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Product-Service Systems across Life Cycle

The role of Product-Service Systems regarding information feedback transfer in the product life-cycle including remanufacturing

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Abstract

With a Product-Service System (PSS), the producer often has control of its products during multiple life-cycles, and thus there are more incentives for design for service and remanufacturing in comparison to traditional sales. The aim of this paper is to explore the role of PSS regarding information feedback transfer in the product life-cycle including remanufacturing. The paper explores two industrial cases where PSS does not yet act as a facilitator for transferring information feedback from remanufacturing to product designers. However, the full potential of PSS is not yet utilized at the companies, and their products are neither designed for PSS nor remanufacturing.

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Keywords: Product life-cycle information; PSS; Remanufacturing

1. Introduction

With the scarcity of material and extensive CO_2 emission rates among other factors, the environment is suffering the consequences of our modern lifestyles [1]. As products are important for the welfare of our societies, it is vital that they are produced, used and taken care of after use in responsible ways. Among the ways to tackle these challenges, circular economy is promoted as one of the most promising strategies. Circular material flows can be achieved via e.g. remanufacturing [2], and the Product-Service System (PSS) is often promoted as one of the ways to move towards a circular economy [3]. A PSS is defined here as an integrated product and service offering in which companies supply their customers with the function that the product enables, without selling the product itself. Instead, the producing company sells the up-time of a product stationed at the customer's site, and thereby guarantees that the function will be provided for the duration of the contract [4]. Hence, the customer need not be concerned about the product, as the producing company takes responsibility for service of the product, and replaces the product with another if it should break down. In this particular instance, the PSS is considered in a business-to-business context, also referred to as an Industrial Product-Service System (IPS²) (e.g. [5]). There are three main turnover models for producing companies to consider: pay on order, pay on availability or pay on production [5]. Although PSS offerings are increasingly common [6], there are few companies that provide true PSS's; it is much more common to apply product and service selling business models [5]. Applying the PSS business model can give both economic and environmental advantages [7], the later foremost when functionality is sold [8]. This has been shown to be especially valid when remanufacturing is conducted on the product and used on PSS's [9].

The aim of this paper is to explore the role of PSS's regarding information feedback transfer in the product life-cycle including remanufacturing.

2. Method

This paper is based on a literature study and case studies. The case studies included semi-structured interviews with product development managers and remanufacturing

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managers at the case companies. Further, study visits were conducted at the manufacturing as well as the remanufacturing facilities in order to get a better understanding of the product and the processes.

The literature study focused on the role of the PSS and remanufacturing in the product life-cycle, in combination with information transfer. Papers were searched for in the *Scopus*, *Science Direct* and *Google Scholar* databases. Search words included *PSS*, *remanufacturing*, *product life-cycle information*, *feedback information*, *design for service*, *design for PSS*, and *design for remanufacturing*.

3. Product-Service Systems

One of the global sustainability goals is to maximize use with a minimum of resources. That is compatible with the aim of the PSS, which is to provide reliable products and reliable services [10]. The longer a product functions without problems the better for the PSS provider, as it lowers the company's costs. Products that are unreliable and hard to service, maintain and remanufacture become a cost issue that the producing company will feel the full impact of if it is a PSS provider. Thus, there is a strong incentive for the producing company to develop robust products that are easy to service. Moreover, since service could extend a product's useful life through maintenance and, for instance, education directed at users on how to best use the product, there are potential benefits to be gained for the environment [11].

Consequently, with carefully planned product design and by providing different services during the use phase as part of a PSS, the producing company has opportunities for revenues throughout the use phase. In fact, the service selling sector where PSS's are included is becoming increasingly important in developed countries, whereas the industry sector advances in developing countries [10]. The PSS is potentially a strategy that can enable developed countries to retain their competitiveness on the global market [12, 13].

Research shows that service costs are much more difficult to predict than production costs [14]. When PSS providers want to price their offers, the total life-cycle cost is a relevant measurement to compare the price of the PSS with [15]. There are costs associated with e.g. spare parts, service, fuel, taxes etc. to be included in the total life-cycle cost. Further, there are difficulties in predicting how technology will develop over time and customer demand changes over time. Therefore, the PSS provider needs to adjust the offer to maintain value for the customer [16].

There are more hidden costs in PSS systems than in common product selling, and difficulties arise when PSS providers sign contracts for long time periods [15]. Predicting how costs will develop over time and what new costs will arise over the next ten years is difficult. Forecasting requires control and information documented from previous experiences. For instance, relevant information could include how many times a product fails over a specific time period, and/or what spare parts needed to be changed.

According to Roy et al. [13], risk management in a PSS context requires information transfer as well as feedback. When the PSS provider offers a contract of availability, it has to ensure that the guaranteed level does not vary with geographical position. According to Datta and Roy [15], individual performance varies from day to day, and is a factor that affects how the service will be carried out. A PSS contract also enables long-term relationships between the customer and the PSS provider, thus establishing opportunities for information exchange. The close relationship that PSS provides also makes it easier to retrieve cores for remanufacturing, since better control of the products is possible during use (see e.g. Östlin et al. [17] and Sundin and Bras [9]). PSS implies a greater motivation for the company to learn more about its products in use and implement that knowledge in the design phase [18] (Goh and McMahon 2009). However, the quality of the data will vary because of factors such as different individuals and nations. Conditioning monitoring, where data objective data is collected, might be one solution to that problem [19].

3.1. Design for Product-Service Systems

To achieve a well-functioning PSS, products should be adapted for all the life-cycle phases that they pass through multiple times before being scrapped. To facilitate this, designers could use different types of DfX methodologies, e.g. Design for Assembly (DfA) [20], Design for Manufacturing (DfM) [21], Design for Service (DfS) [22], and Design for Remanufacturing (DfRem) [9]. Sometimes, these DfX's can contradict each other; this makes it important to understand that the products should be used multiple times, and therefore that some material and/or joining methods should be avoided in order to make the PSS work in a satisfactory manner. Sundin et al. [23] cite three industrial examples from forklift trucks, soil compactors and household appliances which describe how to design for PSS including remanufacturing. Usually, manufacturing companies are quite good at adapting their products for assembly and manufacturing. Utilizing feedback from manufacturing enhances designers' knowledge and supports DfM [24] Feedback from manufacturing personnel to product design is often very detailed [17]. The transition from a traditional business model to PSS in combination with remanufacturing creates a basis for companies to learn more about product design, use and maintenance [19]. PSS design begins with considering the customers' needs and what would give them value; then, it is realised through product life-cycle activities which result in value creation [26]. Thus, having a PSS approach implies that efforts are also directed towards facilitating the later product life-cycle stages, e.g. service and remanufacturing. For that reason, these stages are highlighted further in this paper.

3.2. Design for Service

Prolonging the product's useful life is usually beneficial from an environmental point of view [9, 27]. PSS's enable the provider to carry out preventative maintenance [4] and remanufacturing to avoid product breakdown and assure a high up-time. Products can be designed to ensure an efficient