PM3)" related to the Synthesis.

"**MEPSS (PM4)**" is the PSS design process model which better distributes its activities through the categories, as can be noted in Fig. 5. It provides a phase-by-phase process with focus on the development of sustainable PSS. The model 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.

MEPSS practically complements PM1, once it accentuates "soft" activities, considering much more activities in categories that are not fully covered by other models. Stakeholder and Environmental analyses are examples. The identification and assessment of sustainability aspects and the engagement of stakeholders can be identified during all phases of this model. Other categories such as "Strategy", "Technology and Market Analysis" and "Project Management" are also well discussed.

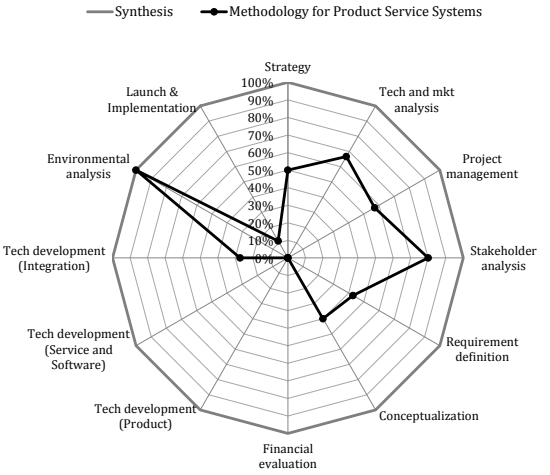

Fig. 5. Profile of "Methodology for Product-Service Systems (PM4)" related to the Synthesis.

The last process model is "The Design Process for the Development of an Integrated Solution" (Fig. 6). This model is influenced by the design school due to the background of its author. In fact, it proposes methods to be used by design professionals for creating new PSS projects.

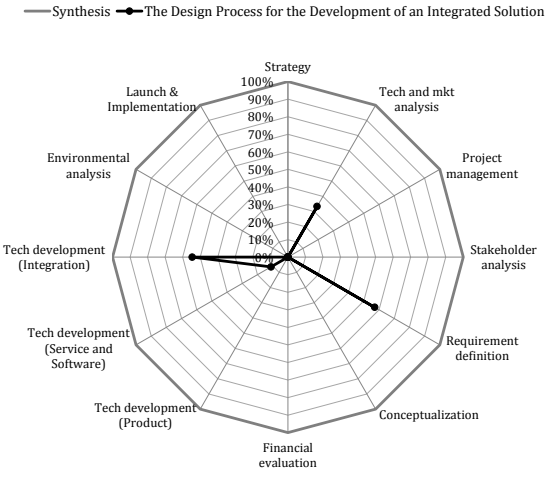

Fig. 6. Profile of "The Design Process for the Development of an Integrated Solution (PM5)" related to the Synthesis.

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. The model contains 12 activities, highlighting the "Requirement Definition" once the interaction between the service designer and the customers is critical, especially in its two first phases (Value proposition and Marketing Analysis).

Another important category in this model is "Technical Development (Integration)", in which the concept is refined, a structure for product/service is proposed and functional requirements are specified and tested. However, it tends to adopt a service-oriented process rather than a traditional product development process. It occurs mainly because products are addressed as artefacts for service offerings. Products are not designed, but selected and combined to satisfy service cases and requirements.

5. Conclusions

This paper presents an analysis of PSS design models. It follows a different approach from that of Tukker and Tischner [17], Clayton et al. [18] and Vasantha et al. [19]. These authors compared process models through their phase level, while the comparison presented in this paper goes further: to the activity level. Therefore, this paper contributes to increase the knowledge about PSS design by conducting a detailed analysis of PSS design models. As a result, it identifies categories and describes those that are not fully explored by these models.

The content analysis of Bardin [25] was used to analyze the publications of PSS design process models. Among all the available models, five of them were selected due to the fact that they are the most cited in the PSS literature according to Mendes et al. [22]. With the content analysis it was possible to explore the process models at the activity level, based on their content.

Based on this study, it is possible to highlight two main implications for the PSS design process research.

First, according to Table 2, the five PSS design process models have activities mainly related to "Conceptualization" and "Technical Development (Product, Service and Software, Integration)" categories. Although these two areas are essential for developing a PSS, they do not represent the complexity of such process. Other areas of knowledge need to be more appropriately addressed for significant improvement of PSS design processes. They include "Environmental Analysis", "Strategy" and "Marketing and Technology Analysis". Particularly, the focus on sustainable PSS is constantly mentioned in PSS literature, however the PSS models reviewed do not emphasize this category. This observation is not only based on the number of activities, but on the emphasis of the models as well.

A second implication is regard to the models. As aforementioned, they focus on different disciplines (technical, service development, service engineering, business and design) depending on the goal of the model and the background of their authors. Thus, in this analysis emerged the understanding that the process models should be considered complementary. Thereby, when a company decides to create its own PSS design process model, it should

not necessarily choose just one generic process model as reference. Based on this fact, this study can conclude that the existing models needs further development to support all the categories involved in the PSS design.

In this sense, the next steps of this research are concerned to the incorporation of more PSS design process models in order to build a more robust Synthesis model to serve as a reference for specific design process models. The Synthesis model would incorporate the potentialities of each process model. It is not expected that a company simple adopt the Synthesis model as its specific PSS design process model. Instead, a company would be able to use the Synthesis model as a comprehensive starting point to define its specific process model. Additionally, the list of activities of the Synthesis model could also be applied as a checklist to select activities when building a project plan.

A complementary research stream is the identification and connection of methods and tools that can be used to perform the Synthesis' activities. In this way, a company will be able to select the activities that should compose its specific process model and to identify methods and tools.

In the end, this paper contributes to theory by providing a critical review of several PSS design process models. The most important limitation of this study is the number of models considered on the analysis. Other limitation is related to the selection of the models. By selecting the most cited models, there is a tendency to choose old models and not consider recently published papers. These limitations can be addressed by increasing new models at the comparison.

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