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# Commonalities and particularities of PSS design process and design thinking

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**Abstract**

Shifting from product-oriented business models to product-service systems (PSS) requires changes and implementation of new ideas related to many business dimensions, such as cultural, procedural, financial, and technological. Searching for new solutions requires creativity. Therefore, the application of a design thinking (DT) approach might help companies in finding innovative value propositions for PSS. DT has the potential to support PSS design processes, even though some practitioners may see DT as a substitute to formalized PSS design processes. In order to understand if and how DT can be used in combination with PSS design process models, this work proposes to identify what are the commonalities and particularities of them. The descriptions of DT methodologies and PSS design process models were treated as a structured content corpus, which was divided in comparable activities based on corpus linguistics and frame semantics. The main findings show that DT is effectively a support and not a replacement to the PSS design process, representing greater integration opportunities with the front-end of innovation (FEI). The detailing and implementation phases of PSS design process have no intersections with DT methodologies, even though DT can be employed whenever creativity is needed.


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*Keywords:* PSS design process; design thinking; activities; commonalities; particularities

## 1. Introduction

The increase of perceived value by aggregating services and products into product-service systems (PSS) is continually reinforced in literature [1–3], leading companies to shift from product-oriented business models to PSS. PSS requires a mindset of offering value in use [3], making the design process more customer-centered and creative by considering increasing stakeholders' involvement and culture renewal [4].

Many user-centered proposals are found in PSS literature to support PSS design process, ranging from single methods to complete approaches [5–7]. Some authors also suggest design thinking (DT) as a possible user-centered approach to support PSS design [8,9] and, in fact, DT has been employed in practice, showing contribution in parts of the PSS design, such as value proposition and business model creation [10].

DT is a human-centered approach that has been popularized and spread out by means of practitioners' toolkits and methodologies. It is based on integrative thinking, which involves reasoning patterns to creatively solve problems. DT emphasizes, according to Lockwood [11], "observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis".

Sometimes, practitioners may take DT for a replacement of the earlier phases of the design process, or even of the whole design process, instead of a support or complement [12]. However, doing this may harm the design process, since DT may lack many aspects that are considered when following a design process model. Yet, it is not clear in literature how DT and PSS design may be properly integrated.

This work is part of a wider research that aims to propose a method for integrating DT into PSS design process models. This particular publication aims to provide a partial result of that wider research, showing the commonalities between DT and PSS design, and the particularities that are intrinsic to each one of those approaches. Those results provide insights


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on how those approaches complement each other and what are the opportunities for integration. Besides, the particularities of PSS design process may illustrate the aspects that lack on DT.

## 2. Research methodology

This work compares activities from DT and PSS design to identify their commonalities and particularities. Activities were observed as one element that is common to both approaches and they can be used as a comparative element.

This research employed corpus linguistics, an approach grounded on qualitative and quantitative techniques focused on analyzing a given corpus [13]. It was selected since it "allows researchers to identify and analyze complex 'association patterns'" [13]. The linguistic structure analyzed is a complex association pattern, since an activity is described by means of distinct words combined in a similar structure.

Activities in DT methodologies are commonly embedded in long descriptions of methods, while PSS design models present synthesized activities. In order to allow their comparison, they need to share a similar structure. Thus, it is necessary to employ a technique to extract activities from the text and to structure those activities in similar formats.

The concept of frame was used to represent the structure in which words are combined to communicate an activity. Fillmore [14] defines frame as "any system of concepts related in such a way that to understand any of them you have to understand the whole structure in which it fits". In the FrameNet research project [15], it is possible to identify a frame proposed for activities, which is illustrated in Fig. 1.

| Frame "Activity" | | | | | |
|---|---|---|---|---|---|
| AGENT [Core] | ACTIVITY [Core] | DURATION [Non-core] | MANNER [Non-core] | PLACE [Non-core] | TIME [Non-core] |

Fig. 1. Frame "activity" used to structure activities extracted from the corpus

It is important to highlight that the frame "activity" has one frame element (FE) also called "activity". The reader should pay attention to when this work refers to one or to the other.

