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Product-Service Systems across Life Cycle

Sustainability factors for PSS business models

Ana Paula Barquet^{a,*}, Johannes Seidel^a, Günther Seliger^a, Holger Kohl^a^a*Institute for Machine Tools and Factory Management, Technische Universität Berlin, Pascalstrasse 8-9, 10587 Berlin, Germany** Corresponding author. Tel.: +49-(0)30-314-27094; fax: +49-(0)30-314-22759. E-mail address: anabarquet@gmail.com

Abstract

A fundamental change in how businesses are conducted and operated is an essential factor to reach more sustainable solutions not only on the industry level but also for the entire society. In this sense, the importance of developing and implementing sustainable product service system (S-PSS) business models is increasing as the number of studies are presenting it. A S-PSS business model is an approach to achieve benefits in the three dimensions of sustainability. Through efficient resource utilization and dematerialization, this type of sustainable business model helps to embed environmental and social aspects into strategic business goals and processes while increases competitive advantage. However, most of the studies that treats PSS business models do not mention their relation to sustainability. In addition, different studies take for granted that implementing PSS leads to benefits in the three sustainability dimensions. Nonetheless, PSS business models can even have a negative effect on the environment while maintaining only economic benefits. Such contradictions and incoherencies hinder the potential of PSS business models to provide sustainability benefits and might be a barrier for its adoption. Therefore, the question this study pursues is: What are the factors that make a PSS a sustainable business model? Through literature analysis, this paper proposes the identification of a set of factors that contributes to the sustainability of PSS business models. The factors identified are investigated in an exemplary case of a bike sharing system.

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Keywords: Product-Service-System (PSS); business model; sustainability; factors

1. Introduction

Regardless of warnings such as the announcement of “limits to growth” [1] humanity has so far continued to follow the destructive path of resource overconsumption e.g. in carbon dioxide emissions to the atmosphere. On the one hand, these emission already now poses a threat to our conditions of living [2]. On the other hand, the conditions of living on earth are far from equally distributed. People in many regions are striving to improve their conditions of living and thereby increase their ecological footprint while early industrialized countries fail to significantly decrease their footprint [3].

By transforming business to include environmental as well as social targets while maintaining economic competitiveness,

business model innovation is proposed as a key to sustainable development [4].

In Product Service Systems (PSS), companies offer a manufactured interlinked bundle of a product and a service, simplified by the term “selling functionality instead of products” are regarded in literature as potential “sustainable business models” [5]. A gap in the literature remains; most studies that treat PSS business models do not mention their relation to sustainability. In addition, different studies take for granted that implementing PSS leads to benefits in the three sustainability dimensions. PSS business models can even have a negative effect on the environment while maintaining only economic benefits. Simply replacing product selling for service offer might not be enough to lead to more sustainable solutions. Such contradictions and incoherencies hinder the

potential of PSS business models to provide sustainability benefits and might be a barrier for their adoption.

The assessment of sustainable PSS is still in the relatively early phase and thus requires clear criteria to define whether a PSS is successful, or, whether it consists with the sustainability requirements [6]. Despite the fact that there has been significant work on how PSS performs as a business concept and may contribute to competitiveness, the sustainability orientated PSS research paid limited attention to business management literature [7]. Sustainability within the PSS field is still associated only with resource efficiency and life cycle assessment [8].

Therefore, the goal of this research is to identify factors that contributes to the sustainability of PSS business models. The factors, identified through literature research, are investigated in a bike sharing system business model.

2. Sustainable business models

A business model is the description of the rationale of how an organization creates, delivers and captures value [9]. Even though “value” can be widely interpreted [10], Osterwalder and Pigneur take an economic point of view in their work.

Adding to this by including benefits to the environmental as well as the social sustainability dimension the concept of business models has been developed further by authors like Lüdeke-Freund [4] and Bocken et al. [5]. Bocken and her team describe eight archetypes of sustainable business models.

The archetype “Deliver functionality rather than ownership” is essentially build around the literature of PSS. Possible sustainability benefits from such a business model are breaking the link between profit and production volume, reduce resource consumption, motivate and enable life-through responsibility of the manufacturer by retaining product ownership, enhance efficiency in use, product longevity and durability as well as increase the amount of materials reused [5].

