Definition of a PSS Engineering Environment: from the Theoretical Methodology to the Platform Implementation

Giuditta Pezzotta*, Roberto Sala*, Fabiana Pirola*, Ana Rita Campos, Antonio Margarito***, Ana Teresa Correia****, Sophia Fotia*****, Dimitris Mourtzis*****

*Department of Management, Information and Production Engineering, University of Bergamo, viale Marconi, 5, Dalmine (BG), 24044, Italy (giuditta.pezzotta@unibg.it, roberto.sala@unibg.it, fabiana.pirola@unibg.it)

** UNINOVA, FCT Campus, 2829-516 Caparica, Portugal (arc@uninova.pt)

***EKA Srl, Bari and Department of Engineering Innovation, Università del Salento, Lecce, Italy (antonio.margarito@unisalento.it)

****Institute for Applied System Technology, ATB-Bremen, Wiener Str. 1, D-28359, Bremen, Germany (correia@atb- bremen.de)

*****Laboratory for Manufacturing Systems and Automation(LMS), Department of Mechanical Engineering and Aeronautics, University of Patras, Rio Patras, Greece, 26504 (fotia@lms.mech.upatras.gr, mourtzis@lms.mech.upatras.gr)

Abstract: The recent years have seen an increasing interest from the companies to differentiate themselves from competitors by enriching their portfolio with new product related services. The introduction of the Product Service System (PSS) worsened the companies' economic performance since the proposed PSSs were not designed using methodologies and tools created to make them sustainable. In order to overcome this problem, the DIVERSITY project proposes a new methodology that considers the entire product life cycle, from the identification of the customer's need to the PSS' conceptualization, design and market performance monitoring. This paper aims at explaining the DIVERSITY methodology and the engineering platform derived from it highlighting the characteristics and functions of each tool.

Keywords: Product Service System, PSS Lean Design Methodology, PSS Engineering Environment

1. Introduction

The last decades have seen an increasing interest of the consumers in a higher personalization of the products along with an increase in the service offering. This change has forced the companies in moving their business from the design of the sole product, separated from the service, to a new market in which the product and the service are bundled. This transformation has required, and requires, a reorganization of the design process and a rethink of the way the products and services are considered and sold (Qu *et al.*, 2016). In fact, the simple offering of new bundles of products and services is not sufficient in order to gain a competitive advantage on the competitor and to obtain an increased economic return from this operation. Therefore, the evolution toward a new business model where the products are integrated with services (i.e. Product-Service Systems- PSS) creates a strong need for methods and tools supporting all the design and development phases (Cavalieri and Pezzotta, 2012).

Moreover, in order to create a PSS that can satisfy the customer/consumers' needs, it is mandatory for the companies to foster the knowledge exchange between the customers/users and the designer (Stokic and Correia, 2015).

Therefore, the necessity to precisely define in an appropriate and affordable way new PSSs has led towards the creation of an engineering environment supporting the design and the development of the PSS from the collection of information from the customer/user to measurement of the implemented PSS in the direction of the continuous improvement. The engineering platform has been developed to help the enterprises in implementing their new business model and in capitalizing new opportunities.

This paper intends to explain how, starting from the methodology developed in the DIVERSITY project, the DIVERSITY engineering platform has been created starting from the definition of the requirements. The theoretical methodology developed in DIVERSITY that covers the whole PSS lifecycle is explained in Section 2, while Section 3 contains a discussion on the identified requirements. Section 4 presents the complete platform describing the how the methodology has been converted into a practical sequence of tools. Finally, Section 5 summarizes the conclusions on the platform theoretical implementation, explaining what are the advantages that the industrial partners will obtain from the utilization of the DIVERSITY environment.