A frame can only be composed by a clause when it contains all core FEs, i.e., agent and activity. The agent is the living subject who is engaged in the activity [15]. The activity, in this context, is composed by sub-elements: an action, which is represented by a verb, and an object, which may be an input, a deliverable, something immaterial or even a person on which the agent performs the action. The object may be represented by a single noun or a clause. This adapted representation with the frame sub-elements (sub-FEs) "action" and "object" is illustrated in Fig. 2.

| Frame "Activity" [Adapted] | | | | | | |
|---|---|---|---|---|---|---|
| AGENT [Core] | ACTION [Core] | OBJECT [Core] | DURATION [Non-core] | MANNER [Non-core] | PLACE [Non-core] | TIME [Non-core] |
| | ACTIVITY [Core] | | | | | |

Fig. 2. Frame "activity" with the sub-FEs that compose the FE "activity"

For example, if the clause "create prototypes" is analyzed, the reader is implicitly the agent, the action is the verb "create", the object is the noun "prototype" and the other non-core FEs are empty. In the context of this work, only the FE "activity" is used. The other FEs are employed in the wider research of which this work is part and their application may be seen in other publications [16].

Employing the frame "Activity" in a previous step of this wider research, activities were extracted from a corpus derived from the descriptive content of 8 DT methodologies [17–24] and 14 PSS design process models [1,25–37]. The whole corpus was structured in "activity" frames, whenever the clause contained all core FEs. The sub-FEs "action" and "object" were codified. For the sub-FE "action", equal verbs or verbs that were semantically related, i.e., hypernyms, synonyms and troponyms (see Table 1) according to the English lexical database WordNet [38], were associated to the same numeric code. For example, in the activities "create prototype" and "build prototype", the action "build" would receive the code "7", and the verb "create", which is a hypernym of "build", would also receive the code "7". It means that both activities are equal, since they have the same action and the same object codes. For the sub-FE "object", equal nouns, synonymic nouns or derivationally related forms from a noun (see Table 1) were associated to a same numeric code. For example, in the activities "identify the users' thoughts" and "identify the users' opinions", the object "users' thoughts" would receive the code "73", and the object "users' opinions" would also receive the code "73", being "opinion" a synonym of "thought" in WordNet. Thus, again, it means that both activities are equal, since they have the same action and the same object codes. The final code for each FE "activity" was composed by the combination of the "action" code and the "object" code, in the following shape: "action code & object code".

Table 1. Semantic relationships for verbs (action) and nouns (object)

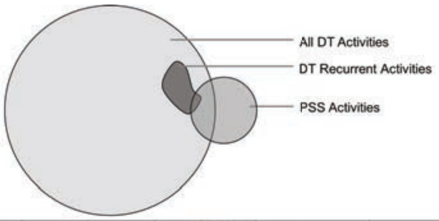
| Semantic Relationship | Description | Example |
|---|---|---|
| Hypernym [noun, verb] | 'A is a hypernym of B' means 'B is a kind of A' | *Car* is a hypernym of *cab* |
| Hyponym [noun] | 'A is a hyponym of B' means 'A is a kind of B' | *Cab* is a hyponym of *car* |
| Troponym [verb] | 'A is a troponym of B' means 'doing A is a manner of doing B' | *To march* is a troponym of *to walk* |
| Synonym [noun, verb] | 'A is a synonym of B' means 'A and B have the same meaning and are interchangeable in a given context' | *Car* is a synonym of *automobile* |
| Derivationally related form [noun, verb, adjective] | 'A is a derivationally related form of B' means 'A and B have the same root form and are semantically related, but are in different syntactic categories" | *Automobilist* is a derivationally related form of *automobile* |

In the previous step of this research, 3326 DT activities with distinct activity codes and 332 PSS design activities with distinct activity codes were identified in the whole corpus. From the 3326 DT activities, 46 of them were identified as the most recurrent ones (i.e., high-level activities cited by at least half of the authors), characterizing the common basis for the DT approach. The whole set of activities may be seen in the file available under the link: <http://www.portaldeconhecimentos.org.br/index.php/por/content/view/full/17780>

Based on the previous analysis, this work proposes a comparison among PSS design activities and DT activities proposed in literature. Both analyses were coded together, using a consistent coding system. Thus, similar activities have equal codes in both approaches. All activities extracted from the 8 DT methodologies and the 14 PSS design models were employed in this comparison. A processing macro was created to analyze all codes, providing the commonalities and individualities of each one of the approaches

## 3. Results and discussion

The results presented in this section derive from comparing all 3326 DT activities with the 332 PSS design activities, all of them extracted from the corpus by means of the methodology explained in last section. The 46 DT most recurrent activities were also compared to the 332 PSS design activities. Those comparisons are illustrated in Fig. 3.




| DT Activities analyzed | # of PSS activities | # of DT activities | # of DT activities compatible with PSS activities | % of DT activities compatible with PSS activities | % of PSS activities compatible with DT activities |
|---|---|---|---|---|---|
| All DT Activities | 332 | 3326 | 68 | 2,0% | 20,5% |
| Most recurrent DT activities | 332 | 46 | 12 | 26,1% | 3,6% |

