The Integrated Design of Product-Service Systems using the DIVERSITY Platform: An Application Case

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Abstract: Companies are nowadays struggling to intercept the new needs arising from the market through the proposal of new offerings to customers and consumers. Simultaneously, they are facing the complexity connected to the transition toward the provision of an offering composed by a mix of products and services, namely the Product-Service System (PSS). As a matter of fact, currently, there is a lack of methods and tools able to support the integration of products and services, which constitutes a pivotal aspect in the PSS design. In response to this, the DIVERSITY Project developed a methodology (the Product-Service System Lean Design Methodology - PSSLDM) and a platform (the DIVERSITY Platform) built upon the concept of integrated design. This paper describes the application of the DIVERSITY instruments in CAREL S.p.A., showing the benefits of the new integrated approach.

Keywords: Product-Service System, PSS, Product-Service System Lean Design Methodology (PSSLDM), PSS design, Design Methodology, Integrated Design

1. INTRODUCTION

In recent years, to be aligned with the new market trends, companies started proposing new combinations of products and services, namely the Product-Service Systems (PSSs) (Mont, 2002). In this context, new problems, pertaining to the integration of the PSS components and, thus, its economic performance, began to arise. In fact, an offering based on PSS requires to focus the design process upon the product and service integration (Park, Geum and Lee, 2012). Indeed, an offering based upon non-integrated, or badly integrated PSS(s), leads to poor economic performance for the company and to dissatisfaction for the customers (Neely, 2008). Therefore, new instruments, supporting the PSS design and management, are required to face efficiently the new market trends (Cavalieri and Pezzotta, 2012). In response, the DIVERSITY project developed a set of theoretical methods and software instruments aimed at guiding the PSS integrated design and supporting its implementation and management. The scope of this paper is to clarify how the DIVERSITY approach and platform can guide the design of an integrated PSS in an industrial environment, discussing then the benefits and limitations of the proposed approach. The paper is structured as follows: Section 2 briefly introduces the DIVERSITY General Scenario, methodology and platform. Section 3 describes the application case that took place in CAREL S.p.A., reporting a description of the company

business, of its current design process and of the application of the DIVERSITY design process. Finally, Section 4 discusses the results of the application case highlighting benefits and limitations of the DIVERSITY Platform, enumerating then the future developments.

2. THE RESEARCH METHODOLOGY

The paper presents an application case carried out in CAREL S.p.A., where the DIVERSITY methods and tools were used to integrate the product and service design phases. Fig. 1 presents the research methodology that led to the application case. A mixed research method was adopted in the development of the DIVERSITY methodology and platform, with the related workflow. From the top-down perspective, a literature analysis (Mourtzis *et al.*, 2016) was conducted in the beginning of the project to support the definition of the DIVERSITY methodology and of all the methods.
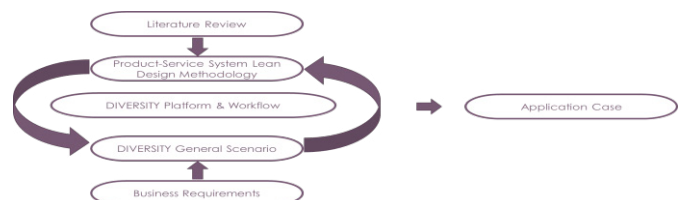

Fig. 1. The Research Methodology

Instead, from the bottom-up perspective, the business requirements were used to develop the DIVERSITY General Scenario, essential for the platform specification. In addition, along all the project, feedback from the companies have been used to improve the theoretical methodology and the software instruments.

