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Development of integrated design methodology for various types of product – service systems

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Abstract

We propose a new generic design methodology for different types of PSS. Product – Service System (PSS) has received much attention recently from academia and industry because of its benefits. PSS can provide customers values and functionalities, as well as physical products, to fulfill economic, social and environmental goals.Many methodologies have been proposed for designing PSSs. Most of the existing methodologies are domain specific and were proposed to solve specific problems in certain projects. Some methodologies are generic but they provide neither guideline to practitioners and designers nor reflect the differences in various PSS types. As a generic approach to guide practitioners and designers in designing PSS effectively, the proposed methodology also takes into account user involvement, business model and organizational structure. The proposed methodology is demonstrated through design examples of different types of PSSs.

Keywords: PSS; Product service system; Design methodology; Product service integration; Integrated design methodology

1. Introduction

1.1 Product service systems

In conventional manufacturing and production, companies sell products to customers. Today, with the economic crisis, increasing competition among manufacturing companies, growing environmental issues and various customer demands, "selling products only" is becoming more difficult [1, 24, 25]. Providing services together with products can enhance competitiveness, achieve social, environmental, and economic goals, as well as attract and retain customers [3, 4, 19]. Combining products and services is the basis of product service systems (PSS) [17].

Goedkoop et al. [7] defined PSS as "a marketable set of products and services capable of jointly fulfilling a user's needs. The product/service ratio in this set can vary, either in terms of function fulfillment or economic value". In this sense, PSS is directly related to functional economy [14]. With PSS, users pay for the use of the solutions not ownership [2]. This "functional thinking" of "hiring products to get jobs done" was mentioned by Bettencourt and Ulwick [3] and was further discussed by Lim et al. [10] as well as Hussain et al. [8]. We can consider PSS as an integrated system consisting of products, services, and the infrastructure to deliver a solution to a customer to satisfy certain needs [4, 24]. Figure 1, which is adapted from Baines et al. [2], shows the difference between a purchase of a "product" and a purchase of a "PSS".

The concept of PSS has been discussed since the 1990s. Early works greatly influenced the development of this new field were the works by Goedkoop et al. [7], Mont [14] and Morelli [15]. Research on PSS has ranged from the definition of PSS elements, generation of PSS offerings, representation of PSS, etc. to the evaluation of PSS offerings, sustainable development, design process for integrating products and services etc. [24].

PSSs were classified into types by Baines et al. [2], who merged ideas from Manzini and Vezolli [13], Tukker [21], and Parkersell [18], as follows:

- Product oriented PSS: Company sells a product with additional services to ensure the working condition of the product. The ownership of the product is transferred to the customer. Services such as: maintenance, repair, recycling, refilling, etc. could be classified into this type.
- Use oriented PSS: Company sells the use or availability of a product not owned by the customer. Examples of this type are product leasing or sharing.

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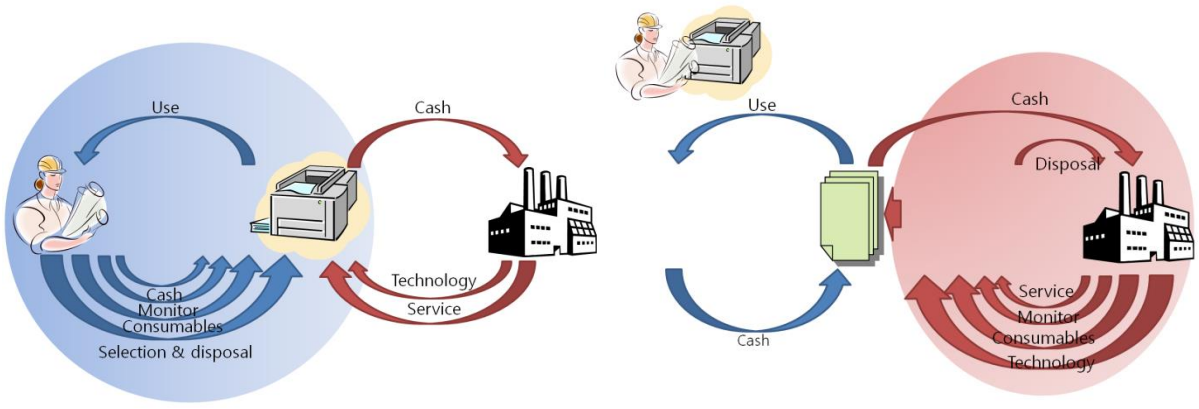

(a) (b)

Figure 1. (a) The traditional purchase of a photocopier, (b) the purchase of document management capability.

- Result oriented PSS: Company sells a result or capability of a product not owned by the customer. For example, instead of selling paint to a customer, the company can sell the result, a painted house.

1.2 Benefits and challenges for the adoption of PSS

Surveys by Baines et al. [2] and Beuren et al. [4] showed the benefits of PSS to the consumer, provider, environment and society. These benefits result from the higher level of satisfaction, increased competitiveness, decreased environmental impact and materials savings. The main benefit of PSS for the company is that it pushes for continuous business improvement, quality improvement, and better company-customer relationship. Table 1, which is adapted from Beuren et al. [4], shows how the PSS benefits the consumer, provider, environment and society.

Table 1. Benefits of product service systems.

