Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 64 (2017) 85 – 90

www.elsevier.com/locate/procedia

The 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems

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

Thayla T. Sousa-Zomer[a]*, Paulo A. Cauchick-Miguel[a,b]

[a]*Post-graduate Program in Production Engineering, Federal University of Santa Catarina, Campus Universitário Trindade, Caixa Postal 476, 88040-970 Florianópolis, SC, Brazil*

[b]*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

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

Peer-review under responsibility of the scientific committee of the 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems.

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

1. Introduction

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

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

Peer-review under responsibility of the scientific committee of the 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems.
doi:10.1016/j.procir.2017.03.060

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

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

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

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

2. Theoretical background

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

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

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

3. Research design

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

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

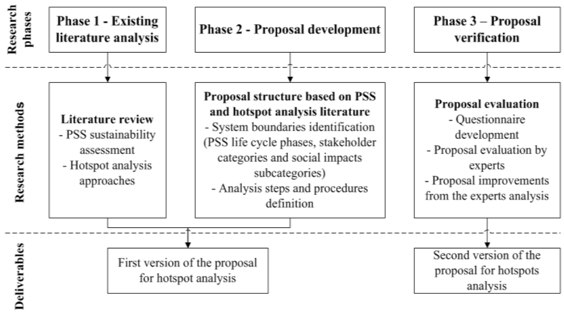

Fig. 1. Scheme of the study' research phases, methods, and deliverables.

The hotspot analysis was identified as valuable to be integrated into PSS design [14]. For this reason, a literature review on hotspot analysis was carried out in Phase 2. A search for publications in the same previously mentioned databases was conducted. An UNEP/SETAC [22] report on existing hotspot analysis methodologies was also reviewed. Hotspot analysis can be applied at different levels [22]: (i) country, (ii) product portfolio, (iii) product category, and (iv) individual product/service. The hotspot analysis methods at the product/service level and those that consider the social dimension were identified and selected for analysis. Choosing a streamlined LCA method involves a balance between simplifying the method and the type of results required [24]. Therefore, from the hotspot methods at the product/service level that consider the social dimension, the Wuppertal Institute's sustainability hotspot analysis (SHSA) [22,23] was selected as one of the starting points to structure the proposal of this work. The main advantage of this method is that it is relatively easy to use and it does not require expert experience. This can be valuable in the PSS design context, because it is still necessary to transfer the know-how from academia to companies and designers [25]. However, in a survey with experts conducted by UNEP/SETAC [22] to identify the applicability of various hotspot analysis methods, SHSA was classified as somewhat relevant for its purpose. Another hotspot analysis method at the product level that enables considering the social dimension is within the scope of the SLCA [26]. This method was considered "essential" regarding its purpose in the UNEP/SETAC survey. Since both hotspot analysis approaches consider the social dimension and have complementary strengths, they were combined for use as the starting points. They were then adapted to suit PSS requirements, considering the application in the early design stages.

The first step for the proposal development (Phase 2) consisted of identifying system boundaries, including life cycle phases and assessment scope, as suggested in the SHSA [22,23]. Life cycle phases are the basis of hotspot analysis and, for PSS, both product and service life cycles should be considered in an integrated way. The literature review conducted in Phase 1 identified some studies that address the life cycle perspective as well as the life cycle phases considered by them. The PSS life cycle was then structured based on those studies. Afterward, the most relevant social impact categories and subcategories were identified in the second step, following the SLCA guidelines [26]. A PSS involves multiple stakeholders, and the possible social impacts on all of them should be taken into account. The SLCA guidelines offer a set of social impact subcategories (i.e. significant social issues), which consider the perspectives of various stakeholder groups [27,28]. This is different from other hotspot analyses that do not make this distinction. This is valuable for the PSS context which involves a range of actors. The guidelines for conducting the social LCA [27] and the methodological sheets that complement those guidelines [28] were examined to obtain social impacts subcategories suitable for PSS analysis.

The stakeholders categories related to PSS actors and discussed in PSS literature were taken into account. In addition, only social subcategories relevant to PSS evaluation in the early design stages were considered, because most of the social issues described in the SLCA guidelines refer to the conduct of companies involved in the life cycle that is not known in the early design stages. Only a few social issues could be directly related to a process/product, which means that there is a causal link between process and impact. Therefore, the criterion to select the most relevant subcategories was: they could be allocated directly to a process/product/service of the relevant life cycle stage. This decision was necessary because all organizations involved in the life cycle are not known during the first stages of PSS development. Finally, the last step of Phase 2 was carried out. It was based on the procedures recommended in the SHSA adopted as starting point and related studies [e.g. 18,22], This step of Phase 2 is detailed further ahead in this paper.