2. DIVERSITY Methodology

By analysing the scientific production on PSS, it results evident that although there was a multiplication of the research over the last few years, many of the methods proposed in this field have been converted to PSS design from the traditional engineering (Cavalieri and Pezzotta, 2012) or the pure service fields (Oliveira, Mendes and Rozenfeld, 2015) (Beuren, Gitirana Gomes Ferreira and Cauchick Miguel, 2013). In particular, the available methodologies lack of some features in order to be completely supportive for PSS design, in particular (Oliveira, Mendes and Rozenfeld, 2015) (Beuren, Gitirana Gomes Ferreira and Cauchick Miguel, 2013) underlined problems with the terminology, the system elements, the reference frameworks models, methods and tools. Furthermore, (Sassanelli *et al.*, 2015) highlighted the necessity of a consistent industrial application of the proposed methodologies. Moreover, most of the methodologies today available don't support the definition of new PSSs considering at the same time the customers' perspective and the companies' performance and the share of knowledge between all the committed actors and functions. On one side, this means that the PSS provided may comply completely with the customers' needs but simultaneously not being sustainable for the company in the long term (Neely, 2009). On the other side, the possibility is to have an inefficient PSS design that leads to continuous reworks and revisions due to the absence of shared knowledge among the different companies' functions (e.g. product design vs service). In the transition process towards PSS, manufacturers need the assistance of tools, techniques, and methods to provide superior service to customers (Qu *et al.*, 2016). In order to fill these gaps a new methodology based on the SEEM methodology (Pezzotta *et al.*, 2016) has been proposed. This new procedure, developed in the DIVERSITY project and called PSS Lean Design Methodology (Lazoi *et al.*, 2016) consists of four phases to be followed by the company's designers and employees in order to define new PSSs and to evaluate them during their lifecycle. The methodology is represented in Figure 1 and is composed by:

1. Customer analysis;
2. Solution concept design;
3. Solution final design;
4. Offering identification and analysis.

These phases can be grouped under two categories: the "customer" related phases (#1 and #4) and the "company" related phases (#2 and #3). This distinction has to be done since they cover a different role in the PSS development. The "customer" related phases are responsible for identifying the gaps between the current PSS offering and the future PSS offering or the new PSS and the customers' needs, while the "company" related phases are responsible for the conceptualization and design of the new PSS able to satisfy the previously identified needs.

2.1 Customer analysis

This phase consists in the analysis of the customers' feedbacks with the scope of identifying their needs (Mourtzis *et al.*, 2016). With this scope different tools are under development as explained in (Neves-Silva, Pina, *et al.*, 2016) and (Neves-Silva, Gamito, *et al.*, 2016). Three different ways can be followed to identify the customers' needs (Rondini *et al.*, 2016):

a. Conduct a social network and sentiment analysis to collect a large number of customers' opinion;

b. Analysis of the data available in the company Wiki;

c. No customer data available.

2.2 Solution concept design

The information identified in the previous phase is here used in order to conceptualize different solutions and identify the best one which will be the designed (Rondini *et al.*, 2016) by the adoption of the Product-Service Concept tree. This method intends to suggest a formal way to:

- Identify PSS solutions capable of fulfilling customer's needs;
- Represent solutions in a structured approach;

Manage the selection of the "best" PSS concept to implement.

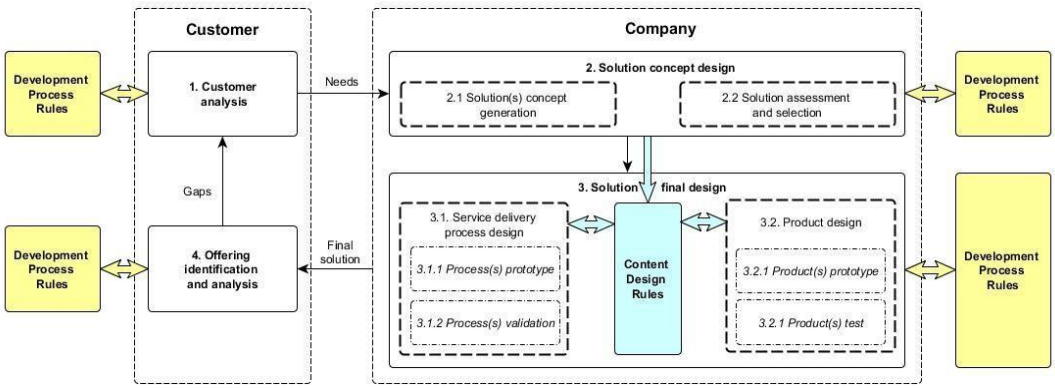

Figure 1 - PSS Lean Design Methodology

2.3 Solution final design

This step contains two phases, which support the design of the two different typologies of elements:

a. The tangible elements that represent the product feature to be implemented identified in the PSCT, the product design is made using approaches/tools already available in the different companies (e.g. PLM)

b. The intangible elements that are expected to be used to deliver the service. The service blueprinting technique (Shostack, 1984) to model the service delivery process is adopted.