	PSS benefits
Consumer	Flexible and personalized service; quality and satisfaction Continuous improvement of products and services
Provider	Customer loyalty and trust Innovation by monitoring products in use Cost and resources reduction; maximization of results; knowledge created during the development process are sold as consulting and training services; products reused in combination with several different services
Environment	Reduction in consumption through alternative use of product; provider responsible for the products and services through take-back, recycling, and refurbishment-reducing waste throughout the product's life; services planned according to the life cycle of the product
Society	Public pressure on environmental issues grows Increase in the supply of services; new jobs

Although PSS brings plenty of benefits, it is still adopted limitedly in the industry for its potentials. The major challenges in adopting PSS were suggested by Mont [14], Baines et al. [2] and Beuren et al [4]: first, consumers may not be enthusiastic about ownerless consumption; second, the manufacturer may be concerned with pricing, absorbing risks and shifting organization; and third, PSS design and development itself is a challenge. PSS is difficult to design because it is an integrated system consisting of products, services, and delivery infrastructure, and is strongly affected by stakeholders. Developing PSS requires both the involvement of many stakeholders who hold different views and the establishment of a business model and organizational structure. Still, there is no holistic and effective design methodology for PSS.

This paper aims to develop a generic PSS design methodology for different types of PSSs, practical enough to act as a guideline for designers and developers. This design methodology is constructed by analyzing the characteristic of PSS types; the design processes of products and services; stakeholder involvement; and the change in business model and organization structure. This research tackles "differences in PSS design process for various types of PSSs" and "co – creation process", which are needed to be researched, as pointed out by Vijaykumar et al. [24].

The rest of the paper is organized as follows: Section 2 reviews relevant research, presents the limitations of existing PSS design methodologies and the purpose of this paper. Section 3 focuses on our proposed methodology and its construction process. Section 4 illustrates the proposed methodology with two design examples of PSS design and further discussions. Section 5 presents the concluding remarks and suggests future research.

2. Literature review

2.1 Methodologies for designing product service systems

Many methodologies for designing PSS are presented in the literature [2, 4, 24]. Some methodologies are case – spe-

Table 2. Details of eight methodologies reviewed by Vijaykumar et al. [24].

Approach	Description
Service CAD	A method to design business models that increase system eco-efficiency from a systemic perspective
Service Model Service Explorer	Focuses on service engineering to design products with a higher added value from enhanced services.
Integrated Product and Service Design Processes	Exploits the potential of interrelations between physical products and non-physical services and the development of corresponding design processes.
Fast-track Total Care Design Process	Develops innovative offerings consisting of hardware and services integrated to provide complete functional performance.
PSS Design	Assists engineers in the joint development of physical products and interacting services to generate more added values.
Heterogeneous IPS² Concept Modeling	A model based approach of diffuse borders between products and services that generates heterogeneous Industrial Product-Service Systems (IPS²) concept models in the early phase of IPS² development.
The Dimensions of PSS Design	A comprehensive description of PSSs capable of generating new PSS concepts.
The Design Process for the Development of an Integrated Solution	Development of methodological tools to support designers and generate systemic solutions including products and services

cific, meaning that they are tailored for specific projects, including the ones proposed by Luiten et al. [11], Manzini and Vezzoli [13], Morelli [16], etc. These are not generic for a broad range of cases.

Other methodologies are suitable for designing of a broad range of PSSs. Vijaykumar et al. [24] summarized eight methodologies in the literature that have been detailed, and applied and demonstrated with industrial examples. These methodologies can be applied in complex PSS development influenced by many factors. These eight methodologies are summarized in Table 2 (adapted from [24]).

2.2 Limitations of existing design methodologies

Vijaykumar et al. [24] pointed out major limitations of existing PSS design methodologies as follows:

- The differences in PSS design processes for different types of PSS (Product/Use/Result oriented) are not discussed.
- The roles and responsibilities of the stakeholders in co-designing PSS offerings are not clearly defined in the methodologies.
- The importance of the co-creation among stakeholders is only mentioned in insufficient detail for understanding the uniqueness of this process and its real-time implementation.
- Integrating products and services is discussed as a major objective. The overall processes involved in this integration are well detailed, but the intricate steps within each stage are not mentioned.

Morelli [17] pointed out that PSS design methodologies should include: (i) identification of the actors involved; (ii) possible PSS scenarios, verified use cases, and sequences of actions and actors' role; (iii) defined requirements for the PSS and the logical and organizational structure of the PSS; and (iv) possible representation and management tools to represent a PSS in all of its components. Beuren et al. [4] commented that the PSS must be planned at a systemic level and that the involvement of the consumer in the creation process is critical.

Aurich et al. [1] pointed out that existing design methodologies faced challenges in providing guidelines for implementation. Beuren et al. [4] argued that these limitations of PSS design methodologies are among the major barriers for the adoption of PSS in the industry. Another important issue regarding existing methodologies is the full coverage of the product – service lifecycle. As pointed out by Cavalieri and Pezzotta [6], no methodology has covered the whole lifecycle of a product –service system.

2.3 Purpose of this paper

This paper aims to develop a PSS design methodology which works for all types of PSSs (i.e., Product/Use/Result oriented) and

- provides guidelines to designers in designing PSS for implementation (i.e., this methodology contains detailed design phases),
- considers the consumer co – creation (i.e., user involvement in the creation of PSS),
- approaches the design of PSS from systemic level, meaning that the PSS design process takes into account all PSS elements: products, services, stakeholders, business models and organizational structure, and
- covers the whole PSS lifecycle.

The proposed PSS design process can be modeled, and programmed to become a practical tool for designers to design and develop PSS effectively. This paper includes design examples to illustrate how the proposed methodology works for various types of PSSs.