3. DIVERSITY METHODOLOGY AND PLATFORM

Fig. 2 depicts the DIVERSITY General Scenario, which encompasses all the phases of a generic PSS design process, starting from the identification of a new business opportunity, going through the PSS design, ending with the PSS performance monitoring on the market. Scope of the general scenario is to depict how the platform is going to be used in the real context. The DIVERSITY General Scenario, in combination with the DIVERSITY methodology, namely Product-Service System Lean Design Methodology (PSSLDM), guided the development of the DIVERSITY Platform and Workflow.
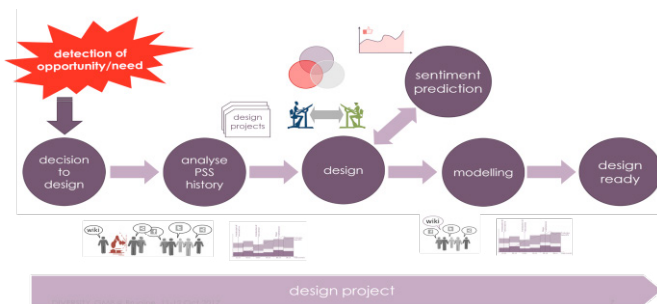

Fig. 2. The DIVERSITY General Scenario

In short, in this scenario, the process starts when the company detects a new business opportunity and, thus, decides to design a new PSS. When this happens, the newly created design team can choose to design an entirely new PSS or to update an old one. In this phase, and when necessary during the design project, the design team can retrieve the knowledge created in the company, which encompasses design projects, KPIs, Sentiment of PSSs available in the market and the rest of knowledge created in the past. Following, the project continues with the design phase. This phase is carried out using the tools developed in the DIVERSITY Platform. Only the product design is performed using legacy CAD/CAM tools. Specifically, DIVERSITY brings here:

- The possibility to identify and assess PSS concept solutions starting from the customer needs;
- The possibility to store, share and search all the knowledge created in the company in a repository called DIVERSITY Wiki;
- The possibility to test, using the sentiment prediction, the acceptance of a new combination of products and services in the PSS design. The prediction uses contextualised opinions extracted from social media, including the Wiki pages;
- The effective identification of old design projects, and of the associated knowledge, relevant for the current design process;

- The provision of design guidelines and rules supporting a better product design thanks to improved knowledge exchange between service and product functions. In particular, Sassanelli *et al.* (2018) defines the Content Design Guidelines as practical prescriptions developed to improve the integration in the product of service feature, while the Content Design Rules as concrete and quantitative instructions to be followed in the product design to implement the guidelines;
- The possibility to design the service delivery process and link it directly to the PSS;
- The possibility to assess the overall PSS once designed in detail.

After the PSS design validation, the design team defines the KPI(s) and the Sentiment Analysis model that will be used for its monitoring. The DIVERSITY General Scenario concludes with the finalisation of the design process, when the project is stored in the repository for further reuse.

3.1 The DIVERSITY methodology: the PSSLDM

A literature analysis supported the development of the PSSLDM (Pezzotta *et al.*, 2016) and of the related tools. The PSSLDM consists of an introductory phase and four main phases composed by several sub-phases, each one dedicated to a specific step in the PSS design project:

- 0. *Development Process*: in here some rules aimed at reducing the waste generation along the project life-cycle are established;
- 1. *Customer Analysis*: in here the customers' feedback is analysed and a set of needs is identified;
- 2. *Solution Concept Design*: in this phase, the Need(s) are used to conceptualize the PSS, defining the Wish(es) (how the customers want their Need(s) to be satisfied), the Solution(s) (proposed by the company) that will satisfy the Need(s) and the Resource(s) supporting the Solution(s) provision. The Product-Service Concept Tree (PSCT) (Rondini *et al.*, 2016) is used to support the representation of the links and relations between needs, wishes, solutions and resources. This phase is composed by two sub-phases: a) Solution(s) concept generation, where the PSCT is created; b) Solution(s) assessment and selection, where the conceptual solutions are evaluated and the best one is chosen;
- 3. *Solution Final Design*: in this third phase the best solution is designed. To guide the product design, to make it compliant with the service provision and to validate it, the Content Design Guidelines and Rules, generated from the DfX techniques, are used (Sassanelli *et al.*, 2018). Once validated the service and product design, the design team deals with the modelling of the KPIs used for the PSS monitoring. For these reasons, this phase is divided in: a) Service delivery process design, in this step the design team exploits the service modeller integrated in the DIVERSITY Platform to design the service delivery map and describe the service feature of the PSS; b) Product design, this step is carried out using the

company legacy CAD/CAM tools for the design and the Content Design Guidelines and Rules to guide the design; c) KPI Modelling, this phase is carried out using the KPI modelling tool built in the DIVERSITY platform. Different types of KPIs can be defined depending on the company interests;

4. *Offering Identification and Analysis*: in this phase the performance of the PSS released on the market is monitored both in terms of KPIs and Sentiment. This phase is composed by: a) KPI Monitoring, where the KPI(s) defined in the previous section by design team can be visualized; b) Global Sentiment Analysis, where the sentiment regarding the PSS and its behaviour over time is observed.

