Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 47 (2016) 418 – 423

www.elsevier.com/locate/procedia

Product-Service Systems across Life Cycle

Product-service systems characterization based on life cycle: application in a real situation

Fernanda Hänsch Beuren[a,]*, Delcio Pereira[a], Alexandre Borges Fagundes[a]

[a]*Universidade do Estado de Santa Catarina, Rua Luiz Fernando Hastreiter, 180. Centenário. São Bento do Sul-SC. CEP: 89.283-08. Brazil*

* Corresponding author. Tel.: +55 47- 3634-0988. E-mail address: fernanda.beuren@udesc.br

Abstract

Given the offer of products, which are losing their competitive value, companies begin to seek solutions to improve their market position through the inclusion of services. The development of product-service systems (PSS) is a solution that has been discussed by the academia in recent years, resulting in an increasing number of publications. The literature not only shows a growing interest in PSS but also points out some research gaps such as the lack of characterization of a PSS and the difficulty of identifying a PSS. In this sense, this paper proposes an application of a framework that characterizes a PSS in a real situation. The aim is to check if the real situation presents the characteristics of a PSS highlighted by the framework. The framework presents conceptual elements throughout the life cycle of a PSS: Requirements definition of a PSS; Development of a PSS; Implementation of a PSS; Monitoring a PSS; and Post-use disposal of a PSS. These elements are intended to identify the characteristics of PSS for each stage of the cycle. The real situation identified in the existing literature on PSS presents basic characteristics of a PSS, it contains its four main factors: product, service, actors network and infrastructure and presents the similarity of the three types of PSS (product-oriented, use-oriented and results-oriented). Thus, the framework is applied in the practical case to identify characteristics of PSS. This application is carried from a questionnaire based on conceptual elements arranged in stages of the life cycle of the PSS. The responses were analyzed highlighting main conceptual elements characteristics. With the information obtained from the questionnaire, the results demonstrate the company's current situation and the PSS characteristics that could be implemented.

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle

Keywords: Product-service system; PSS characterization; PSS life cycle.

1. Introduction

The effects caused by the raise in production and consumption in the past years have shown that product availability itself isn't enough for a competitive strategy [1]. Including services into products is being considered as a great business opportunity because it is hard to copy by competitors [2]. With products being manufactured in large aiming to reduce production costs to obtain competitive prices in longer life cycle [3]. The consumer replaces the product more frequently [3]. Frequent product replacement is a recent problem that raises the amount of waste on environment as a result of inappropriate product discard [1]. Furthermore, consumer doesn't know where the products are destined in the end of the life cycle [4].

Society is worried about the raise in waste amount and is looking for alternatives to make the situation better [4]. For that, one solution that aims to lower environmental issues caused by the growing product consumption is the Product-Service System (PSS).

PSS offers functionalities to consumers aiming to reduce environment impact [5], being a business opportunity that is being widely discussed by researches worldwide and they emphasize that it is a trend that must be considered by companies [6]. A raise in the amount of articles written about PSS has been notices in the past years, showing that the

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle
doi:10.1016/j.procir.2016.03.116

Academia is interested about it [7]. From 2011 to 2013, the number of papers increased drastically, indicating a fast growing interest in PSS. Papers published from 2011 to 2013 represents 78,8% of the total [7].

However, a Gap has been identified by [4, 8 and 9]: there is the need of empirical analysis. These analysis aims to contribute to the PSS theory that is complex and needs researches about its practical adoption [10].

The criteria used to identify a PSS business must be explored because a PSS isn´t solely an offer of products and services but also the planning of all the elements involved (called Actors Network) and the needed infrastructure to attend all the business levels and, mainly, to be planned accordingly to its life cycle [11], [12] and [13].

The motivation to develop this paper was the difficulty to identify if a business is a PSS and not only the offering of products and services. So it makes necessary to consider the conceptual elements identified in all stages of the PSS life cycle (its characteristics elements). Given the scarcity of empirical work about PSS and the difficulty of identifying whether a business is a PSS, the research question is: what criteria should be used to identify a PSS based on its life cycle? These criteria are presented in this paper as conceptual elements which aim to characterize a PSS based on the literature. Moreover, a real case is analyzed.

