APPLICATION OF PRODUCT SERVICE SYSTEM (PSS) CONCEPT IN AN INTEGRATED PRODUCT DEVELOPMENT PROCESS (PDP)

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Abstract. *Product Service Systems can be presented as a viable alternative for the development of products and services that meets specific demands of users and, at the same time, provide better environmental performance (lowest environmental impact). As matter of fact, PSS-based solutions tend to be more sustainable than the conventional business model of selling products. In this sense, manufacturers are focusing less on product manufacturing and dedicating more efforts towards creating value added solutions to the consumer. From a company's standpoint, PSS provides closer contact with end users, access to new markets, higher market shares and the possibility to redefine its core activities, which, in turn, represent competitive advantage through strategic, unique and distinctive features. From a social standpoint, PSS can deliver a more sustainable solution from different perspectives, for it is based on the assumption that product optimization can significantly reduce environmental impact due to more effective use during its lifetime and proper addressing of end-of-life strategies. Despite the existence of a large number of PSS practices (methods and tools) identified in the scientific literature, there is no evidence of works regarding the systematization and integration of these practices into the new product development process (NPD). Therefore, additional barriers associated to the adoption of PSS-based solutions may come across, such as: (1) lack of knowledge about PSS concept, (2) unclear presentation of opportunities for reducing environmental impacts and obtaining economic gains, and (3) required organizational changes to leverage the deployment of a PSS model. The present paper presents a proposal for the integration of PSS practices into an existing reference model for new product development, that focus on sustainability issues.*

Keywords*: Product Service System, New Product Development, Sustainability*

1. INTRODUCTION

Nowadays, it can be noted the increasing pressure, attention and effort allocated to sustainable development, aiming to keep the balance among environmental protection, economical and social development. In particular, producers are expected to exercise corporate social responsibility to promote sustainable development and achieve the planned revenues. In addition, legislation is also an important driver to motivate companies to consider the environment aspects throughout its lifecycle (from raw material extraction to end-of-life) during the product development process.

Surely the company that manages the aggregate supply of competitive sustainable products and services will highlight the market. According to Mello and Chimendes (2006), in order to achieve meaningful environmental improvements, companies must deploy technological (incremental and radical eco-designed products), cultural and institutional innovations, which requires a shift in company' strategy and business model. According to McAloone and Andreasen (2002), it is necessary to move the focus from design and development of a simple artifact (physical product), to the development of an entire system (PSS), where the traditional producer-consumer relationship is rearranged in order to deliver environmental and economical benefits to the shareholders and stakeholders. Developing economies, such as Brazil, have a great potential for the implementation of new systems – the concept extends strategic opportunities for development, based on the requirements of sustainability.

Mont (2002a) suggests that PSS consists of a combination of eco-designed products reinforced by services designed in different stages of a product life cycle. And certainly for both consumers and producers, PSSs can sometimes involve changes in products property rights. According to Yang *et al.* (2007), Webster and Mitra (2007), the company must be responsible for managing the product lifecycle, regardless the business model deployment based on product-service systems or not. Thus, in this case it is advantageous to ensure as long as possible the use of the functions within the product and introduce incentive systems to expand the product's durability, adaptation, reuse and renewal.

According to Williams (2007) and Baines *et al*. (2007) the PSS main benefits are:

a) The possibility to provide strategic market opportunities for traditional producers, improving the total value offered to consumers by increasing services elements;

b) The environmental consciousness towards sustainability. The producer becomes more responsible for their products, and in this sense, develops services activities in views of product return, recycling and renewal (reducing waste through the life of the product). Another activity taken by producers is to design products that are easier and cheaper to dismantle, recycle and renew. Concepts such as modularity and product upgrades can become important assumptions in the process of product development;

c) Delivery of same or improved product with increased value in use through less energy and/or material consumption, providing reduction in costs and in environmental impacts. The replacement of products by using

recovered components instead of using virgin material will not affect the consumer demand, can promote an environmental responsibility image and protect product monitoring and discontinuance.