According to Tukker, PSS can be classified in three main categories, namely product-oriented services, use-oriented services, result-oriented services. Potential benefits for social and environmental sustainability vary between these categories. Regarding environmental sustainability in product-oriented services, only effects through better maintenance could be an outcome, but selling as many products as possible remains as a business incentive. In use-oriented services, such as leasing, there can be the negative effect that products are treated with less care by the customer, while there is the chance to increase resource usage such as in car sharing systems. Social effects are increased availability of a product for individuals who cannot afford to own a product, e.g. personal mobility for people who cannot afford to own a car, but have access to a car through a sharing provider. Result-oriented are until today the most unconventional PSS and have a large potential for sustainability benefits, since material resources are only a cost factor for the provider and more products produced do not lead to increased revenue. However, each case has to be evaluated individually, since simply outsourcing e.g. providing lunch to a catering service might only have marginal efficiency effect [11].

3. Sustainability factors of PSS business models

The method used to identify the sustainability factors of PSS was systematic literature review, whereas the databases researched were Web of science and Science direct. The keywords used were Product-Service System and synonymous, such as: servitization, functional sale, functional product, integrated product service offering and integrated product service engineering together with the words sustainability and sustainable. The quest was limited by searching the keywords in titles and abstracts as sustainability and PSS should be the two main topics of the papers. Taking out repetitions, 25 articles were found and the factors were extracted of 17. Analysis of the different factors lead to 5 main factors and further sub-factors, presented in Figure 1.

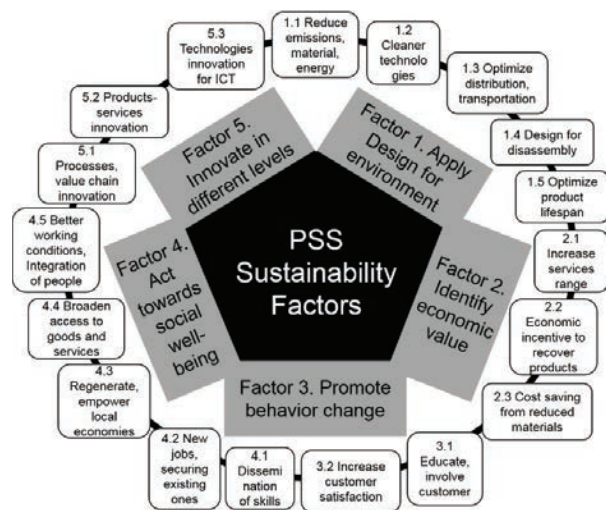


Fig. 1. Factors and sub factors for PSS sustainability.

3.1. Factor 1 – Design for Environment (DFE)

A variety of authors agree that the optimization of resources (mostly material and energy) during the entire PSS lifecycle phase is one of the most common practice to contribute to the sustainability of PSS business models [12, 13, 14, 15, 16, 17, 18, 19]. This practice is possible because of the increase in product use by means of sharing or renting and by extending material and product lifecycle through adding services during the use phase and the application of end-of-life (EOL) strategies, such as remanufacturing, reuse, recycling.

These actions, which lead to waste minimization and avoid use of new energy and material since they postpone both disposal and manufacturing a new product, are inside the scope of the Design for environment (DFE). For Vezzoli, Manzini [20] and Roy [21], the main strategies to increase the environmental performance of products and services during its entire lifecycle:

- Minimize material consumption (e.g. reducing the weight or volume of materials in the product) and select low-impact materials (e.g. renewable, recycled);

- Minimize energy consumption and select systems with energy-efficient operation stage;
- Minimize toxic emissions and select harmless materials;
- Use cleaner (e.g. less wasteful, polluting) technologies for manufacturing;
- Optimize distribution and transportation;
- Apply principles of design for disassembly and optimization of product lifespan, which covers the design of appropriate lifespan and design for reliability. Also actions to facilitate upgrading, maintenance and adaptability and design for end of life strategies, such as repairs, reuse and remanufacture, should be taken into account.

In the PSS development, standardization and modularity aspects, which can help reducing process time and cost, as well as durability and longevity aspects, which extend the product lifecycle, are also relevant to be considered [14].

3.2. Factor 2 - Identify economic value for each stakeholder

The first aim to implement any business model is to reach economic value for the different stakeholders involved in providing the PSS, e.g. manufacturers, service providers, distributors. Economic value can be obtained mainly by three ways: cost savings due to reduction of material, economic incentives to extend PSS lifecycle and profitability of new services.

Cost savings are a consequence from reduced quantities of product materials required [22, 12], since one product can be utilized longer and with more frequency. This decreases the amount of products in a given moment and place [13]. Yet, there are cost savings because both the disposal costs and the costs of manufacturing a new product are postponed [22].

