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A Service Engineering framework to design and assess an integrated product-service

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ABSTRACT

Companies are striving to create new sources of value, providing integrated product-service solutions to customers, evolving from a "pure product" orientation towards a Product-Service System (PSS) perspective. In this context, Service Engineering (SE), the discipline concerned with the systematic development and design of product-services, is becoming a predominant field. Most of the available Service Engineering models, methods and tools come from traditional engineering, business and computer science approaches adapted to the Service System or Product-Service System. In order to fill this gap, this paper proposes a Service Engineering framework that integrates a product-service design modelling tool developed at the Tokyo Metropolitan University with a discrete event simulation test-bench, enabling the comparison of several PSS configurations considering both customer satisfaction measures and internal performance. A sample case is reported to exemplify the different phases of the framework implementation.

1. Introduction

The manufacturing sector has undergone tremendous changes in recent years. Manufacturing businesses that operate in today's competitive global economy – in which products are easily commoditized – are increasingly coerced to adopt strategies aimed at innovation and differentiation [1]. To withstand the sharp marked downfall, traditional firms need to extend their core manufacturing activities – focused primarily on purely physical products – with the provision of complementary services. This change in manufacturing companies, usually referred to as *servitization* [2], is largely motivated by a rising need to create new sources of value for customers, by either reactively fulfilling explicit requirements or proactively offering them new integrated solutions of product and service. [3]. From pure product orientation, businesses have thus evolved towards a Product-Service System (PSS) perspective, which refers to the whole cluster of products, services, supporting networks and infrastructures [4].

As repeatedly underlined in academic and managerial literature, mastering a servitization strategy can provide financial, strategic, marketing and environmental benefits [5,6]. However, although services are delivered to attain higher margins, most manufacturing companies find it quite difficult to perform the required transition successfully: a Bain and Co's survey revealed that only 21% of the sampled companies experienced lasting success with their service strategy [7]. When increasing their service offerings, companies sometimes incur higher costs and eventually fail to achieve the expected returns. [8,2]. Overcoming this hitch – referred to as the *servitization paradox* in the literature [9] – represents a major managerial challenge: companies need to re-design their organisational principles, structures, processes [8], capabilities [10], as well as the relationships with customers [11] and suppliers [12]. Indeed, the design and development of a PSS raise new issues; the service component introduces new requirements that are less (or not at all) relevant in a traditional, product-based business model. In particular, the substantial cultural shift, from a transaction-based approach to a long-term relationship with customers, needs to be thoroughly understood by companies, along with the acquisition of suitable models, methods and tools for collecting, engineering and embedding into a PSS all the knowledge that meets or exceeds people's emotional needs and expectations.

As reported by Cavalieri and Pezzotta [3] and Rapaccini et al. [13] a significant portion of the extant literature on PSS provided relevant contributions on methods and tools to manage the above-discussed aspects and address issues effectively. However, the majority of these approaches were developed in other fields (such as product and system engineering), and only subsequently

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adapted to the PSS field: indeed, to our best knowledge only a few methods and tools have so far been developed specifically for service and PSS design and engineering.

Because of this, Service Engineering (SE), a "technical discipline concerned with the systematic development and design of PSS using suitable models, methods, and tools" [14] has gained ascendance. SE is becoming a key approach for managing the complexity of a mechatronic PSS, meant as a combination of products, ICT (Information and Communication Technology) components and services, which demands a profound understanding of the system since its early stages of development.

However, despite the many advantages of SE amply attested in the literature [3,14], only a few authors have so far proposed tailored methodologies and tools that can easily be adopted by industrial companies, and these have in turn maintained a largely product-centric focus during PSS design. In other words, industrial companies still focus on engineering, the "tangible" part of their integrated solutions, adopting rather intuitive processes and methods to develop "intangible" elements. The achieved value therefore lacks optimisation, and appears as an unstructured mashup of "something methodologically and systematically approached" and "something rudimentarily developed" [3].

