Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 30 (2015) 138 – 143
www.elsevier.com/locate/procedia

7th Industrial Product-Service Systems Conference - PSS, industry transformation for sustainability and business

Product-service systems as a promising approach to sustainability: exploring the sustainable aspects of a PSS in Brazil

Sousa, T.T.[a*], Cauchick Miguel, P.A.[a]

[a]*Production and System Engineering Department, Federal University of Santa Catarina, Campus Universitário Trindade, Caixa Postal 476, 88040-970 Florianópolis, SC,Brazil*

* Corresponding author. Tel.: +55 48 3721 7039; *E-mail address: thayla.ts@gmail.com*

Abstract

Product-Service Systems (PSS) represent a business proposition with potential to provide a wide range of economic, environmental, and social benefits, allowing achieving the sustainability. However, PSS does not necessarily lead to sustainable solutions and this potential must be assessed in each case. In this sense, the aim of this paper is to investigate sustainable aspects of a 'result oriented PSS' (a reverse osmosis water filter system) available in Brazil and compares it with the conventional product, the bottled water. Some aspects from the literature, mentioned as important in each sustainability dimension, were selected to analyze the PSS under study. A qualitative analysis was performed and demonstrates that in comparison with bottled water, the water filter PSS is competitive, satisfy customer needs, and has a relatively lower environmental impact. However, besides conceiving sustainable solutions, is necessary to identify which factors drive the implementation and diffusion of PSS. Some findings of this study suggest that the effects caused by unexpected consumer behavior and incorrect PSS application may compromise PSS sustainable performance during operational phase. An analysis of these effects during transition process is essential to successful sustainable strategies. The study aimed to contribute to the PSS empirical knowledge and to assist building a theoretical basis regarding PSS and sustainability.

Peer-review under responsibility of the International Scientific Committee of the 7th Industrial Product-Service Systems Conference - PSS, industry transformation for sustainability and business

Keywords: product-service system; PSS; sustainable product-service system; sustainability; environmental impact

1. Introduction

Product-service systems (PSS) represent a promising model to drive the current patterns of production and consumption towards sustainability [1]. Although PSS can be seen as an innovation strategy capable to fulfill consumers' needs through the sale of the function instead of the product itself, PSS does not necessarily lead to sustainable solutions [2]. PSS models should be studied to better identify when they actually assist in reorienting current unsustainable trends and can be referred as a sustainable product-service system [2]. In this way, more PSS solutions should be studied to better identify its sustainable potential as well as its constraints [3].

PSS has become a popular subject and a wide range of research in the PSS and sustainability fields have been developed. However, despite all the knowledge accumulated, the application of this concept is still very limited, because PSS solutions are radical innovations in most cases and the adoption of PSS strategies brings significant challenges [4]. To shift towards eco-innovations like PSS, companies should be able to anticipate the acceptance of these innovations in the market [5] in a way to generate satisfactory value for customers and fulfill the sustainable requirements at the same time [6]. These requirements cannot be limited to environmental dimension and require the three dimensions of sustainability, i.e. environmental, economic, and social. In addition, consumer behavior plays a crucial role in the application of eco-innovations and their resulting impacts [5]. Hence, to be successful and sustainable, it is needed not only to design sustainable PSS but also to understand how the process of PSS implementation and operation takes place in practice. Moreover, since the consumers generally show a lack of knowledge and understanding about PSS concept [1], the

Peer-review under responsibility of the International Scientific Committee of the 7th Industrial Product-Service Systems Conference - PSS, industry transformation for sustainability and business
doi:10.1016/j.procir.2015.02.025

measurement of its sustainable potential compared with traditional products and reporting of PSS solutions performance can help PSS diffusion.