Because the PSS provider has the responsibility and/or ownership of the product, he has an economic incentive to recover used products and material in the end of life. For that, actions such as updating, repairing, remanufacturing, recycling are recommended to provide multiple lifecycle to products [22].

Finally, the increased range of services is also a new element of profitability. Updating, repairing [22] as well as maintenance are example of services that might increase competitive advantage for the producer and can be additional income source for manufacturers or retailers [14].

3.3. Factor 3 - Promote behavior change for customer and PSS provider

The symbolic value of owning products is an aspect that hinder the potential of PSS, especially in case for highly visible products embedded in cultural issues, such as cars [23]. Behaviour change, a relevant social aspect of PSS, is possible by means of education, involvement and understanding customers, which could facilitate actions to increase value perception and finally acceptance and satisfaction [12, 15, 16].

Education provides customers' sustainable consciousness to act and behave in a more responsible way [14]. One action to educate customers is to make transparent and enhance their

social sustainability. Involve customers in the development of offers is an important learning experience to teach them about responsible and sustainable behaviour [13]. The customer could be involved in the design, decision process, manufacturing, implementation, and/or customization of his own product-service system [13, 22]. Then, PSS would have the role not only to meet customer needs but also to transform them [23].

In addition of participating in the creation of an offer, other aspects that can increase customer acceptance and satisfaction are: appearance and usability of the offer, price [14], safety [18], cost and time saving, sustainably lifestyle [6].

The ones involved in providing the PSS should also perceive value in changing towards PSS. Therefore education for employees, suppliers, and retailers is necessary [14] and a new mindset about product responsibility and ownership should be developed [12]. Acceptance of PSS provider is also relevant and it is related to increase equity and justice, safety and health, welfare and care in the workplace [6], as presented in next factor.

3.4. Factor 4 - Delineate actions to social well-being

PSS should be able to create new jobs and help securing existing ones, or help tackle long-term unemployment [14]. Better working conditions are expected, e.g. health and safety at work [12, 13, 14, 15, 16], adequate working hours, fair wages and justice [14], and conditions enhancing the satisfaction, motivation and participation of the employees [13]. Also, the promotion and enhancement of fair and just relations within the partners are included [13].

As PSSs are more labour and relationship oriented, the increase in local employment can also lead to dissemination of skills [22]. An example are the skills and knowledge required to provide services and support the product [19].

Integration of people by considering the elderly, the unemployed and any minority or marginalized social group as part of the value creation of a PSS. This is a manner to improve social cohesion in communities but also between generations, genders and different cultures [13].

Another aspect is the promotion of systems that regenerate and empower local economies, by, for example, respecting local cultural characteristics and favouring local-based enterprises or initiatives [13].

PSS can broaden access to goods and services to lower income segments [22] as it is functionality instead of ownership oriented. Customers will have less initial investment (e.g. there is no need to purchase a solar panel) as well as running costs (e.g. costs for repair are responsibility of the PSS provider) [22]. By broadening the accessibility, PSS contributes to improve the quality of life of the customers [14].

3.5. Factor 5 – Innovate in different levels

New organizational, financial, legal and social arrangements, as well as innovative product, service and technology, may be needed to make a PSS practical or economic prosper [21]. Despite the fact that product and

services are central in the PSS definition, innovations in technology and value chain are the most mentioned in research about sustainable PSS business models.

In a traditional business, the different stakeholders that take part in the entire lifecycle of a PSS (e.g. raw materials suppliers, producers, retailers, customers, end-of-life managers), tends to optimize their own ‘segment’ of the process, i.e. their phase of the cycle. Therefore, no alignment between economic value for each stakeholder and an overall systemic resource optimization is reached. A starting point to create a PSS business model is to set the goal of achieving an integrated solution [24], which should be obtained by innovating the design of the value chain, where the interaction of stakeholder and the convergence of their interests are clear specified as well as actions to extend the sum of the products’ lifespan and intensify the overall sum of the products’ use [13]. When the full system uses less resources, it has a lower overall cost and higher gains, which can be shared among the stakeholders [24].

Technology innovation might be required to avoid higher initial investment for service providers, e.g. by applying easily adoptable or new efficient technologies [13]. Latest technologies can lead to more environmental friendly products, by involving reduced consumption of energy, materials and emission. [13, 19] and also be employed to develop new services, such as shared transport, in a more user-friendly and convenient way [21]. In the sense of information and communication technologies (ICT), production of the value from hardware to software can be shifted [17]. Examples are on-site assembly or production for information and data transfer as well as remote controlling for maintenance and repair of products [13].