3. Proposed methodology

3.1 Differences in the design sequence of 3 types of PSSs

The characteristics of 3 PSS types are different, so their design activities are sequenced differently. The portioning of the product and service "parts" in the 3 types of PSSs are

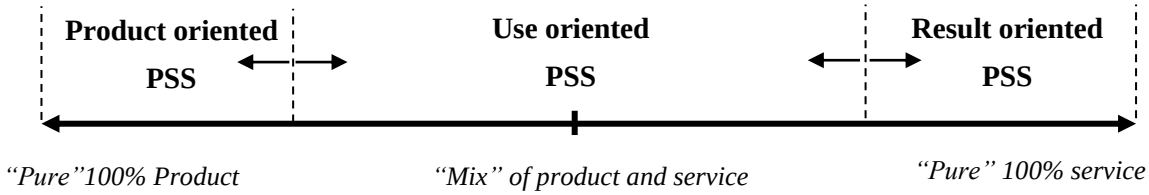

Figure 2. Portioning of the product and service "parts" in 3 types of PSSs.

shown in Figure 2 .

Figure 2 shows the various portions of "product component" and "service component" in certain types of PSSs. The PSS types show a basic difference in the role of product/service compared with the other. This statement can be explained as:

- For the product oriented PSS, product is already available and service can be considered as an "additional value" to the product.
- For the result oriented PSS, the final "outcome" or "value" is what the customer wants to achieve. In this case, the decision of what kind of service to deliver to the customer is essential and the product can be considered as a "means" to realizing the service.
- For the use oriented PSS, depending on the portions of product and service, this type of PSS can resemble a product oriented PSS or a result oriented PSS at a certain level. A use oriented PSS can be considered as the most "general" type of PSS while a product oriented PSS and a result oriented PSS can be considered as "extreme" types of PSSs (when one component – either product or service – has the dominant portion compared with the other).

Based on the different characteristics of the 3 PSS types, we discuss the sequence for designing the product and service components:

- For the product oriented PSS, in a certain design phase, the "product component" should be designed before the "service component" is designed. This is natural because the product exists before the service is added in a product oriented PSS.
- For the result oriented PSS, in a certain design phase, the "service component" should be designed before the "product component" is designed because the customer almost always do not care about the product, but is primarily interested in the value and subsequently, in the service which delivers that value.
- For the use oriented PSS, depending on the portions of product and service, the design sequence of this type of PSS can resemble that of the product oriented PSS or the result oriented PSS.

Identifying the sequence of design activities is very important in designing a PSS. Once the design sequence is identified, the design problem will become less abstract and the designer will have a starting point to deal with the design problem which now has lower degree of freedom and becomes less complicated.

3.2 The analogy between product and service design processes

The product and service design processes are treated as different processes in the PSS literature. But some design practitioners, such as IDEO, argue that the design processes of product and service are not fundamentally different [5]. In academia, Ulrich [22] also proposed that either a product or a service can be considered as an "artifact", which is designed by a human with the same process. Figure 3 shows how an artifact (i.e. product or service) can be designed using Ulrich's approach [22].

From this perspective, we construct the design process of PSS as a unified process.

3.3 Co–creation–the involvement of stakeholders

The benefit of customer and stakeholder involvement has been discussed many times in the PSS literature [24]. Stakeholders can get involved in the design process through various activities such as idea development, requirement identification, concept development, testing, etc. Customer involvement in the product design process is mentioned in the work of Kleemann [12] under the name of crowdsourcing.

This paper considers the involvement of all stakeholders in

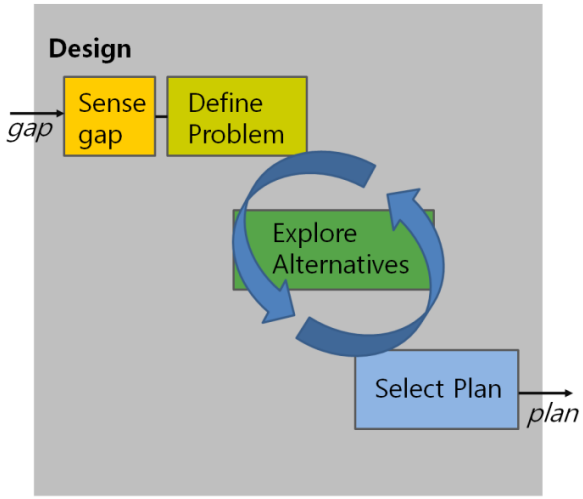

Figure 3. The design process of "artifacts" by Ulrich [22].

all possible PSS design phases to maximize the innovation from stakeholders as well as to make the PSS better address all stakeholders' requirements.

3.4 Systemic approach and the design of the whole PSS lifecycle

The proposed methodology in this paper takes into account all PSS elements, the product, service, business model (PSS delivery channel), stakeholders, business model and organizational structure, to optimize the PSS design process. Also, the design process designs the whole lifecycle of the PSS, from the beginning of life, middle of life to the end of life.

3.5 The proposed methodology

Considering all arguments from 3.1 to 3.4, the objectives of this paper, and the product design and development process by Ulrich and Eppinger [23], we propose the design process in Figure 4. G1, G2, G31, G32, G33, G41, G42, G43 are the approval checkpoints. They check the validity of PSS ideas (G1), the feasibility of PSS planning (G2) and the compatibility of product, service and other PSS elements, such as the delivery channel (business model) and organizational structure (G31, G32, G33, G41, G42, G43). The design activities, characteristics and the involvement of various stakeholders are shown in Table 3.

