Development of a strategic prototyping framework for product service systems using co-creation approach

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\section*{Abstract}
There are more and more applications of Product Service Systems (PSS) in today’s industry in both B2B and B2C sectors. PSS is able to bring plenty of benefits to the customer, the provider, the environment and the society. In order to unleash the full potential of PSS in terms of industrial adoption, there is a need for the improvement of (i) customer’s perception of its value, (ii) pre-launch evaluation, and (iii) design quality. None of the existing methodologies and tools provides a comprehensive approach for all of those three aspects.

In this paper, the authors propose a strategic framework for PSS prototyping. The proposed framework can support the customer’s perception of value, the evaluation of PSS design before actual implementation and the improvement of design quality. An illustrating example of implementation of the proposed framework is also included for demonstration purpose.

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\textbf{Keywords:} product service systems; pss; prototyping; co-creation; evaluation; design improvement

\section*{1. Introduction}
\subsection*{1.1. Product service systems}

Product service system (PSS) is a new concept emerging in recent years due to the rise of competitive business environment, the call for sustainable development as well as the need of finding new ways for customer engagement. Generally, PSS is the combination of product, service, delivery network and related stakeholders. In this new paradigm, a company provides its customers with an offering including tangible product and intangible service. This new concept of providing “offerings” is much different from the traditional selling of solely physical products which is becoming more and more difficult to compete, especially in today’s scenario of economic crisis, growing environmental issues and diversified customer demands \cite{1,2,3}. As mentioned in literature, the utilization of PSS in business can help companies to enhance competitiveness, achieve social, environmental, and economic goals, as well as attract and retain customers \cite{4,5,6}.

There exist several formal definitions of PSS by various authors. Goedkoop et al. \cite{7} defined PSS as “a marketable set of products and services capable of jointly fulfilling a user’s needs”. Goedkoop’s definition makes the concept of PSS close to functional economy \cite{8} where customers pay for the “function” or the “use” of the solutions, not for the physical products. PSS concept also matches with the thinking of “hiring products to get jobs done” which was mentioned by Bettencourt and Ulwick \cite{4} and was extensively discussed by Lim et al. \cite{9}.

Some researchers suggested that PSS could be considered as an integrated system consisting of products, services, and the infrastructure to deliver a solution to a customer to satisfy certain needs \cite{1,5}. An example of PSS is the “document management solution” which was discussed in the work of Baines et al. \cite{10}. In this example, with the “PSS model”, the customer only “buys” the capability of document management
and leaves the rest of the work (refill, maintenance, replace parts, etc.) to the manufacturer.

Early works on PSS related topics were carried out more than a decade ago with pioneer researchers such as: Goedkoop et al. [7], Mont [8] and Morelli [11]. As summarized by Vasantha et al. [1], research on PSS has ranged from the definition of elements, generation of offerings, representation of PSS, etc. to the evaluation of offerings, sustainable development, design process for integrating products and services etc.

Tukker [13] classified PSS into three types which are: product oriented, use oriented, and result oriented PSS.

1.2. Benefits and challenges for the adoption of PSS in the industry

Surveys by Baines et al. [10] and Beuren et al. [5] showed the benefits of PSS to the consumer, provider, environment and society. These benefits result from the higher level of satisfaction, increased competitiveness, decreased environmental impact and increased materials savings. The main benefit for the company is that it pushes for continuous business improvement, quality improvement, and better company-customer relationship.

Although PSS brings plenty of benefits, it is still adopted limitedly in the industry for its potentials. There are three major challenges in adopting PSS having suggested by Mont [8], Baines et al. [10] and Beuren et al. [5]: first, consumers may not be enthusiastic about ownerless consumption; second, the manufacturer may be concerned with pricing, absorbing risks and shifting organization; and third, PSS design and development itself is a challenge.