4. Sustainability factors of a bike sharing system case

A sharing system business model for a Pedelec was developed taking into account the possible future development of the city of Berlin. The main value proposition of this system is to provide a sustainable alternative to urban mobility. Figure 2 shows the main characteristics of the business model developed for the trial phase of the Pedelec. The information utilized to evaluate the sustainability of this business model was gathered in [25, 26, 27, 28, 29], where more information about the product and the business model is presented.

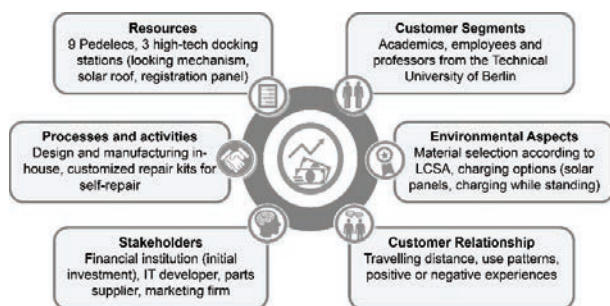


Fig. 2. General characteristics of the business model

4.1. Evaluation of the sustainability of the Pedelec case

Table 1 presents characteristics of the Pedelec business model according to Factor 1. Minimization of material, energy and emissions are addressed as well as ways to optimize product lifecycle. Cleaner technologies to manufacture, design for disassembly and optimization of distribution and transport are weak points as they were not considered during the creation of the business model.

Table 1. Characteristics of the Pedelec business model according to Factor 1

Factor 1 – Design for Environment (DFE)	Characteristics
Minimize material consumption and select low-impact materials	End-of-life strategies will be applied according to the value embedded of the used Pedelec. Product parts will be categorized according to possibility of reuse, remanufacturing or reconditioning, recycling, energy recovery, incineration or landfilling.. Material as lightweight will be selected with the support of LCSA (lifecycle sustainable assessment).
Minimize energy consumption and select systems with energy-efficient operation stage	End-of-life strategies will be applied according the value embedded of the used Pedelec. In the use phase, different charging options will be possible, such as solar panels in docking stations and the concept of “charging while standing”.
Minimize toxic emissions and select harmless materials	In the use phase, any direct GHG emissions will be produced due to the fact that the Pedelec is running solely on human power and solar generated electricity.
Apply principles of optimization of product lifespan	End-of-life strategies will be applied according to the value embedded of the used Pedelec.

Table 2 shows the characteristics related to Factor 2. Cost saving from reduced amount of materials and economic incentive to recover the product are part of the business because of EOL strategies are planned to be applied. Provision of new services cannot be considered, a new entry of revenue as all services offered will be covered by the fee the customer should pay to use the Pedelec.

Table 2. Characteristics of the Pedelec business model according to Factor 2

Factor 2. Identify economic value for each stakeholder	Characteristics
Cost savings result from reduced quantities of materials	LCSA will assist to select light material but not on how to reduce the amount of them. However, the application of EOL strategies will avoid the use of new material.
Economic incentive to recover products	As the product ownership and responsibility belongs to the PSS provider, they will have easy access to the product in end of life
Increased range of services	The variety of services offered are already included in the price paid by the customer. Therefore, the amount of available services will not influence the revenue of the provider.

Table 3 exhibits characteristics of the business model related to Factor 3. Value perception is addressed with potentials to increase customer satisfaction. However, actions to educate customers towards behavior change, such as

actions to decrease customer resistances and increase their involvement in the development of the offer, were not defined.

Table 3. Characteristics of the Pedelec business model according to Factor 3

Factor 3. Promote behavior change	Characteristics
Educate customers	The main resistance for customers to use the Pedelec is the necessity for behavior change. For students, behavior change is related to product ownership and price, since they pay for public transportation on a semester-basis. Professors and employees use cars or public transportation (in few cases own bicycles). For them, behavior change is related to agility.
Involve customers in the development	Customer will interact during some selected activities of the development, but it is limited to test product usability and functionality when prototype is ready.
Increase customer satisfaction	A variety of benefits are planned to be offered to customers in order to increase satisfaction, such as: availability, convenience, safety, sustainably lifestyle, and increased health, share experiences with other users, transport goods and people, comfort, product quality. For instance, the comfort aspect will be reached by improved ergonomics within a special seating position, designed to protect driver during trip and to offer a comfortable ride. Seat is also adjustable for drivers of different heights.

