Is the Industrial Product-Service System really sustainable?

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Abstract

As the product-service system has shifted from its original concept to the Industrial PSS, its scope has expanded to include industrial products. Furthermore, the overall goal of reducing environmental impacts has been left behind. Despite the PSS's potential as a business model for a more sustainable production and consumption system, the mere addition of services to conventional products does not necessarily lead to a reduction of environmental impacts. This paper aims to discuss the concepts related to PSS, the need for considering environmental impact reduction as a critical issue for sustainability, and the role of ecodesign practices in the development of PSS.

Keywords

Product-Service System (PSS), Industrial Product-Service System (IPS^2), environmental sustainability, ecodesign

1 INTRODUCTION

According to the World Commission on Environment and Development (WCED) [1], sustainable development is defined as the 'development that meets the needs of the present without compromising the ability of the future generations to meet their own needs'. This definition, known as the Brundtland definition for sustainable development, is a rather general statement and leaves much scope for different interpretations among individual organizations [2]. Cowell et al. [3] state that 'although there is no consensus on the meaning of sustainable development or sustainability, there is common acceptance that it involves the consideration of economic, environmental and social aspects'. Thus, it can be deduced that sustainability requires a balance between economic, social and environmental aspects. Within this context, this paper explores the environmental sustainability of product-service systems (PSS).

The ever growing consumption of products is the origin of most of the pollution and depletion of resources caused by our society [4]. Because most existing environmental impacts are product-related, a significant decrease in materials and energy flows is required in order to achieve sustainability.

Traditional approaches to environmental management have evolved from pollution control and end-of-pipe treatments to preventive or cleaner production technologies, defined as the continuous redesign of industrial processes and products to prevent the generation of pollutants and waste at their sources and to minimize risks to humans and the environment. This approach was applied initially to industrial processes (hence cleaner technologies) and then, to make it more inclusive, to the industrial products themselves (hence cleaner products) since the environmental impacts observed throughout the life cycle of a product are, to a large extent, determined in its development phase [5].

Long-term economic growth combined with reduced pressure on the environment requires changes in production and consumption systems and the firm commitment of all actors in society. Therefore, the solution to environmental issues must be put into the context of the entire society, considered as a complex system with several main actors: government, manufacturers, recyclers and consumers. Since it is the interaction between these actors that finally determines the environmental performance of a product over its entire life cycle, the development of the issues raised must be accompanied by an in-depth study of the mechanisms of the entire complex system [6].

The need to consider environmental issues during new product development (NPD) gave rise to two research lines: the field of ecodesign, which deals with the integration of the environmental dimension into the initial stages of NPD, and the field of product-service systems (PSS), which involves the development of products and services systems and which is perceived as having a much higher potential to achieve environmental sustainability than ecodesign.

In this context, the Product-Service System (PSS) emerges as a promising approach for a more sustainable society. The concept of PSS implies a shift in business thinking from selling products to providing service solutions to customer needs. The introduction of new ownership patterns, such as leasing focused on extending a product's lifespan, increases manufacturers' interest in designing for durability and enables the reuse and remanufacturing of products prior to recycling, making possible the dematerialization of products.

This paper discusses the various concepts related to PSS, the need to consider environmental impact reduction as a critical issue towards sustainability, and the role of ecodesign practices in PSS development.

The 'Introduction' section described the context of this paper. The next section, 'Methodology', explains the methodology adopted in writing the paper. This is followed by the 'Product-Service Systems' section, which presents the most relevant PSS concepts available in the literature and the types into which they are usually classified. The 'PSS and environmental sustainability' section then addresses opportunities for increasing environmental sustainability by means of PSS, followed by the section on 'Ecodesign practices for PSS development', which describes ecodesign practices that can be used in the

development of PSS with improved environmental performance. The subsequent section then discusses the 'Role of Ecodesign in PSS sustainability'. The last section presents the authors' 'Final Remarks', discussing the conclusions of the paper, which are followed by the 'Acknowledgments' and the 'References' cited herein.

2 METHODOLOGY

The main methodology employed in this study was the systematic literature review, a specific research methodology, which involves collecting and evaluating the available studies on a subject by means of a defined and strict sequence of three methodological steps: (1) problem formulation, (2) database definition and data collection, and (3) data analysis and evaluation [7].

Systematic literature reviews enable the researcher to map all the existing knowledge and initiatives currently and previously developed in a specific field. In addition to a preview of discoveries, techniques, ideas and exploratory modes for the topic, systematic reviews allow for an evaluation of the relevance of the information to the issue in question.