In the study's Phase 3 experts on PSS design and sustainability assessment were asked to find out strengths and weakness of the proposal in order to enhance it. Researchers in the fields of PSS and sustainability were selected based on the following criteria: (i) experience in PSS design and sustainability assessment; or (ii) experience in life cycle assessment. Sixteen researchers from different countries were identified and invited by email to answer a questionnaire. Ten agreed to participate in the proposal evaluation. The questionnaire included 36 five-point Likert scale questions and one open-ended question for each item. The questions involved: (i) the life cycle phases, (ii) stakeholder categories, and (iii) social subcategories. For stakeholders groups selected, for instance, experts were asked if they "strongly disagree", "disagree", "neither agree nor disagree", "agree" or "strongly agree". Additional questions comprised criteria used in other studies that have proposed streamlined methods [15,24] also in addition to criteria for assessing reference models [29]. The questions involved, for instance, assessment of the proposal regarding its utility, completeness, scope, etc. Finally, some improvements were introduced in the proposal accordingly to the respondents' recommendations. The alignment with PSS literature was used as the main criterion to consider the suggestions regarding the inclusion of social impact subcategories, since some of the suggested subcategories could not be applied for analysis of all PSS categories and the proposed approach aimed to be general enough to be applied during the design process of all PSS categories. Next section presents the proposal.

4. Structure of the proposal for hotspot analysis

The complete hotspot analysis procedure consists of four different steps, following SHSA [18,22]: (i) system boundaries definition, (ii) two different ratings (relevance of each social aspect and each life cycle phase), (iii) multiplication of social aspects and life cycle phase scores (to identify possible hotspots), and a (iv) summary of hotspots and actions for improvements.

PSS life cycle phases should be established to define the system boundaries (first step for structuring the proposal). This is similar to other studies that explored streamlined methods (e.g. ref. [15]). In Phase 1 of this study (literature analysis), PSS life cycle phases were identified. The successful offering and realization of a PSS extend the involvement and responsibility of the provider from the design and realization stages (beginning of life - BoL), passing through the usage and maintenance stages (middle of life - MoL), and finishing with the dismission (end of life - EoL). PSS life cycle stages were structured based on those stages (BoL, MoL, and EoL). Only the operative phases were taken into account because most of the impacts are generated in those phases. The life cycle phases considered were: (i) manufacturing, (ii) implementation, (iii) use, and (iv) end of life. Those are the general life cycle phases frequently addressed by past publications.

The second step of system boundary identification consisted of defining the assessment scope, by following the guidelines for SLCA [26] to identify stakeholder categories and social impact subcategories. The selected stakeholder categories - aligned with PSS literature - were: (i) workers, (ii) consumers, (iii) local community where the PSS will be located, (iv) society, and (v) business partners (the value chain actors, e.g. sponsors). Those categories are deemed to be the main stakeholders potentially impacted by the life cycle of a PSS.

After stakeholder categories definition, social impact subcategories were selected (applying the criterion discussed in section 3). Since the impacts to all stakeholders involved in the offering should be measured [19], the social impact subcategories were grouped according to each group of stakeholders involved. The main social impact subcategories suitable for PSS analysis at the early design stages are summarized in Table 1. The subcategories are not discussed in detail in this paper due to paper's length constraints in length. For more details of the meaning of each subcategory, refer to UNEP/SETAC guidelines [26].

Continuing the second step, it is necessary to grade each life cycle phase to reflect the contribution to the overall social impact of the PSS life cycle. The life cycle phases are gauged against one another. The assessment should be done according to a scale suggested by previous studies addressing SHSA [18,22]: "high relative significance" (3), "moderate relative significance" (2), and "low relative significance" (1). This analysis can be done based on available life cycle information of scientific studies on the product or services involved in the offering as well as other data sources like the Social Hotspots Database (SHDB) [30]. The life cycle stage with the most dominant social effects for the reference system (i.e. the traditional business models) is given a higher score. Although this analysis is dependent and based on existing studies, analyzing the reference system in PSS design is a common practice reported by other studies (e.g. ref. [21]). In situations where a PSS system cannot be compared with a reference system available in the market, the system can be compared with a set of individual products and services that have the same combined functionality for the consumer. If data are not available, or if the design team is not aware of the relevance of the life cycle phase, a low score should be given [22].