Although some studies have been explored in the literature, there is still a lack of understanding about PSS implementation process [1] and consumers' behavior, and how these factors may affect the PSS sustainable performance. In fact, attention has focused mainly on production changes [7], while consumption patterns are also an important challenge for PSS diffusion. Environmental improvement compared with traditional products, PSS cost-benefit [8] as well as PSS sustainability assessment [6] are other issues that should be explored. To do so, empirical investigations may be conducted to help refine the theory [8] and to identify factors that influence PSS performance. The findings may also provide guidelines to better design and implement PSS business models. In this sense, the aim of this paper is to investigate sustainable aspects of a PSS business model available in Brazil.

The paper is organized as follows: the context of the research is described in this first section. The second section presents a literature review by covering PSS and sustainability issues. The third section starts with the description of the PSS under investigation followed by research design and procedures. The fourth section discusses the findings of this work. Finally, concluding remarks are drawn in addition to insights for future work.

2. Product-service system as a sustainable solution

The development of eco-efficient and sustainable PSS requires moving from product thinking to system thinking [1, 3,9]. PSS environmental performance depends on the systems' design and the efficiency of networks and infrastructure [10]. Thus, it is essential to appropriately design the stakeholder network configuration in order to make stakeholders economically incentivized in improving the environmental and social PSS performance [1]. Equally, analysis of stakeholder networks, identification of potential conflicts of interest, studies about consumer behavior in relation to ownerless consumption as well as evaluating customer satisfaction with newly developed PSS are also necessary [10].

Although PSS literature is expanding, there is concern that sustainable PSS has still not been widely implemented and diffused [11]. One reason for this may be that little attention has been paid to understanding how the process of PSS introduction and diffusion takes place and how it may be managed and orientated [4,12,13]. Moreover, little attention has been given to how PSS knowledge developed in literature may support transition to more sustainable PSS [14]. Despite several methods and tools have been developed in the last years to support the designing of eco-efficient and sustainable PSS [1], an assessment of how these tools perform in practice is still required [8].

PSS sustainability assessment is in the relatively early phase and thus requires criteria to define whether a PSS is successful [6]. In addition, most of the literature on PSS sustainability evaluation has been focused in environmental dimension [15]. Since PSS involves a range of stakeholders that have economic interest, the economic dimension should be also considered. Likewise, the social impact itself takes a role as a key driver of PSS development and should be taken into account [15].

Available PSS design methods and tools usually put little emphasis on the implementation phase, just providing general suggestions and guidelines [1]. Factors that influence the PSS implementation need to be understood, because the introduction of eco-efficient PSS is a complex process [16], i.e. there is no guarantee that PSS will be necessarily less environmentally problematic than traditional products during the operational phase, even if it were properly designed. In order to assess PSS sustainability, it is necessary to develop criteria based of three dimensions of sustainability and addressing all PSS life cycle phases. As PSS sustainability assessment is an emerging field, the theoretical basis should be built [6].

The sustainability oriented PSS research paid only limited attention to business management literature and case study research was often driven by normative sustainability goals and failed to analyze the reasons for poor PSS implementation, such as a lack of consumer acceptance or business interest [17]. However, case studies have revealed (and continue to expose) diverse PSS designs and practices, each embedded in their own trajectories, logic and institutional arenas [14], that contribute to the development of PSS theory [8]. Indeed, case studies may provide empirical evidences of how PSS performs in practice, i.e. what are the factors related with consumers and other stakeholders that may affect PSS economic and environmental performance and what are the challenges faced in transition and implementation processes in contextual conditions. It is also known that PSS success is highly dependent on being sensitive to the culture in which it will operate [1].

In short, the combination of literature review and case studies can provide significant insights and understanding on how the introduction and diffusion of sustainable PSS takes place [1]. In order to contribute with knowledge and experience regarding sustainable PSS, a PSS with high sustainable potential is presented in next section, followed by research methods adopted to analyze it concerning sustainability dimensions.