In this sense, a systematic literature review was made to collect and interpret available data on Product-Service Systems and Ecodesign. The PSS literature was studied to determine the concepts different authors put forward to define PSS and the context in which they were developed. In addition, a study was made of the potential reduction in environmental impacts provided by the different types of PSS. This review revealed the answer to the main question of this paper, namely, "Is PSS really sustainable?"

The literature on ecodesign was also examined to determine if it could contribute to increase the environmental performance of product and PSS development, contributing to its sustainability. Finally, an analysis was made of the possibility of applying ecodesign practices in the development of PSS, and a proposal was drawn up to integrate the two concepts, PSS and ecodesign, in order to achieve environmental sustainability.

3 PRODUCT-SERVICE SYSTEMS (PSS)

The traditional industrial economy in which value is attributed to material products that are exchanged has shifted towards the new service economy, in which value is more closely related to the performance and real utilization of the products integrated in a system [8].

Business-to-business and business-to-customer markets have a tendency to offer a combination of products and services, which are sold in one package to meet the customer's needs. These combinations of products and services are called product-service systems (PSS) or industrial product-service systems (IPS^2), in the case of industrial applications [9].

The services that are of interest in the field of sustainable development are known by many different names: eco-services, eco-efficient services, sustainable services, product-service systems (PSS), sustainable service systems, and sustainable product-service systems [10]. These terms, mainly "Product-service" and "product-service systems", are rarely used in the mainstream business literature, where the terms functional sales, experiences and/or satisfaction and integrated solutions are quite common [11]. The following sections present the definitions of PSS and also the categories into which it is classified.

3.1 Definitions of PSS

Since the concept of Product-Service System (PSS) emerged in northern Europe in the late 1990s, many definitions have been proposed to clarify the composition of this new business model. First, Goedkoop and his collaborators [12] defined PSS as 'a marketable set of products and services capable of jointly fulfilling a user's need'.

According to Baines et al. [13], a PSS can be seen as a new market proposal that extends the traditional functionalities of a product through the incorporation of additional services. Instead of centering on 'traditional' forms of sale, ownership, consumption and disposal of products, a PSS focuses on the delivery of a 'function' to the customer. In practice, this may mean the provision of combinations of products and services that are capable of 'jointly fulfilling users' needs' [12 apud 14].

Brezet et al. [15] defines eco-efficient services as 'systems of products and services that are developed to cause less environmental impact than traditional business models'.

Manzini and Vezzoli [16] present PSS as the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services that can jointly meet clients' specific demands.

Mont [17] states that, in a PSS, the traditional forms of manufacturing and product use are replaced by the possibility of meeting consumers' needs by providing services that are more intangible, which are associated with changes in ownership structure and that target environmental improvements. According to this author, PSS can be defined as 'a system of products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs, and cause a lower environmental impact than traditional business models'.

In the context of the SusProNet project that aimed to exchange, analyze, complete and make easily available information on best practice of PSS, in 2006 Tukker and Tischner [11] developed the following definition of PSS: 'the product-service including the value network, technological infrastructure and governance structure (or revenue model) that produces a product-service – a value proposition that consists of a mix of tangible products and intangible service designed and combined so that jointly they are capable of fulfilling final customer needs'.

Industrial Product-Service Systems (IPS^2) can be characterized as a combination of tangible products and intangible services, providing a value to the customer via the complete life cycle [18]. An IPS^2 is defined as 'an integrated industrial product and service offering that delivers value in use' and represents a change in the competitive strategy for manufacturing companies, enabling innovative function, availability and results-oriented business models [19].

3.2 Types of PSS

The distinction between products and services can be difficult to define. In practice, there is a continuum of products and services, in which the total offer is a product-service mix [10].

The product/service ratio in this set may vary, either in terms of function fulfillment or of economic value [12].

PSS can be classified in different ways, as can be seen in [12], [17] and [20], but it is most commonly divided into three categories: (1) product-oriented, (2) use-oriented,

and (3) result-oriented, as presented in [11]. In summary, the categories differ basically in the importance ascribed to the product (physical part) and to ownership patterns.

In product-oriented PSS, the customer owns the product and relevant services are offered to ensure the product's functionality and durability, such as after-sales services (installation, maintenance, repair, upgrading and recycling, and helping customers optimize the application of a product through training and consulting) [13].

Use-oriented PSS comprises product rental, leasing, sharing and pooling. In this category, the product still plays the central role in the system, but its ownership remains under the manufacturers' responsibility. The consumer pays a fee only to use a specific product.