Table 3. Design activities, characteristics and the involvement of various stakeholders.

Design Step	Design Activities	Stakeholder Involvement	Checkpoint
PSS Idea Development	• Opportunity Scanning • Business Model • PSS Type • PSS Idea	• **User:** Idea Generation, Idea Evaluation • **Others:** Idea Generation, Idea Evaluation	**G1** Validity of PSS ideas
PSS Planning	• Resources Allocation • Team Formation • Market Segmentation • PSS Scheduling.	• **User:** PSS Portfolio Evaluation • **Supplier:** Technology Availability (support systems)	**G2** Feasibility of PSS plan
Requirement Analysis	• Needs Identification • Needs Analysis • Benchmarking • PSS Specifications	• **User:** Requirement input, Specification Evaluation • **Others:** Specification Evaluation	**G31, G32, G33** Consistency of product, service and other PSS elements: business model, organizational structure as a system
Design and Integration	• Concept Design • Detail Design. • PSS Integration	• **All Stakeholders:** Concept Evaluation	**G41, G42, G43** Compatibility of product, service and other PSS elements: business model, organizational structure
Test and Refinement	• Test implementation • Feedback & Refinement	• **User:** Test & Feedback	PSS is ready to deliver
Implementation	• PSS Delivery • Use • Support	• **User:** Utilization & Feed back	
Retirement & Recycling	• PSS Retirement • Disposal/Recycling	• **User:** Disposal • **Suppliers:** Disposal Plan	End of life

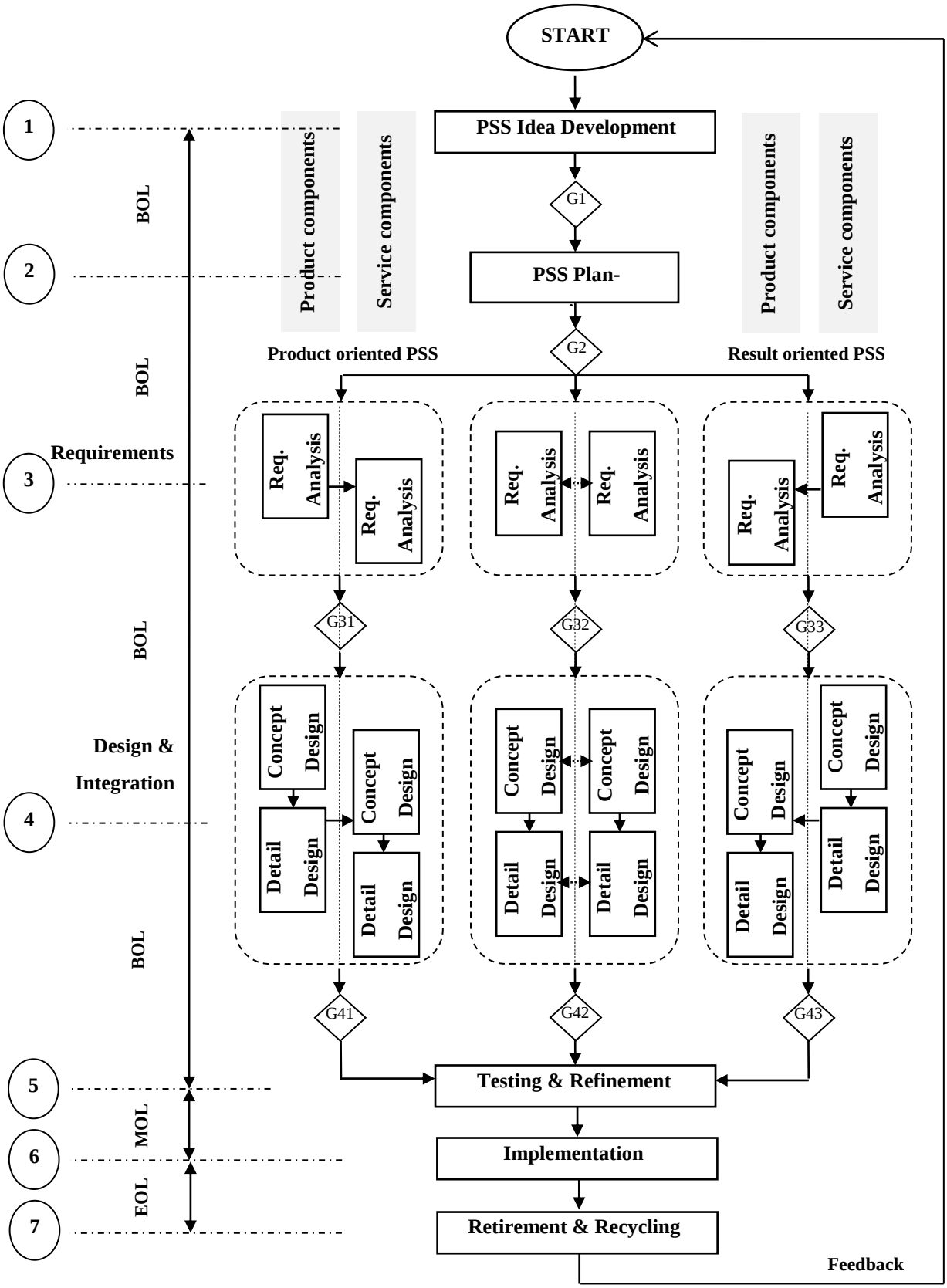

Figure 4. The proposed PSS design process.

