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Product service-systems implementation: A customized framework to enhance sustainability and customer satisfaction

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ABSTRACT

New trends in product development aim at integrating the improvement of all activities related to the products' life-cycle, particularly when considering environmental issues. Within this context, Product-Service System (PSS) appears as a promising model, representing a win-win solution for both companies and customers. In particular, the medical devices industry is a sector where the PSS approach can assume a key role. However, despite the potential benefits deriving from the implementation of PSS solutions, few studies on PSS consider this sector.

To accomplish this, the paper proposes a methodology based on the analysis of the market demand and customers' needs by means of the Quality Function Deployment (QFD) method, and the simulation of life-cycle scenarios through the Screening Life Cycle Modelling (SLCM) method supported by Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) tools.

A case study performed in collaboration with a manufacturer of biomedical devices showed the benefits of the proposed methodology in the development of sustainable PSS solutions. Actually, the results demonstrate the validity of such an approach in enhancing customer satisfaction, while reducing environmental concerns and costs.

1. Introduction

Novel approaches in product development aim at integrating the improvement of all activities related to products' life cycle in order to enhance their performances (Sakao et al., 2009; Vezzoli et al., 2015). This is particularly true when considering the environmental impact of a product, as underlined by the recent deployment of product-related environmental legislation (Pigosso et al., 2016). Main intervention areas, which can allow companies to carry out a comprehensive life cycle evaluation, merge economic and environmental performances, and concern (WBCSD, 2010): dematerialization, closed loops production, service extension and development, as well as functional extension. As per Manzini and Vezzoli (2002), transferring the business focus from developing physical products only, to the offering a set of products and services, represents a win-win solution, both for companies and customers. Such a process, defined by Morelli (2003) as "servitization", consists in the evolution of product identity based on material features, to a position where the physical component is joined to the service system indissolubly. Accordingly, "service engineering" aims at intensifying and improving the development of services related to a product's life cycle (Sakao and Shimomura, 2007), providing solutions that integrate goods, services, and knowledge in order to add value to the core product offerings. As remarked by Song and Sakao (2016), the Product-Service System (PSS) approach is an important component of servitization, representing one of the most promising business models for companies. In literature, different PSS models have been presented, which can be classified into three main categories: product-oriented, use-oriented and result-oriented PSS (Tukker, 2004). In all three types, the product's provider retains the responsibility of the "after gate" life cycle stages of the product (Kjaer et al., 2016). From this point of view, manufacturers have all the incentives to optimize the product's life cycle, especially in the case of products with a high environmental impact during their use phase (Amaya et al., 2014; Tukker, 2015). Accordingly, in recent years numerous studies have discussed the ways to implement a PSS model, providing a review of the latest achievements in this field (Meier et al., 2011; Vasantha et al., 2012; Park et al., 2012; Boehm and Thomas, 2013; Beuren et al., 2013;

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Lindahl et al., 2014; Annarelli et al., 2016; Haber and Fargnoli, 2017a). As noted by Cavalieri and Pezzotta (2012), such a "popularity" is due to the possibility of realizing competitive and sustainable businesses. The development of PSSs can allow companies to achieve better environmental performances, while augmenting the product's value during its whole lifecycle (Bertoni et al., 2016; Sousa-Zomer and Cauchick-Miguel, 2017). The latter aspect was also remarked by Gao et al. (2011), who reviewed PSS models based on the competitive advantage they can provide manufacturers with, distinguishing between product-oriented (PPSS), application-oriented (APSS) and utility-oriented (UPSS) models. In particular, they argued that at present the APSS model, mainly concerning high-tech and heavy investment products (e.g. large medical equipment and engineering equipment), represents the target of most companies due to its economic and environmental benefits.

Furthermore, the integration of services with a product can increase the satisfaction of customers (i.e. the PSS receivers), offering the PSS provider the possibility to augment its competitiveness in the market (Sakao and Shimomura, 2007; Salazar et al., 2015). Coherently, the improvement of companies' performances cannot disregard the enhancement of customer satisfaction and environmental concerns (Baines et al., 2007; Sakao and Fargnoli, 2010; Durugbo, 2013; Sakao and Lindahl, 2015).