In the last category, result-oriented PSS, a given function is agreed upon between the provider and the customer. The product, which is seen simply as a tool to attain the desired result, is chosen by the supplier. Outsourcing activities and pay per service units are well known examples.

According to Tukker and Tischner [11], the potential of moving PSS to greater sustainability is directly proportional to radical changes made in the system. Furthermore, whether the available potential is achieved depends on a focused effort to design PSS to be as sustainable as possible, preferably stimulated by the right framework conditions and suitable tools. Hence, sustainability is not an automatic mechanism built into the PSS concept but depends on many conditions.

4 PSS AND ENVIRONMENTAL SUSTAINABILITY

To date, the shift from selling products to providing services has not been driven by environmental concerns but instead by business motivations. These include increasing competitiveness, reducing costs, serving a market's need for speed, providing customer convenience and flexibility, improving corporate identity, or responding to a discrete business opportunity [10].

The generic eco-drivers for the adoption of PSS are [21]:

For companies:

- Threat of legislation;
- Response to client's wishes;
- Increased employment;
- Provide jobs for local markets;
- Move towards green purchasing by authorities;
- Fewer waste management concerns from the domestic and manufacturing sector;
- Companies considering themselves environmentally and socially responsible;
- More sustainable economy based on higher levels of services.

For consumers:

- Lower costs and fewer problems associated with the purchase, use, maintenance, and eventual replacement of products;
- The service provider is stimulated to use and maintain equipment properly, increasing both efficiency and effectiveness.

However, the global footprint forces research and industry to engage in activities aimed at improving sustainability. IPS² could have a positive influence on the sustainability issues as the changing market environment gives rise to new customer demands. The contribution of IPS^2 to sustainability is based on four different types of motivation [19]:

- Economic: there is little profit in selling machines, but more profit in delivering services;
- Technical: the equal focus on product and service development enables innovation;
- Social: integration of product and service engineering enables high-income countries to protect and build up employment; while countries with low technical qualifications improve their performance levels;
- Ecological: IPS2 reduce the consumption of resources.

Thus, according to Manzini and Vezzoli [16], PSS (and IPS^2) is a feasible and promising business strategy potentially able to help achieve the leap that is needed to move to a more sustainable society, and can be seen as a strategic innovation that companies may choose in order to:

- Separate resource consumption from its traditional link to profit and standard of living improvements;
- Find new profit centers,
- Compete and generate value and social quality while decreasing (directly or indirectly) total resource consumption.

According to Tukker and Tischner [11], the potential environment benefits of PSS are:

- Lower materials and energy consumption during the phases of production and use of services compared with products;
- Lower stock of products in manufacturing, since it encourages leaner manufacturing because products are more valuable;
- Potential for environmental benefits through economies of scale;
- Extension of the manufacturer's responsibility for the product, making it more palatable to the consumer, manufacturer and environment;
- More durable products, diminishing the total stock of product required in the cycle to meet a specific need at any given time;
- Renting potentially opens up the possibility for more intensive use of the product, with the same environmentally beneficial outcome;
- Manufactures may take more professional care of the product over the use phase, thus ensuring a higher quality end-stock and less downcycling;
- Manufacturers, which are also the main operators of the PSS, will have no incentive to sell excess material, will be in a better position to optimize the products to their true function, and will have far better knowledge about the true requirements and characteristics of the equipment.
- Collection of end-of-life products will be significantly easier, thus increasing the rate of utilization of end-of-life products;
- Development of better end-of-life disposal processes, since there will be clear pressure to design for this stage of the product life-cycle, starting from the concept generation phase onwards;
- Manufacturers encouraged to develop innovative uses for end-of-life products;
- Easier upgrading to more eco-efficient technologies.

Comparing the PSS types, Tukker [22] states that they can contribute differently to the environment (Figure 1). According to this author:

- Product-related service, advice and consultancy, and product lease have probably marginal environmental benefits, since at best mainly incremental change such as better maintenance etc. can be expected. Cases of

product leases may even have negative environmental effects if the lessee feels encouraged to use the product less carefully than if he owned it;

- Renting, sharing or pooling can have major environmental benefits if the burden is related to the production of the artifact, since the same product is shared and used more intensively. However, if, in the case of product renting or sharing, the use phase dominates and does not lead to a low use behavior there is little positive outcome. In such cases, pooling leads to lower impacts since more people make use of the product at the same time;
- Activity management/outsourcing PSS will lead to lower environmental impacts if (monetary) efficiency gains are related particularly to materials and artifacts, and not to human time inputs;
- The pay per unit use overcomes the split incentive between production costs of a product and costs incurred in the use phase. It is likely that at least incremental gains will be realized, but since the technological system in principle does not change radically, no significant improvements can be expected.
- In theory, functional result PSSs have the highest potential since the provider offers a result closer to a final client's needs and therefore has greater freedom to design a low-impact system.

