Toward a PSS lifecycle management systems: considerations and architectural impacts

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ABSTRACT: Lean design methodologies can be used to foster and improve the integrated product-service design process. The PSS Lean Design methodology supports the PS requirements management definition and the design of the activities to define and later perform the service. The introduction of the design of product-service system in manufacturing companies needs to re-think the common management of the product structure including also service elements and also changing the structure to be adapted in the provision of service. Integration of the PSS Lean Design methodology to optimize the product-service design requires an appropriate redefinition of a PLMS main components. The paper proposes a description of relations and impacts for the development of a PSS lifecycle management system.

KEYWORDS: Product-Service System, Product Lifecycle Management

1. Introduction

Market volatility, customer requirements and the competition of emerging countries make companies struggling to stay ahead of competition. The number of companies that are enlarging their offer portfolio toward the provision of product-service system (PSS) is always increasing but the number of companies failing in successfully implementing servitization strategy is even more (Neely, 2008).
As highlighted by the scientific literature there is still a lack of methodologies and methods supporting the transition induced by the servitization shift, in particular at engineeing and operational level (Medini & Boucher, 2015) (Cavalieri & Pezzotta, 2012).

One of the major gaps in the SE models and methods described in literature is their focus on the customer perspective, with practically no consideration of the company's internal performance (Pezzotta, et al. 2014). This exclusively customer-centred perspective can lead to the development of PSS fulfilling customer needs completely. On the other side, this can potentially undermine the company economical sustainability in the long term. Based on this premise, the paper presents the PSS Lean Design methodology and its relations and impact on the data and information management of a product-service system lifecycle.
The PSS Lean Design methodology supports the PS requirements management definition and the design of the activities to define and later perform the PSS. Generally, companies are familiar in the management of data and information of a product lifecycle through specific IT systems, defined as PLMS – Product Lifecycle Management Systems.
A shift in the product lifecycle management is needed to be more focalized and integrated also with the service view of the offering provided to a customer.
Integration of the PSS Lean Design methodology to optimize the PS design requires an appropriate redefinition of some PLMS components: configuration management, product configurator, workflow modeller, data modeller and requirement management. The introduction of the design of PSS in manufacturing companies needs to re-think the common management of the product structure including also service elements and also changing the structure to be adapted in the service provision. The paper proposes a detailed description of relations and modules customization for the development and diffusion of a PSS lifecycle management system to be applied in different industrial sectors.

2. PSS Lean Design methodology

The PSS Lean Design methodology, developed in the DIVERSITY project (DIVERSITY, 2016), aims at supporting servitizing companies during the engineering of their PSS offering. This methodology is be based on the SEEM methodology (Pezzotta, Pinto, Pirola, & Ouertani, 2014) for PSS and it includes aspects coming from concurrent engineering and lean product development theories. It hence guarantees (i) more effective PSS design thanks to a better link with the front-end and the product design, and (ii) more efficient PSS design by anticipating reworks and revision at the early phases of the design process with the ultimate objective of reducing time to market and costs. In the specific, Lean design rules are created and used all along the methodology steps to ensure that (i) customer needs and requirements are respected and embedded in the PSS to be designed and delivered, (ii) the company internal performance are optimised.

The PSS Lean Design methodology encompasses four phases namely: i) front end analysis, ii) solution concept design, iii) solution final design, and iv) offering identification and analysis.
As shown in Figure 1, the first and the fourth phases belong to the customer area, while the central phases belong to the company area. Lean design rules occur at two

different levels: the *content design* level and the *development process* level, and refer to product, service, or system. Such rules concretely support the PSS development through a SEEM based approach, under a continuous improvement fashion.

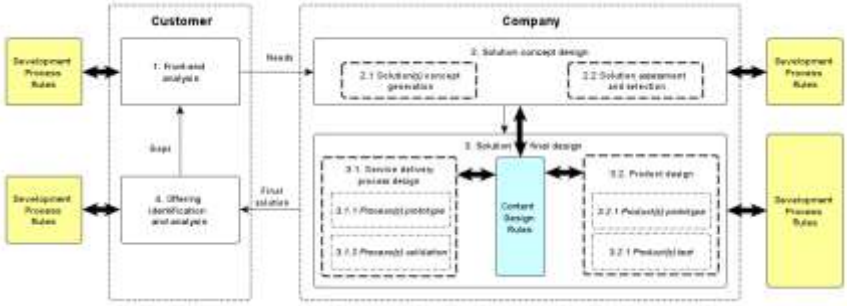

Figure 1. *SEEM based methodology structure.*

1 - Front End analysis: The first phase in engineering a new PSS includes the analysis of the customers' needs and what do they value most. This step can be implemented in several ways: context-sensitive analysis, market research, customers' interview, focus groups or expert panels.

2 - Solution concept design: The customers' needs identified in the first phase are used as input for the development of the second phase of the methodology, which is decomposed in two tasks. The output of this phase is a high-value solution concept design, which represents the company value proposition.

3 - Solution final design: Starting from the solution(s) previously identified, a more detailed design is needed.

The solution(s) identified are split in:

- *Tangible elements* that need to be designed or considered in the product design. New product features or a new product enabling the PSS, which have been previously identified is designed in this phase.
- *Intangible elements* that need to be considered in the definition of the service delivery process: this sub-phase involves the representation of the service delivery process(s) for the selected solution. In particular, the Service Blueprinting technique is adopted.

The use of *content design* rules drives the design of both types of elements by providing concrete rules and instructions for PSS development inside the company. In particular, the product design is driven by content design rules defined under the umbrella of the Design for X (DfX) techniques. Techniques such as Design for Maintainability, Design for Life Cycle, and Design for Serviceability are strongly considered in the product design process.