Within such a context, a lifecycle perspective is suggested by Sundin et al. (2009) in order provide better PSS performances. In particular, Fujimoto et al. (2003), considering the manufacturers perspective, suggest the implementation of life cycle simulation when focusing on the development of a service-oriented product to reduce environmental impacts while extending business opportunities considering its whole life cycle. To achieve such goals it is fundamental to provide solutions that satisfy both customers' and companies' needs (Kimita et al., 2009; Gao et al., 2011). However, facing these challenges is a complex task since it requires ensuring the design quality of both products and services based on customers' requirements (Akasaka et al., 2012; Mourtzis et al., 2017). In addition, it has to be noted that the complexity arising from the management of these issues when developing a PSS increases in the case of companies operating in regulated markets, e.g. the medical device sector, where the customers (i.e. the hospitals) have to follow public procurement rules and the end-users (i.e. doctors and technicians) have lower impact on the decision-making process when products and services are purchased (Bergman and Lundberg, 2013; Lingg et al., 2017). While several studies have recognized the great potential of PSS implementation in this sector (Oliva and Kallenberg, 2003; Xing et al., 2017), practical investigations have scarcely addressed this issue.

Accordingly, the purpose of the present study is to provide a possible answer to the following research question: how can manufacturers effectively address PSS implementation in a regulated market simultaneously augmenting customer satisfaction and environmental sustainability?

- Based on this, the present work is aimed at investigating the effectiveness of product life cycle management as a means to implement a PSS approach considering the manufacturer standpoint. Actually, apart from interventions that modify the product's technical characteristics (i.e. product re-design), the optimization of these product's life cycle phases such as use and maintenance, and disposal, can allow engineers to increase both environmental sustainability of the PSS, and the company's bottom line (Fujimoto et al., 2003; Fargnoli et al., 2012; Amaya et al., 2014).

To accomplish this, the paper proposes a methodology based on two key elements: a detailed analysis of the market demand and customers' needs by means of the Quality Function Deployment (QFD) method (Akao, 1990), as well as the simulation of life cycle scenarios by means of the Screening Life Cycle Modelling (SLCM) method (Fargnoli and Kimura, 2006). The study consisted in analyzing a practical case study in collaboration with a manufacturer of medical devices that also provides customers with consumables and maintenance services. To verify the feasibility of a PSS solution, environmental and economic effects of its implementation were estimated using the Life Cycle Assessment (Wenzel et al., 1997) and Life Cycle Costing (Woodward, 1997) methods. The results of these analyses brought to light the possibility to augment the business model, aligning the company's profit with customer expectations derived from the analysis of the market demand and customers' expectations.

More in detail, the following section discusses the motivation for the work presented. Section 3 proposes our research approach, while section 4 shows its practical application to the case study. Hence, section 5 discusses the results of our work and section 6 draws the conclusions, addressing future research work.

2. Background and motivation

Nowadays engineers need to identify and manage environmental aspects of a product considering its whole life cycle, with the aim of counterbalancing environmental performances against other aspects, such as usability, reliability, costs, market competitiveness, etc., including normative requirements (Mont and Lindhqvist, 2003; Kimura, 2007; Fargnoli et al., 2012; Pigosso et al., 2016). Given that PSS implementation requires a long-term perspective (Ceschin, 2013; Rabetino et al., 2015), the development of scenarios which take into account both environmental concerns and cost estimation are required (Alix and Zacharewicz, 2012; Dyllick and Rost, 2017). In addition, PSS development requires an in-depth understanding and involvement of users (Ceschin and Gaziulusoy, 2016). Nemoto et al. (2015) recognized the analysis of customers' requirements as one of the important issues in PSS research, while existing studies lack in focusing on their identification (Cavalieri and Pezzotta, 2012; Vasantha et al., 2012; Qu et al., 2016). Similarly, Hakanen et al. (2017) stressed on the need to further investigate the customer's perceptions of value associated with a PSS in order to address the manufacturer's strategies.

Hence, more practical case studies are needed to advance knowledge of improvement possibilities through PSS implementation (Lindahl et al., 2014), mainly focusing on the use phase of a product due to its large impact on both costs and environmental performances (Gronroos, 2011; Fargnoli et al., 2014; Vezzoli et al., 2015; Shu et al., 2017). Therefore, the need of focusing on service-oriented manufacturing (Kimita et al., 2015) assumes a key role in the ambit of the production of health-care devices (Gao et al., 2011). In this market sector, the product life cycle has to be linked to the service life cycle, taking into account different actors: the manufacturer, which usually provides maintenance services; the hospital technicians, who use the device; and the final consumer, i.e. patients who receive the treatment.

Furthermore, it has to be noted that most of the purchasers of this type of equipment are public hospitals, who have to apply the EU regulations concerning the so-called "public procurement" system by means of the issue of calls for tenders (Gelderman et al., 2006; Uyarra and Flanagan, 2010). This system requires that companies provide both the equipment and maintenance services for the duration of the contract, guaranteeing the respect of safety and environmental mandatory requirements (Hatzopoulos and Stergiou, 2011; Fargnoli et al., 2013). Considering this complexity, it is crucial to well understand the network of actors and their needs, including mandatory requirements (Mittermeyer et al.,