Table 4 presents characteristics related to Factor 4. While the dissemination of skills is a relevant point thanks to a developed assistant system, all the other sub-factors are weakly embraced.

Table 4. Characteristics of the Pedelec business model according to Factor 4

Factor 4. Delineate actions to social well-being	Characteristics
Increase and maintain jobs	As a new business will need to be created, new jobs will be available. It is already defined that four new jobs should be created for the manufacturing, assembly and maintenance of the Pedelec sharing system.
Dissemination of skills	An assistance system has been developed to support the worker in learning new manufacturing processes. The system covers a Microsoft Kinect low cost 3D sensor and software components that are able to recognize the 3D position of the worker's hands and the corresponding work step in process. For more details, see [27]
Broaden access to goods and services	The strategy of the business is based on differentiation and not on cost, so lower income segments are not part of the business model
Regenerate and empower local economies	The business model was defined for Berlin and most of the activities are planned to be undertaken by one stakeholder.
Integrate people	No unemployed, minority or marginalized social group was included as players of the business model.

The characteristics of the business model related to factor 5 are demonstrated in Table 5. Innovation is a strong point of this business model as new aspects for product, service,

technology, value chain and manufacturing process are defined in the business model.

Table 5. Characteristics of the Pedelec business model according to Factor 5

Factor 5. Innovate in different levels	Characteristics
Product and service innovation	The innovation of the product include improved ergonomics of the seating arrangement, the modularization aspects that allows the products to be adapted to different usage scenarios and the decreased energy consumption because of charging options (by means of solar panels and break recuperation). For the service element, the advanced concept for user's interaction during use can be highlighted.
Value chain innovation	Through the concept of "self to self-help", the customer will have another role in the value creation and, using customized repair kits, will be able to repair in the Pedelecs they are using. As an incentive to perform the self-repair, the customers receive free time to use the Pedelecs.
Technology innovation	The IT service oriented "Multiperspective user interface" aims to measure health conditions and Pedelec utilization for sports; enable the customer to perform maintenance (help to self-help); monitor energy consumption; access internet and communicate to users of other Pedelecs and allow smartphones to be charged. Another technological innovation is the assistance system (mentioned in "Dissemination of skills").
Manufacturing innovation	A method for the manufacturing of the Pedelec was created, which generates alternative options for its components according to equipment required, production location and production process. Such alternative options are interrelated to different sustainability goals, e.g. reduction of environmental burdens through material selection.

4.2. Discussion about the evaluation

By evaluating the sustainability of the Pedelec case, it was possible to realize some improvement points on the sub factors "Broaden access to goods and services", "Regenerate and empower local economies", "Integrate people" and "Better working conditions", as Factor 4. "Delineate actions to social well-being" is the one with less aspects taken into account on this business model. Factor 5. "Innovate in different levels" is the strongest point of the business model. However the "innovation for cleaner technologies" (Factor 1. "Design for environment") is not part of the business and could be also a potential to improve the environmental aspect of the product and reduce even more emission and use of material and energy, which could also bring cost savings for the provider (Factor 2. "Identify economic value for each stakeholder").

Factor 3. "Promote behavior change" is partially considered and potentials of their sub factors can be further explored. For instance, involving the customer earlier in the development of the offer could also lead to learning experiences, ways to reduce resistances and a more responsible and sustainable behavior.

5. Final Considerations

The identification of the factors that make a PSS a S-PSS is a proactive approach that will ensure that social, economic and environmental benefits are reached during the creation of a business model. In addition, getting to know these factors can stimulate companies to adopt S-PSS business models as a way to implement and create sustainable practices and solutions.

It is important to mention that some of these factors are not limited to sustainability of PSS but are also related to other types of sustainable business models, e.g. improve working conditions. Yet, some factors and sub factors overlap each other, however the classification proposed aims to facilitate the understanding of such factors.

As each PSS business model must be designed, developed and delivered case by case, the evaluation of each case is also essential to guarantee that sustainability benefits are reached and unwanted side effects, referred as rebound effects, not generated. An example of this effect concerns the factor consumer behavior change. Outsourcing, rather than ownership of products, could lead to careless behaviors.

Not just to avoid rebound effect but to ensure that sustainability benefits are considered not only in the creation of the business model but during the implementation, indicators should be developed considering the different sustainability factors and sub factors. Indicators development as well as improvement actions to increase the sustainability of the Pedelec business models are topics to be approached in future research.

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