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A customization-oriented framework for design of sustainable product/service system

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ABSTRACT

Many manufacturers today are striving to offer high value-added Product/Service System (PSS) due to increasing competition and environmental pressure. PSS design activities face a variety of challenges such as a high level of customization as well as its resulting challenges, i.e., hidden requirements in product use phase, potential conflicts of design attributes, and internal complexity of service processes. However, existing insights for PSS customization are fragmented and insufficient to support manufacturers. Thus, it is necessary to develop a systematic and comprehensive support to solve those issues. In order to support PSS customization in early design phase, this paper proposes a design framework that involves a design process. The proposed design framework is module-based and thus flexible according to the user needs. In addition, it takes advantage of some existing methods. A case study of elevator PSS design shows the feasibility and potentials of the design framework and its associated design process to its broad usage in industry.

1. Introduction

With the increasing competition (Uppenberg and Strauss, 2010), diversification of customer demands (Hu et al., 2011) and environmental pressures (Umeda et al., 2012), many manufacturing companies are striving to re-position themselves as solution providers by offering high value-adding services (Meier et al., 2010). Those manufacturing companies are undergoing a servitization journey towards a tightly-coupled integration of products and services (Beuren et al., 2013; Vandermerwe and Rada, 1988). Servitization can be considered as a process to shift from selling products to selling Product/Service System (PSS) and involves strategic innovation of a company's capabilities (Baines et al., 2007; Vandermerwe and Rada, 1988). PSS is a system consisting of products, services, networks of players and supporting infrastructure, which are jointly capable of fulfilling specific client demands in an economical and sustainable manner (based on (Mont, 2002, Tukker, 2004)), which is an important component of servitization. PSS has been heralded as one of the most effective instruments for enhancing resource-efficiency (Tukker, 2015). PSS can also help manufacturers to be differentiated from competitors (Meier et al., 2010).

Early design of PSS is critical to success of PSS design. As compared with physical product design, PSS design concerns more about value in use (Meier et al., 2011). Value as such is individual to its recipient (Ulaga and Chacour, 2001), and thus customization in PSS becomes relevant. Effective customization depends on accurate requirements capturing and handling (Jiao and Tseng, 2004). However, due to a higher number of and more variable stakeholders involved in PSS, PSS requirements management with the conventional methods for product requirements elicitation is challenged. Moreover, different value propositions to the stakeholders may lead to potential conflicts between design attributes, which is not thoroughly addressed in past PSS design researches (Berkovich et al., 2011; Vasantha et al., 2012). Besides, when customer requirements change in product use phase, it is usually expected to re-arrange service processes and resources, and may even redesign the whole PSS to cope with the changes. This might lead to increase of service response time, as well as cause wasting previous designs. Embedding modularity is effective to avoid this problem, because it brings benefits such as increased feasibility of change, increased variety, and ease of design and testing (Gershenson et al., 2003). Thus, customization involves different steps spanning a wide range of activities from requirements

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elicitation to module-based configuration, and a systematic and comprehensive support is necessary to achieve effective and efficient PSS customization. However, existing frameworks for PSS design are fragmented and insufficient to support customization, because most of them lack systematic and comprehensive support to specifically guide PSS customization from early requirements identification to design conflict resolving, and to later PSS configuration (Berkovich et al., 2011). This lack of systematic methodical support for the customization process may cause implementation difficulty in practice of PSS customization.

Therefore, this paper proposes a systematic and comprehensive framework with a design process for PSS customization. The design framework consists of four successive design stages. Using merely a set of different methods to effectively design PSS is not necessarily novel, but providing a systematic and comprehensive framework employing specific design process and methods with synergetic effects among them has not been found in previous works. The proposed framework would systematically provide designers with standardized design process reference from the beginning requirements identification to the later concept configuration. Specifically, early conflict resolving mechanism in the framework aims to reduce possible defects in subsequent process of detailed design and delivery. Modularization process and methods of the framework will facilitate frequent design reuse and easier trace-back of failures, and thus enhance design efficiency. The module-based configuration in the framework could help the service provider to achieve flexible PSS customization.

