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Configuration of Product-Service Systems value networks – Evidence from an innovative sector for sludge treatment

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ABSTRACT

Product-Service Systems are increasingly emerging in response to market volatility and more demanding customer requirements. Their development process, however, is not as straightforward as for traditional physical goods. For instance, the configuration of a Product-Service System entails taking several factors into account, such as the points of view of the different actors in the value network. This paper proposes a methodological framework supported by modelling and simulation to evaluate the performance of different configurations of the value network, referred to as scenarios, and the impact of different input parameters within these scenarios. The proposed approach is illustrated by a case study which highlights the main drivers of a new innovative sector for sludge treatment.

Introduction

Market volatility and customer requirements are obliging companies to seek new customer-centred business strategies to provide customers with more added value and highly personalized solutions. This situation has led to the emergence of new services in the business field. Business is currently shifting from traditional physical products to a combination of products and services, known as Product-Service-Systems (PSS). The strategic and organizational transition from a manufacturing-oriented company to a PSS-oriented company is known in the scientific literature as 'servitization' [1–4]. This servitization process involves complex changes for the decision-makers of the focal company leading the PSS offer design and implementation, but also all the other companies collaborating in such integrated offers. Baines defines servitization as "*the innovation of an organization's capabilities and processes to better create mutual value through a shift from selling products to selling PSS*" [5]. Such a transition involves major challenges in terms of organizational transformations, process reconfiguration and cultural change.

Although the scientific literature indicates that consistent advances have already been made in the technical engineering of PSS solutions [6], there is still a lack of tools and methods to support the organizational transition induced by the servitization shift, in particular at operational level [7–9,42]. In addition to guidelines for the implementation of a PSS, decision-makers need feedback on the viability of a PSS solution prior to its implementation. PSS are based on a complex integration of product and service components, requiring the interoperability of several collaborative companies in the delivery network. The literature underlines that, before designing the detailed structure of a PSS, the viability of the solution in terms of the overall architecture of the system and its delivery network need to be assessed [6,10]. More specifically, PSS introduce new economic balances based on selling the use instead of the product. These balances are very sensitive to variations of the final PSS users' behaviours [11]. The anticipation of these economic impacts remains an important gap for PSS design [12]. The development of decision-making approaches meeting such requirements remains an important objective. Furthermore, generally speaking a PSS cannot be delivered by a single company meaning that the whole value network involved in the delivery process should be considered in the evaluation. Hence, a multi-actor perspective is crucial to assess the economic and technical viability, involving the various actors of the value network [7–9,13,14]. These peculiarities of the PSS context introduce a significant amount of risk underpinning the PSS implementation. Hence, an upfront assessment whether the intended business model will generate profit is crucial and proper tools are needed for this purpose.

In this perspective, simulation is one of the most common tools used in the PSS context to enable well-informed decisions on PSS alternatives [10,13,15–18,32]. Here the alternatives refer to the various PSS offers and are evaluated from a single perspective, i.e. customer point of view or company point of view. However, the

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various possible scenarios of delivery networks are poorly addressed and evaluation often uses classical performance indicators such as cost and lead time, despite some improvements proposing performance monitoring to PSS [19]. Thus, there is no clear support to the decision making process on how to proceed with the design of the overall architecture of PSS solutions, considered with their delivery networks. Basically, this highlights the lack of multi-actor perspective in the evaluation of PSS alternatives and methodological guidance throughout the design and implementation processes of these alternatives [7–9].

In order to support the industrial shift towards PSS, the first aim of this research work is to provide decision-makers with methodological and technical solutions to evaluate whether a PSS-oriented business model is economically viable and to assess the practical implications of alternative configurations of the PSS value networks. Simulation is included in this methodological approach to enable the virtualization of a large panel of performance drivers' variations. The decision-makers concerned are those in charge of designing the overall architecture of PSS solutions together with their value networks. They can belong to the various stakeholders of the required PSS delivery network.

Beyond the development of a decision support system dedicated to a specific PSS case study, a second and complementary objective of this paper consists in structuring a generic framework for PSS modelling and analysis, aimed at supporting the generalization and re-use of generic components of the decision support system. This methodological framework supports the development and implementation of contextualized Decisions Support Systems dedicated to the analysis of PSS network configuration, then the use of these DSS to generate concrete analyses of PSS case studies.