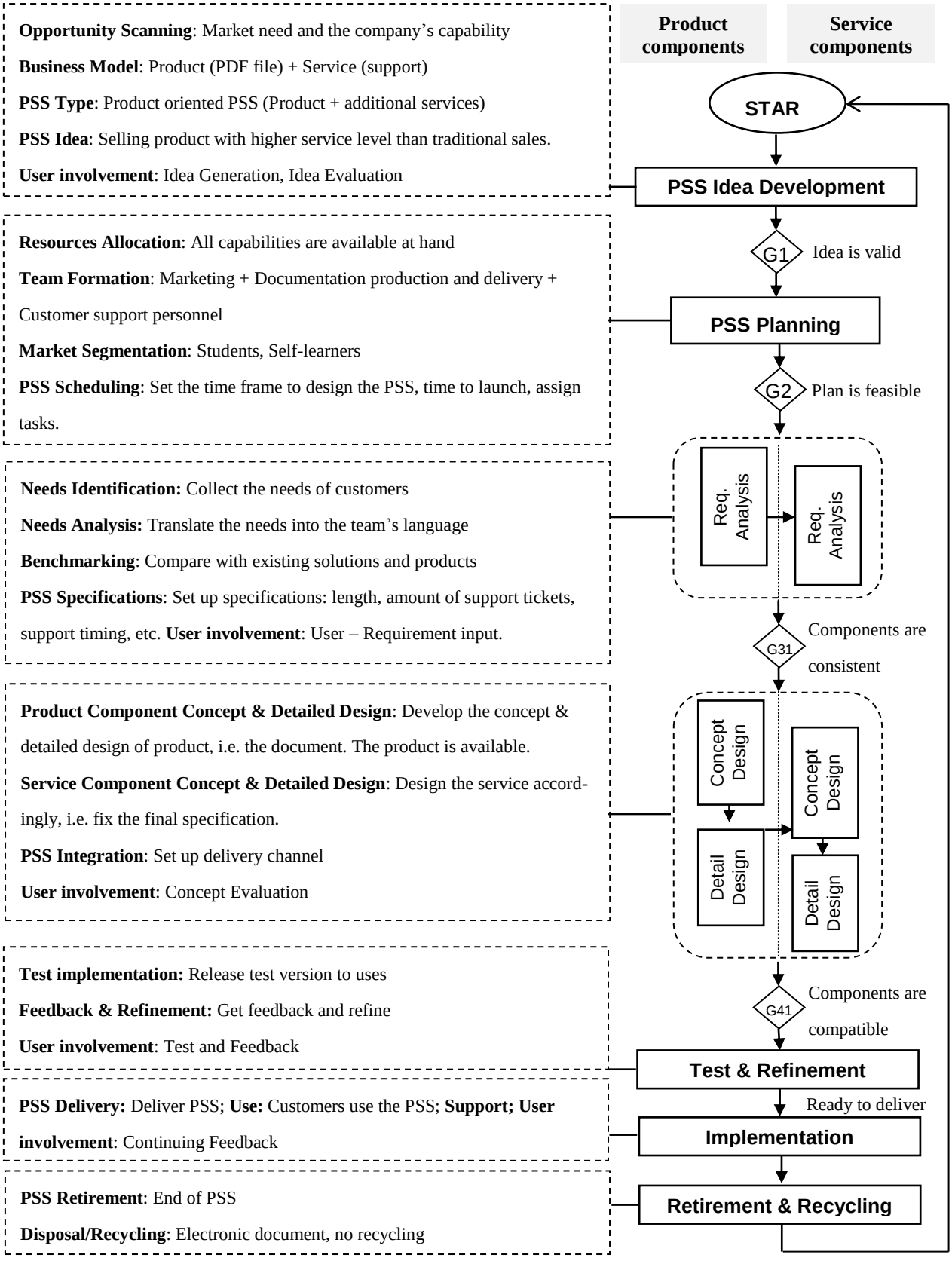

Figure 5. The PSS design process for company A.