Table 1. Stakeholder and social impact subcategories of the proposal.

Stakeholder categories	Subcategories	References
Workers	Health and safety	[13,19,22,27]
	Hours of work	
Consumers	Health and safety	[12,22,27]
	Feedback mechanisms	[5,11,27]
	Privacy in the use phase	[27]
	End of life responsibility	[27]
Local community	Safe and healthy living conditions	[12,19,20]
	Access to material resources	[13,27]
	Access to immaterial resources	[13,27]
	Community engagement	[12]
	Local employment	[13,20]
	Cultural heritage	[27]
Society	Public commitment to sustainability issues	[27]
	Contribution to economic development	[27]
	Technology development	[13,27]
Value chain actors	Supplier relationships	[12]

Afterward, each social subcategory must be identified as having a 'low', 'moderate', or 'high relevance' concerning each life cycle phase (i.e. the impact subcategories are analyzed along the life cycle using the same scale to gauge the life cycle stages mentioned before in the previous paragraph). The assessment of the relevance of each subcategory in each life cycle phase should be done based on the literature, such as scientific journals addressing life cycle assessment of the products involved in the system or other studies involving the reference system. In addition, if the location where life cycle phases take place is known, the Social Hotspots Database may be used to support the analysis. Sources consulted to evaluate the social subcategories along the life cycle should be documented [22]. The third step consists of multiplying the scores given to each social subcategory by the respective scores of the life cycle phase (Equation 1). This is carried out to identify the hotspots:

$$X_{nxm} \times w_{mx1} = H_{nxm} \quad (1)$$

Where: X_{nxm} is a matrix of the scores given to each social subcategory n in each life cycle phase m; w is a matrix of the weights given to the life cycle phases m; and H is a matrix of the hotspots that allows to identify if the social subcategory might be a hotspot in the respective life cycle phase, if the value of $H_{i,j}$ is 6 or 9, as proposed in SHSA [18]. The last step (iv) recommends that stakeholders review the results [22].

By including a stakeholder review, robust analysis results are ensured [22]. This is also relevant in the context of PSS design, because it is highly recommended that the actors involved in a PSS offer get involved in the design process [10]. The hotspots in each life cycle phase should be summarized, and actions for design improvements should be planned by the design team. Next section presents the results of the proposal evaluation by experts.

4.1. Proposal evaluation by experts and improvements

The proposed hotspot analysis was evaluated by 9 experts on PSS plus 1 on life cycle assessment. Some suggestions for improvements were made (Table 2).

Table 2. Experts suggestions for improvements.

Aspect	Suggestions/ recommendations	Decisions
System boundaries - life cycle	Inclusion of pre-production phase	Accepted
System boundaries - life cycle	Division of the end of life	Partially accepted
Stakeholders categories	Division of the stakeholder category ‘society’	Partially accepted
Stakeholders categories	Inclusion of the stakeholder category ‘shareholders’	Partially accepted
Social impact subcategories	Elimination of the subcategory privacy in the use phase in the stakeholder group ‘consumers’	Accepted
Social impact subcategories	Inclusion of knowledge transfer/awareness, income generation and empowerment in the stakeholder group ‘consumers’	Partially accepted
Social impact subcategories	Inclusion of income generation and empowerment in the stakeholder group ‘local community’	Partially accepted
Social impact subcategories	Inclusion public policies in the stakeholder category ‘society’	Accepted

Regarding the system boundaries and the life cycle phases, the suggested inclusion of the pre-production phase was considered, since it is commonly addressed in LCA studies. Publications that address PSS life cycle assessment were analyzed [9], and, in general, the raw material extraction is considered by them. Therefore, although the life cycle stages considered a life cycle management perspective, the raw material processing phase was also included. In addition, the division of the end of life according to each PSS strategy (i.e. if the product is recycled, redesigned, and/or remanufactured at the end of life) was suggested. In fact, as pointed out by Kjaer [14], this represents a challenge for life cycle analysis, because PSS often pursue product lifetime extensions through multiple life cycles, thereby challenging the definition of the reference system. Different scenarios and possible social impacts associated with them should be considered in the analysis.