1.3. Proposal and structure of this paper

Resolving the problems regarding the three challenges above might increase the adoption of PSS in industry. Among the solutions, increasing user’s perception of PSS value (i.e. value perception) through value visualization, reducing the risk in developing PSS through evaluation and improving PSS design quality through testing and refinement are substantial. This work is dedicated to proposing a prototyping framework which can simultaneously support user’s value perception, evaluation and quality improvement of PSS design using co-creation approach. We aim to develop a prototyping framework because, in a PSS design process, the tasks of value visualization, design evaluation and improvement are strongly related to prototyping. The proposed framework is expected to work with all types of PSS in both B2B and B2C environment. In this work, the term “value” indicates what customers or users receive from a PSS which helps to fulfill their needs.

The rest of this work will be organized as follows: Section 2 reviews related works in the field, Section 3 analyzes theoretical issues and proposes our prototyping framework, Section 4 introduces one example for illustrating of how the framework can be implemented in a real case of an industrial product service system in B2B environment, and Section 5 draws concluding remarks.

2. Related works

2.1. Value perception

For a PSS, value perception is an essential issue. Without proper perception, customers would not be persuaded to buy a PSS because normally, the value of “service” or intangible part is not ready to be seen [9,10,11]. In some cases, the presence of product is so small and most of the value lies on the service. This leads to the necessity of value visualization which aims to maximize customer’s perception.

Many authors mentioned about value visualization in literature. Kowalkowski and Kindstrom [14] noted that value visualization is concerned with the way that firms communicate and demonstrate the value of their product-service systems, both internally and externally. Due to its intangible nature, the communication of PSS value to customers is critically important and it is more complex than the communication of product values which are conveyed through its physical appearance and technical features and value visualization is vital for winning new contracts and retaining existing ones [14]. Other authors such as Sakao et al. [15], Kim et al. [16] and Maussang [17] mentioned about the importance of value and included value proposition in the PSS design and engineering processes. Tan et al. [18] also proposed value proposition as one of the four dimensions of a PSS. Baines [10] found that a PSS “achieves differentiation through the integration of product and services that provide value in use to the customer”. They also pointed out organizations needed new methods to understand the perceived value that a potential customer might hold in order to evaluate the service level.

Several authors have been working on the topic of value visualization so far. Morelli [11] proposed a model in which he emphasized value proposition in PSS design. Other authors proposed various tools which supports the value visualization. Lim et al. [9] proposed the “PSS Board” using which the value can be perceived. Bertoni et al. [19] proposed color coded CAD models to communicate value of PSS design alternatives. But the above works focused on the recognition of PSS value of developers and decision makers rather than the perception of customers and thus, they could not effectively inspire customers to accept offerings.

One notable work which focused on increasing customer’s perception of value was done by Kowalkowski and Kindstrom [14]. In this work, they proposed a visualization strategy framework for PSS development. The work provided a broader approach to visualization in all development phases and included different visualization techniques as well as different visualization strategies for each particular development stage of the PSS. Although the work was well presented and the details were much useful in terms of application, the work limited itself in the domain of industrial markets.

2.2. User involvement in evaluation and design improvement

Many authors were aware of the importance of evaluation in the development stage including: Lim et al. [9], Yoon et al.
[20], Komoto and Tomiyama [21], Exner et al. [22], and Shih et al. [23]. But, as found by Baines [10] and later confirmed by Vasantha et al. [1], the evaluation of PSS is one of the area that is not matured with adequate results and breakthroughs.

Komoto and Tomiyama [21] proposed a lifecycle simulation model for maintenance service. This model supports the evaluation of user behavior and assists the provider to design competitive maintenance packages. Lim et al. [9] proposed a structured tool called the “PSS Board” to visualize the PSS process in which the evaluation was taken into account. Exner et al. [22] implied the evaluation of PSS performance through a validation process using prototyping approach. All of these three works focused more on the “internal evaluation” meaning that the evaluation itself is limitedly related to the customers. In this sense, the evaluation is mostly for the developers.

One of the main differences of PSS from traditional product is the increasing involvement of customers (i.e. users) not only in use stage but also in the very early design stage. PSS design itself is a participatory design process and users need to be allowed to participate actively in as many design activities as possible [1,10,24]. Shih et al. [23] proposed an integrated PSS development process in which the evaluation played an important role. In that work, the customers’ feedbacks are heard and used for the design refinement. Also, Yoon et al. [20] suggested an algorithm for evaluation based on the balance between customer satisfaction and the company’s technical capability. These two approaches appreciated customer’s involvement to some extent but they did not consider customers as sources of innovation for PSS evaluation and potential design quality improvement.