The information collected in the fourth phase should be used as input to identify gaps in the company offering and, if necessary, to start a new design project from the *Customer Analysis*. Value co-creation aspects are considered in all the process phases as reported in (Pezzotta, Cavalieri and Romero, 2017).

3.2 The DIVERSITY Platform

The PSSLDM development led to the creation of the tools belonging to the DIVERSITY Platform. To guarantee the correct design and management of a new PSS, an engineering workflow was defined. The DIVERSITY Workflow follows all the phases of the PSSLDM and defines the schema to follow to use the platform and related tools correctly exploiting their potential. The workflow is composed by 11 steps and is detailed in Table 1. In this perspective, different tools have been integrated in the DIVERSITY platform:

- The *Product Service Concept Tree (PSCT)* tool: it is used to conceptualize the new PSS(s). Its scope is to assist the brainstorming of the design team and to foster the evaluation and identification of the most suitable solution;
- The *Lean Design Rules* tool: it is used as a repository for the Content Design Guidelines and Rules. Using this tool, the designers are guided in the design phase and this should reduce the redesign and wastes along the whole project. The Content Design Guidelines and Rules are targeted for the design phase while the Development Process Rules (Rossi, Taisch and Terzi, 2012) cover the complete process;
- The *PSDM/PSLM* tools (Pezzotta *et al.*, 2017): the DIVERSITY Platform and the company legacy environment are linked using these tools. They are used to connect and store the information regarding the products BoM and the service map. They allow to retrieve easily the PSS composition;
- The *Service Delivery Process Modeller* tool: it is used to design the service delivery process map. Thanks to the exploitation of the BPMN and the blueprint technique it is possible to depict the resources used and the interactions between the actors;
- The *KPI Modelling and Monitoring* tool (Mourtzis *et al.*, 2016): it is used to model and monitor the KPI(s) associated to a certain PSS. Using the information displayed by this tool it is possible to monitor the PSS

on the market and identify new opportunities to start a design project;

- The *Social Sentiment Analysis* tool (Neves-Silva *et al.*, 2016): the evolution of the sentiment of a PSS is monitored using this tool. As for the KPI(s) tool, it is possible to use the results obtained from this tool to monitor the degree of success of a PSS and, if needed, to identify opportunities to start a new design project;
- The *Knowledge Acquisition* tool: it has the scope to collect the knowledge retrieved from the customers and inside the company. It can be adapted to the company exigencies;
- The *Context Knowledge Modelling and Provision Modules* (Stokic and Correia, 2015): they are used to retrieve all the knowledge shared in the company. These modules can be used every time the design teams need it.

Table 1 summarizes the relations between the PSSLDM phases, the DIVERSITY Platform workflow and the tools.

Table 1. Relationships between the PSSLDM, the DIVERSITY Platform workflow and the tools

PSSLDM phase	Platform workflow	Tool
Development process	Make It Leaner	Lean Design Rules tool
Customer Analysis	Monitor KPI	KPI Modelling and Monitoring tool
	Monitor Sentiment	Knowledge Acquisition tool
		Social Sentiment Analysis tool
Solution Concept Design	Design Concept	Product-Service Concept Tree
	Associate Design Rules	Lean Design Rules tool
Solution Final Design	Design PSS	PSDM/PSLM tools
	Design Service	Service Delivery Process Modelling tool
	Validate PSS	Lean Design Rules tool
	Model KPI	KPI Modelling and Monitoring tool
Offering Identification and Analysis	Monitor KPI	KPI Modelling and Monitoring tool
	Model Sentiment	Social Sentiment Analysis tool