3. Research procedures

This paper reports on the results of an explorative and qualitative study involving a B2C (i.e. business to consumer) PSS, since knowledge and experience regarding the PSS business models are still limited [8]. In comparison with quantitative research approach, qualitative data gives deep insights in the phenomenon under study by considering context-specific factors, complex patterns and causal relationships [18,19], which are very important in PSS context. The literature review shows that research work is in early phase of understanding when a PSS is sustainable and successful during the implementation and operational phases in addition to what are the factors and criteria to assess the sustainability. Thus, the research question arises as following: what are the factors related to contextual conditions that should be taken into account and could influence the PSS sustainable performance? What are the evaluation criteria to assess a PSS? Empirical investigations are required to provide

insights to theory construction process. The following section firstly describes the PSS under study and then the next one presents the research methods adopted to analyze it.

3.1. Reverse osmosis water filter system

The unit of analysis for this exploratory investigation is a water filter PSS available in Brazil. It consists of public water supply purification through a reverse osmosis process. The PSS under study aims to provide 'purified water' to consumers as an alternative to the products 'bottled water' and 'water filter'. In this context, the consumers pay for the result 'purified water', rather than the product. Contractual agreements are established between the service provider (called 'the company') and commercial establishments (e.g. supermarkets, bakeries, etc.), and an equipment is installed at the establishments' infrastructure to be offered to consumers. The equipment purifies water (that comes from the public water network) in the moment of purchase. The consumers purchase one of the options of volume available. They come to the places where the equipment is installed bringing their own containers (e.g. glass bottles, plastic gallons, etc.).

The studied PSS provides a solution for overcoming a common problem in the region where it is located since the public water supply quality might be questionable. As consumers usually do not trust in water quality, bottled water consumption has increased. Another problem currently faced in Brazil, mainly in the Southeast region, is the lack of water. The extreme weather events, overconsumption, and bad urban planning threaten the water supply in large cities, leading to increased bottled water consumption. However, bottled water industry and the bottle waste are leaving an enormous environmental footprint, including environmental releases of toxic substances and massive waste as millions of unrecycled bottles pile up in landfills [20].

In this context, it is necessary to develop alternatives focusing on a reduction of bottled consumption while providing at the same time quality water to population in order to decrease the environmental impact that overconsumption has generated. The water filter system has the potential to provide the conditions to enable communities to pass to less resource-intensive system. For being unique and revelatory to the understanding PSS sustainable potential when compared with traditional product (i.e. bottled water) the water filter system was selected as a PSS under study.

To collect data, a combination of techniques based on observations and semi-structured interviews with PSS actors were carried out. The results of this study were synthesized in the light of the existing literature revealing some relevant findings. At a first stage, a literature review was performed addressing tools and techniques as well as criteria that could be used to assess PSS sustainability aspects, outlined in the next section.

3.2. PSS sustainability analysis criteria

To achieve sustainability through PSS, the first issue to be considered is 'how to' measure sustainability [15]. It is needed to define evaluation criteria regarding three sustainability dimensions. The criteria for sustainability assessment usually come from the combination of various aspects and indicators [6].

Most of the literature on the evaluation of PSS has tried to measure 'environmental' performance [15]. The environmental impact come from the efficiency of each unit of function delivered to consumer [21]. Recently, simulation methods and tools have been used for PSS sustainability assessment. Approaches may vary, and a number of works has focused on life cycle assessment (LCA) and life cycle costing (LCC). Although LCA takes a holistic approach and has been largely accepted as a useful method to quantify and evaluate environmental impacts, LCA is a complex assessment tool [22]. In addition, the social dimension, which is essential in PSS assessment, is not considered in LCA perspective. Regarding PSS, LCA studies have focused on academic simulation model that is hard to implement in practice, while other studies focus on the analysis of specific PSS cases and comparison with similar product is not provided [23].

Beyond LCA, other works have presented sustainability indexes to PSS assessment (e.g. [6,24]). Nevertheless, a great part of publications analyzes PSS sustainability qualitatively. Due to applicability limitations of existing tools to assess PSS sustainability, as well the own study limitations (e.g., a lack of data from all PSS life cycle phases), a qualitative analysis was performed concerning some elements cited in other publications as important in each sustainability dimension. Those are summarized in Table 1. Next section presents the main results of the analysis.