This paper endeavours to fill this gap by proposing a framework that integrates the design capabilities of a computer-aided modelling tool for Service Design (namely, the Service Explorer presented in [20]) with a simulation test-bench. The adoption of simulation is meant to enable comparison of alternative PSS configurations and an assessment of their technical, operational and economic performance. Within this framework, the central idea is to provide manufacturing companies with a valuable and user-friendly tool for designing PSSs methodically. Starting from a functional analysis and the definition of implicit (or context-related) and explicit customer needs, this framework envisages the adoption of simulation techniques for testing alternative scenarios and their impact on both customer and company needs. A preliminary version of the framework was presented in Pezzotta et al. [21] at the 11th IFAC Workshop on Intelligent Manufacturing Systems in São Paulo in 2013. The present paper provides a thorough description of a refined version of the framework, based on the feedback gathered from several applications in real-world industry cases. With a view to gaining an in-depth understanding of the developed framework and its related advantages, we will carry out a thorough analysis of the case study and of the results obtained. It should be stressed however that for the purpose of this paper, we focused exclusively on the engineering of PSS service elements, which include service content, provision process and related resources. To this end, we have laid out this paper as follows: a literature review on SE with a focus on design and simulation methods and tools nowadays available is presented in Section 2. Then, overviews on the Service CAD (Computer Aided Design) methodology, on the Service Explorer tool, and on Discrete Event Simulation (DES) are introduced in Sections 3 and 4. Section 5 provides a description of the framework through a sample case, while conclusions and further research developments are reported in the last section.

2. Product-service system engineering

The first definition of product-service appears in the literature in the '70s, in the words of Rathmell [22]: "Services may be an accompanying sale of a product". Although Rathmell's definition preserved a sharp distinction between product and service, it offered a new perspective for their mutual integration with the goal to improve customer satisfaction. Today, this concept has a new meaning. The basic idea behind the PSS concept originates from shifting the business focus from the design and provision of physical products to the design and provision of complete systems that consist of products, services, supporting networks and infrastructures [15,4] and also encompasses intelligent and mechatronic systems which group products, IT-components and services. These are jointly capable of fulfilling specific customer demands and needs.

The profit generation and the commercial success of a PSS critically depend on its conceptualisation, design and development, even though this notion has been largely ignored [14]. According to Baines et al. [15], the plethora of tools and methodologies available for designing PSS are typically a rearrangement of conventional processes. Therefore, they suffer a substantial lack of a critical and in-depth evaluation of their performance in practice. As highlighted in [23], when compared to physical products, services are generally under-designed and inefficiently developed.

This is the main factor behind the upsurge of SE as a technical discipline since the '90s and its prominence today. In the words of Bullinger et al. [14] and Shimomura and Tomiyama [24], SE may be termed as a technical discipline concerned with the systematic development and design of services aiming at increasing the value of artefacts. Through the adoption of a rational and heuristic approach based on modelling and prototyping methods, SE also aims at systematically integrating product and service contents, enhancing the functionalities and/or the quality of the physical product, and improving the service content and the provision channel. In particular, the provision of services and of enhanced functionalities in innovative and future products calls for the introduction of increased product smartness, such as the use of embedded mechatronics in product-service components [25,26]. This will necessitate a strong interconnection between product engineering and SE.

One of the salient features of SE is its orientation to the design and development of product-service offerings which take into account the internal perspectives of both customer and company. Despite that, existing SE models [13,15–19] focus mainly on designing solutions able to satisfy customer needs from a functional point of view, and largely neglect the equally crucial aspect of operational excellence in the delivery phase of the service solution.

Consideration of the literature on SE shows that a significant number of contributions focuses on how to carry out the SE process through the adoption of suitable practices, methods and tools. However, only a limited number of methods have been developed specifically for service and PSS design, development and engineering. In fact, most available SE models, methods and tools derive from the adaptation of traditional engineering, business and computer science approaches to Service System (SS) or PSS [3,27,28].

In addition, some of the available methods were proposed as a part of a broader methodology to support the SE process and all the related activities and tasks. These include the Methodology for Product-Service System (MePSS) [17] and the Service CAD [29], a modelling methodology created to describe and develop customer value and its ground, the relationship between customer value and service contents, and the service contents delivered by products and/or services [30,31]. These methodologies marked the need to support theoretical research by creating a specific IT tool which aims at translating theoretical knowledge into viable industrial applications [3].

Among the different authors approaching SE, Arai and Shimomura [29], Hara et al. [30] and Sakao and Shimomura [20] focused their attention on two main outputs: the establishment of a new discipline called Service/Product Engineering (SPE), and the development of the Service CAD. The focus of the SPE is close to the SE, but it puts more emphasis on customer value creation, which must be accomplished not only through the provision of products, but also with all the service activities, a relevant feature concurring in the creation of customer value. In SPE, product and service activities are designed in parallel according to the value provided to the final customer.