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Procedia CIRP 47 (2016) 150 – 155

www.elsevier.com/locate/procedia

Product-Service Systems across Life Cycle

A Literature Review to Understand the Requirements Specification's Role when Developing Integrated Product Service Offerings

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Abstract

This paper's objective is to analyze, based on a literature review, how existing IPSO design methods support and manage requirements when developing an IPSO. Issues analyzed are e.g. which types of aspects existing methods should consider, such as environmental issues and demands from stakeholders and customers. Another issue is what types of stakeholders are involved in the process. There is also an interest in finding out which of these methods are used in the industry. The goal is that the results will provide insight into how the requirements specification is used when developing an IPSO in theory, and in what way this insight will contribute to future studies on how companies currently derive and manage requirements when developing an IPSO.
The literature review started out with the analysis of 201 papers, yielding 22 papers within the area of working with requirements for an IPSO. These papers were reviewed and summarized with the above issues and interests in mind. Findings are that when deriving requirements, existing IPSO design methods are lacking in regard to a holistic life cycle and system perspective of the offering. Few of the methods consider both requirements regarding the environmental impact of the offering and demands from all involved stakeholders, normally only the customer. Furthermore, few studies have ended with a clear work process regarding how to initially find the requirements to analyze them and later interpret them as actual metrics. There are also no signs that existing methodology is used in the industry's day-to-day work.

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle

Keywords: Product Service System (PSS); Integrated Product Service Engineering (IPSE); Engineering design

1. Introduction

1.1. Background

An Integrated Product Service Offering (IPSO), also known as a Product Service System (PSS)[1], consists of combinations of physical products, services and systems that have been integrated and optimized from a life cycle perspective in relation to customer value [1]. Service in this paper includes e.g. operation, maintenance, repair, upgrade, take-back, and consultation. An IPSO often implies that instead of buying the actual product, the customer pays for the function [2]. This transfers the responsibility of care for the product to the provider instead of the customer, and moves the focus from consuming to using products. Therefore, the IPSO is often seen as a way toward a more resource-efficient and effective solution with less environmental impact, see e.g. Tukker and Tischner [3].

The integration and collaboration with stakeholders and actors in an IPSO is, according to e.g. Vasantha, Roy, *et al.* [4] and Mont [5], seen as an important aspect of creating a successful IPSO. Lindahl, Sundin, *et al.* [6] highlight in their conclusions that it is important to be able to handle and balance various types of requirements (identified physical or functional needs that a design must be able to perform), and not only from either environmental or customer-driven aspects. Mont [5] has also found the relationship between the suppliers and developers essential when creating an IPSO in order to have a sustainable production and consumption system. In their review of IPSO methodologies, Vasantha, Roy, *et al.* [4] found that creating requirement lists when developing an IPSO and stakeholders' involvement is some of the areas with the weakest maturity among different aspects for developing an IPSO.

[1]In this paper, IPSO is used as a synonym for PSS.

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle
doi:10.1016/j.procir.2016.03.225

1.2. Objective and research questions

The Mistra REES program – Resource-Efficient and Effective Solutions – is a 8M€ 4-year research program started in 2015 and with the vision *"…to advance the transition of the Swedish manufacturing industry towards a circular and sustainable economy"*. This includes determining which IPSO design methods are used in the industry, and an identified research gap, that is seems to lack of a wider understanding of the requirements specifications' (RS) role when developing an IPSO. With this initial study for a wider understanding as the objective, three research questions (RQ) were identified as important in relevance to the objective of both this paper and the research program.

RQ1. What types of stakeholders are involved when deriving requirements for an IPSO?

RQ2. What types of aspects are considered in a requirements specification for an IPSO?

RQ3. What IPSO methods are utilized in the industry to derive and manage requirements?

Since environmental aspects are of importance in the program, they will be crucial when answering the research questions above, especially RQ2. The answers to these questions should provide a good perspective on how the RS is used and worked with when developing an IPSO with existing methods. It will also be possible to compare the answers with what the literature says about how the development should be in later development stages to see how these aspects are considered in the RS.

2. Method

To fulfill this paper's objective, there was a need to find out what methods exist and what areas are taken into consideration when developing a RS for an IPSO. To realize the literature review to accomplish this, the methodology from Jesson, Matheson, *et al.* [7] was used. A structured approach will ensure reproducibility and that the study is explicit.

In order to limit the scope, this study covered only journal and conference articles written in English and published during or after 2000. The literature search was conducted on the 5th of October 2015, and Scopus and Web of Science was chosen as the databases for this study. 16 different search combinations with distinctive search terms and filters were used out to find a result with relevant papers. The search that was the basis for this literature review used the following search terms: *Product & service & system & requirement & develop* & design* & (lifecycle OR "life cycle" OR sustainab*)*.

The result was 354 papers, 340 when excluding non-English papers, and 275 when also excluding papers written before 2000. This resulted in 201 unique articles after removing duplicates. After reading all 201 articles' abstracts and conclusions, 22 articles [8-29] were found to show a connection to driving and working with requirements within the IPSO area. When performing the search for literature it was rather difficult to get relevant hits, as few of the resulting papers actually dealt with how a RS is derived and managed when developing an IPSO.The main search was limited to papers with a clear focus on requirements management within some sort of product and service system. Several of the papers found from the different search combinations were either not about developing or designing IPSOs, or they dealt with requirements on IPSO design methods, and not how requirements were handled for the IPSO itself. For each of the 16 different search combinations approximately 20 of the first abstracts were analyzed, and the combination with the highest relevance and appropriate scope was chosen. In future research a search combination with *(develop* OR design*)* will be used, but was for this initial paper rejected due to the limited scope. Regarding the decision to only look at articles from during or after 2000, it has to be emphasized that this only excluded 19 unique papers.

Data in the included papers were extracted and organized into different categories connected to the research questions. In this way, each identified IPSO design method or tool could be easily coupled to what aspects and stakeholders were taken into consideration and how they have been used in the industry.

3. Theoretical framework

3.1. Integration of stakeholders

The importance of a high level of integration of stakeholders involved in the development of an IPSO [4-6] was highlighted earlier. The early stages of the development process have a high impact on the final performance of the developed concept [30-32], sometimes called the design paradox, as illustrated in Figure 1. Time spent on developing a well-founded RS and truly understanding the customers' needs will be recovered later in the development process [32].

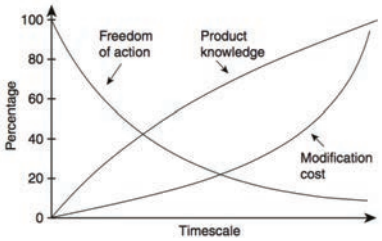

Fig 1. Illustration of the design paradox [32]

3.2. Requirements specification

Many different terms, more or less synonyms, are used in design processes to describe the RS concept (e.g., product design specification [33], performance specification [34], target specification [35] and design specification [36]). The RS is essential in all types of design processes and is the compilation of requirements on the potential offering (a combination of products and services) that is aimed to be developed. All requirements ought to be quantified or in any case defined in the clearest possible way; i.e., they must be comprehensive, unambiguous and cover all relevant life cycle phases of the potential offering (see and compare, e.g., with Pugh [33] and Pahl and Beitz [37]). In the end of the design process the outcome, i.e., the offering, must be in balance