Despite the existence of an amount of PSS practices (methods and tools) in the literature, there are no systematization and integration of these practices into the new product development (NPD). This fact can contribute to increase the barriers associated to PSS development, described by Mont (2002b) such as: (1) lack of knowledge about PSS concept, (2) unclear presentation of opportunities for reducing environmental impacts and obtaining economic gains, and (3) required organizational changes to leverage the deployment of a PSS model.

In addition, to reach a successful PSS, it is necessary to deploy tools and techniques that enable all information related to the process which will be used to improve the current development of a product or service, or those who will come to be developed. It is also important to have clear information and activities flow regarding new product development. Considering these facts, this work aims to collect PSS practices (methods and tools) and integrate them into a reference model for product development process, targeting a more competitive and sustainable product and related services.

Regarding to the structure of this work, it can be observed that the PSS concept and categories are presented in sections 2 and detailed methodology is described in section 3. Section 4 presents the NPD reference model to be considered in the PSS practices integration and section 5 lists the methods and tools related to PSS and NPD raised in the systematic review. This section also addresses methods and tools in new products development and suggests in which PDP phase can be applied. Section 6 presents the discussion and finally, section 7 presents the conclusion.

This study covers partial results of an international project called BRAGECRIM (Brazilian German Collaborative Research Initiative in Manufacturing), which is being held in conjunction among the following institutions: UTFPR/PPGEM (Federal University of Technology – Parana, Mechanical and Materials Engineering Graduate Program), USP/NUMA (University of São Paulo, Nucleous of Advanced Manufacturing), UFSC (Federal University of Santa Catarina) and TU BERLIN (Berlin University of Technology).

2. PRODUCT-SERVICE SYSTEM (PSS) CONCEPT

Product service system achieves differentiation through the integration of products and services, providing use value to the customer. What can a PSS deliver that simply product development cannot? From the consumer's perspective, it can deliver new usage patterns, lifestyle, selling process and flexibility. From the company standpoint, it can close contact with end users, accomplish new markets, higher market shares and redefinition of key activities. And from society perspective, it can raise the possibility of a sustainable growth. PSS is based on the assumption that the product optimization can significantly reduce the environmental impact that occurs with the effective appropriation of the product during the consumption stage. Thus, the products are certainly more efficient by better maintenance, repair and control. Despite of that, Tukker (2004) mentions that the simple application of any PSS category may not present a significant and automatic result towards sustainability, that is not clear whether there will be a reduction in environmental impacts or not. It should be made a thorough analysis, case by case, because PSS is often applied viewing improvement of the business itself, without having the objective of environmental improvement. Tukker (2004) also cites that PSS has a great potential for the sustainable integration of requirements, which may be included in all phases of the project.

The most popular concept of PSS raised in the literature presents three different PSS categories, even though Tukker (2004) proposed eight PSS types, as presented in Figure 1. The following section describes the PSS categories based on Tukker's (2004) definition.

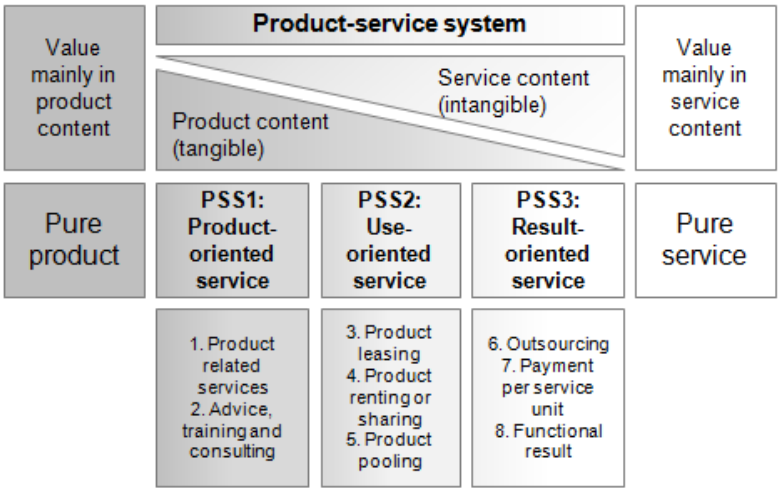

Figure 1. PSS categories and subcategories as proposed by Tukker (2004).