The suggestions concerning the stakeholder categories included the division of the stakeholder group ‘society’ into other groups, such as the government and regulatory institutions. The division was partially addressed because this category considers the impacts on society as a whole and this distinction should be made in cases that it is extremely relevant. Another recommendation was the inclusion of shareholders as a stakeholder category. However, shareholders are already included in the category ‘value chain actors’, and it is suggested that in cases this category is essential it should be considered as a subgroup. The design team should analyze specific new stakeholder groups particular to each situation and identify relevant social subcategories for them.

Some suggestions for subcategories inclusion were also made. The subcategory ‘privacy in the use phase’ in the stakeholder group ‘consumers’, was suggested to be excluded because it seems to be specific to some PSS (e.g. car sharing systems). In fact, it is not for all PSS cases that consumer privacy in the use phase is essential, such in the cases that the property is transferred to the consumer in the product-oriented category, and this subcategory was then excluded. In addition, knowledge transfer/awareness, income generation and empowerment were suggested to be included in the consumers’ group. These subcategories may be especially relevant for PSS implementation in low- and middle-income contexts, and it is suggested that those are considered when analyzing solutions that will be implemented in the mentioned contexts. The inclusion of similar subcategories (income generation and empowerment) was also suggested to the stakeholder category ‘local community’. These are also relevant for low- and middle-income regions, and should be analyzed in the case of PSS development to be implemented in those regions. The inclusion of the subcategory public policies and instruments in the stakeholder category ‘society’ was also made as suggested, because public policies may facilitate PSS implementation and diffusion. The inclusion of the suggested stakeholders categories and impact subcategories, as well as the consideration of the suggested life cycle stages (pre-production and different EoL strategies) improved the first version of the proposal.

In addition, experts were asked to evaluate the hotspot analysis regarding various aspects (e.g. utility, clarity, relevance). On the one hand, the proposal was evaluated as relevant regarding its utility and simplicity to be applied during the early design stages. This is an important aspect because, as mentioned before, there is a lack of sustainability assessment approaches in the PSS literature suitable for the early design stages. In addition, it is also important that the results of streamlined approaches are easy and simple to interpret since an interpretation of results of a LCA requires the expertise of the design team. Therefore, its simplicity may be valuable and warrant increased use by the design team.

On the other hand, the proposal was criticized regarding the evaluation depth and its scope of the sustainability dimensions covered. In fact, the hotspot analysis enables a rough overview of relevant social aspects in a short period and it is based on existing studies [18]. It is expected that in the following stages of development a quantitative assessment will be performed when more detailed information is available. Moreover, only the social dimension was considered because it is the sustainability pillar covered by the hotspot methodologies chosen as the starting points and due to the study focus. The next section summarizes the main concluding points of this work.

5. Conclusion

Since there is a lack of sustainability assessment methods and tools that can be applied in the early design stages of PSS design, the proposed hotspot analysis may be suitable for providing an overview of possible social impacts based on reference systems and the location where life cycle stages take place. Conclusively, the results are valuable for identifying improvements in the social performance along the PSS life cycle. The social impacts on all stakeholders are also addressed in the proposal, which may be valuable because most of the existing studies only consider the provider and consumer perspectives.

From a practitioner's perspective, the hotspot analysis seeks to resolve the common trade-off between comprehensiveness of analysis and feasibility of data collection during the early design stages. The proposed approach can be applied by practitioners in industry and it does not require the same level of knowledge required by complex assessments such as LCA, although some knowledge of scientific literature is also necessary. This may contribute to the application of theoretical approaches in real contexts, which is also a research gap in PSS literature. The main limitation of this study is the proposal's evaluation conducted so far that involved only researchers so far. The next step is the application of the proposed hotspots analysis in a real PSS design context as well as its evaluation by practitioners from industry. Further work will also integrate the environmental dimension into the approach in order to improve the proposal scope.

Acknowledgements

The authors thank CNPq for the financial support of this research project (grant 478166/2012-5). The authors are also very grateful for the experts from Brazil, France, and Netherlands and their valuable contributions.