2.3. Research gap and purpose of this work

Successful implementation of PSS cases would encourage the expansion of adoption in industry. In order to gain success, PSS must be accepted by customers at a satisfaction level which is as high as possible. This acceptance of customers strongly depends on how providers can: i) visualize the value to maximize customers’ perception; ii) evaluate whether offerings satisfy customers; and iii) continuously improve the design quality so that it becomes better and gains higher level of customer satisfaction. So far, there is no such framework to support these three aspects simultaneously.

This work aims to develop a strategic framework which employs the involvement of customers/users to support value perception, evaluation and design quality improvement of PSS. This framework works on the testing and refinement phase in design and development stage, after the preliminary design and before the final release. Using this framework, an offering which is the outcome of the PSS design process can have higher level of success in terms of customer acceptance and satisfaction.

3. The proposed framework

3.1. Position of the proposed prototyping framework in PSS development process

Figure 1 which is redrawn from our previous work [25] shows a generic PSS development process. Our proposed prototyping framework lies on the phase 5: “Testing and Refinement”. This means that the proposed framework aims to work on the final prototype, not the prototype at idea or conceptual level.

3.2. Our approach to PSS prototyping

Since a PSS is a complex system, in order to represent it as a prototype, the following elements need to be considered:

- **Product**: The physical product which is provided as a part of a PSS. For example, it can be a car in car sharing [20].
- **Service**: The intangible service which is provided as a part of a PSS. For example, it can be the “sharing” function in car sharing.
- **Process**: The sequence of activities which happen when the PSS is launched. For example, it can be the sequence of activities of users, providers, etc. in a car sharing. This process can be in serial or parallel or combined mode.
- **Parameters**: The metrics which represent the magnitude or level of product and service features. For example, how much the charge per one mile is, how long the response time is, how far the car station is, etc. in car sharing.
- **Network**: The environment where PSS is taken place and the linkage among product, service, stakeholders, etc.
- **Stakeholders**: The parties who are involved in the action of a PSS including: providers, users, suppliers, and other influencers.
- **Value proposition**: The model of how the PSS benefits various stakeholders.

There are various techniques to represent a prototype as a complex system including the above elements such as: blueprinting, participatory simulation, virtual reality, etc. Depending on the specific application, an appropriate technique will be selected. We will clarify this through the example in Section 4. The set of all elements is called a “PSS configuration” in this work.

3.3. Implementation of co-creation concept

As mentioned in Section 2, the design and development of PSS is a participatory process and thus, co-creation has been mentioned in literature as one of the success enabling factor for PSS [1,10]. Co-creation refers to the participation of customers or users in various phases of its lifecycle such as: ideation, design and development and implementation (i.e. use), etc. The role of user participation is critical to the success because of the importance of users in a PSS model. Users are among the most important stakeholders and because of the presence of “service” part in which users only buy or hire things that help them to get jobs done [4,9], users’ voices deserve a deep consideration. Unfortunately, the co-creation
of users in design and development process is still limited, as pointed out by Baines et al. [10] and Vansantha et al. [1]. The participation of users has been said to bring impact and significant changes to the design and development process [26]. The simplest form of co-creation is getting user feedbacks for concepts or prototypes. Other forms include open innovation, crowdsourcing, or customer participatory games or tests, etc. In this work, we use various activities of co-creation to enhance the prototyping in testing and refinement. These co-creation activities include collecting user feedback and suggestions, user generated PSS configurations and user evaluation. Since “prototyping” is a complex development task, it should be clarified and simplified in order to maximize the participation level of users. We implement this strategy in the proposed framework by conducting basic training to the users so that non-expert users can participate easily.

3.4. The proposed framework and supporting elements

Combining the above analysis and the understanding of prototyping in reality, we propose the framework in Figure 2.

