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Product-Service Systems across Life Cycle

Open Innovation for ideating and designing new Product Service Systems

Eugenia Marilungo[a]*, Eva Coscia[b], Angelo Quaglia[b], Margherita Peruzzini[c], Michele Germani[a]

[a] *Università Politecnica delle Marche, via Brecce Bianche - Monte Dago, Ancona (AN) 60131, Italy*
[b] *Holonix, corso Italia, Meda (MI) 20821, Italy*
[c] *Università di Modena e Reggio Emilia, via Vivarelli 10, Modena 41125, Italy*

* Corresponding author. Tel.: +39-071-220-4880; fax: +39-071-220-4708. E-mail address: e.marilungo@pm.univpm.it

Abstract

For modern manufacturing companies, the combination of physical products and intangible services (called Product-Service Systems or PSS) has been proved by time to be useful to enhance the product features by adding value throughout new functionalities, and bringing competitive advantages in a specific target market. Through PSS, companies create new business opportunities, extend the market share, differentiate the product portfolio, and improve sustainability. The PSS approach shifts the company attention from producing physical products to offering integrated systems. However, ideating and designing a PSS is a complex and multifaceted process, which requires multiple competences and cross-functions cooperation within the manufacturing company. In fact, the design phase requires to simultaneous dal with the characteristics of the physical product and of the intangible services, the last ones being by their nature fuzzy and difficult to define. Furthermore, the two entities have to be synergistically delivered and strategically managed thanks to the adoption of a PSS lifecycle management methodology and tools, in particular for the creation of a proper PSS infrastructure to delivery and maintain all the components from the design to the end of life phases. Several methodologies to design PSS can be found in literature. Most of them focus on technical development stages, while some of them face also the innovation aspects and sustainability. However, traditional product-centered approaches are not able to fully support the processes that manufacturing companies have to put in place for creating PSSs. This paper presents a new approach, based on the combination of the Open innovation method with IT solutions supporting information sharing and intra-team cooperation, in that any manufacturing company could adopt to manage the design process of a PSS. In particular, the methodology and the tools are focused on the early stages of the PSS design process, as Ideation and Concept definition that have been developed within the European FP7 project FLEXINET.

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Keywords: Product Service System (PSS); PSS Design; Product Service Lyfecycle Management (PSLM); Open Innovation

1. Introduction

Currently Product-Service System (PSS) is a widespread trend consisting of adding services to the physical product in order to create new value for customers [1]. According to this definition, PSSs management represent the new challenge for the manufacturing domain. In fact, the design process is still structured for traditional products, even if recently several researchers have started to address the design of PSS as a whole. Several methodologies to design a PSS are explained in literature [2], and in some cases, they also achieved a preliminary industrial prototype [3]. However, industrial sector is still far from the adoption of PSS management solutions inside the companies, due to a scarce research, development and improvement of the reference processes that support all the PSS design phases. In fact, the ideation and design processes for PSSs are complex and multifaceted, requiring multiple competences and cross-functions cooperation within the manufacturing company. Moreover, the strong interconnection between product and service along the PSS design process implies that they cannot be managed as independent entities, adopting Product Lifecycle Management (PLM) and Service Lifecycle Management (SLM) approaches separately. Therefore, any tool or application that monitors the evolution and the change of PSS offer, must provide a holistic approach able to manage their concurrent evolution. Analyzing the main phases of the

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Products and Services lifecycles, it is possible to observe some commonalities and some differences harmonize.

This paper has the scope to show an innovative combination of methodology and IT tools able to offer a Product Service Lifecycle Management (PSLM) approach for collecting and managing information on Product and related Services along the PSS design process.

2. State of the art

2.1. Product Service System design and PSLM approach

When the concept of Product-Service System (PSS) is transferred into the business of industrial companies, it is necessary speak about the Servitization process. It is the mean to find new business opportunities by shifting the focus from offering physical, tangible products, towards offering customers intangible services that sometimes do not require customers to own the products, but just to use the services [4][5][6].

According to the Servitization process, the traditional product-centric companies can change their business, moving across different steps [7] until being more service-centric. This is probably the most innovative challenge that presently industries need to face. Indeed, the main difficulty is to combine the Product Lifecycle Management (PLM) jointly with the Service Lifecycle Management (SLM). In literature several authors have focused on such a topic, defining first of all the PLM and SLM models [8, 9, 10], and then proposing their interaction [11]. Normally, PLM solutions support manufacturing companies to manage the wide range of information related to the product, covering for example the markets, the customer requirements, the partners involved in the value chain, etc., covering only part of the whole lifecycle that is design and production. PLM originates from Product Data Management (PDM), which focused on design and engineering data. Recently new approached are merging, to extend the PLM focus to the whole lifecycle phases. Similarly, SLM systems supports data collection and management for design and engineering in a service-centered approach, as products are managed in a product-centered approach.

Stark proposed a product manufacturer’s view of the lifecycle - described through the following phases: Imagine, Define, Realize, Support/Service, Retire [12] - that allows the distinction between product and service activities, but it does not cover the interactions between them.

The theory for the integration between the PLM and SLM needs to start from the definition of their mutual relations, as defined in the literature by [13]; they distinguished four alternative types of interactions between Product and Service Lifecycles may be:

- Service Lifecycle Management is triggered by the Product Lifecycle Management (SLM depends on PLM);
- Completely opposite to the previous case, the PLM happens accordingly to SLM (PLM depends on SLM);
- Product and Service are managed regularly. Mostly, the product and the related service lifecycle have the same length but their interactions happen when it is necessary;
- Both lifecycles are managed in a highly integrated way, so that the separating managerial boundaries between PLM and SLM disappear.