4. THE APPLICATION CASE

CAREL S.p.A. is a world leader in control solutions for air-conditioning, refrigeration and heating, and systems for humidification and evaporative cooling (HVAC/R). CAREL S.p.A. designs products with the aim to lower the environmental footprint of machines and systems, improving their energy savings. CAREL S.p.A. is focused on the B2B market, and its products have commercial, industrial and residential applications. The customers are represented by OEM, System Integrator, Installers and not by the final users. The company's portfolio is centred on the products, and only

a small part of it is dedicated to the services. Due to the evolution of the market requests, CAREL S.p.A. is interested in widening the current portfolio, enriching it with a set of new services tailored on customers' needs. Because of this, and to increase the benefits achievable through the service provision, CAREL S.p.A. wills to introduce the Product-Service System (PSS) offering in its portfolio. Thanks to this new approach, the company intends to (a) strengthen the relationship with the actors close to the customers, (b) increase the flexibility of the Business Units, (c) develop specific service competencies. This main transition is relevant for the humidification business, since final product is sold to the installer who is then installing it in the user infrastructure.

4.1 The current design process

The current design process of CAREL S.p.A. is originated by an analysis of the customers' claims, classified according to their seriousness. Starting from this, a series of products ideas (along with a draft of the design team) are proposed to face the claims. This initial phase is followed by a second one where the human resources (from 3 to 5) are negotiated and assigned depending on the project (small or big) and the employees' skills. Once a project is approved, a value proposition is defined and submitted for approval. The product design phase is subjected to a periodical check according to the milestones and the plan previously defined. Once completed the design and verified its consistency through tests ad hoc, the product is launched on the market. In the following months, standard data are collected, and the product's performance is evaluated through a standard set of KPIs, which is used to evaluate all the products in the company. Periodically, CAREL S.p.A. analyses the product performance and applies corrective actions to solve the problems. Since the service offering is related only to problems in the products quality, the services and their engineering are not considered in the design phase.

4.2 The DIVERSITY design process

A product already on the market, belonging to the humidifiers division and part of the top segment of CAREL S.p.A.'s portfolio was used in this application case.

4.2.1 Development Process

The first step of the workflow, *Make it Leaner*, was executed at company level, where a set of rules, namely the *Development Process Rules,* were established with the aim to reduce the wastes and problems that could arise during the project life-cycle.

4.2.2 Customer Analysis

Following, in the *Customer Analysis* phase, an inquiry on the actual performance of the product under analysis was carried out. The company Claim Management Tool (CMT) was used in this application case to collect the textual feedback from the customers. The CMT is a proprietary tool used by CAREL to collect feedback from customers concerning the products status and/or problems. In the *Monitor* KPI step, the feedback collected through the CTM were categorized using

the *KPI Modelling and Monitoring tool* and then visualized in plots (Fig. 3). According to the results of the Claim Analysis, the installation phase was recognised as the more challenging one. For this reason, specific feedback on the installation phase was collected by the company, which requested the installers to fill a structured questionnaire on the installation phase.
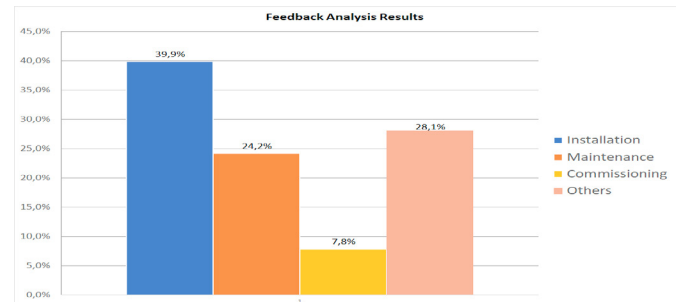