2. Literature Analysis

Services are increasingly being considered as business opportunities due to its competitive differential and for being hard to be copied by competitors [2]. The inclusion of different kinds or services offers to consumer's customization so new business models are being created, strategically transferring product sales to service provision [15] and [2]. There are three reasons to this strategically transfer [2]: (i) competition on product sales, (ii) value added from service provision, (iii) product servitization changing the product physical properties to increase functionality. Consumer uses the product function without having it.

Product-service system is a business opportunity that is considered a trend by the researches. It aims at solutions that decrease the environmental issues caused by intense product consumption and aims to be a competitive business model for companies that look for competitive differentiation. This differentiation is related to service inclusion to add value to the offer products.

The main benefits of PSS are related to continuous business improvement with innovation on quality and looking to progressively satisfy the consumer needs [16]. With this providers can build long term relationships with consumers that become loyal. Besides that, all the obtained info from this relationship can be used on new systems development to improve its performance [13]. This way companies can improve their position on the value chain increasing their innovation potential [17]. Companies can also contribute to the lack of resources and environmental degradation becoming responsible for products and services aiming to reduce waste [3].

A PSS must be planned at the systemic level [18, 13], considering all the life cycle based on products, services, actors network and infrastructure. This planning must be continuously improved being adapted to the consumer needs. For this it is necessary to involve the consumer on the creation stage, valuing their ideas and through all the system use as the consumer knowing the system important aspects of it can be known.

Market faces continuously changes and the PSS is a way of following this change through the connection with all the involved actors. However, it is necessary to involve the companies too, adapting their traditional structures focusing on product use and service provision. Manufacturing companies need to set their internal production to allow efficient associated product and services delivery [19]. The change to a PSS is complex and needs more researches about services that must be offered with products, aiming continuous consumer satisfactions [20]. The execution actions and process to deliver products and services must also be researched [21].

The product life cycle must be linked to the service life cycle [22, 23]. Services are offered to consumers and products are used as a way to this service provision. The PSS behavior must be analyzed through its life cycle [24]. Although the PSS life cycle is present in the literature it is not shown on a wider and bigger approach [11, 12, 13], in other worlds, the complete PSS life cycle, respecting all of its stages (Figure 1).

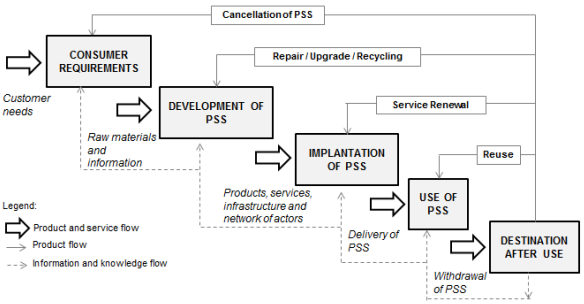

Fig.1. Life cycle PSS.

This paper highlights the PSS life cycle on a systemic way (Table 1), aiming to be used as a base to conceptual elements identification in the literature to characterize practical situations and if this situation can be considered as PSS or not.

Table 1. PSS life cycle stages

Life cycle stages	
Requirements of PSS	Attend a consumer that uses a PSS
PSS development	How a PSS must be developed
PSS implementation	How a PSS must be used by the consumer
PSS monitoring	Attendance improvements obtained from information gathered through the use
PSS post use destination	Analysis of each situation at post use stage

3. Research methods

The first stage of this paper development was the selection of bibliographic references from the past 10 years (2004-2014). The Scopus and Science Direct database were used for paper search and the EndNote software for data management. The literature revision begun with the main keyword "product-service system" [14] and its combinations with "sustainability", "remanufacturing", "service design", "service economy", "product substituting service", "dematerialization", "system solution", "functional economy". 283 papers were obtained and the Procedia CIRP, Journal of Cleaner Production and Journal of Manufacturing Technology Management were the main periodicals.