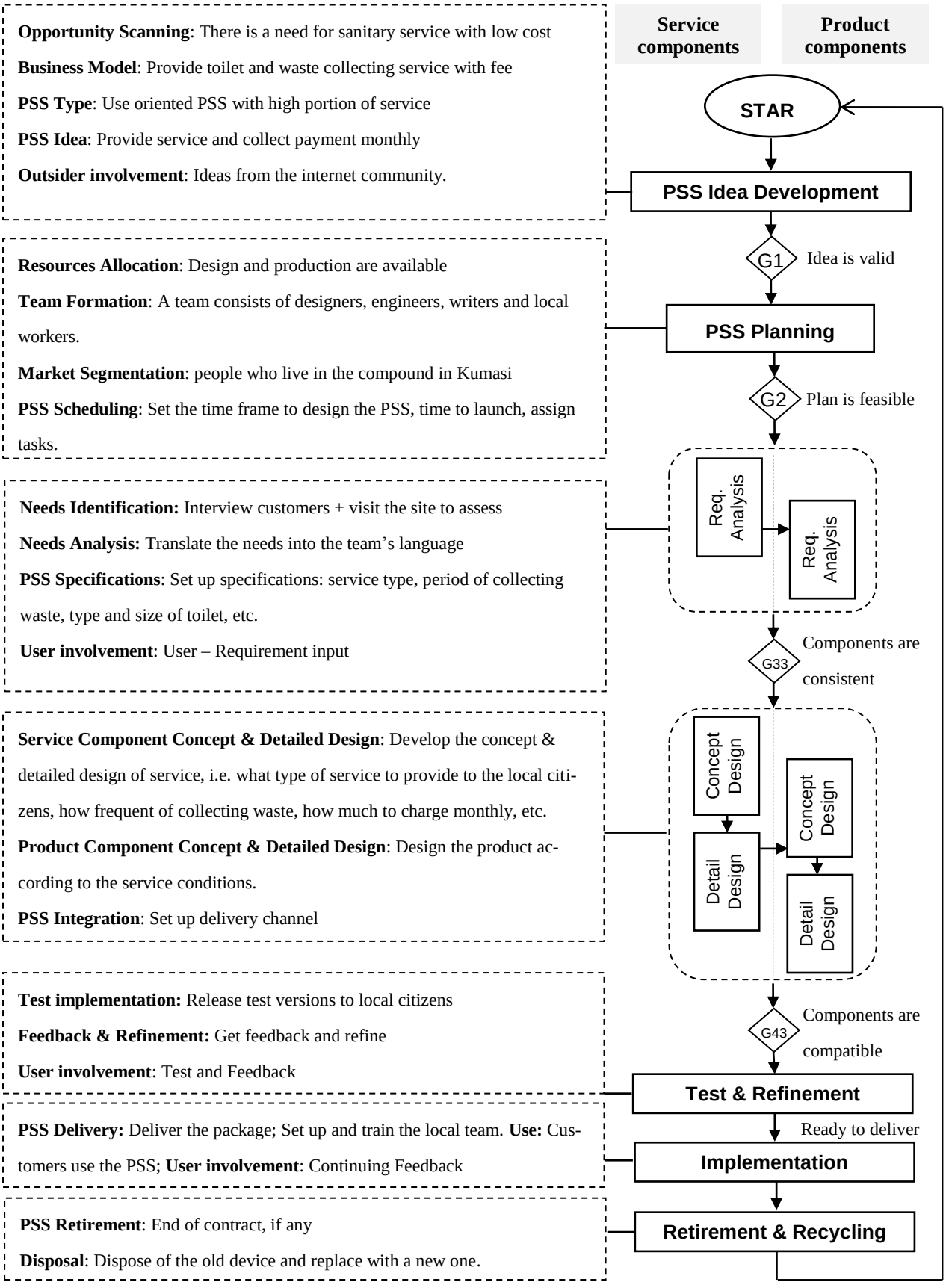

Figure 6. The PSS design process for the sanitary project of IDEO.ORG.

4. Illustrating examples

4.1 Product – oriented PSS

Company A is involved in engineering and the industrial training area. One of its products is lecture material, sold to the customers in the form of portable document format (PDF) files. Traditionally, when the customer purchases a document from the website, he receives a hyperlink to download the file from the company's repository. This business model is rather simple but implies certain limitations: first, with this type of "pay and download" of purchase, there is no guarantee that the files will not be shared to the public or among non-buyers illegally, and second, when providing support services to customers (i.e. answering the questions which are related to the lectures, correcting bugs, providing latest updates to the content, etc.) via the website, the company has no way to know if the support requester is the one who truly purchased the product.

The company then decides to move from this business model to a newer business model which combines product (i.e. the lecture materials) and services (supportive activities). The company sells each PDF file with one uniquely embedded tracking code so that it can track of which file is purchased by which customer. This tracking code will be used as the support code (with a limited number of support tickets); whenever customers ask for support from the company, they would need to declare their own support code. When a support ticket has been completely used, the support history of the customer will be updated and the number of remaining tickets will be subtracted.

This new product – service system can solve the current problem of company A. Since the company sells the product with additional services and the ownership of the product is transferred to the customer, the PSS is product – oriented and thus, using the proposed PSS design process, company A's new PSS can be designed with the process illustrated in Figure 5.

4.2 Use – oriented and result – oriented PSS

IDEO is a company currently working in the field of designing products and services. They have a branch project which is located at www.ideo.org whose mission is to solve social problems, such as poverty, health care, gender, etc. through design. One of IDEO.ORG projects is the sanitary project in Ghana [9]. Kumasi, Ghana lacks sanitary services, and most of the citizens in the area cannot afford a toilet at home and the public toilets have serious problems in terms of cleanness and convenience. There is certainly a need of an affordable sanitary service and the IDEO team tackles this with a PSS: providing the citizens with toilets, waste cartridges (as products) together with the service of collecting waste cartridges, replacing new cartridges, and disposing of