Fig. 3. Feedback Analysis Results

The answers were stored into the DIVERSITY Wiki, in CAREL S.p.A. instantiation where, thanks to the sentiment analysis performed on the answers it was possible to visualize the sentiment behaviour over time (Fig. 4). This task is carried out in the *Model Sentiment* (Neves-Silva *et al.*, 2016) step of the DIVERSITY workflow.
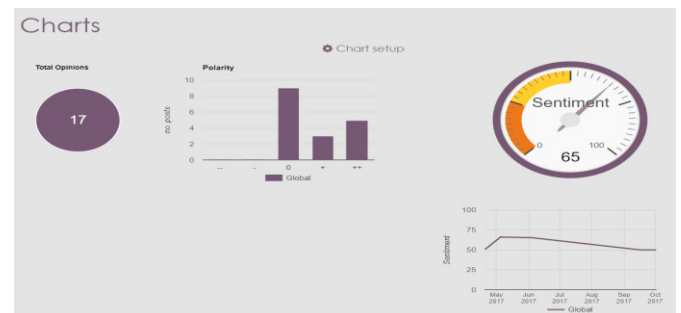

Fig. 4. The Sentiment Analysis Charts

The *Sentiment Analysis* performed on the questionnaires allowed to recognize a decreasing sentiment, which led to the decision to design a new PSS.

At this point, the company created a design team composed of four employees and started a design project. With the aim to cover all the aspects of the design phases described in the PSSLDM, employees with different skills were selected. In the initial phase of the design project, the *Customer Analysis,* the *KPI* and *Social Sentiment Analysis* results were retrieved and used to support the customers' needs identification. According to these, two needs were identified and used in the *Design Concept* step:

- Long Life Cycle;
- Continuous Functioning of the Product.

4.2.3 Solution Concept Design

Here, the Needs were used as a starting point for the definition of the wishes, solutions and resources composing *Product Service Concept Tree*. Several solutions were proposed in this step. By this, it was possible to compare and

evaluate each one of them, identifying the best one. Two parameters were considered: Impact and Effort. Table 2 reports the results of the evaluation. The scores of each solution were evaluated comparing them to the others. Based on the evaluation and on the company strategy, the best solution was selected.

Table 2. Solutions Evaluation

Solution	Effort	Impact
Increase of service in foreign countries	5	4
Easy Manual (or instruction)	1	2
Automatic installation and commissioning	4	5
Poka-Yoke in the product	4	5
Better knowledge of final customer	4	1
Maintenance intervention traceability	2	2
Remote monitoring of the machine	3	2
APP based on augmented reality	2	3

In this case, the solution "APP based on augmented reality" resulted to be the best one because of the good impact achievable with its implementation and the relatively low effort required to put it in practice.

In the fifth step of the workflow, *Associate Design Rules*, the design team, using the *Lean Design Rules tool*, was required to choose a set of *Content Design Guidelines* that the designer(s) should (or must, depending on the guideline importance) follow to design the product(s) appropriately. The *Content Design Guidelines* are built in a way that fosters the product and service components integration. Using the DfPSSu methodology (Sassanelli *et al.*, 2017), new *Content Design Guidelines* were created by the design team to allow a coherent product design for the solution under development. One or more *Content Design Rules* are associated to each *Content Design Guideline*. The *Content Design Rules* provide detail knowledge to the designer and are classified according to the parameters used for the *Content Design Guidelines*. As for the *Content Design Guidelines*, also the *Content Design Rules* are defined so that they will guide the design fostering the product and service components integration. An example of *Content Design Guidelines* is reported in Table 3.

Table 3. Content Design Guidelines

GL Code	Guideline
GL01	Create visual cues allowing macro areas detection to improve installation speed
GL05	Use standard connections to improve installation simplicity

4.2.4 Solution Final Design

In the following steps, namely the *Design PSS, Design Service, Validate PSS* and *Model KPI*, the design team was required to the design the solution and to define the KPIs used in the monitoring. In *Design PSS*, all the information regarding the solution under design were stored in the *PSDM/PSLM tools*. The product's Bill of Materials (BOM) and the service delivery process map details were updated during the design phase. The *Design Service* phase envisaged the usage of the *Service Delivery Process Modelling tool* for

the service delivery process map while legacy CAD/CAM tools were used for the Product Design. The product design was guided by the *Content Design Guidelines* and, therefore, through the associated *Content Design Rules*. The designer was encouraged to add new *Content Design Rules* (with the same methodology that can be used for the *Content Design Guidelines* creation) if something was lacking in the database. Table 4 reports an example of the *Content Design Rules* with the associated *Content Design Guidelines*.