2.1 PSS1 – Product-oriented service

In this category, there is no change in the process of product selling. Basically the difference is related to the addition of some after-sales services in order to ensure functionality and durability. Often these after-sales services are offered during a contract lifetime established by law and include maintenance, repair and product upgrade. According to Webster and Mitra (2007), the company may or may not be responsible for the product's end of life and in the case that the company is responsible for collecting the product at end of life, may be done by the producer or service provider, depending on the strategy adopted by the company.

According to Williams (2007), maintenance contracts, extended warranties and provision of spare parts may change the product concept, and can potentially extend the life of the product. Baines *et al*. (2007) state that companies which encompass the responsibility for after-sales services and product end of life are motivated to introduce a PSS upon their NPD in order to minimize use extended costs and consider smooth operation in regards to the end of product life cycle. According to Tukker (2004), if the producer considers PSS during NPD, the producer might win twice, because will design a lower manufacturing energy consumption product aiming ease of maintenance, reuse or recycling, thus it will spend less time and resources with after-sales activities.

Morelli (2006) states that product-oriented services (PSS1) and use-oriented (PSS2) often contribute to lower environmental burdens in terms of more careful use of the product as well as increasing productivity of resources. Zhao (2010) reinforce exemplifying that the "economic use" of vehicles is a good example of use-oriented service with ecological benefits, since there are reduced emissions and lower fuel consumption. With respect to product-oriented services, preventive maintenance and adjustments are strong collaborators for the closed chain manufacturing. Services are great enablers for sustainability.

2.2 PSS2 – Use-oriented service

This PSS category is characterized by the use of a product that is not owned by the customer. According to Baines *et al*. (2004), the element of negotiation is the product use or product accessibility. Since the producer or a third party company is the product owner, is motivated to create a PSS. Tukker (2004) states that PSS2 seeks maximizing the product use to meet demand and NPD considering product`s life and service provision.

In this model, the company is responsible to provide not only the product itself for customer use, but also to enable product features to achieve the desired results. The customer obtains utility (use of functions) but does not own the product that produces the results, paying only for the time the product is used. Depending on the contract, this time can vary from one use or a period where the product can be used several times (in parallel or sequentially).

2.3 PSS3 – Result-oriented service

This model is the most sophisticated of the three. In this PSS category, a result or solution is replaced by a physical product. Examples include the provision of thermal comfort, refrigeration, cleaning, among others. The producer or service providers offer a personalized service or a mix of products, where all products are owned by these companies. According to Baines *et al*. (2007) the consumer pays only for results, without involving any direct use of physical product. The producer or service provider presents the user some instructions and suggestions for a more efficient use of the product. Since the customer pays for the results, he has no responsibility among the problems and costs involved in the product acquisition, use, maintenance and products end of life.

The advantages of this type of PSS include minimization of energy, materials consumption as well as optimized product use. Service payment is based on the service quality and not on the resources consumption. Surely the companies that provide the result or solution aim for a more economical and efficient product use. The loss on the product property requires a cultural consumer's acceptance; however, the PSS3 is well accepted and represents the most popular interpretation of the characteristics of a PSS.

3. METHODOLOGY

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

In this sense, a systematic literature review was made to collect and interpret available data on PSS. This review was guided by a main question: "What are the existing methods and tools for the development of new product-service systems?". The key words were Product Service System, New Product Development and Sustainability PSS related. The data base for data collection was Emerald, Elsevier, Science Direct, Google academic and CSA Illumina.