Fig. 3. Comparison of DT activities and PSS design activities

Before the results presented in Fig. 3 are discussed, it is necessary to understand some characteristics that distinguish PSS design models and DT methodologies. PSS design process models are commonly presented in a systematized way, with easily identifiable sequential high-level activities, such as "create concept". On the other hand, DT is presented as sets of methods and their descriptions. This description is textual and usually reaches a low-level of detail. In this work, DT activities were extracted from the description of those methods by means of the frame structure, as explained in the methodology section. Thus, low-level activities were also extracted, such as "draw a circle on the selected idea". This is the reason why there are about ten times more activities in DT than in PSS design. That is also why the high-level most recurrent DT activities were selected in the previous step of the wider research of which this work is part. Those activities characterize the common way authors describe DT. Thus, in order to analyze how much of the PSS design process has similarities with DT, comparing the complete set of DT activities with all PSS design activities may be a proper means, since PSS activities already have an adequate level of detail and no DT low-level activity will be equal to a PSS design activity. However, when analyzing how much of DT has similarities with PSS design process, considering all DT activities would lead to the conclusion that only about 3,6% of DT is prescribed by PSS design process models. This statement, however, is not true, since there are many DT low-level activities, and PSS design process models do not reach this level of detail. Thus, the most recurrent DT activities, which represent the common characterization of DT with an adequate level of detail, are a better means for comparing how many activities of DT are prescribed in PSS design.

When comparing all DT activities with PSS design activities, it is possible to notice that about 20% of the PSS design process is similar to DT. Thus, 80% of the activities from PSS design process models are not found in DT methodologies. This analysis shows that DT cannot replace the full PSS design process. To understand how much of DT has similarities with PSS design activities, the most recurrent ones are compared, reaching about 26% of DT activities.

The commonalities between DT approaches and PSS design process models are mainly composed by activities that involve objects such as needs, people, ideas, concepts, solutions and value. Some common activities may have different aspects. For example, the activity "analyze people [who are relevant for the process]" is cited only once in the PSS design process models, by Nguyen et al. [26], where the focus is exclusively on customers. It only highlights the need of "deeply understanding" the customer and the operational environment. Nguyen et al. [26], however, state that, during the execution of the case used for testing their PSS design process model, this activity was not performed, since, "due to a long-term relationship, all customers and the operating environment" were "well known". This contradicts directly the DT approach, which keeps a constant emphasis on making "the familiar unfamiliar" [22], endeavoring "to assume a posture of wonder and curiosity", especially with familiar circumstances [17]. It is also possible to notice that the activity "analyze people" in DT deals with more than just the user or the customer, but also deals with other external people who are relevant for the process, such as experts and extreme users [16]. Besides, many types of analyses may be performed, such as observing, interviewing, and surveying [16]. Thus, having two activities with a similar name does not mean that they are equally proposed. There is a potential for complementing the PSS design process by considering the information attached to each activity in DT, such as specific guidelines and methods that may be employed to perform it.

There are some particularities of the PSS design process that highlight some aspects lacking on DT. DT lacks approaching technology assessment, development, and any other technological handling. This reinforces the criticism made by Woudhuysen et al. [12], who say that DT is a force broadly hostile to technological innovation. In fact, only two activities in the whole set of 3326 activities are related to technological consideration during the DT approach. Each one of them is only cited once by one author each. There are other fields that are unconsidered by DT, besides technology. It is possible to notice a lack of sustainability-related activities, what may turn DT into an incomplete option to choose as a support for PSS design process. The DT approach also lacks market analysis-related activities. In fact, DT authors criticize treating customers as "numbers", claiming that they must be observed and understood one by one.

DT also has particularities that are absent in PSS design process models. One of the highlights is the lack of conceptual prototyping and testing, which is seen as a good practice in design processes [39]. PSS design process models commonly recommend prototyping during detailed design. Another activity that lacks in PSS design process models but is recurrent on product design, mainly on the front-end of innovation (FEI) [40], is opportunity identification. The only PSS design activity referring to opportunities was "scan opportunity", which is cited by one single author [35].

Other insights emerge from evaluating how PSS design activities that are similar to DT activities are distributed through the design phases. In order to perform this analysis, the PSS design phases were unified under generic design phases proposed by Costa et al. [41]. The phases unification proposed for the PSS design process models is illustrated in Fig. 5. It was based on the scope of each phase proposed by each author and by means of the activities proposed in each phase. The distribution of PSS design activities and of the DT activities among the generic phases is illustrated in Fig. 4.