With the papers identified and analyzed in the literature the base to identify the conceptual elements of the PSS life cycle were identified, as seen on Figure 2.

To answer the research question and identify a PSS, conceptual elements are identified on literature with the objective of PSS characterization. To identify these elements the PSS life cycle was used and it is divided as: Requirements definition of a PSS; Development of a PSS; Implementation of a PSS; Monitoring PSS; and Post-use disposal of a PSS, as seen on Figure 2.

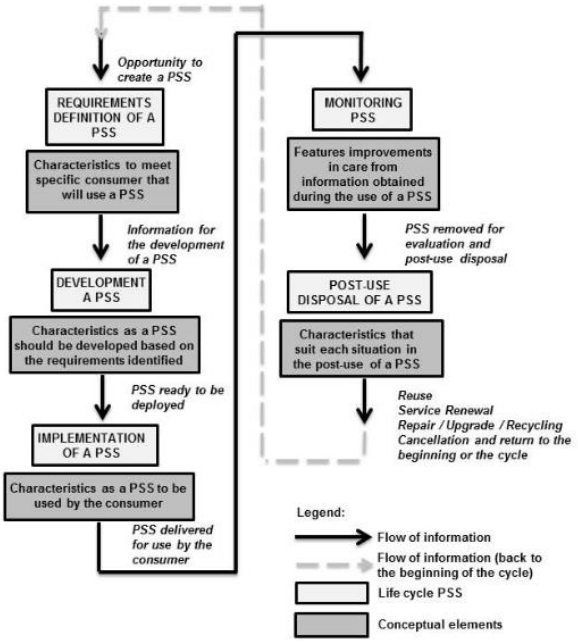

Fig.2. Basis for the identification of conceptual elements from the input and output stages of the PSS life cycle.

Figure 2 highlights how a PSS must be developed based on the identified requirements. Since the definition of the requirements until its post-use disposal it must attend to determined characteristics of each stage of the PSS life cycle. The presented flow highlights all the stages of the PSS life cycle that is first presented as a creation opportunity. The conceptual elements that define the PSS requirements (Figure 2) are meant to attend a consumer that may use a PSS. So these elements consider what kind of PSS it is (product oriented, use oriented or results oriented).

The conceptual elements to develop a PSS (Figure 2) are characteristics of how a PSS must be developed based on the identified requirements. These conceptual elements must consider the product, service, actors network and needed infrastructure. For the product, its life cycle must be considered [13]; For the service, the service life cycle for the consumer must be considered as it covers from the consumer needs to the service withdraw; for the actors network, all the possible interactions between the PSS actors are considered; for the infrastructure all the product, service and actors network development stage are considered. The conceptual elements for the PSS implementation (Figure 2) are stages and characteristics of how a PSS must be used by the consumer. It shows how the product and service must be used, how the actors should behave to attend all the needs of a PSS that is being implemented and which infrastructure is more appropriate.

The conceptual elements for monitoring a PSS (Figure 2) are characteristic of improvements in customer service from information obtained during the use of a PSS. It is considered the classification of PSS (product oriented PSS, use oriented PSS and result oriented PSS). It is considered that classification is needed to identify improvements in business from the use of the product and services by the consumer.

The conceptual elements for post-use of a PSS (Figure 2) are features that suit every situation in post-use of a PSS. It is considered to reuse the product; renewing the service, wherein the product remains the same; repair / upgrade or recycling of parts and materials of the product; and cancellation of the PSS, which returns to the beginning of its life cycle.

The identification of the conceptual elements was based on the PSS life cycle and with that the PSS characterization model was obtained. This model was then analyzed on a real situation through an applied survey. Some practical situations were chosen considering its similarities to real PSS cases present in the literature as: bike rental, water purifier rental and car sharing. Some basic PSS characteristics were also considered (i) product, service, actors network and infrastructure; and (ii) to present the similarity with one of the three kinds of PSS (product-oriented, use-oriented and results-oriented). The survey was applied online to make it easier to obtain the answers and the data analysis. Directions to the answering were presented requesting the respondents to select only the options that they considered as part of their business.