The shift from buying products to buying services provided by the result-oriented PSS therefore has a major potential to minimize environmental impacts [23].

In this context, it can be concluded that the development of PSS is not intrinsically sustainable, and there are also cases in which the environmental impacts are higher than in a traditional system (leasing, for instance) [11].

5 ECODESIGN PRACTICES IN PSS DEVELOPMENT

It is essential that considerations of environmental sustainability be integrated into all the steps of a PSS development and design process, that its market launch is carefully prepared to ensure success, and that the solution on the market is reviewed in terms of economic, environmental and social impacts [11].

A paramount goal of product–service systems should be to minimize the environmental impact of consumption by [17]:

- Closing material cycles;
- Reducing consumption through alternative scenarios of product use;
- Increasing overall resource productivity and dematerialization of PSSs;
- Providing system solutions aimed at perfecting the system's integrating elements while simultaneously improving the resource and functional efficiency of each element.

Ecodesign can be defined as a strategic design activity whose purpose is to conceive and develop sustainable solutions. It generates sets of products, services and knowledge that enable consumers to achieve sustainable results. Ecodesign can also be seen as a proactive management approach that guides product development towards the reduction of environmental impacts throughout a product's life cycle, without compromising other criteria such as performance, functionality, aesthetics, quality and cost [24-30].

The development of PSS is the highest level of innovation in ecodesign. According to Charter and Tischner [21], there are four levels of environmental considerations in the product development process. The fourth level is described as the level where the functionality concepts are conceived to be compatible in a sustainable society. Brezet and van Hemel [31] define system innovation as the last level of innovation in ecodesign, corresponding to new products and services that require changes in infrastructure and in the systems involved in the use of the product. Finally, the last intervention level is defined by Vezzoli and Manzini [32] as the creation of new scenarios for a sustainable way of life.

In a PSS, the physical product is responsible for the majority of environmental impacts caused by the PSS because the flows of materials and energy are related mainly to the physical product along its whole life cycle, from the extraction of raw materials to its end-of-life disposal (Figure 2).

Due to its great potential, therefore, design is one of the most influential factors in the development of sustainable production systems and products [6].

A variety of ecodesign practices have been developed to evaluate environmental impacts resulting from the product's life cycle, bringing to light potential problems/conflicts and facilitating the choice among possible product aspects. Ecodesign methods and tools can be defined as any systematic means to deal with environmental issues during the product development process [33, 34], while guidelines are general rules that can guide designers and engineers during the product development process.

PSS type		Environmental impacts compared with a reference situation (product)				
		worse	equal	incremental reduction (<20%)	considerable reduction (<50%)	radical reduction (<90%)
Product-oriented	1 Product-related service		←	→		
	2 Product-related consultancy		←	→		
Use-oriented	3 Product lease	←		→		
	4 Product renting and sharing		←	→		
	5 Product pooling		←	→		
Result-oriented	6 Pay-per unit use		←	→		
	7 Activity management		←	→		
	8 Functional result		←	→	→	→

Figure 1: Environmental impacts according to PSS types (adapted from [11])

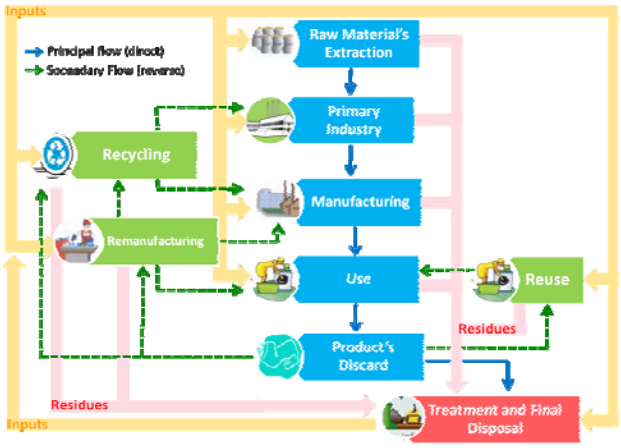

Figure 2: Material Life Cycle

The main ecodesign strategies to increase the environmental performance of products, according to Vezzoli and Manzini [32], are:

Minimizing material consumption:

- Minimize material content;
- Minimize scraps and discards;
- Minimize or avoid packaging;
- Engage more consumption-efficient systems;
- Engage systems of flexible materials consumption;
- Minimize materials consumption during the product development phase.