Table 1. Sustainability elements analyzed.

Conceptual element	Authors
Greenhouse gases emissions Renewable resources use Efficient use of resources	Manzini, Vezzoli (2003) [3]
Waste generation Energy consumption Efficient use of transport	Omman (2003) [25]; Evans et al. (2007) [26]; Lee et al. (2012) [15]; Hu et al. (2012) [27]
Health and safety	Omman (2003) [25]; Lee et al. (2012) [15]; Hu et al. (2012) [27]
Employment of labor	Omman (2003) [25]; Devischer, Mont (2008) [28]; Hu et al. (2012) [27]
PSS acceptance	Mont (2004) [10]; Devischer, Mont (2008) [28];] Hu et al. (2012) [27]; Armstrong et al. (2014) [29]
Operational costs	Evans et al. (2007) [26]; Devischer, Mont (2008) [28]; Tonelli et al. (2009) [30]; Hu et al. (2012) [27]
Added value	Omman (2003) [25]; Devischer, Mont (2008) [28]; Hu et al. (2012) [27]

4. Results and discussion

The company that provides the equipment and the commercial establishments share the services to keep a purification function available. The main service (water purification) is provided to consumers at the commercial establishments. The company is responsible by installation, equipment maintenance, repairs and replacement (if needed), and disposal. The product of the PSS is the reverse osmosis equipment. The consumer buys the output of the product according to the level of use (water volume available). In this sense, this PSS can be classified as 'result oriented' PSS, according to ref. [31], in a pay per service unit model. The system works as follows: the equipment collects water from the local public water network (the water reaches the

purification equipment through the water distribution network) and the water is purified by a reverse osmosis process. Consumers acquire the purified water in predetermined volumes, for immediate consumption or in larger volumes for further use.

The studied PSS does not provide packaging. The consumers use any kind of packaging he/she likes. The PSS does not incentives plastic bottles usage. Some consumers use glass bottles, while others use plastic gallons acquired earlier. Most of these packages (except 20 liters) are not reusable for acquisition of bottled water in the usual process (buying bottled water). Generally, the bottles are discarded after consumption. In the PSS, those packages can be reused. The company ensures the quality of water supply in accordance with the Brazilian standards, but the consumer is responsible for the quality and cleanliness of their packaging. Water quality is assured by the maintenance and chemical tests performed periodically by the company. This is supervised by a city council laboratory. The equipment provider and the merchants share the risks and the responsibility to the consumer. The provider is responsible for the purification process quality, which is established by a contract. The equipment provider and the merchants share the profits, and the payments to commercial establishments are structured according to the service usage. In the contractual agreement they establish the percentage on the profits, but generally start with 25% for commercial establishments in the first year.

PSS sustainability aspects are analyzed in a qualitative perspective during the operational phase. As the aim of this paper is to explore PSS sustainable aspects in order to provide some insights regarding what may influence PSS sustainable performance during its implementation and operational phases, the results were not compromised.

Concerning environmental aspects, the PSS under study can contribute to minimizing the environmental impacts of bottled water consumption, since it provides the same result, 'good quality water', with less environmental burden. Producing plastic bottles and transporting the filled water bottles to market is an energy-intensive business [20]. Most of that energy comes from petroleum, which is the feedstock for both the disposable PET (polyethylene terephthalate) bottle itself and the fuel used to transport the filled bottles. There is also energy needed to treat the water as well as to fill, label and seal the bottles [20]. In Brazil, trucks perform most of bottled water transportation, which is an energy intensive shipping mode.

In PSS, the energy used is related to the operation of two hydraulic pumps that provide the pressure required for the filtering process. However, the used pumps do not have high-energy consumption, since part of the required pressure for water filtration comes from water supply network. During the PSS operational phase, energy consumption is minimum compared with the amount used in bottled water. The energy used in equipment manufacturing cannot be analyzed due to lack of data. The equipment is imported and its transportation to Brazil is made by sea shipping, which is a less energy intensive shipping mode [20]. To perform equipment installation and maintenance, the company plans the routes in order to minimize the transport.