In order to allow a proper exchange of information between the product and the service design, DfX techniques are adopted (Sassanelli *et al.*, 2015). Lean content design guideline and rules are defined to enable the abilities related to the service features of the PSS already during the product design. More in details:

a) The Content Design Guidelines, which can be defined as high level rules since they are very generic and usable for many products;

b) The Content Design Rules, defined previously and specific for a certain product.

Once the product and the service are designed and the final PSS is ready to be implemented, a set of relevant KPIs to monitor the solution is assigned.

2.4 Offering identification and analysis

Once the new PSS has been conceptualized, designed and implemented, its performances are monitored in order to identify new gaps to be fulfilled with new versions of the PSS, this analysis is done using the KPIs defined during the solution final design phase.

2.5 Development process rules

In order to have an optimized design process the Development Process Rules are adopted. Based on the My Waste (Rossi, Taisch and Terzi, 2012) the PSS edition defines rules of "good behaviour" for the company normal work life trying to reduce the valueless activities in a continuous improvement vision.

3. Requirements definition

The methodology above described has been used to define the DIVERSITY Engineering Platform, for this reason the requirements definition phase has been relevant in order to define the architecture and the tools' features. This definition has been done through brainstorming and workgroups with scientists and managers with the objective of finding the features that could lead to the creation of powerful but intuitive tools for the conceptualization, definition and monitoring of new PSSs. In order to express ISO9126 and, because of that, categorizing them into functional and non-functional requirements. The first category groups all those requirements that describe the functionalities that the tool should have in order to be usable. correctly the different peculiarities of each tool the requirements description has been done following the The second category contains all those instructions that explain how these tools have to be presented in order to be intuitive and easy to use for the different actors who will interact with them. As an example, in the following the requirement analysis performed for tools mainly focused around the conceptual and final design of the PSS are described.

3.1 Lean Design Rules Tool requirements

This tool is meant to support the definition and the use of the PSS Lean Design Rules. A Lean Rule is an instruction given to the designer in order to explain a characteristic, feature or request has to be implemented in the considered product or process. The scope of a rule is to simplify the design phase making it more structured and avoiding the time and money wastes caused by the continuous reworks. The functional requirements focus on the necessity for the user to be able to define and classify the rules in a simple but precise way in order to facilitate their usage and search. An example of the requirements for this tool is provided in Table 1.

Req_ID	Requirement
r_BC_fun_01	The tool shall allow the creation and the storage of Content Design Guidelines and Content Design Rules
r_BC_fun_02	The tool shall keep in memory the information inserted in the fields until the user submits them, also when he/she switches between the tool's sections
r_EC_usa_01	The tool must be easy to use in order to allow the user to work without the need for supplementary training sessions in addition to the initial one.

Table 1 - Requirements for the Lean Design Rules tool

3.2 Product-Service Concept Tree Tool requirements

The Product Service Concept Tree is the tool developed in order to conceptualize the solution for the customers' needs.

Req_ID	Requirement
r_BC_fun_01	The tool shall allow the creation and the storage of a PS concept tree and shall enable to user to upload and modify previous work
r_BC_fun_02	The tool shall not allow working on a step without having completed the previous one
r_EC_usa_01	The tool must be easy to use in order to allow the user to work without the need for supplementary training sessions in addition to the initial one.

Table 2 - Requirements for the Product Service Concept Tree tool

This tool has to foster and encourage the collaboration and brainstorming between the different actors of the company. This tool has to foster and encourage the collaboration and brainstorming between the different actors of the company. In order to do that this tool has to be simple to use. The PSCT tool requires a simple but clear representation of the PSS concept tree in order to underline the relations and hierarchies between the different elements.

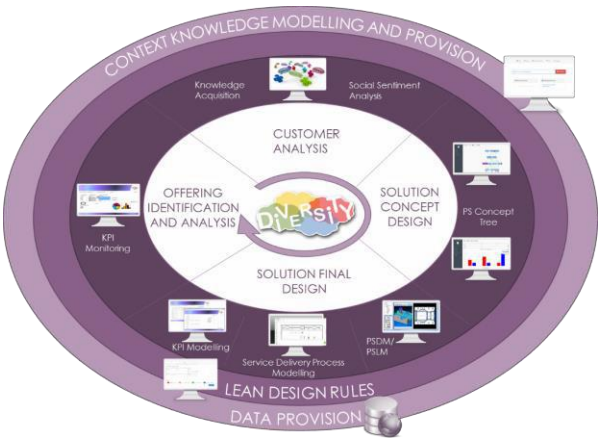

Figure 2 - The DIVERSITY platform

The functional requirements for this tool focus on the description and classification of the PSS characteristics in terms of needs, wishes, solutions and requirements. An example of the requirements for this tool is provided in Table 2.