About 240 articles have being pre-selected by its Title. Initially all *Abstracts* were read to be able to select the article as per a established criteria, taking as premise the three PSS categories – Product oriented to the Service (PSS1), Use

oriented to the Service (PSS2) and Service oriented to Results (PSS3). In sequence was developed a complete reading and analysis of selected articles. Some articles, even though its abstract presented some relevance about the PSS subject, had no acknowledge information along the article. In this way, some articles were removed from previous selection. The results of this analysis were developed in a sheet format (.xls file). This data provided an overview of the practices (methods and tools) that could be applied through the development of a PSS.

Thus, the second question of the study was "How to systemize the PSS practices and apply to a PDP reference model for a sustainable PSS development?" An analysis was made of the possibility of applying PSS practices in a NPD reference model, and a proposal was drawn up to integrate the two concepts, PSS and NPD, in order to achieve environmental sustainability.

4. REFERENCE MODEL

According to Rozenfeld *et al*. (2005), the NPD process used in one company as a reference for defining the scope of product development projects is normally represented in a specific reference model, also known as standard process. When the reference model contains a collection of best practices and is related to an industry segment it is known as a generic reference model or simply reference model. Rozenfeld and Eversheim (2002) present a generic reference model that was created in a joint project of three research institutions based on a community of practice on the internet for knowledge sharing among universities and companies in product development. A general view of the reference model, divided into macro-phases, is presented in Figure 2.

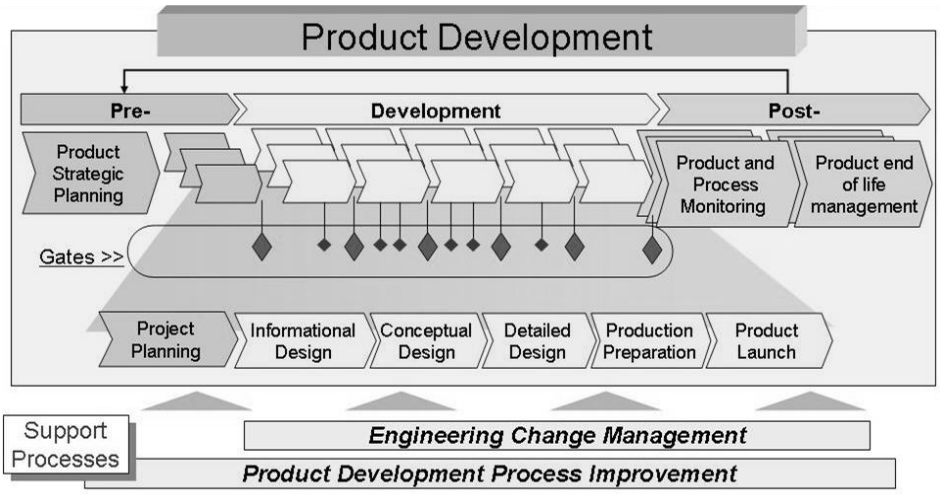

Figure 2. Reference model for product development process presented by Rozenfeld and Eversheim (2002).

The product strategic planning phase includes product portfolio management in accordance to the business strategic plan, taking into consideration market and technological innovations. This phase deal with the whole portfolio of product whereas the following phases are related to a specific product, i.e., a unique project. In the project planning phase, the project scope, resources, people in charge, effort, duration and costs are defined. If the project plan is approved through a formal gate process as presented by Valeri and Rozenfeld (2004), the project begins and will end at the product launch phase. The product life cycle, the stakeholders and their requirements are determined in the informational design phase. The product requirements, which must be quantified in measurable variables with target values, derive from the stakeholders' requirements. This is not the first time the requirements are defined, since their definition begins in product strategic planning, when marketing delivers information about the market, which is now detailed in the informational design for a specific product. The product functions (physical, quality, interface, etc.) are established in the conceptual design phase to meet the product requirements. The technological solutions and product architecture are also determined at this point. Innovations may emerge based on new technologies developed by the R&D process (which is complemented by the NPD process).