Data collection was obtained through the questionnaire sent to Beta company, which pointed out which would be the conceptual elements to be part of the water purification business model. The data analysis was organized in spreadsheets in order to cross the data and thus identify the classification of PSS that the business is part of and what are the conceptual elements that are part of the business model.

Figure 3 highlights the group of conceptual elements of the first stage of the PSS life cycle (Definition of requirements for a PSS). For the other 4 stages other conceptual elements were identified. 103 elements were identified for all the 5 stages of the PSS life cycle.

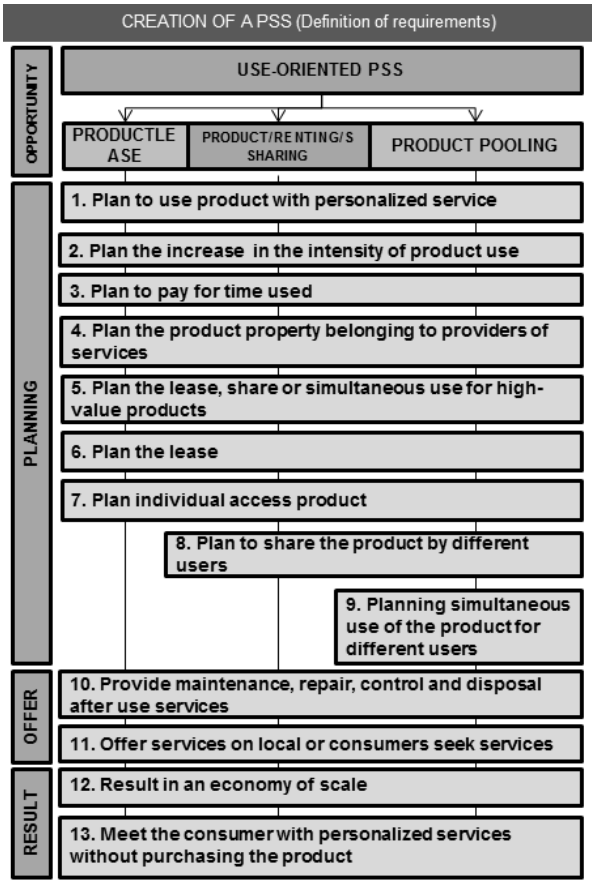

Fig.3. Organization of conceptual elements for a PSS in "Definition of requirements to PSS use-oriented".

Figure 3 is a part of the list of conceptual elements identified in the literature and represents the use-oriented PSS (kind of PSS identified in the practical case of water purification). A business opportunity is initially shown that for this kind of PSS (use-oriented) should cover the elements listed in Figure 3 (e.g.: Plan to use the product with personalized service; Plan the lease, between others). After identifying the opportunity for this kind of PSS, it is set if the PSS is: product lease; product / renting / sharing; or product pooling. For each PSS there are unique conceptual elements. To identify the conceptual elements that every business model covers the respondent points out the questionnaire that is part of his business and analyze the data, knowing what are the main conceptual elements that should be considered in every kind of business.

4. Results

The actual situation used in this work is the Beta Company that develops and manufactures products in the household appliances sector. (Traditional products of the company are developed and sold almost with no services included during the use stage, except for conventional warranty service with specified period. The company invests in research in order to meet a new Market niche in order to offer innovation through a new business focused on leasing services. The business model is focused on leasing a water purifier which was created to enable the company to enter this new market niche, which had no presence until then.

The property of the product is from the company that offers the system to the consumer in the lease, maintaining contact during use. The development of the components of the exemplified product is made by subcontractors that are specialized in specific parts, such as the filter.

The purifier is installed and maintained by the company in the consumer's home or installed on any commercial company by paying a monthly fee (including maintenance every six months, repair and exchange of refills at no extra cost). The value may vary according to the product specification and model level to be provided.

The Beta practical situation is analyzed to identify the PSS characteristics on its 5 life cycle stages.