4 - Offering identification and analysis: The last phase of the methodology refers to the definition of new or re-arrangement of the offering. The solution(s) prototyped and validated is in this stage added to the company value proposition.

Moreover, crosswise to the methodology phases, *the Lean Design development process rules* are defined and used in order to ensure that the process of developing a PSS is the most valuable and waste-free as possible. In the product development field,

some methodologies already exist, between those, the MyWaste methodology (Rossi, et al. 2011) has been identified in the DIVERSITY project as a reference method given his simplicity and effectiveness.

3. A general Product Lifecycle Management System

A Product Lifecycle Management (PLM) is a strategic business approach that supports all the phases of product lifecycle, from concept to disposal. Integrating people, processes, and technologies and assuring information consistency, traceability, and long-term archiving the PLM enables organizations to collaborate within and across the extended enterprise (Corallo, et al., 2013). Information systems developed to support the PLM approach in managing product lifecycle and product related data are widely known as Product Lifecycle Management Systems, or PLMS (Saaksvuori & Immonen, 2008). These systems are often made up of several integrated applications or components that work together to manage the various aspects related to the development and management of complex products (Stark, 2011).
The main PLM components that are strategic for the application of the PSS Lean Design methodology in the development of a new PSS are described in the table:

Component	Description
Configuration Management	It implements a methodology for defining and managing product data structures.
Product configurator	It allows a development team to easily select/define the best product configuration between all different product families according to customer requirements and specifications.
Workflow modeller	A workflow modeller allows the modelling of workflow in a usable, efficient and graphic way.
Data modeller	Its purpose is to represent the standard model to be used as a reference for any enterprise program/project and the set of data related to the different domains (engineering, manufacturing, etc) and points of view on product.
Requirement management	It provides features to manage requirements (functional and non-functional) and to assure that product are compliant to standards, quality, efficiency and environmental constraints.

Table 1. *List of PLM component relevant for PSS Lean Design Methodology*

4. A PSLMS main architecture and relations

The PSS Lean Design methodology needs tools to support the definition of PSS structure during the four phases of development. Due to the novelty of the approach, the *Front End analysis* and *Solution concept design* will be supported by tools that must be specifically developed and identified as *PSS Lean Design Tools*. These tools must handle all the concepts covered by the methodology, i.e. market front-end analyses, customer needs and value proposition specification, the lean design rules.
The introduction of the design of PSS in manufacturing companies needs to re-think the common management of the product structure including service elements and changing the structure to be adapted in the provision of service. This is particularly evident when we start the *Solution final design* phase. In this phase, in fact, we enter

a domain in which companies have already well defined tools and design methods, such as PLMS. At this stage, it is therefore necessary to interface the *PSS Lean Design Tools* with existing *PLMS* that provide an excellent starting point for the PSS detailed design thanks to the logic developed over the years for product design.
For this reason and to provide a comprehensive technological support to the PSS Lean Design methodology, in the DIVERSITY architecture, the main PLMS components are extended and adapted to allow them to manage the typical PSS concepts, data and development logics.
An *Integration and Abrstaction Layer* will be developed to decouple as much as possible the PSS Lean Desing Tools from typical PLMS implementation.
The integration layer will enable the information exchange between PSS design tools and the PLMS. In addition, where possible, it will use the extension features commonly provided by PLMS systems to add service concepts (and in general PSS concepts), in these systems, primarily designed for product development and not able to work properly with the product-service combination. Where not possible, instead, additional code must be developed to extend such components. In the following the main impacts that will have on each components are presented.
First of all is required an extension of the data model implemented in the PLMS in order to include data and metadata necessary for the collaborative development and management of the service part of a PSS solution, describing entities (or classes) that represent concepts relevant in the PSS domain and the relationships between them. In addition, PLM data model usually consider product data, but do not pay attention to the information related to resources during product evolution process. The resources information is particularly important for the service part of a PSS and needs to be managed (Li, Wan, & Xiong, 2011).
The Configuration Management component needs to be extended in terms of service-related and product-related data during the whole life cycle. Product and service configurations must be bound together to manage PSS versioning and its baselines, even if product and service lifecycle are different and independent. The service dimensions requires re-arranging configuration along the different lifecycle stages.
The Workflow Modeler must be able to capture process related to service development and its delivery. In addition, existing workflows must be modified, so they can deal with PSS concepts and assure the correct product-service configuration.
Furthermore, the requirement management component within a PLMS needs to be enhanced. It has to capture and organize PS requirements in an integrated way, using a common shared environment where all stakeholders can access these information.
Finally, the product configurator component must provide quickly the best PS structure starting from key parameters. The structure must satisfy the PSS requirement previously defined. The best PSS structure to be used must take into account also evaluation parameters strictly related to the service dimension of a PSS.

5. Conclusion

The proposed PSS Lean Design Methodology plays an important role for leading manufacturing companies in the diffusion of an integrated design of product and

service. The application and introduction of the methodology in an industrial context needs to prepare a technological strategy that impacts on the available IT systems. Specific tools are introduced for the management of PSS and existing tools needs to be adjusted. The tool mainly impacted is the PLMS. As proposed in the paper, for the introduction of the PSS Lean Design Methodology the core elements of a PLMS needs to be customized for managing a full set of integrated information about product and service.

The effect of the PSS Lean Design methodology on a PLMS can vary based on the newness/impact on the company products structure. It depends on if the company has yet a PLMS and if the product structure is yet available on the PLMS or not. Future research explores the application of the PSS Lean Design methodology in these cases.

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