The distribution of PSS design activities through the phases respected the proposition of each author, as represented in Fig. 5. For example, the activity "create concept" was proposed by Nguyen et al. [26] in the phase "IPS$^2$ planning", which is considered in Fig. 5 as part of the FEI, similarly to other three design models [34,35,37]. However, Moser et al. [1] prescribes the activity "create concept" in the beginning of the phase "Development", which covers the embodiment design phase according to Fig. 5. Thus, in Fig. 4, the activity "create concept" was counted once for the FEI and once for embodiment design. This is why the total sum of the activities in the picture is greater than 332, even though only 332 activities were identified.

Among the PSS design activities, it was possible to identify many activities equal to DT activities. There are DT activities distributed all over the FEI, embodiment design, detailed design and implementation. Yet, most DT activities are prescribed in the FEI. The phases of use and end-of-life do not share activities with DT. Finally, embodiment design and detailed design have an even distribution of DT activities, even though less intense than the FEI.

The first conclusion that derives from this analysis is that DT cannot cover all activities of the FEI either. Actually, DT activities represent only about 31% of the FEI activities in PSS design. Thus, there is a high potential for DT to support those activities, but it should not be seen as a replacement.

Looking at the recurrent activities that characterize DT, it is possible to notice that 11 appear on the FEI. Only one activity appears on the embodiment design, which is "create concept". However, this activity is cited by five PSS design process models as part of the FEI, being cited only once in the embodiment design. Thus, this activity is more commonly found on the FEI. Two activities also appear in detailed design: "create scenarios" and "give feedback". The first is a similar case of "create concept". Two authors cite this activity as part of the FEI, while only one places it on detailed design. Thus, it is possible to say that 11 DT recurrent activities appear on the FEI, while only 1 appears on detailed design.

It is noticed that DT has a greater affinity with the FEI than other design phases. However, the presence of DT activities in other design phases shows a possibility of using some DT methods to punctually support those phases too. Even though this compatibility is seen, the greatest compatibility for DT integration is still observed on the FEI.

## 4. Conclusions

Based on a corpus linguistics approach associated with frame semantics elements, a comparison of the PSS design activities and DT activities was performed, achieving their commonalities and particularities in order to guide further integration of DT into PSS design process models. The method employed in this work provides a distinct approach from usual publications that compare design approaches and models. It is a time-consuming method; however, it provides a systematic procedure that assures this analysis replicability.

Commonalities were observed among the approaches (about 20% of the PSS design activities and about 26% of DT most recurrent activities), illustrating integration capabilities between PSS design and DT. There are complementation opportunities by means of additional information that is commonly prescribed in the description of DT activities, such as guidelines and methods (the guidelines proposed within the most recurrent activities may be seen in another publication [16]). Besides, the fact that 80% of the PSS design activities are not prescribed by DT methodologies proves that DT may be seen as a support or complement to PSS design process, but never as a replacement.

Greater integration opportunities were observed in the FEI of the PSS design process, where the number of common activities is more relevant, with about 31% of the FEI. However, DT is also not capable of fully replacing the FEI.

The particularities derived from the DT approach show the limitations of PSS design process models that DT may

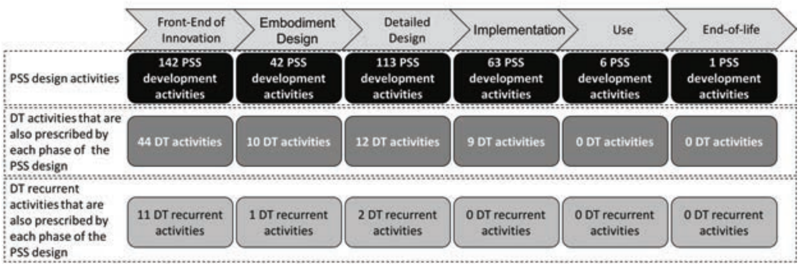



Fig. 4. Distribution of PSS design activities and DT activities throughout the PSS design process phases