The rest of this paper is organized as follows: Section 2 reviews literature on PSS and PSS design including PSS customization; In Section 3, the framework for PSS customization is formulated, and the associated implementation process is also provided; In Section 4, a case of PSS customization project with an elevator provider is presented to illustrate the feasibility and potentials of the proposed framework. Conclusions and future research suggestions are presented in Section 5.

2. Literature review

A brief review of PSS and PSS classification had been conducted (see Section 2.1), and then, the literature addressing customization of PSS was searched for (see Section 2.2). Based on the literature review results in Section 2.1 and Section 2.2, knowledge gaps were identified. Although some research efforts have been made in PSS definition, benefits, and classification, there is still a lack of systematic methodical support covering entire design process for PSS customization as shown in Section 2.3.

2.1. Product/service system

PSS has attracted academia and industry based on its economic potentials well as expectation of its environmental superiority (Tukker, 2004). Some review articles have discussed PSS definition, specific features of PSS as well as the benefits and drawbacks, e.g., Beuren et al. (2013). The basics of PSS is not included much here due to the limited space limitation. As opposed to the conventional standardized after-sales service such as spare part provision, PSS offers customized service portfolio to flexibly meet customer's requirements (Kindström and Kowalkowski, 2009). There are different ways of categorization of PSS. Manzini (1999) categorizes PSS into two modes, i.e., use-oriented and result-oriented modes. Roy (2000) further extends the categories to include four modes, i.e., result services, shared utilization services, product-life extension services, and demand side management. Tukker (2004) proposes product-oriented services (e.g., maintenance and repair) adding services to current products, use-oriented services (e.g., product renting, sharing, and pooling) intensifying the use of products, and result-oriented services focusing on customer requirements fulfillment. Among these attempts to categorize PSS, the most widely used is the classification by Tukker (2004), which considers the relationship between the provider and customer and revenue model (Geum and Park, 2011). The paper mainly addresses the first category of PSS, i.e., product-oriented PSS, as many manufacturers seem to work but to face challenges on this type.

2.2. Customization of PSS

The literature addressing customization of PSS was searched for. This review consisted of three steps: 1) identified articles describing methods for PSS customization, 2) searched methods potentially useful for PSS customization, and 3) analyzed the methods from the previous two steps. For the first step, keyword search was used. The population to this search consisted of publications written in English as article or review in the Web of Science databases, Scopus, Springer link, and Ebsco. The search conditions applied was that the topic should include “product service system”, “functional product”, “integrated product service offering (IPSO)”, “industrial product service systems (IPS^2)”, “hybrid solution”, “integrated solution”, and “servitization” (all as a phrase), combined with the term “customization”. This was followed by content check if each article provides a method (or a framework) for PSS customization. In the second step, journal articles cited by those identified from the first step were mainly targeted. Table 1 shows the keyword search results in different databases. m/n in Table 1 indicates that n articles were found to describe a method in m searched papers.

As a result of the keyword search in the first step, 126 articles were hit as of June 26th, 2016. After the content check, only four articles without duplicates were found to describe a customization method. This shows the small amount of the searched insights. In addition, among the four articles, no comprehensive support for PSS customization has been proposed, which is a strong motivation for this research. From the second step, 18 articles were found. Table 2 shows outcomes from the 22 articles in total as a result from the third step (the four articles from the first step are marked with *). The other 18 ones could be potentially useful to achieve the goal of the article.

Table 1
The keyword search results in different databases.

Keywords	Web of science	Springer link	Scopus	Ebsco
product service system, customization	12/3	14/1	25/2	0/0
functional product, customization	5/0	0/0	7/0	0/0
integrated product service offering (IPSO), customization	0/0	0/0	0/0	0/0
industrial product service systems (IPS^2), customization	2/0	4/0	3/0	0/0
hybrid solution, customization	0/0	2/0	3/0	0/0
integrated solution, customization	5/0	2/0	9/0	0/0
servitization, customization	5/0	19/0	9/0	0/0