A case study in the sludge treatment sector is used to illustrate the proposed approach and helps identifying the main drivers for the economic performance of the PSS value networks considered. The case study pointes out some key performance drivers for the innovative sector of industrial sludge treatment and discusses the relevance of the developed decision support system to the analysis of alternative business models viability.

The rest of the paper is organized as follows. Section 'Literature review and research positioning' reviews the literature to identify PSS development methodologies and requirements. The PSS design framework is presented in section 'Proposed framework' which joins the requirements identified from the literature to previous research outputs in the PSS domain. The illustration with a case study and the result analyses are detailed in section 'Case study in the sludge treatment sector'. The paper ends with concluding remarks and perspectives in section 'Conclusions and research perspectives'.

Literature review and research positioning

A non-exhaustive literature review was performed in order to provide the theoretical foundations of the paper, by shedding more light on the most common PSS design requirements. The search for articles was limited to the ScienceDirect database and to the last decade. A recent literature review revealed that the Journal of Cleaner Production, Journal of Manufacturing Technology Management, and CIRP Journal of Manufacturing Science and Technology were among the journals with the highest PSS publication frequency over the last decade [9]. Thus, the focus was put on these journals as well as the Proceedings of the Industrial Product-Service Systems Conference. The first filtering criterion relates to the relevance of article titles to PSS design, performance and simulation. The second filtering criterion is the papers' abstracts allowing for the number of papers to be considerably reduced.

In coherence with the current research orientation, 3 key topics are highlighted: stakeholder integration, PSS design and configuration, PSS simulation and assessment. Further research gaps and requirements are identified and summarized towards the end of this section.

As predicted by many authors over the last decade, service advantages are progressively starting to dominate the business world [7,20–22]. Services are being combined with products to provide customer-centred and integrated solutions. According to Meier et al. [7], an Industrial PSS is characterized by the "integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in Business-to-Business applications and represents a knowledge-intensive socio-technical system". PSSs represent high benefit potential to all the actors involved. Higher revenues, longer business relationships and lower resource consumption are some of the benefits to the PSS provider. As for the customer, PSS could lead to a higher level of productivity and lessen customer responsibility with regard to physical products [7,9]. Furthermore, PSS has the potential to reduce the environmental impact of capital goods through dematerialization [9,13,23,24]. To promote these benefits, proper methodologies are needed to jointly develop products and services and monitor PSSs throughout the product lifecycle [7,13,25]. The following sections shed more light on the need for stakeholder integration and PSS design and configuration approaches, in order to clearly point out the gaps in this field (section 'PSS design requirements').

Stakeholder integration

As observed by many authors in the PSS literature, all the stakeholders interested in the PSS should be involved in the design process [7,8,26,27]. Morelli [26] proposed a set of PSS engineering methods focused on the representation of the PSS and PSS partners. The author stressed the need for collaboration between PSS value network actors as well as external stakeholders in order to support an integrated PSS solution. Accordingly, a PSS network should be designed prior to developing the PSS solution, which supports both the design and operation phases of the PSS solution. This is because the PSS, unlike traditional manufactured products, draws upon a lot of internal and external resources [10,27]. Additionally, PSS development requires not only technological knowledge on products and services but also regulations and the cultural backgrounds of the actors. This increased complexity in the design and delivery of PSS solutions induces a need to integrate multiple know-how and a full service network, in particular when considering PSS customers at territorial level [8]. Subsequently, customer satisfaction with the PSS depends on the way services are delivered. Thus, it is important to gather customer requirements properly by involving them in the PSS design and value-creation processes [14,28]. Consequently, stakeholder integration gives rise to efficient design of PSS solutions and mitigation of the risks accompanied with the servitization process [8]. Such risks can be further mitigated by designing proper assessment tools and methods to be applied to the evaluation of alternative PSS network configurations. This highlights research needed in the development of consistent PSS assessment solutions with real integration of stakeholder points of view.

PSS design and configuration

In the PSS literature the focus is put on the product and service design process itself, while methods relating to PSS configuration and evaluation remain scarce.

Marques et al. [25] proposed a generic PSS development methodology relying on the integrated design of product and