The manufacturing and transport of bottles results in considerable greenhouse gases that contribute to global warming [20]. Manufacturing a 20g plastic water bottle generates almost four times the bottle's weight in greenhouse gases [32]. Moreover, several transports are performed until the bottled water reaches the point of sales, which contributes to the emission of pollutants into the atmosphere. As the studied PSS does not use standard plastic bottles, the emissions are related only with transports performed to equipment installation and maintenance. The transportation may be minimized since the company plans the maintenance routes. Furthermore, the water reaches the equipment by the pipes of the public water supply, and the consumers acquire the water in the moment of their purchasing. All purification is made locally, i.e. in the place where the equipment is installed and because of this, no transportation of water (by trucks, for instance) is required.

Bottled water industry generates wastes at all stages of the process, related to the plastic bottles, labels, caps, seals and contaminated water. According to Brazilian National Department of Mineral Production (DNPM) legal requirements (Brazilian mineral legislation, ordinance n. 387), the bottles of 10 and 20 liters have useful life up to 3 years, and can only be manufactured with virgin resin. In PSS under study, filters are the only waste during the operational phase. Providing maintenance helps to extend equipment and components life, and at the end of a product's life the company performs repair and refurbishment of the equipment and its components (e.g. hydraulic pumps), and reuses it, minimizing the waste.

Regarding the use of renewable resources and their efficient use, the bottled water industry is classified as a large consumer of water since the mineral water is used in all steps involving water as an input. According to Brazilian legal requirements (Brazilian mineral legislation, ordinance n. 374), last rinse of returnable containers (10 and 20 liters) must be carried out with water from the source itself, and mineral water use in the entire process became a common practice in Brazilian enterprises. In contrast, there is almost no water wasted in the studied PSS, as the consumer owns their clean container for filling and purchase exactly the desired volume. Water losses occur in the purification process, because the volume captured from water distribution network does not match the purified volume, due to water impurities. Nevertheless, the company has a water recycling system, i.e. a bypass: after passing through reverse osmosis filter, water that is not purified goes through the filtering process again, in order to be reused.

In the economic dimension, the PSS allows gains to all stakeholders (e.g. for consumers, the price is US$ 1.65/20 liters, while the price of the equivalent bottled water volume is around US$ 4.15). To commercial establishments, the PSS under study adds value to the business and provides monetary gains with low operational costs (the establishments have a 25% profit on sales). A number of consumers began shopping at the establishments more frequently due to the PSS so there is an opportunity for the establishments to increase the sales of other products. This may represent a proposal that adds value to the business. To the company, operational costs are also low, allowing a high profit margin, according to provided information.

In the social dimension, the studied PSS has potential to generate more jobs, as it involves a wider range of actors.

However, the bottled water industry is still responsible for a large employment of labor. Nevertheless, the manufacturing process of bottles itself involves a number of chemical constituents that are potentially hazardous to workers in the plant, including antimony trioxide, listed as a possible human carcinogen substance [20]. In addition, antimony leaches into the water when the bottle is filled. Several studies done in Europe have also detected low levels of synthetic compounds known as phthalates in water bottled in PET plastic, considered as reproductive toxicants [20]. So, even little is known about the health effects that might result from drinking bottled water, is evident that it offers risks to human health and is not secure to drink water that has been stored for a long period. In comparison, the studied PSS does not offer health risks for both workers and consumers. Another potential social advantage of the PSS under study is to bring water in regions where drinkable water is not available.

In relation to consumer acceptance, according to the company that commercializes the PSS, demand is increasing continuously, which shows that more consumers are using this kind of PSS. In an interview performed with some merchants from commercial establishments where PSS is installed, the majority claimed that consumers are satisfied with the provided services, although no formal inquiries have been detected by this study so far. As PSS is embedded in consumers' lifestyles routine, i.e. it is present in their daily purchases, PSS acceptance is easier to obtain. However, one barrier reported by the company and the merchants is the consumers' knowledge about that PSS. Some of them have doubts about the filtering process and the equipment maintenance. Therefore, they do not trust in water quality output. Consumer satisfaction is vital to PSS diffusion and can be a promising strategy to help further reduce the bottled water consumption.