4.1. Definition of requirements for a PSS

The survey applied to the Beta practical situation showed that it must be considered as a PSS Use-Oriented and is specifically related to the subcategory "Product lease".

In practical application it was found that there are conceptual elements 1, 2, 3, 4, 6, 7, 10, 12 and 13 (as shown in Figure 3). The other elements are not used in the business model.

4.2. Development of a PSS

Most of the selected conceptual elements in the PSS development stage show that this practical situation is related to planning and the PSS project. It is concluded that the company that offers water purifiers rental also develops the product accordingly to the PSS specifications.

The service development is also related to a PSS as the interviewed marked most of the conceptual elements. It is noticed that the actors network development is linked to the product and services development accordingly to the PSS specifications.

The actors network must be planned along the product and services that will be offered to the consumer because actors from different areas are needed to make a PSS [25] and [26] such as suppliers, producers, maintenance technicians, cleaning technicians, fitters, consumers and other stakeholders.

The development or adaptation of an existing infrastructure also must be planned along the product, service and actors network [27].

The Beta practical situation has almost all the PSS development elements showing that all the data mapping of the product, service, actors and infrastructure development is known and that they all must be monitored aiming to continuous improvement.

4.3. Implementation of a PSS

As in the PSS development stage the Beta company has almost all the conceptual elements in the PSS implementation stage. From the delivery until payment of the provided service the infrastructure and involved actors to better attend the consumer are present. Some elements identified are: to advice on effective use; Provide advice on hygiene; Install the product and / or provide the service at the place established by the consumer; Identify a technician responsible for testing and simulating the product, among others.

4.4. Monitoring of a PSS

As identified in the first stage of the PSS life cycle that the Beta practice situation is a Use-Oriented PSS the conceptual elements are confirmed in this PSS category.

A presented example is the conceptual element "identify with the consumer problems and solutions that were observed through the use of the product with individual access (leasing)". It is related to the element that was identified in the PSS requirements definition stage. The communication between the service provider and the consumer is important as with the other actors involved in the process [28].

4.5. Destination after use

The conceptual elements of the Destination After Use stage are related to the reuse of products, the service renovation and repairing, updating, recycling and PSS canceling. The real analyzed situation has almost all the conceptual elements in this PSS life cycle stage so the analyzed company has the business objective centered in the offering of Product-Service systems.

5. Conclusions

With all the study it is confirmed that the PSS is a growing trend in the literature and is attracting interest from the researches. As the PSS theory still isn't consolidated and needs more researches about its practical adoption, this paper aimed to identify the difference from a PSS to a simple offer of a product with service together. So to clarify this difference the conceptual elements were identified in the literature based on the PSS life cycle to differentiate the situation that offers a simple link of a product and a service from a situation that offers a PSS.

The Beta real situation that was analyzed in this paper showed about 70% of the conceptual elements (from a total of 103) of the five stages of the life cycle. Thus it is concluded that this result may be related to the business objective that involves all the stages of the life cycle or for the time that the company develops a PSS.

With the conceptual elements used on this paper it is possible to represent the characteristics of a PSS and know its processes in each stage of the life cycle and to differentiate a practical situation that offers only products and services from a PSS. However the concept elements can't measure how much a specific situation has of the PSS characteristics being a limitation of this research.

With the analysis made on the conceptual elements that characterize a PSS it is possible to verify the real situation of the company, identifying the PSS characteristics and, with this data, it is possible to plan what the company could include on its business to present a bigger number of PSS characteristics. So with the increase of conceptual elements in each stage of the life cycle the company can be more competitive in the market.

The conceptual elements in the practical case analyzed in this paper that were not contemplated are presented in sequence as each stage of the life cycle of PSS. It is noteworthy that when analyzing the conceptual elements, the analyzed situation is a use-oriented PSS.

PSS requirements identification stage:
- Plan the increase in product use intensity;
- Advise on effective use of the product;
- Plan the lease, share or simultaneous use for high-value products;
- Plan to share the product with different users;
- Plan simultaneous use of the product with different users;
- Provide on-site services or consumers looking for services;
- Plan payment for an outsourced activity;
- Plan the product property belonging to service providers;
- Outsource an activity to the consumer, and the consumer assumes all the stages.

