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Proposal of a hotspot-based approach to identifying social impacts along the product-service systems life cycle in the early design phases

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Abstract

The potential for sustainability has been highlighted as one of the most important characteristics of product-service systems (PSS). Nevertheless, a PSS is not intrinsically sustainable. Methods and tools for PSS sustainability assessment should be developed to be integrated into the design process, especially in the early design phases, in order to conceive sustainable solutions. In addition, a PSS should be planned considering the three sustainability dimensions, from a life cycle perspective. However, PSS design and assessment considering the full life cycle is scarcely addressed in the literature, especially concerning the social dimension of sustainability. In this sense, this study proposes a streamlined life cycle assessment based approach to identify potential social impacts along the PSS life cycle that can be integrated into the early PSS design stages. The proposal is based on a hotspot analysis, which identifies where in the life cycle the most significant issues may occur. The proposal was developed in three main phases, anchored in both hotspots analysis and PSS literature. After developing it, 10 experts in PSS and sustainability assessed the proposal strengths and weakness. Some suggestions were offered by the researchers and improvements were introduced to the proposal regarding PSS life cycle phases and the social impact subcategories. The experts considered the hotspot analysis suitable to be applied in the early design stages when there is not much information yet regarding the system to conduct a complete life cycle assessment. The next step of this research is the proposal assessment by practitioners in industry. Further work will also integrate the environmental dimension of sustainability into the proposal.

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Keywords: sustainable product-service systems; sustainability assessment; social impacts; early design stages.

1. Introduction

The sustainability potential has been highlighted as one of the most important characteristics of product-service systems (PSS) [1]. However, PSS solutions are not intrinsically sustainable [2]. A PSS needs to be properly designed in order to have sustainability potential when compared with the traditional business models [3]. The design process, therefore, is one of the most influential factors in developing PSS solutions that have a high potential for sustainability [2].

In fact, to conceive sustainable solutions, sustainability aspects must be included as early as possible into the PSS

design process [4]. Careful evaluation of PSS sustainability potential must be conducted in the early design stages [5], which can determine the quality of the final PSS solution [6]. In addition, PSS design and assessment should be conducted from a life cycle perspective [7,8], which ensures effects do not increase during the PSS life cycle [9]. However, few methods and tools have been developed to assess PSS sustainability potential from a life cycle perspective [8], especially in the early design stages [10]. Moreover, the social dimension of sustainability often occupies a minor position in the PSS design and assessment [11-13]. There are, in fact, a limited number of studies that consider PSS social effects

[12]. More research should be conducted addressing potential PSS social impacts, because to be considered as a real sustainable solution, a PSS should provide environmental, economic, and social benefits [3,12]. The development of support methods and tools for PSS sustainability assessment is necessary, especially with regard to the social dimension [13], its integration into the early design stages and from a life cycle perspective [5,8,14].

In this sense, this paper proposes a streamlined method for assessing PSS social sustainability potential during the design process. Streamlined assessment methods have been recommended as suitable when strategic decisions have to be made without many detailed data, such as in the early design stages, and these methods apply a life cycle perspective [15]. Although the life cycle assessment (LCA) has a potential for PSS assessment [14], conducting a complete LCA during PSS early design process may be a challenge, as in the case of products design [16,17].

This proposal is based on hotspot analysis, an approach that allows identifying the most significant issues throughout the life cycle [18]. The goal of the structured hotspot analysis is to get an overview of possible social impacts that can be valuable to identify actions that may be applied to improve the PSS social performance. Hotspot analysis has been highlighted as useful to optimizing PSS design [14], but there is still limited research on this subject, especially regarding the social dimension. Thus, this paper aims to explore the hotspot analysis application in PSS design, in order to provide a broad overview of possible social impacts and support the decision-making process regarding impacts mitigation.

The remainder of this paper is organized as follows. Section 2 provides a brief literature review concerning PSS sustainability assessment. Section 3 describes the phases of the research design. Section 4 presents the proposed hotspot analysis approach, finalizing by outlining the proposal evaluation by 10 experts in the field. Finally, section 5 draws the conclusions and limitations of this work.

2. Theoretical background

The PSS sustainability potential has been highlighted in various publications [e.g. 1-3,13]. To achieve sustainability through PSS, a very important issue to be considered is how to measure sustainability [19]. Some publications have been addressing PSS sustainability assessment [e.g. 5,13,19,20]. Life cycle assessment [9,14] and life cycle costing – LCC [21] for instance, have been applied to assess PSS environmental and economic impacts. However, research gaps concerning PSS sustainability assessment remain, as already pointed out by ref. [13]. Only a few approaches proposed in the literature can be applied to or adapted for PSS assessment during the design process. Additionally, a limited number of methods address the social dimension of sustainability and permit to analyze effects from a life cycle perspective. Nevertheless, due to uncertainties during the early design phases, novel methods and tools are essential to enable the design team to assess the degree of sustainability of a given product or service [16]. Moreover, design planning that is centered on the life cycle is essential to achieving sustainability

improvements; integrating socioeconomic modeling with design and life cycle assessment is a research gap, even for physical products [16].

Kjaer et al. [14] pointed out that LCA can be applied to PSS evaluation in three scopes. The first one focuses on PSS optimization in order to identify hotspots and evaluate different improvement options. This evaluation is relevant both in designing a PSS in order to optimize environmental performance and optimizing a current PSS offering [14]. The second scope concentrates on comparing PSS alternatives. The third one assesses the consequences to an existing system of implementing a PSS solution. Nevertheless, many challenges to apply LCA for PSS assessment remain, as already pointed out by ref. [14]. In addition, producing an LCA method adapted to design situations is a true challenge, mainly due to the time and effort needed for the data collection phase, the LCA modeling, and then the evaluation and interpretation of results [17]. Moreover, while LCAs are vital to a complete life cycle assessment, it typically supports the final stages of product design, when most features are fixed [15]. LCA also focuses only on the environmental dimension, and a limited number of studies regarding social life cycle assessments (SLCA) have been conducted so far.

Other LCA-based assessment tools, including streamlined LCAs, have appeared in the literature to mitigate the complexity inherent in LCAs as its application to the design process [17]. Actually, the literature discusses various streamlined methods [15], including hotspot analysis, which is valuable for the prioritization of resources and actions in countries, industry sectors, products, and services that matter by virtue of their environmental, social and ethical impact profile [22]. Since hotspots analysis allows covering the social dimension of sustainability from a life cycle perspective [23], and can be valuable for PSS design [14], it was explored as a potential method to be applied in the early stages of PSS design, to identify potential social impacts throughout PSS life cycle. Next section presents the research design to structure the proposal of this study.

3. Research design

The goal of this study is to develop an approach to be applied during the PSS design process, in order to identify where are possible hotspots located in the PSS life cycle, and the social impact categories associated with the hotspots. This information may be valuable for identifying improvements in the social performance along the PSS life cycle and for suggesting mitigation strategies. From the identified research opportunity, the research procedures were divided into three phases, as showed in Figure 1.

Firstly (Phase 1), the literature on PSS and sustainability subjects was reviewed by a search in relevant databases (Scopus, Web of Science, and Compendex). After discarding papers that were not aligned the cited subjects and the duplicates, 116 articles were retrieved and analyzed. Fifteen publications that address PSS sustainability assessment were selected. This phase was valuable to provide an overview of existing PSS sustainability methods and to support the proposal development process. This literature review

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