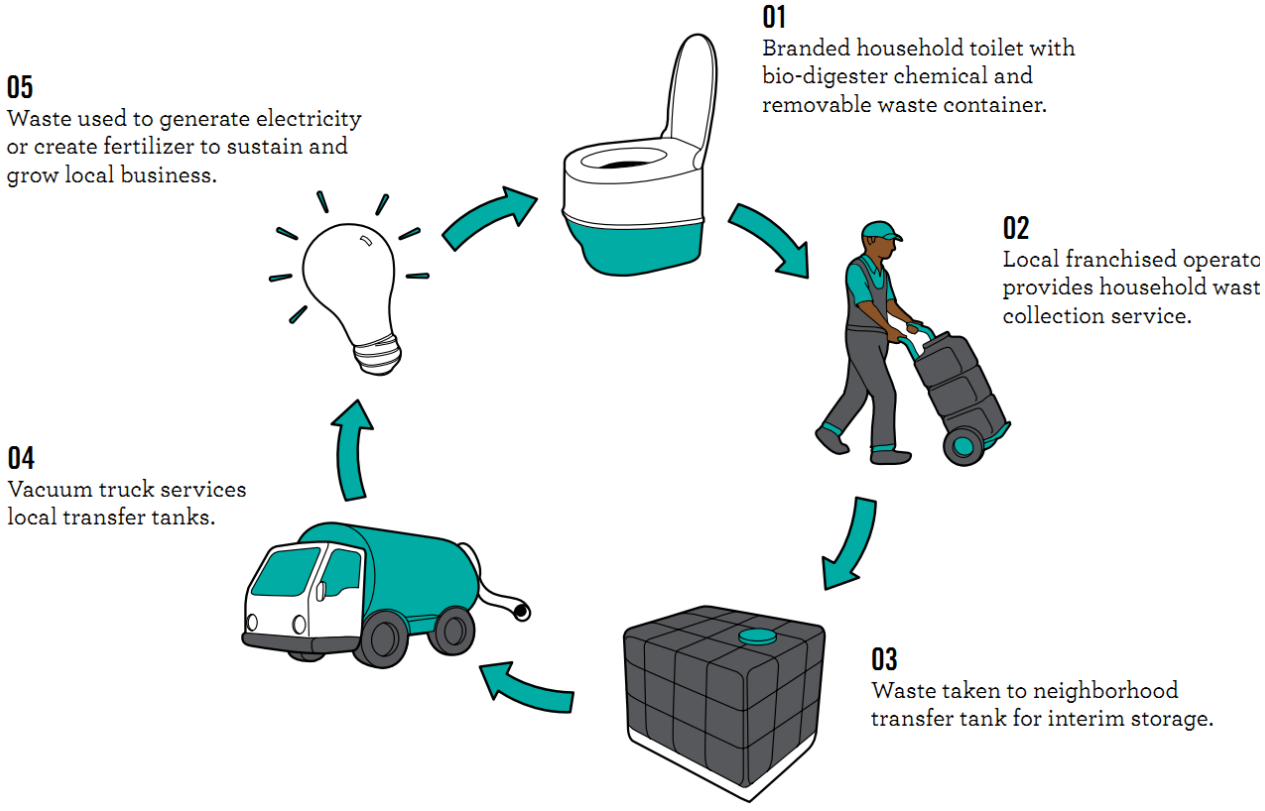

Figure 7. Business model for the sanitary project of IDEO.ORG.

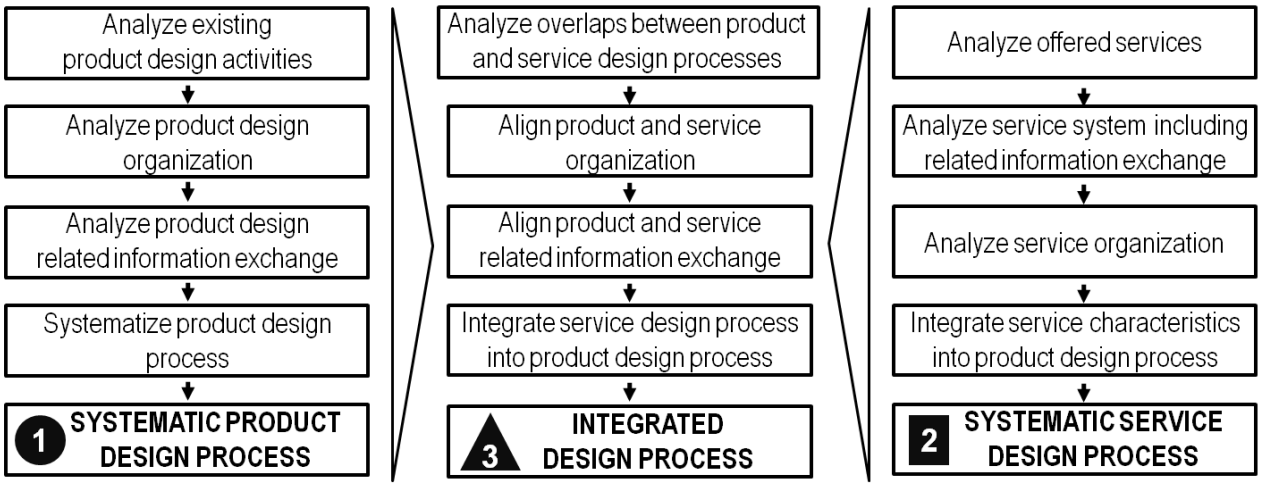

Figure 8. PSS design process which was proposed in Aurich's methodology (adapted from [24]).

the waste. In this case, the company sells the use or availability of a product not owned by the customer, and thus, this is a case of use oriented PSS. Since the service part of this PSS is more essential and due to the "ownerless" manner, this PSS can be designed with the process of designing result oriented PSS in which the service related components will be determined ahead of the product related components. Figure 6 shows the steps to designing this PSS using the design sequence for the result–oriented PSS which is suggested by the proposed methodology. In fact, through this project, in 2012, the company piloted 100 toilets and they set a goal of serving 12,000 households in 2013. Figure 7 illustrates the actual business model of this project as of 2012.