PSS development stage:
- Plan that the leased product has individual access and / or can be shared among different users and / or can be used simultaneously by different users;
- Designing services with the product (s);
- Plan that suppliers use low environmental impact resources;
- Plan that technicians are responsible for the repair, upgrade, product recycling and materials and the reverse logistics;
- Designing a PSS balancing work among stakeholders;
- Plan the economy and appreciation of the local culture.

PSS implementation stage:
- Identify the technical responsible for advising on the use of PSS.

PSS monitoring stage:
- Identify the need of looking for actors to continuously improve a PSS;
- Identify with the consumer any problems and solutions while using the product shared by different users;
- Identify with the consumer any problems and solutions during simultaneous use of the product for different users;
- Keeping in touch while using the service.

PSS post use destination stage:
- Send a technician responsible for meeting the consumer reuse of parts and materials;
- Send a technician to meet the consumer in the renewal of services;
- Repair damaged parts on the product;

- Use the necessary infrastructure for possible repairs in the product.

The list of conceptual elements for each stage of the PSS life cycle that was not contemplated by the analyzed situation was presented above. The aim is to analyze each situation to be able to meet all the conceptual elements and thus make the business as close as possible of a pure PSS. Pure PSS would meet as much of the conceptual elements for each stage of the life cycle and thus make the PSS a success.

With future possibilities more researches can be developed including other practical situations related to the three categories of a PSS. Furthermore, the analysis of every conceptual element should be studied seeking continuous improvement of the conceptual elements at each stage of PSS lifecycle. As future research, the conceptual elements can be used as a reference for the development of new PSS.

References

[1] Yu, M., Zhang, W., Meier, H. Modularization Based Design for Innovative Product-Related Industrial Service. Proceedings of the IEEE International Conference on Industrial Engineering and Engineering Management; 2008. p. 48-53.

[2] Sakao, T., Sandström, G.Ö., Matzen, D. Framing research for service orientation of manufacturers through PSS approaches, Journal of Manufacturing Technology Management 2009; 20, 5: 754-778.

[3] Baines, T.S., Lightfoot, H.W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J.R., Angus, J.P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I.M., Wilson, H. State-of-the-art in product-service systems. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 2007; 221, 10: 1543-1552.

[4] Baines, T., Lightfoot, H., Smart, P. Servitization within manufacturing operations: An exploration of the impact on facilities practices. Proceedings of the Institution of Mechanical Engineers, PartB:Journal of Engineering Manufacture 2012; 226, 2: 377-380.

[5] Goedkoop, M.J., van Halen, C.J.G., te Riele, H.R.M., Rommens, P.J.M. Product Service Systems, ecological and economic basics. Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ), 1999.

[6] Kimita, K., Watanabe, K, Hara, T., Komoto, H. Who realizes a PSS?: an organization framework for PSS development. 7th Industrial Product-Service Systems Conference - PSS, industry transformation for sustainability and business. Procedia CIRP 30; 2015. p. 372-377.

[7] Oliveira, M. G., Mendes, G.H.S., Rozenfeld, H. Bibliometric Analysis of the Product-Service System Research Field. 7th Industrial Product-Service Systems Conference - PSS, industry transformation for sustainability and business. Procedia CIRP 30; 2015. p. 114-119.

[8] Durugbo, C., Erkoyuncu, J.A., Tiwari, A., Alcock J.R., Roy, R., Shehab, E. Data Uncertainty Assessment and Information Flow Analysis for Product-Service Systems in a Library Case Study. International Journal of Services Operations and Informatics 2010; 5, 4: 330-350.

[9] Durugbo, C., Tiwari, A., Alcock, J.R. A review of information flow diagrammatic models for product-service systems. International Journal of Advanced Manufacturing Technology 2011, 52, 9-12: 1193-1208.

[10] Baines, T., Lightfoot, H., Benedettini, O., Whitney, D., Kay, J. The adoption of servitization strategies by UK-based manufacturers. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 2010; 224, 5: 815-829.