The next phase is the detailed design, which consists of three integrated cycles: detailing, acquiring and improving cycles. Calculations, simulations, product modeling, drafting, bill of materials, process plans, failure analysis, prototypes, evaluations and tests are carried out in this phase and all the manufacturing resources are specified. Product handbooks and instructions for technical assistance are also produced, as well as sales support information systems. The supply chain is defined at the beginning of product development, when agreements are made with main strategic partners and co-developers. The last supplier contracts must be signed in the detailed design phase. Based on the prototypes, the product is then certified. In the next phase, production preparation, new equipments defined in the previous phase are installed and tested. A pilot production is run to certify the production facilities and products being manufactured with the definitive resources, since during the detailed phase prototypes might, for instance, be build with

non mass production equipment. In this phase, a new production business process can be mapped and established to define, for instance, whether production will be controlled based on orders or Kanban. The product launching phase takes place in parallel to production preparation. Other business processes are mapped in this phase, such as technical assistance and customer service. In short, production preparation aims at defining the supply chain from the internal standpoint and the product launching phase to the external standpoint (market and customers). After the product is launched, production and sales business processes begin under the responsibility of other areas of the company. The project phase (development macro-phase – see the Figure 2) is concluded, the team is disbanded, and its members are allocated to other projects or return to their original functional areas. Nevertheless, product life cycle management continues, since efforts must now focus on monitoring the product and its manufacturing process (product and process monitoring). Ongoing customer support and engineering change management (ECM) must be provided to eliminate failures or improve product performance. At this time, configuration management ensures product information integrity throughout the product end of life management. At the end of the lifecycle of a product, the product is discontinued and could be reused, remanufactured, recycled, disposed according to the end-of-life (EOL) plan, which is normally developed during the development macro-phase.

This brief description of the process provides only an overall functional vision of NPD, since only the main activities have been mentioned. Other complementary visions have not been addressed here.

5. NPD AND PSS PRACTICES INTEGRATION IN THE PDP REFERENCE MODEL

According to Baines *et al*. (2007) and Morelli (2006), for a PSS success is the necessary early involvement with consumers and changes in producer and provider organizational structures. It is recommended to run some tools to assess differences between what the market needs, what the service provider can offer and what competitors are offering. It is suggested to use techniques and formal methods for gathering ideas for the process of generating ideas.

Mello, Neto and Turrioni (2006) state that regardless of the consumer need to be tangible or intangible, all non-technical statements that express the need or client expectation must be translated into design patterns. It is necessary to deploy tools and techniques that enable all information relating to the process being used to improve the current development of the service or those who will come to be developed.

In regards to a strategy that focuses on designing and selling an interconnected system of products and services, creating new product-service offerings, some authors (Baines *et al*., 2007; Kang and Wimer, 2009; Yang *et al*., 2009) present MEPSS (Methodology for Product Service Systems) as a method that can help actively use visualization, analysis and stakeholder management in this type of product design process. Silva *et al*. (2009) developed a comparison between the MEPSS and unified reference model for product development (NPD), and as final consideration, states that the emergence of environmental discourse and their correlation with consumption increasing and production directed to the requirements of sustainable development, can define the PSS as one of highlighted interventions. However, the practical implementation of the PSS still needs to overcome several barriers, because the proposal of innovative scenarios is still treated with caution by the productive system, society and professionals in product development. Thus, the integration of PSS (as one of the tools of design for sustainability, which covers the development of systems, products and services) to the NPD reference model provides a greater coordination among the production processes and sustainability in its various ramifications.

The PSS practices can be combined and applied in different phases of an NPD model. Table 1 shows the list raised methods and tools in the literature review in regards to ideas collection, analysis versus consumer needs for NPD, raised in the literature that can support the development of PSS practices. The practices (methods & tools) association with PDP model is based on the suggested results presented in the literature.