4. The DIVERSITY Engineering Platform

The development and the interaction between the different tools of the DIVERSITY platform (Figure 2) follow the predetermined schema derived from the PSS Lean Design Methodology, that has the scope to guide the designer towards the creation of new PSSs considering the customers'/users' needs. In the following sub-sections, a brief description of the tools and of their usage inside the platform is provided. The order of the sub-sections represents the sequence the designer should follow in order to use properly the tools.

4.1 Knowledge Acquisition tool

This tool based on MediaWiki software has the scope of being a repository for the information coming from the customers and consumers. The industrial partners involved in the project decided to use this tool in different ways depending on the kind of relationship they have with their customers/consumers.

4.2 Social Sentiment Analysis tool (SSA)

The SSA (Neves-Silva, Gamito, *et al.*, 2016) has the scope to analyse the customer and consumers' feedback stored both in the Knowledge Acquisition tool and in the social networking services and provide to the marketing managers and designers information useful to improve the current PSSs or to create new ones.

4.3 Lean Design Rules tool

The Lean Design Rules tool helps the designers in retrieving previously defined guidelines and rules and in defining new ones. The tool manages both the Lean Design Content Rules and Development Process Rules. This tool is used more than once during the "company-related phases", the first time for the definition of the rules that have to be followed and then once the design is completed in order to verify that all the design rules have been satisfied.

4.4 Product Service Concept Tree tool (PSCT)

This tool has the aim to help the designers and the managers in conceptualizing the new PSSs. In particular, once the different PSSs have been defined they are evaluated through an impact-difficulty matrix that is used to order them and to select the most suitable for the customer necessities. The selected solution is specified in terms of product and service resources. This distinction is fundamental, since in this phase the Lean Content Design Guidelines and Rules are linked to the solution and its resources. The result is a list of guidelines and rules aiming at helping the designers in properly define all the related features.

4.5 PSDM/PSLM tool

At the product design stage, it is necessary to interface the DIVERSITY tool with existing PSLM that provides an excellent starting point for the PSS detailed design thanks to the logic developed over the years for product design. The PSDM/PSLM tool represents a link between the DIVERSITY platform (used for the conceptualization of the PSS and the design of the service) and the PLM company environment (that uses proprietary tools to design the product). In particular, to make the PLM working within the DIVERSITY concept in the DIVERSITY architecture, the main PSLM components have been extended and adapted to allow them to manage the typical PSS concepts, data and development logics. (Lazoi *et al.*, 2016)

4.6 Service Delivery Process Modeller tool (SPDM)

The SPDM is used in this environment in order to design the service delivery process associate to the product. This tool uses two standards in order to provide its function: the blueprinting technique and the Business Process Model and Notation (BPMN). This tool using the resources identified in the PSCT is responsible for the definition of the sequence of actions that the considered resource has to follow in order to provide the service that it has been selected for.

4.7 KPI Modelling and Monitoring tool

The KPI Modelling and Monitoring tool is used in two different phases (Figure 2). This tool is used for the definition of the KPIs that will be used in order to evaluate it. Moreover, this tool can be used also to support the identification of needs, since a certain behaviour of a defined KPI can signal a certain dissatisfaction of the customers. On the other side, the KPI analysis can also underline the improvements achieved by the company thanks to the implementation of the DIVERSITY platform inside its work environment.

4.8 Context Knowledge Modelling and Provision module

This module contains the Intelligent Search tool, which can be used in any moment during the PSS design process and is used in the DIVERSITY platform in order to classify and search between all the shared knowledge.

The idea behind this tool is to have a simple way to search for all the information linked to a certain word, PSS or component in a fast and structured way (using for this purpose the PSS and User-centric ontologies defined in the project). This should allow the designer to have a complete vision of all the information available allowing in to design a better PSS and to access the information useful to satisfy all the client's needs. The Ontology Modelling tool supports the description of main concepts for the PSS and user-centric ontologies which together form the Context Model for the PSS. Finally, Context extraction identifies context of a data set based on the context model. This component monitors raw data, identifying current context, and enables data comparison based on context similarity. This is then used by the Intelligent Search tool to provide refined search results.