As mentioned before, consumer behavior plays a crucial role for a sustainable PSS success, because even when a PSS is properly designed to be a sustainable one, consumer behavior during the operational phase can contribute to adverse environmental impacts. In this sense, next section presents some findings that may influence PSS sustainable performance.

4.1. Findings on sustainable PSS

Moving to sustainable PSS is a hard task, because change from product offer to PSS requires changes in consumers' consumption patterns. Scenarios can be used to support PSS transition to discuss alternative perspectives in different contexts [33]. Regarding assessment of PSS that is intended to become more sustainable than traditional product, some sustainability assessment tools like LCA have been used to check life cycle improvements. However, consumers' reactions should also be analyzed and quantified in the PSS transition process and life cycle studies, because not considering them may result in a mistaken estimate of the impacts that can be generated in the operational phase, i.e. rebound effects.

In the water filter system, although company does not provide or encourage the use of plastic packaging, for instance, some consumers use returnable plastic bottles in the studied PSS. Even if the packaging or mineral water consumption is not increasing and generating the associated impacts, the use of plastic packaging is still internalized in consumer behavior. As an indirect effect, consumers may continue using plastic bottles. In this context, an analysis of unexpected consumer behavior, incorrect PSS application, and magnitude estimation of the direct or indirect rebound effects are key factors in PSS implementation process, because these aspects may compromise PSS sustainable performance. Socio-technical experiments can be used by companies to learn about the different contextual factors that could influence PSS implementation [1,4], and should also include an analysis of possible rebound effects.

In another point of view, the use of plastic bottles is associated with water consume. This is the possible reason why consumers use it in the studied PSS, perhaps in an unconscious state of mind process. The need itself involves the bottles and this may be a cultural association. This confirms that PSS innovations cannot therefore be planned considering just the existing practices and needs, they should be approached as a transformation of existing practice and needs [7]. Practices and needs are dynamic, and in some cases have linkages with other practices [7]. Practices with tightly coupled elements may be more resistant to the absorption of innovations, because they require alterations in meanings [7]. These issues should be taken into account in PSS design and transition processes and demonstrates the important role of the changes in consumption patterns to achieve sustainability.

On the other hand, many consumers have perceived the environmental benefits associated with less bottles consumption. Some of them reported in interviews performed in one commercial establishment that they were attracted by lower cost, but after using the PSS they realized how much mineral water consumption generates wastes. They have perceived environmental benefits that were not noticed when using the bottled water, because that consumption behavior was part of their routine. Therefore, in order to obtain consumer acceptance, a PSS must be embedded as a stimulus that could be used to make emerge new beliefs and habits in their existing lifestyles routines [1]. In other words, when actions become routines the underlying structure is more and more embedded in the culture [1].

The relationship between actors (consumers, commercial establishments, and company) was noted as an important aspect in consumer satisfaction. The involvement of consumers in a continuous equipment improvement process has contributed to achieving a PSS offer that responds to consumers' wants and needs. A number of improvements were made in the equipment to meet the needs of consumers. In this sense, the actor network and infrastructure play an important role in consumer and provider interaction process, allowing improvements in PSS quality and increasing consumer loyalty.

This article presented empirical evidence of a PSS instance, portraying the sustainable aspects of the business model compared to bottled water. Some findings related with contextual conditions were pointed out and should be taken into account in PSS development because they might affect PSS sustainable performance. Next section presents the main conclusive points of this work.

5. Conclusions

Due to environmental impacts associated with bottled water, it is necessary a replacement with a safer and environmentally preferable alternative. The PSS under study may offer a solution with sustainable potential. In addition, the water filter PSS represents a significant opportunity for contexts where people do not have access to potable water or with fewer economic possibilities.