Minimizing Energy Consumption

- Minimize energy consumption during pre-production and production;
- Minimize energy consumption during transportation and storage;
- Select systems with energy-efficient operation stage;
- Engage dynamic consumption of energy;
- Minimize energy consumption during product development.

Minimizing Toxic Emissions

- Select nontoxic and harmless materials;
- Select nontoxic and harmless energy sources.

Renewable and Biocompatible Resources

- Select renewable and biocompatible materials;
- Select renewable and biocompatible energy sources.

Optimization of Product Lifespan

- Design appropriate lifespan;
- Design for reliability;
- Facilitate upgrading and adaptability;
- Facilitate maintenance;
- Facilitate repairs;
- Facilitate reuse;
- Facilitate remanufacture.

Improve Lifespan of Materials

- Adopt the cascade approach;
- Select materials with the most efficient recycling technologies;
- Facilitate end-of-life collection and transportation;
- Material identification;
- Minimize the number of different incompatible materials;
- Facilitate cleaning;
- Facilitate composting;
- Facilitate combustion.

Design for Disassembly

- Overall architecture;
- Shape of components and parts;
- Shape and accessibility of joints;
- Engage reversible joining systems;
- Engage easily collapsible permanent joining systems;
- Co-design special technologies and features for crushing separation.

According to Bhamra and Lofthouse [10], products for PSS will need to be more durable than those that exist today and may have different features that reflect the need of the service. In this sense, the strategies 'Optimization of product lifespan' and 'Design for Disassembly' are of considerable importance.

6 ROLE OF ECODESIGN IN PSS SUSTAINABILITY

Once the company has strategically decided to develop a product-service system (PSS), the whole development process must be adjusted to the new intrinsic PSS requirements, such as design for disassembly, increase of product's durability, and design for maintainability, among others.

It is extremely important to include ecodesign practices (methods, tools, guidelines, software) in the PSS design and development in order to minimize its environmental impact, contributing to achieve the PSS sustainability potential that is currently being disregarded by companies worldwide.

All the ecodesign practices presented above can be applied successfully during the PSS development in order to ensure the product's improved environmental performance, which contributes to increase the sustainability of the entire system. The focus of the PSS, however, should be on the "Optimization of Product Lifespan" and also on the "Design for Disassembly" strategies.

Ecodesign strategies can also be addressed during the development of the service, focusing on the reduction of the system's overall environmental impacts.

Compared to Ecodesign cases, the transition towards PSS will often entail an important process of change by the company towards new thinking on how it should create value, produce, distribute and approach its clients.

7 FINAL REMARKS

Although it did not do so explicitly, the first PSS concept developed by Goedkoop et al. [12] embraced the concern of decreasing impacts on the environment. Albeit recognized as an important part of the PSS concept, Tukker and Tischner [11] believe that 'a (PSS) term should not implicitly include the normative notion of sustainability but, if relevant, that this should be indicated specifically'.

The authors of this paper believe that PSS/IPS^2 definitions that fail to consider sustainability as a central issue of the PSS concept represent a regression in the concept's development and application worldwide, which may result in little achievement of the sustainability potential through PSS.

PSS does not follow the tendency of reducing the environmental burdens associated with products along its whole life cycle, which is the concept that underpins the Integrated Product Policy (IPP). The Green Paper on Integrated Product Policy (IPP) launched a broad debate on how to achieve a new growth paradigm through wealth creation and competitiveness on the basis of green products, and proposed strategies intended to reinforce environmental policies, with the aim of integrating environmental requirements into product standards [6].

As presented by Tukker and Tischner [11], the development of PSS is not intrinsically sustainable, and there are also cases in which PSS causes higher environmental impacts than a traditional system (leasing, for instance).

It is argued that a PSS can only be considered a "true" PSS if it was designed to minimize environmental and social impacts throughout its whole life cycle. In this sense, the consideration of environmental concerns must be intrinsic to the PSS concept. Higher environmental performance ought to result when ecodesign practices are addressed in PSS design and development.

As McAloone and Andreasen [35] state, there is a need to readdress the way in which we develop and provide products to users and consumers, so that leap-changes can be made in the environmental profile of products, rather than merely minor incremental improvements. In other words, we need to shift from focusing on the design and development of the simple artifact to the innovation of a whole PSS, in which the traditional manufacturer-vendor-user relationship is rearranged, allowing for the delivery of environmental, social and economic benefits.

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