![Fig. 2. The proposed strategic prototyping framework](image)

The working mechanism of the proposed framework can be described as follows. At first, the company has an initial prototype which is built based on the result of the preliminary design stage and which is supposed to be demonstrated, evaluated and improved after the prototyping process. The company implements the following steps:

- **Step 1 – Demonstration:** The company demonstrates the initial prototype to a group of users. This prototype includes all elements such as: product, service, process, environment, and parameters. The users see and experience how the PSS works and learn about its architecture. This prototype can be presented in the form of a working prototype such as: participatory prototyping or in the form of a storyboard, a simulation or any media-based illustration, depending on the type and characteristics of the PSS.
- **Step 2 – Participation:** After seeing, experiencing and understanding how the PSS works through Step 1, the users will participate actively in the process by sending feedbacks, suggestions for possible improvements. This is somewhat similar to the “traditional” testing and refinement process. In the proposed framework, moreover, users are allowed to propose their own “PSS configurations” meaning that, they somehow customize the design according to their own preferences. In order to maintain the ability of providing the future PSS, some restrictions or boundary conditions might be set for elements. Users can create PSS configurations within this limit. The user participation activities can be carried out with web forms, spreadsheets or in-person participation. The form of co-creation (i.e. participation) can vary. For B2B environment, co-creation can appear in the form of open innovation or the participation of “extended teams” of close customers/partners. For B2C, it can be in the form of crowdsourcing.
- **Step 3 – Refinement/Analysis:** This step consists of two tasks which are performed in a parallel manner.
  - **Step 3a – Refinement:** The company collects users’ feedbacks, suggestions in Step 2 and refines the initial prototype.
  - **Step 3b – Analysis:** The company analyzes user-generated PSS configurations and identifies the most “favorite” configurations (i.e. the “pattern”). Based on the analysis, the company builds new prototypes, i.e. “user-generated prototypes”.
- **Step 4 – Visualization:** The company visualizes the revised prototype and the new user-generated prototypes. This is for the ease of evaluation in the next step. The way of visualizing and demonstrating prototypes can be the same as in Step 1.
- **Step 5 – Evaluation:** The company invites new group of users to evaluate the prototypes which were previously visualized in Step 4. The users see, experience prototypes and then vote, rate, comment on prototypes. Based on the evaluation results, the company can select the winning (i.e. the best) prototype. This activity can be carried out with web forms, spreadsheets or in-person participation as in Step 2. Developers also evaluate company related aspects.
- **Step 6 – Modification:** The company can modify the winning prototype by selecting strong aspects of other prototypes and implement these aspects to the winning prototype achieve “improved prototype”.

By performing the above six-step process, the company can achieve the final prototype which performs better in terms of customer acceptance. Through the above process, the value is visualized and communicated to the users, the PSS design itself is evaluated properly in a customer centered manner and the quality of PSS design is improved thanks to the collective creativity from user participation.

In the next section, we will illustrate the framework with one example.

4. Illustrating example

4.1. Case introduction

The example in this section is a company X who is currently active in the area of office furniture. One of its product lines is a low cost set of desk and chairs for using in the office of startup companies and small cafes named “The Startup F-Kit” (shortened as “F-Kit”). The company does not sell the F-Kits. Instead, it offers the leasing service to startup
companies. According to that offering, the startup companies who have newly established their office can use company X’s F-Kit and pay per use. The usage fee is charged monthly and the customer can end the service whenever they wish. All the maintenance, upgrade, renovation, fixing, etc. will be taken over by company X, i.e. the manufacturer and service provider. This is a B2B industrial PSS model in a small scale. This model helps startup companies to reduce the amount of investment and the financial risk and they can invest more in their core competencies. This also helps company X to take better care of their products, provide better service to their customer and increase their competitiveness. By leasing the furniture and taking care of the maintenance, upgrade, renovate, fixing, etc., the life of the furniture is extended and this reduces environmental impact.

The scenario is as follows: the developers of company X have developed a new design of the F-Kit for next year’s plan. Before making final decision of the design and moving to production stage, they need to test and refine the design and service preferences (i.e. the design of the PSS as a whole) in order to ensure that the customers would perceive the value and accept the PSS when it is released. They also want to improve the quality of the offering as much as possible. In the next part, we will use the proposed framework for this case to help company X to achieve their goals.