In comparison with bottled water, the PSS under study is competitive, satisfy customer needs, and has a lower environmental impact. Although was not possible to assess the PSS sustainable potential quantitatively due to available data, a qualitative analysis was performed. On the other hand, even if quantitative calculations could be performed to confirm the environmental improvements, there is still a limit for considering the social implications. This may be explored in future work.

The qualitative analysis demonstrated PSS environmental, economic, and social benefits. Moreover, the contextual conditions were analyzed and show that it is evident that PSS should be designed with a low environmental impact in the various life cycle phases, but it is not enough to assure that it will be a sustainable PSS. Besides conceiving sustainable solutions, it is necessary to identify which factors drive the implementation and diffusion of PSS.

Some findings of this study are from unique empirical evidence. The results suggest that the effects caused by unexpected consumer behavior and incorrect PSS application may compromise PSS sustainable performance during the operational phase. An analysis of these effects during transition process is essential to establish sustainable strategies. Further studies are needed to identify and measure the dimension of rebound effects during PSS operational phase. Regarding consumer satisfaction and acceptance, PSS must be embedded in their existing lifestyles routines in order to facilitate their acceptance.

This study aimed to examine a PSS situation in an emerging economy with sustainable potential, regarding aspects discussed in the literature in the three sustainability dimensions. This may contribute to the PSS empirical knowledge. Although there are limitations, this study identified some insights that can be analyzed in future work that might contribute to theory building on PSS linked with sustainability.

References

[1] Ceschin F. Sustainable Product-Service Systems. 1st ed. London: Springer; 2014.

[2] United Nations Environment Programme. Product-service Systems and Sustainability: Opportunities for Sustainable Solutions. Milan: INDACO, Politecnico di Milano University; 2002.

[3] Manzini E, Vezzoli C. A strategic design approach to develop sustainable product service systems: examples taken from the environmentally friendly innovation Italian prize. J Clean Prod. 2003; 11(8):851-7 .

[4] Ceschin F.Critical factors for managing the implementation and diffusion of eco-efficient product-service systems: insights from innovation sciences and companies experiences. J Clean Prod. 2013; 45:74-88.

[5] Hermosilla JC, Río P, Könnölä T. Diversity of eco-innovations: reflections from selected case studies. J Clean Prod. 2010; 18:1073-83.

[6] Chou CJ, Chen CW, Conley C. An approach to assessing sustainable product-service systems. J Clean Prod. 2015; 86:277-84.

[7] Mylan J. Understanding the diffusion of sustainable product-service systems: Insights from the sociology of consumption and practice theory. J Clean Prod. In press 2014.

[8] Beuren FH, Gomes FerreiraMG, Cauchick Miguel PA. Product–service systems: a literature review on integrated products and services. J Clean Prod. 2013; 47:222-31.

[9] Manzini E, Vezzoli C, Clark G. Product service systems: using an existing concept as a new approach to sustainability. J Des Res. 2001; 1:12–8.

[10] Mont O. Product-service systems: panacea or myth? [Doctoral dissertation]. Lund: IIIEE; 2004.

[11] Vezzoli, C, Ceschin, F, Diehl JC, Kohtala C. Why have 'sustainable product-service systems not been widely implemented? Meeting new design challenges to achieve social sustainability. J Clean Prod. 2012; 35:288-90.

[12] Tukker A, Tischner, U. Product-services as a research field: part, present and future. Reflections from a decade of research. J Clean Prod. 2006; 14:1552-56.

[13] Baines TS, Lightfoot HW, Evans S, Neely A, Greenough R, Peppard J, et al. State-of-the-art in product-service systems. Proc. Inst. Mech. Eng., B. J Eng. Manuf. 2007; 221(10):1543-52.

[14] Cook M. Fluid transitions to more sustainable product service systems. Environ Innov Soc Transitions. 2014; 12:1-13.