[11] Alix, T., Zacharewicz, G. Product-service systems scenarios simulation based on G-DEVS/HLA: Generalized discrete event specification/, Computers in Industry 2012; 63, 4: 370-378.

[12] Yang, L., Xing, K., Lee, S.H. A New Conceptual Life Cycle Model for Result-Oriented Product-Service System Development. School of Advanced Manufacturing and Mechanical Engineering of University of South Australia 2010: 23-28.

[13] Sundin, E. Life-Cycle Perspectives of Product/Service-Systems in Design Theory. In: Sakao, T. and Lindahl, M. (Eds.) Introduction to Product/Service-System Design, Springer, London 2009: 31-49.

[14] Hänsch Beuren, F., Ferreira, M.G.G., Cauchick Miguel, P.A. Product-service systems: a literature review on integrated products and services. Journal of Cleaner Production 2013; 47, 2: 222-231.

[15] Oliva, R., Kallenberg, R. Managing the Transition from Products to Services. International Journal of Service Industry Management 2003; 14, 2: 160-172.

[16] Aurich, J.C., Mannweiler, C., Schweitzer, E. How to design and offer services successfully. CIRP Journal of Manufacturing Science and Technology 2010; 2, 3: 136-143.

[17] Tukker, A., Tischner, U. New business for old Europe: product service development, competitiveness and sustainability, Greenleaf Publishing, Sheffield, UK, 2006.

[18] Lee, J, Abuali, M. Innovative Product Advanced Service Systems (I-PASS): methodology, tools, and applications for dominant service design. International Journal of Advanced Manufacture Technology 2011; 52, 9-12: 1161-1173.

[19] Baines, T., Lightfoot, H., Peppard, J., Johnson, M.,Tiwari, A., Shehab, E., Swink, M. Towards an operations strategy for product-centric servitization. International Journal of Operations and Production Management 2009; 29, 5: 494-519.

[20] Sakao, T., Panshef, V., Dörsam, E. Addressing Uncertainty of PSS for Value-Chain Oriented Service Development. In: Sakao, T. and Lindahl, M. (Eds.), Introduction to Product/Service-System Design, Springer, London 2009: 137-157.

[21] Baines, T., Lightfoot, H., Kay, J. Servitized manufacture: practical challenges of delivering integrated products and services. Proceedings of the Institution of Mechanical Engineers Part B-Journal of Engineering Manufacture 2009; 223, 9: 1207-1215.

[22] Aurich, J.C., Fuchs, C., Wagenknecht, C. Life cycle oriented design of technical Product-Service Systems, Journal of Cleaner Production 2006; 14, 17: 1480-1494.

[23] Gu, X.J., Li, X., Qi, G.N., Ji, Y.J., Tang, R.Z., Jiang, P.Y. Theory and key technology of product service system. Journal of Zhejiang University (Engineering Science) 2009; 43, 12: 2237-2243.

[24] Meier, H., Uhlmann, E., Krug, C. M., Völker, O., Geisert, C., Stelzer, C. Dynamic IPS2 networks and operations based on software agents. CIRP Journal of Manufacturing Science and Technology 2010;.3, 2: 165-173.

[25] Unep-United Nations Environment Programme. Product-Service Systems and Sustainability: Opportunities for Sustainable Solutions. INDACO Department, Politecnico di Milano, Milão: 2004.

[26] Mittermeyer S.A., Njuguna, J.A., Alcock, J.R. Product-service systems in health care: case study of a drug-device combination. The International Journal of Advanced Manufacturing Technology 2010; 52, 9-12: 1209-1221.

[27] Mont, O. Product-service systems: panacea or myth? Doctoral Dissertation, 259p. The International Institute for Industrial Environmental Economics (IIIEE). Lund University, Sweden 2004.

[28] Mien, L., Feng. L., Leng, R.G.K. An integrated manufacturing and product services system (IMPSS) concept for sustainable product development, In: International Symposium on Environmentally Conscious Design and Inverse Manufacturing 2005; p.656-662.