4.2. Implementation of the proposed framework

Step 1: Demonstration
Company X presents the prototype of the “F-Kit” in a form of a working prototype. They prepare the prototype of the furniture set itself (i.e. the physical product), set up the environment of the PSS: the online/offline stores where the customers can purchase, the “use” environment where the users can experience the whole PSS in use stage. They also provide additional media: photos, diagram, videos, etc. and narration so that the users can gain the maximum level of experiencing and understanding the PSS model.

They invite a group of 20 individuals from startup companies (i.e. the potential users) to come to their site to experience the model and participate in the process.

Step 2: Participation
The users above, after experiencing the PSS and fully understanding of the mechanism, are invited to participate in the process with two tasks:

- Sending their feedbacks and suggestions: Users write down their comments, feedbacks and suggestions on A4 sheets of papers and handle the note to the company X.
- Proposing their own “PSS configurations”: Company X allows users to generate their PSS configurations by filling in a template as in Figure 3. In the case of using crowdsourcing, this printed template can be replaced by a web form. A short training is implemented so that the users can use the template correctly. The templates which are filled are collected for analysis.

Step 3a: Refinement
In this step, the comments, feedbacks, suggestions which were collected in Step 2 will be implemented selectively to refine the initial prototype. The revised prototype will be called P0 from now on.

Step 3b: Analysis
From user-generated PSS configurations collected in Step 2, company X’s developers analyze and select three “most suggested” PSS configurations (i.e. patterns) and use these configurations to build three new prototypes, namely, P1, P2 and P3.

After Step 3a and Step 3b, company X has four prototypes: P0, P1, P2 and P3. Due to the scope and limit of this paper, we do not present the detail configuration of each prototype. This will be shown in details with real data in the near future in another paper.

<table>
<thead>
<tr>
<th>Customer ID: U1-012</th>
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<tbody>
<tr>
<td>Product</td>
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<td>Service</td>
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<tr>
<td>Process</td>
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<tr>
<td>1. Announcement of Offering</td>
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<tr>
<td>2. Customer purchases. Deliver to customer</td>
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<tr>
<td>3. Customer uses + receives services</td>
</tr>
<tr>
<td>4. Hotline support/Quick onsite service</td>
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<tr>
<td>5. Receive feedbacks and prepare for next version</td>
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<td>o Service uptime: 24/7</td>
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<td>o Service Fee Policy: 100% included in Leasing Fee</td>
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<td>Network Stakeholders Value proposition</td>
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<td>o Manufacturing and Supporting networks</td>
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<td>o Developers, Users, Suppliers</td>
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<tr>
<td>o Bring the long term benefits to the customers: reducing the amount of investment and focus on their core competencies</td>
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</table>

Fig. 3. Template for proposing PSS configuration (example)

Step 4: Visualization
Company X’s developers visualize the four prototypes using similar methods as in Step 1.

Step 5: Evaluation
Company X invites another group of 20 other individuals from the potential customers to experience and evaluate the four prototypes visualized in Step 4. The evaluation form is shown in Figure 4. The prototypes will be ranked using Decision Matrix. The “Importance” factor in Figure 4 is decided by the company. After the evaluation process, the company identifies P2 as the winning prototype.

Step 6: Modification
The company performs the last stage of the process by selecting strong aspects of prototypes P0, P1 and P2. They try implementing these aspects to the winning prototype (P2) to achieve improved prototype, namely, the P2s. The P2s is the final prototype which performs better in terms of customer acceptance.
Fig. 4. Evaluation results submitted by users and developers (mean value)

5. Conclusions and future work

In this work, the authors propose a strategic framework for PSS prototyping. This framework provides a step by step guideline for developers in the testing and refinement stage of the PSS development process. It supports customer’s value perception, evaluation and improvement of PSS design. Through an illustrating example, it is verified that the proposed framework can help companies to achieve improved prototype thanks to the active participation of users. Unlike existing works in the literature on PSS prototyping, this work focuses more on the process innovation rather than the techniques and tools.

For future work, we would perform more case studies, report real data and present the analysis as well as results in details. We would also make a comparison of the results with and without the implementation of the proposed framework. These efforts support the verification and validation of the proposed framework.

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References