4.3 Discussions

For most of the existing PSS design methodologies, one of the drawbacks that limit the potential applications of PSS in industry is the ability to act as practical guidelines for PSS designers. Most of PSS design methodologies in the literature do not have a step by step design process and the usefulness of those methodologies to PSS designers has been limited. With the methodology proposed in this paper, PSS designers can follow design steps to design and develop PSS from the start with PSS idea to the final PSS offering as the output of the process.

Among the existing PSS design methodologies, only the one from Aurich which was reviewed by Vijaykumar et al. [24] and is shown in Figure 8 considers the "step by step" manner of the PSS design process. This methodology might perform better than other existing methodologies in terms of guiding PSS designers but it still has limitations. It does not imply the design sequence of product and service components when designing PSS, although this sequence is essential for the effective design of PSS as we discussed in Section 3. Without considering the design sequence properly, the design problem becomes much more abstract, and difficult for designers to identify the starting point of the design process. Also, if designers do not properly choose the right design sequence , more "trial and error" design efforts will increase the amount of design changes and thus increase the time and cost of PSS design and development. The proposed methodology in this paper solves the above problem by considering design sequence of the product and service components properly.

5. Conclusions

Based on the previous works about PSS design methodology, analysis of the differences in the characteristics of PSS types, the analogy between the design processes of products and services, the benefits of enabling co – creation in designing PSS and the systemic approach to PSS design, the authors proposed a new PSS design process and methodology. The proposed PSS design is generic so that it can work with various types of PSSs, practical enough to guide designers. The proposed methodology also takes into account user involvement, business model and organizational structure in designing PSSs.

The proposed design process is still at conceptual level. For future work, we plan to detail the design process with more insights to make the design process more practical for designers. We will also include more case studies to clarify the design methodology and compare our methodology to previous works. The outcome of our design process will also be evaluated in future research.

Acknowledgments

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References

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

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

[3] Bettencourt LA, Ulwick AW. The customer–centered innovation map. Havard Business Review. 2008; 5: 109-114.

[4] Beuren FH, Ferreira MGG, Miguel PAC. Product–service systems: a literature review on integrated products and services. Journal of Cleaner Production. 2013; 47: 222-231.

[5] Bhavnani R, Sosa M. IDEO: Service Design (A&B). INSEAD Case 11/2006-5276.

[6] Cavalieri S, Pezzotta G. Product–service systems engineering: state of the art and research challenges. Computers in Industry. 2012; 63: 278-288.

[7] Mark J, Cees JG, Harry RM, Peter JM. Product service systems, ecological and economic basis. Report to Ministry of Housing, Spatial Planning and the Environment Communications Directorate. The Hague, NL; 1999.

[8] Hussain R, Lockett H, Vijaykumar GAV. A framework to inform PSS conceptual design by using system–in–use data. Computers in Industry. 2012; 63: 319-327.

[9] IDEO.ORG [Internet]: Ghanasan Project Report. [cited 2013 Jul 4]. Available from: http://www.ideo.org.

[10] Lim CH, Kim KJ, Hong YS, Park KT. PSS board: a structured tool for product–service system process visualization. Journal of Cleaner Production. 2012; 37: 42-55.

[11] Luiten H, Knot M, van der Host T. Sustainable product-service systems: the Kathalys method. In: Proceedings of the 2nd International Symposium on Environmentally Conscious Design and Inverse Manufacturing; 2001 Dec 11-15; Tokyo; p. 190-197.

[12] Kleemann F. Un(der)paid innovators: the commercial utilization of consumer work through crowdsourcing. Science, Technology & Innovation Studies. 2008; 4: 5-26.

[13] Manzini E, Vezolli C. A strategic design approach to develop sustainable product service systems: examples taken from the "environmental friendly innovation" Italian prize. Journal of Cleaner Production. 2003; 11: 851-857.

[14] Mont OK. Clarifying the concept of product–service system. Journal of Cleaner Production. 2002; 10: 237-245.

[15] Morelli N. The design of product-service systems from a designer's perspective. Common Ground (London): Staffordshire University Press; 2002.

[16] Morelli N. Product–service systems, a perspective shift for designers: a case study–The design of a telecentre. Design Studies. 2003;1: 73-99.

[17] Morelli N. Developing new product service systems (PSS): methodologies and operational tools. Journal of Cleaner Production. 2006; 14: 1495-1501.

[18] Parkersell. Case study: Methodology for product-service systems (MEPSS). 2004.

[19] Sakao T, Birkhofer H, Panshef V, Dorsam E. An effective and efficient method to design services: empirical study for services by an investment machine manufacturer. International Journal of Internet Manufacturing and Services. 2009; 2: 95-110.

[20] Sakao T. What is PSS design?–Explained with two industrial cases. Procedia–Social and Behavioral Sciences. 2011; 25: 403-407.

[21] Tukker A. Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Business Strategy and the Environment. 2004; 13: 246-260.

[22] Ulrich KT. Design-creation of artifacts in society. 1st ed. University of Pennsylvania (PA); 2011. 145 p.

[23] Ulrich KT, Eppinger SD. Product design and development. 5th ed. McGraw – Hill (Irwin); 2012. 432 p.

[24] Vijaykumar GAV, Roy R, Lelah A, Brissaud D. A review of product–service systems design methodologies. Journal of Engineering Design. 2012; 23(9): 635-659.

[25] Weber C, Steinbach M, Botta C, Deubel T. Modelling of product–service systems (PSS) based on the PDD approach. In: International Design Conference; 2004 May 18-21; Dubrovnik, Croatia; p. 547-554.