- Existent practice and activity in the PDP model (∗)
- New practice and existent activity in the PDP model (●)
- New practice and new activity in the PDP model (♦)
- Technique to be used on current PDP activity (≈)

Table 1: Practices (methods & tools) related to PSS in association with PDP model.

Methods & Tools	Method/Tool description	NPD phase where tool can be used (integrated)	NPD activity in which the practice should be used
RIC – Requirement Information Cell (Feng *et al*., 2009)	The Requirement Information Cell (RIC) consists of the cell register set, information set, operation set, and interface set. It can be described as a method for acquirement, analysis, management, and utilization of customers' requirement information in order to forecast new product	Product Strategic Planning	(♦) Analyze the company projects portfolio. It is suggested to be applied before the product portfolio changes proposal.

	requirements and collaborate with the members of the supply chain to try to provide personalized products and services for the customers.		
EVA – Economic Value Added (Tukker, 2004)	EVA is an estimate of a firm's economic profit.	Product Strategic Planning	(∗) Evaluate the economic feasibility of projects portfolio. This practice can flush the firm to develop new projects focused on new products or contract services.
Kano Model (Lee, Sheu and Tsou, 2008; Yadav and Goel, 2008)	The Kano model can effectively classify customer demand attributes. Combining the Kano model and QFD, can provide a new way to optimize the product design and also enhance customer satisfaction and loyalty, and minimize dissatisfaction.	Product Strategic Planning	(•) Proposal of changes in product portfolio. This practice can support the definition of new projects or PSS that will meet customer requirements.
CLD – Causal Loop Diagram (Bianchi *et al*., 2009) SFD – Stock and Flow Diagram (Bianchi *et al*., 2009)	Causal loop diagram is a diagram that aids in visualizing how interrelated variables affect one another. The relationships between these variables, represented by arrows, can be labeled as positive or negative.	Conceptual Design	(•) Define the integration between product systems, subsystems and components, in order to define the product architecture
Target costing (Filomena, Neto and Duffey, 2009)	Target costing is a pricing method used by firms. It is defined as "a cost management tool for reducing the overall cost of a product over its entire life-cycle with the help of production, engineering, research and design".	Project Planning, Informational Design, Conceptual Design, Detailed Design, Production Preparation, Product Launch, Product and Process Monitoring	(∗) Monitor economic and financial product feasibility. To be used on the development of NPD and PSS.
PDKM – Product Data and Knowledge Management (Yang, Moore and Chong, 2009)	Data repository to systematically integrate, manage and consolidate detailed data from all lifecycle phases, creating knowledge from information.	Product Strategic Planning, Informational Design, Conceptual Design, Detailed Design, Production Preparation, Product Launch	(•) Analyze and plan the product discontinuity. This method provide data that will support the product end of life plan, product goals plan, product and market strategies and final report of the changes to be implemented in the product.
QFD – Quality Function Deployment (Lee, Sheu and Tsou, 2008; Mello, Neto and Turrioni, 2006; Yadav and Goel, 2008)	It is one of the structured methodologies that are used to translate customer needs into specific quality development.	Informational Design	(∗) Identify consumer requirements. These identified attributes will guide the product and/or service design.
DSS – Decision Support System software (Yang, Moore and Chong, 2009)	Simulation techniques for improving decision-making.	Product Strategic Planning, Conceptual Design, Detailed Design, Production Preparation, Product Launch	(•) Verify product portfolio feasibility, Functionality design of the product, Analyze product systems, subsystems and components, Select the product conceptualization,