[15] Lee S, Geum Y, Lee H, Park Y. Dynamic and multidimensional measurement of product–service system (PSS) sustainability: a triple bottom line (TBL)-based system dynamics approach. J Clean Prod. 2012; 32:173-82.

[16] Ceschin F. How to facilitate the implementation and diffusion of sustainable productservice systems? Looking for synergies between strategic design and innovation sciences. In: Ceschin F, Vezzoli C, Zhang J, editors. Sustainability in design: now! Challenges and opportunities for design research, education and practice in the XXI century. Proceedings of the Learning Network on Sustainability (LeNS) conference 1; 2010 Sep 29-Oct 1; Bangalore, India. Sheffield: Greenleaf Publishing; 2010. p. 440-54.

[17] Tukker A. Product services for a resource-efficient and circular economy – a review. J Clean Prod. In press 2013.

[18] Velamuri VK, Bansemir B, Neyer AK, Möslein KM. Product service systems as a driver for business model innovation: lessons learned from the manufacturing industry. Int J Innov Mgt. 2013; 17(1):1-25.

[19] Eisenhardt KM. Building theories from case study research. Acad Manage Rev. 1989; 14(4):532-50.

[20] Griffin S. The toxic footprint of PET-bottled water in British Columbia.Vancouver: Toxic Free Canada; 2009.

[21] Mont O. Clarifying the concept of product-service system. J Clean Prod. 2002; 10(3):237-45.

[22] Curran MA. Life cycle assessment: a review of the methodology and its application to sustainability. Curr Opin Chem Eng. 2013; 2:273-7.

[23] Peruzzini M, Germani M. Investigating the sustainability of product and product-service systems in the B2C industry. In: Meier H, editor. Proceedings of 5th CIRP International conference on Industrial Product-Service Systems, 2013 mar. 14-15; Bochum. Germany: Springer; 2013. p. 422-34.

[24] Chun, YY, Kondohb S, Mishimab N, Lee KM. A study on Total Performance Analysis of service oriented eco-businesses. In: Proceedings of 17th ISPE International conference on concurrent engineering, 2010, Cracow. London: Springer London; 2010. p. 419-27.

[25] Omann, I. Product service systems and their Impacts on sustainable development: a multi-criteria evaluation for Austrian companies. In: Proceedings of ASCW Frontiers; 2003; Adelaide. Darlinghurst: Australian Computer Society; 2003. p. 1-34.

[26] Evans S, Partidario PJ, Lambert J. Industrialization as a key element of sustainable product-service solutions. Int J Prod Res. 2007; 45(18):4225-46.

[27] Hu HA, Chen SH, Hsu CH, Wang C, Wu CL. Development of sustainability evaluation model for implementing product service systems. Int. J Environ Sci Technol. 2012; 9:343–54.

[28] Devisscher T, Mont O. An analysis of a product service system in Bolivia: coffee in Yungas. Int J Innov Sust Dev. 2008; 3(3/4):262-84..

[29] Armstrong CM, Niinimäki K, Kujala S, Karell E, Lang C. Sustainable product-service systems for clothing: exploring consumer perceptions of consumption alternatives in Finland. J Clean Prod. In press 2014.

[30] Tonelli F, Taticchi P, Sue ES. A framework for assessment and implementation of product-service systems strategies: learning from an action research in the health-care sector. WSEAS Trans Bus Econ. 2009; 6(7):303-19.

[31] Tukker A. Eight types of product-service system: eight ways to sustainability? Experiences from Sus-ProNet. Bus Strateg Environ. 2004; 13:246-60.

[32] Franklin Associates. Life cycle inventory of five products produced from polylactide (PLA) and petroleum-based resins. Merrickville: Athena Institute; 2006.

[33] Lelah A, Boucher X, Moreau V, Zwolinski P. Scenarios as a tool for transition towards sustainable PSS. In: Proceedings of 6th CIRP International conference on Industrial Product-Service Systems, 2014 may. 1-2; Windsor. Canada: Springer; 2014. p. 122-7.