References

[1] Qu M, et al. State-of-the-art of design, evaluation, and operation methodologies in product service systems. Comput Ind 2016;77:1-14.
[2] Pigosso DCA, McAloone TC. Maturity-based approach for the development of environmentally sustainable product/service-systems. CIRP J Manuf Sci Technol 2016;15:36-41.
[3] Vezzoli C, Ceschin F, Diehl JC. Sustainable Product-Service System Design applied to Distributed Renewable Energy fostering the goal of sustainable energy for all. J Clean Prod 2015;97:134-136.
[4] Maussang N, Zwolinski P, Brissaud D. Product-service system design methodology: from the PSS architecture design to the products specifications. J Eng Des 2009;20(4):349-366.
[5] Chen DP, et al. PSS solution evaluation considering sustainability under hybrid uncertain environments. Expert Syst Appl 2015;42(14):5822-5838.
[6] Shimomura Y, Nemoto Y, Kimita K. A method for analysing conceptual design process of product-service systems. CIRP Ann - Manuf Technol 2015;64(1):145-148.
[7] Doualle B, Medini K, Boucher X, Laforest V. Investigating Sustainability Assessment Methods of Product-service Systems. Procedia CIRP 2015;30:161-166.
[8] Kim K-J, et al. An evaluation scheme for product–service system models: development of evaluation criteria and case studies. Service Business 2016;10(3):507-530.
[9] Amaya J, Lelah A, Zwolinski P. Design for intensified use in product–service systems using life-cycle analysis. J Eng Des 2014;25(7-9):280-302.
[10] Doualle B, et al. Design of Sustainable Product-service Systems (PSS): Towards an Incremental Stepwise Assessment Method. Procedia CIRP 2016;48:152-157.
[11] Halme M, Jasch C, Scharp M. Sustainable homeservices? Toward household services that enhance ecological, social and economic sustainability. Ecol Econ 2004;51(1-2):125-138.
[12] Sousa-Zomer TT,Cauchick-Miguel PA. The main challenges for social life cycle assessment (SLCA) to support the social impacts analysis of product-service systems. Int J Life Cycle Assess 2015. In press.
[13]Chou C-J, Chen C-W,Conley C. An approach to assessing sustainable product-service systems. J Clean Prod 2015;86:277-284.
[14] Kjaer LL, Pagoropoulos A, Schmidt JH,McAloone TC. Challenges when evaluating Product/Service-Systems through Life Cycle Assessment. J Clean Prod 2016;120:95-104.
[15] Arena M, Azzone G,Conte A. A streamlined LCA framework to support early decision making in vehicle development. J Clean Prod 2013;41:105-113.
[16] Ramani K, et al. Integrated Sustainable Life Cycle Design: A Review. J Mech Des 2010;132(9):091004-091004.
[17] Andriankaja H, Vallet F, Le Duigou J, Eynard B. A method to ecodesign structural parts in the transport sector based on product life cycle management. J Cleaner Prod 2015;94:165-176.
[18] Liedtke C, Baedeker C, Kolberg S, Lettenmeier M. Resource intensity in global food chains: the Hot Spot Analysis. Brit Food J 2010;112(10):1138-1159.
[19] 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;32:173-182.
[20] Hu HA, et al. Development of sustainability evaluation model for implementing product service systems. Int J Environ Sci Technol 2012;9(2):343-354.
[21] Lindahl M, Sundin E,Sakao T. Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases. J Clean Prod 2014;64:288-296.
[22] UNEP/SETAC. Hotspots Analysis: mapping of existing methodologies, tools and guidance and initial recommendations for the development of global guidance. France: Life Cycle Initiative; 2014.
[23] Liedtke C, et al., Wuppertal Institute Design guide—Background Information & Tools. Germany: Wuppertal Institute for Climate, Environment and Energy; 2013.
[24] Hochschorner E,Finnveden G. Evaluation of two simplified Life Cycle assessment methods. Int J Life Cycle Assess 2003;8(3):119.
[25] Ceschin F,Gaziulusoy I. Evolution of design for sustainability: From product design to design for system innovations and transitions. Design Studies 2016. In press.
[26] UNEP/SETAC. Guidelines for Social Life Cycle Assessment of Products. France: Life Cycle Initiative; 2009.
[27] Benoît C, et al. The guidelines for social life cycle assessment of products: just in time! Int J Life Cycle Assess 2010;15(2):156-163.
[28] Benoît-Norris C, et al. Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. Int J Life Cycle Assess 2011;16(7):682-690.
[29] Vernadat F. Enterprises modeling and Integration: Principles and Application. Uxbridge: Springer; 1996.
[30] The Social Hotspots Database. 2016. Retrieved from: http://socialhotspot.org/.