			Develop make or buy analysis and Evaluate/Approve development phases
Life cycle oriented PSS design model (Yang *et al*., 2009)	Use of software to run scenarios and use cases.	Product Strategic Planning, Project Planning, Informational Design, Conceptual Design, Detailed Design, Production Preparation, Product Launch	(●) Develop risk analysis, Support the development of product specification (identifying product functions)
IDEF0 – Integration Definition for Function Modeling (Mello, Neto and Turrioni, 2006)	Refers a family of modeling languages in the field of systems and software engineering. They cover a wide range of uses, from functional modeling to data, simulation and knowledge acquisition.	Conceptual Design	(●) Establish the global product function, Establish alternative functional structures. This tool may support the selection of the functional structure.
Service blueprint (Mello, Neto and Turrioni, 2006)	This technique is a customer-focused approach for service innovation and service improvement that allows firms to visualize the service processes, points of customer contact, and the physical evidence associated with their services from their customers' perspective.	Product Strategic Planning, Conceptual Design, Detailed Project, Production Preparation, Product Launch, Product and Process Monitoring, Product end of life management	(♦) This practice may suggest the need for new phase and activities in regards to service development.
GUI – Graphic User Interface (Álvares and Ferreira, 2008)	The GUI characteristic is a collaborative design procedure embedded into the interface, considering customer involvement in the co-creation of value. Examples: * In this GUI, the user inputs the information on the design features and then these data are sent to a server (Open Innovation).	Conceptual Design	(●) Develop the alternative product solutions/concepts
Benchmarking (Mello, Neto and Turrioni, 2006)	Benchmarking is the process of comparing one's business processes and performance metrics to industry bests and/or best practices from other industries. Dimensions typically measured are quality, time and cost. Improvements from learning mean doing things better, faster, and cheaper.	Informational Design	(∗) Identify customer requirements and verify product and or service competitively in the market
Focus groups (Mello, Neto and Turrioni, 2006)	A focus group is a form of qualitative research in which a group of people are asked about their perceptions, opinions, beliefs and attitudes towards a product, service, concept, advertisement, idea, or packaging.	Product Strategic Planning, Informational Design, Conceptual Design, Detailed Design	(∗) Review and update the product scope, Manage product improvements (capture information for changes definition)
Brainstorming (Mello, Neto and Turrioni, 2006)	Brainstorming is a group creativity technique designed to generate a large number of ideas for the solution of a problem.	Project Planning, Information Design, Conceptual Design	(∗) Project schedule definition, Risk analysis, Identify consumer requirements, Develop the product solution alternatives
Storyboarding (Mello, Neto and	Storyboards are graphic organizers such as a series of illustrations or	Conceptual Design	(●) Develop the product solution alternatives

Turrioni, 2006)	images displayed in sequence for the purpose of pre-visualizing a motion picture, animation, motion graphic or interactive media sequence, including website interactivity.		
FMEA – Failure Module Effect Analysis (Mello, Neto and Turrioni, 2006)	It is a procedure in product development and operations management for analysis of potential failure modes within a system for classification by the severity and likelihood of the failures. A successful FMEA activity helps a team to identify potential failure modes based on past experience with similar products or processes, enabling the team to design those failures out of the system, reducing development time and costs.	Detailed Design	(∗) Evaluate systems, subsystems and components when developing new products
SDO – Design Orienting Sustainability Toolkit (Tanure *et al*., 2006)	The objective of this tool is to orientate the design process towards sustainable PSS solutions, setting sustainability priorities, using sustainable design orienting guidelines and checking and visualizing the improvements in relation to an existing reference system and its sustainability priorities.	Product Strategic Planning, Conceptual Design, Detailed Project	(●) Consolidate the new products ideas list, Define product scope, and target specifications, Identify product critical aspects and evaluate alternative concepts
Service Engineering (Yang *et al*., 2009)	Codesign method between products and services, modeling services, CAD Service, New Service Development.	Product Strategic Planning, Conceptual Design, Detailed Project, Production Preparation, Product Launch, Product and Process Monitoring, Product end of life management	(♦) This practice may suggest the need for new phase and activities in regards to service development
Regression analysis (Neely, 2009)	Techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables.	Conceptual Design, Detailed Design	(●) Define product requirements, Define product target specifications, Model product functionality, Develop product alternative solution, Define product architecture and concept
RFID – Radio-Frequency Identification (Mien, Feng and Leng, 2005)	Techniques for online real-time user interface.	Product and Process Monitoring, Product end of life management	(≈) Monitor product performance (technical, economic, production and services)
IDU – Intelligent Data Unit – (Yang *et al*., 2007)	The product unit equipped with an intelligent data collection. The data are transmitted to a service provider and information are processed for delivery of needed services. Use of automatic identification technologies to capture information about the product use during life cycle.	Product and Process Monitoring, Product end of life management	(≈) Monitor product performance (technical, economic, production and services)
SERVQUAL (Mello, Neto and Turrioni, 2006)	SERVQUAL is a service quality framework that measures the gap between customer expectations and experience.	Product and Process Monitoring	(≈) Monitor product performance (technical, economic, production and services)