5. Conclusions

The growing importance of the services in the last decades has forced the companies to change their business model moving it from a product-oriented one to a new one in the product and the service are bundled. This has caused the rising of new problems for the companies because of the lack of methodologies for the creation of PSS compliant with the consumers' requests and the companies necessities. The PSS Lean Design Methodology developed in the DIVERSITY project tries to fill this gap creating a structured methodology for design process and fostering also the collaboration between the different actors of the process. The practical transliteration of this methodology is the set of tools developed in the DIVERSITY platform. In fact, using this platform, the companies should be able to identify and monitor easily the customer needs resulting from the market analysis. At the same time, they should be able to create PSSs that are customer driven and at the same time economically sustainable in the long term (this also by avoiding valueless reworks and activities). The final output is an improvement of the company performance both internally (e.g. on the operational side) and externally (e.g. gaining a certain competitive advantage on the competitors).

Acknowledgements

This work was funded by the European Commission through Diversity Project (Cloud Manufacturing and Social Software Based Context Sensitive Product-Service Engineering Environment for Globally Distributed Enterprise), GA 636692. It is a European project funded under the H2020 program, started in February 2015 and planned to finish in January 2018.

References

Beuren, F. H., Gitirana Gomes Ferreira, M. and Cauchick Miguel, P. A. (2013). Product-service systems: A literature review on integrated products and services. *Journal of Cleaner Production*, 47(May 2013), pp. 222–231.

Cavalieri, S. and Pezzotta, G. (2012). Product-service systems engineering: State of the art and research challenges. *Computers in Industry*, 63(4), pp. 278–288.

Lazoi, M., Pezzotta, G., Pirola, F. and Margarito, A. (2016). Toward a PSS lifecycle management systems: considerations and architectural impacts. *Enterprise Interoperability VII*. Springer International Publishing.

Mourtzis, D., Fotia, S., Gamito, M., Neves-Silva, R., Correia, A. T., Spindler, P. and Rossi, M. (2016). PSS Design Considering Feedback from the Entire Product-service Lifecycle and Social Media. *Procedia CIRP*. Elsevier B.V., 47, pp. 156–161.

Neely, A. (2009). Exploring the Financial Consequences of the Servitization of Manufacturing. *Operations Management Research*, 1(2), pp. 1–50.

Neves-Silva, R., Gamito, M., Pina, P. and Campos, A. R. (2016). Modelling Influence and Reach in Sentiment Analysis. *Procedia CIRP*. Elsevier B.V., 47, pp. 48–53.

Neves-Silva, R., Pina, P., Spindler, P., Pezzotta, G., Mourtzis, D., Lazoi, M., Ntalaperas, D. and Campos, A. R. (2016). Supporting Context Sensitive Lean Product Service Engineering. *Procedia CIRP*. Elsevier B.V., 47, pp. 138–143.

Oliveira, M. G. De, Mendes, G. H. S. and Rozenfeld, H. (2015). Bibliometric analysis of the product-service system research field. *Procedia CIRP*. Elsevier B.V., 30, pp. 114–119.

Pezzotta, G., Pirola, F., Rondini, A., Pinto, R. and Ouertani, M. Z. (2016). Towards a methodology to engineer industrial product-service system – Evidence from power and automation industry. *CIRP Journal of Manufacturing Science and Technology*. CIRP.

Qu, M., Yu, S., Chen, D., Chu, J. and Tian, B. (2016). State-of-the-art of design, evaluation, and operation methodologies in product service systems. *Computers in Industry*. Elsevier B.V., 77(April), pp. 1–14.

Rondini, A., Pezzotta, G., Pirola, F., Rossi, M. and Pina, P. (2016). Science Direct How to design and evaluate early PSS concepts : the Product Service Concept Tree. *26th CIRP Design Conference*. Stockholm: Elsevier B.V., pp. 0–5.

Rossi, M., Taisch, M. and Terzi, S. (2012). Lean product development: A five-steps methodology for continuous improvement. *18th International Conference on Engineering, Technology and Innovation*.

Sassanelli, C., Terzi, S., Pezzotta, G. and Rossi, M. (2015). How lean thinking affects: Product service systems development process. *20th Summer School 'Francesco Turco'*, (Industrial Systems Engineering), pp. 97–104.

Shostack, G. L. (1984). Designing services that deliver. *Harvard business review*, 62(1), pp. 133–139.

Stokic, D. and Correia, A. T. (2015). Context Sensitive Web Service Engineering Environment for Product Extensions in Manufacturing Industry. *Service Computation 2015*. Nice, France: IARIA XPS Press, pp. 9–13.