Table 4. Content Design Rules

GL Code	Rule Code	Rule
GL01	R01	The sticker for water input and output must resist to condensation (100% of moisture) in the long run
GL05	R08	To ensure geographical customization, for the American version of the product provide a dual voltage (220 or 110 V).

The *Service Delivery Process Modelling tool* uses the Service Blueprinting and the Business Process Model and Notation (BPMN) to create the service map. The service designer was able to specify all the relations and the physical evidence that has to be considered in the service delivery, highlighting the relations and the level of interaction between all the actors. Fig. 5 depicts a detail of the service delivery map created for this application case.
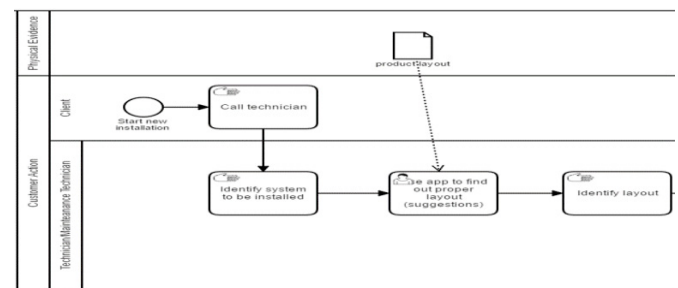

Fig. 5. Detail of the Service Delivery Process Map

The following step was *Validate PSS*. This validation took place with the support of the *Lean Design Rules tool* that showed all the *Content Design Guidelines* selected in the *Associate Design Rules* step and the related Rules. The designer selected all the Guidelines and Rules considered during the design phase. To validate the PSS design, all the fundamentals Guidelines and Rules were checked. To conclude the design phase, it was necessary to associate a list of KPIs to the newly designed PSS. To do this, in the *Model KPI* step, the design team used the *KPI Modelling and Monitoring tool*, which allowed them to retrieve previously created KPIs and to define new ones. The tool allowed to retrieve the list of KPIs associated to several PSSs, to see the complete list of KPIs already defined and to filter them according to their characteristics. The design team defined four KPIs according to the new PSS:

- Number of Service Tickets opened for installation support;
- Time for PSS development or improvement;
- Number of new need identified;

- Percentage of redesign required.

These KPIs covered the aspects that the new PSS had to be compliant with to increase the customers and consumers satisfaction.

4.2.5 Offering Identification and Analysis

In the last phase of the application case, the *KPI Modelling and Monitoring tool* was used to monitor the performance of the KPIs defined in the previous phase. Moreover, a new model, able to monitor the sentiment of the new PSS, was created by the design team using the *Social Sentiment Analysis tool* in the *Model Sentiment* step. Because of the particular PSS, constituted by a humidifier for the product side, it was not possible to collect feedback on the social networks or on a web marketplace. For this reason, the new model was set to perform the analysis on specific questionnaires given to the customers (the installers).

5. DISCUSSION AND CONCLUSIONS

The paper described an application case that took place in CAREL S.p.A. with the aim to show the main advantages of a new design process integrating since the early phases the product and service features through the simultaneous usage of the PSSLDM and of the DIVERSITY Platform. The application case highlighted the main aspects this new design approach which allows focussing on either the product and the service features at the same time. Indeed, the DIVERSITY approach uses the customers' needs as a starting point for the design of integrated products and services. The service design phase gains remarkable importance in the DIVERSITY process, encouraging the definition of a wide range of services tailored to the customers' needs. Besides the comparison between the two design approaches, the application case also demonstrated the benefits deriving from the usage instruments developed specifically to handle the PSS design and management. The employees that took part in the application case evaluated the overall experience with the DIVERSITY approach and platform as positive. Regarding the possible improvements, some the feedback collected concerned the platform interface, not usability and workflow. Regarding software aspects such as installation, data entry, ease of use of the tools, etc. the overall impressions were positive. As explained in the introduction, an organizational evolution is nested in the path towards the PSS provision, which implies resources entirely dedicated to the service design and provision. The next steps in the DIVERSITY project will be focused on the adoption of the DIVERSITY methodology and DIVERSITY Platform on a large scale.

ACKNOWLEDGMENTS

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