6. DISCUSSION

Some practices identified as PSS precursors were identified as practices already applied on the NPD model. The collect of PSS practices (methods and tools) for integration proposal into a reference model for product development process, targeting a more competitive and sustainable product and related services, presented that "Pre" and "Development" macro product development phase are the most affected. Most PSS proposed practices should be integrated in the product strategic planning, information design, conceptual design and detailed design. The "Post" macro phase has great importance in regards to services monitoring.

For product strategic planning, informational design, conceptual design and detailed design it is suggested to integrate new practices on the existent PDP activities and in regards to some practices, develop new activities. When related to risk analysis, the integration of PSS practices into project planning and information design can be enrolled though simulation related to life cycle oriented PSS model. In regards to the production preparation and product launch phases, some new practices are suggested into existent activities and new activities. Only PSS practices related to services development and target costs are suggested to be integrated into product and process monitoring phase and product end of life management phase. It will demand new activities and also the integration of the some techniques into existent activities.

The main limitation of this research is related to the fact that was not identified in the systematic research the full implementation of a PSS practice and its results. In this sense, it was not possible to identify the best sustainable practices that might have improved environmental performance.

Is recommendable further study to be enrolled in regards to the establishment of relationships and dependencies between the identified PSS practices (methods, tools, precursors, barriers and benefits) within NPD phases, and if necessary create new phases (besides new activities). In order to control the PSS sustainable performance, is suggested the development of a monitoring tool. Another suggestion is the classification of PSS practices according to PSS categories. In this sense, depending on the service strategy (product-oriented, use-oriented or result-oriented service) to be adopted it will be possible to focus on specific methods and tools through NPD.

7. CONCLUSION

The PSS creates new market opportunities and more jobs in industries. It is therefore characterized as a competitive advantage through the use of local manpower and knowledge when related to international competitors.

It is a fact that there are still many barriers to PSS. During the systematic review it was possible to verify the reasons for the lack of enthusiasm in the world of business with respect to PSS. But once a product-service system is deployed, the benefits appear when compared to the traditional manufacture, as a result of transferred daily investment, smaller stocks (being able to even disappear in a fully functional market). The long-term customer loyalty planning can be raised as well as optimized resources allocation.

This research has identified that is necessary to consider related PSS practices in the "Pre", "Development" and "Post-development" NPD macro phases. In this sense it might be possible to develop new products that already consider a rearranged producer-consumer relationship in order to deliver environmental and economical benefits to the shareholders and stakeholders. The integration of most of identified PSS practices are related to existent NPD activities. Some new activities are proposed mainly when related to services development, cost and risk analysis. This is value for mostly product development phases like informational design, conceptual design and detailed design. New activities are suggested to be integrated in all "Pre", "Development" and "Post-development" macro phases.

Concerning the integration of sustainability within PSS, a new business model integrating product and services development may guide companies to make money and reduce materials consumption without affecting the consumer demand and desires, by delivering an efficient and effective combination of existing products with services and knowledge. And due this, the use and growth of non-material elements supported by the PSS may tend this system to be more sustainable than a conventional selling products model.

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