<table>
<tr><th>PSS Design Process Models</th><th colspan="4">Front end of innovation</th><th colspan="2">Embodiment Design</th><th colspan="5">Detailed Design</th><th colspan="2">Implementation</th><th>Use</th><th>End of Life</th></tr>
<tr><td>Alonso-Rasgado and Thompson (2006)</td><td>Stage 1: Business Ambition of the Client</td><td>Stage 2: Potential Business Solutions</td><td colspan="2">Stage 3: core definition of Total Care Product plus Total Care Product options</td><td colspan="3">Stage 4: Enhanced definition of the potential Total Care Product</td><td colspan="2">Stage 5(i): Business case risk analysis of options</td><td colspan="2">Stage 5(ii): Business case validation and evaluation of alternatives</td><td colspan="2">Contract</td><td colspan="2"></td></tr>
<tr><td>Nguyen et al. (2014)</td><td colspan="2">IPS² planning</td><td colspan="2">IPS² concept modeling</td><td colspan="2"></td><td colspan="3">IPS² detailed design</td><td colspan="2">IPS² prototyping</td><td colspan="2">IPS² implementation</td><td colspan="2"></td></tr>
<tr><td>Brezet et al. (2001)</td><td>Exploration</td><td>Policy formulation</td><td colspan="2">Idea finding</td><td colspan="2"></td><td colspan="5">Strict development (design)</td><td colspan="2">Realisation</td><td>Evaluation</td><td></td></tr>
<tr><td>Aurich et al. (2006)</td><td>Idea finding (product)</td><td>Demands identification (service)</td><td colspan="2">Feasibility analysis (service)</td><td>Concept development (product)</td><td>Concept Development (service)</td><td>Product construction (product)</td><td>Product detailing (product)</td><td>Prototype development (product)</td><td>Service modelling (service)</td><td>Service testing (service)</td><td>Manufacturing preparation (product)</td><td>Realization Planning (service)</td><td colspan="2"></td></tr>
<tr><td>Luiten et al. (2001)</td><td colspan="2">Future Exploration</td><td colspan="2">System design</td><td colspan="2"></td><td colspan="2">Product/Service Specification</td><td colspan="3">Drawing in detail and testing</td><td colspan="2">Implementation</td><td colspan="2"></td></tr>
<tr><td>Morelli (2003)</td><td colspan="2">Value proposition</td><td colspan="2">Market analysis</td><td>Product/ service definition</td><td>Use-case analysis</td><td colspan="2">Tentative architecture</td><td>Test</td><td colspan="2">Final definition</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Kar (2010)</td><td colspan="4">Analysis</td><td colspan="2">Preparation</td><td colspan="5">Synthesis</td><td>Implementation</td><td>Test</td><td colspan="2"></td></tr>
<tr><td>Sakao and Shimomura (2007)</td><td colspan="2">Making a preliminary flow model</td><td>Describing the target receiver</td><td>Describing the value</td><td colspan="2">Generating a realization structure</td><td colspan="5">Modifying the flow model</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Van Halen et al. (2005)</td><td>Startegic analysis</td><td>Exploring opportunities</td><td colspan="2">PSS Idea Development</td><td colspan="2"></td><td colspan="5">PSS Development</td><td colspan="2">Preparing for Implementation</td><td colspan="2"></td></tr>
<tr><td>Marques et al. (2013)</td><td>Phase 0 Organisation preparedness</td><td>Phase 1 Planning</td><td colspan="9">Phase 2 Design</td><td colspan="2">Phase 3 Post-processing</td><td colspan="2"></td></tr>
<tr><td>Moser et al. (2015)</td><td colspan="4">Planning</td><td colspan="4">Development</td><td colspan="3">Preparation</td><td colspan="2">Market Performance</td><td></td><td>Replacement</td></tr>
<tr><td>Tran and Park (2014)</td><td>PSS Idea Development</td><td>PSS Planning</td><td>Requirement Analysis</td><td>Design and Integration…</td><td colspan="2"></td><td colspan="2">…Design and Integration</td><td colspan="3">Test and Refinement</td><td colspan="2">Implementation</td><td></td><td>Retirement and Recycling</td></tr>
<tr><td>Kim et al. (2015)</td><td colspan="2">Strategic Planning</td><td colspan="2">Idea Generation and Selection</td><td colspan="2"></td><td colspan="2">Service Design</td><td colspan="3">Product Development</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Sutanto et al. (2015)</td><td>Identify design requirements</td><td>Determine design requirements rating</td><td colspan="2">Integrating product and service</td><td colspan="11"></td></tr>
</table>

Fig. 5. Unification of PSS design process model phases

support, such as conceptual testing, deeper stakeholders understanding and opportunity identification. However, the particularities derived from PSS design activities also show limitations of the DT approach, such as lacking technology-related activities, limited support on overall market analysis and limitations on sustainability issues.

The method employed in this work has some limitations. Its quality depends on language consistency. However, some activities may have synonymic pairs that were not identified through the method, such as "interview people" and "command interviews". An analysis of each activity in order to identify synonymic structures would not be feasible, due to the amount of activities in the database. Even though it may cause some disturbance on the final calculations, an overall evaluation of the activities based on samples estimates that this disturbance is not meaningful, ranging from 1% to 2%.

The results of this work will compose the input of the next step of the wider research of which this work is part: proposing a method for integrating DT into specific PSS design process models instantiated by companies.

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