According to this context, the research work proposed in this paper uses a Product Service Lifecycle Management (PSLM) approach already defined by [14], which fits the third definition of PLM and SLM interaction, where Product and Service Lifecycles are managed together. Defining a new approach as PSLM to manage the integration of PLM and SLM in the aim of propose a PSS instead of traditional product, a new challenge is to identify the methods and tools able to support each phase inside the PSLM.

In literature, the most common methodologies able to approach the PSS design [15] are based on different approaches and theories:

- Business assessment and Value creation [16, 17];
- Functional modelling [18];
- Service Engineering [19, 20];
- Requirement Elicitation (RE), that is the main approach able to design a PSS, in order to identify the main requirements related to the market and customers to reach;
- PSS sustainability assessment [21];
- PSS validation [22].

In order to investigate the customer needs, RE proposes the adoption of the following approaches:

- multi-level analysis or the Design Structure Matrix (DSM), that can be used to define the main PSS functions;
- Business Use Case (BUC) analysis, which defines the use-case model and a goal-oriented set of interactions between external actors and the system under consideration [15];
- Serious Games to elicit PSS requirements and investigate the PSS lifecycle [23];
- Quality Functional Deployment (QFD) technique [14] that allows mapping the customer needs with the PSS functions to elicit the final PSS requirements for the solution to be developed by the correlation by means of a sequence of Houses of Quality (HoQ).

Research results pay more attention to PSS design and development methodologies rather than validating the PSS during the design phase; this implies to have a first PSS prototype only at the end of Product Service System design process which means that if the testing is negative, it is necessary restart the PSS design process from the beginning.

This paper aims to define a method able to manage the PSLM according to the third alternative proposed by [13], where also the Open Innovation approach is involved.

2.2. Open Innovation approaches

Due to the huge advancements in the fields of electronics and the deployments of communication systems, mobile devices and ubiquitous services able to provide anytime-anywhere connectivity to the users, spread rapidly over the past decade. This trend today is seen like an opportunity to interlink the physical world with the cyber world [24], leading to the emergence of Cyber-Physical Systems (CPS) [25][26]. The peculiarity of CPS is that the ICT system is designed together with the physical components to maximize the overall efficiency, thus being in contrast with classic embedded systems where the goal is to include electronics, computing, communication, in an already operating physical world. This concept is perfectly aligned with the definition of PSS given.

Four main technologies fall within CPS:

- Automation of knowledge work;
- Internet of Things (IoT);
- Advanced robotics;
- Autonomous/ near-autonomous vehicles.

Among them, IoT is considered by the research community the paradigm with the highest economic impact [27]. This technology is wide used by several manufacturing companies that approach the transition from product-centered production to create a PSS value proposition. However, in order to reach such scope, these companies need to investigate their current processes and technologies to create a collaborative environment, both internal and external to themselves.

According to this approach, several companies are faced to Open Innovation paradigm. In fact, it focuses on the idea and discussion about the use of both inflows and outflows of knowledge to improve internal innovation and expand the markets for external exploitation of innovation [28][29]. Indeed, this paradigm assumes that firms can and should use external ideas as well as internal ideas, internal and external paths to market, as the firms look to advance their technology [30]. This means that industrial company should innovate with external partners by sharing both risk and reward. The boundaries between a firm and its environment have become more permeable and innovations can easily transfer inward and outward.

Talking about Open Innovation, several models already exist in literature, which cover the following areas [31][32]:

- *Product platforming*, which aims to provide a framework to access, customize, and exploit the product. The goal is to extend the platform product's functionality while increasing the overall product value for everyone involved;
- *Idea competitions*, which entails implementing a system that encourages competitiveness among contributors by rewarding successful submissions. This method provides organizations with inexpensive access to a large quantity of innovative ideas, while also providing a deeper insight into the needs of their customers and contributors;
- *Customer immersion*, which involves extensive customer interaction through employees of the host organization. Companies are thus able to accurately incorporate customer input, while also allowing them being more closely involved in the design process and product management lifecycle;
- *Collaborative product design and development*, which differs from platforming in the sense that, in addition to the provision of the framework on which contributors develop, the hosting organization still controls and maintains the eventual products developed in collaboration with their contributors. This method gives organizations more control by ensuring that the correct product is developed as fast as possible, while reducing the overall cost for developing;
- *Innovation network*, which differs from idea competition about the fact that the network of contributors are used to develop solutions to identify problems within the development process.

This paper would uses the Open Innovation paradigms described above, but extending some of them to design a new PSS solution, creating a collaborative environment.

2.3. PSS value creation

In the PSS context, where tangible product and intangible services are integrated to provide a new solution for customers, the PSS value creation depends on the close cooperation among all the actors involved in the PSS dedicated cluster (e.g. virtual manufacturing enterprise, global production network, etc.). Therefore, all the stakeholders (e.g. customers, suppliers, research partners, etc.) participate in PSS value creation process, where there is the customer's willingness to pay for service, unlike the traditional product value realization, based on its delivery [33].

In literature, different authors discussed about the concept of product and service co-design. For example, Baxter et al. [34] approached such the topic identifying the main requirements involved in the PSS co-design, while Ordanini and Pasini [35] investigated the role of customers as value creator. Moreover, Annamalai et al. [36] defined an approach to help the PSS designer to manage the activities along the process in an efficiently and effectively way, in order to reach a better value creation and customer satisfaction.

In this paper, the main concepts coming from this literature review about PSS value creation (i.e. close cooperation and product service co-design) were used and integrated in the ICT tool developed and shown in the next chapters.

3. Methodology design

The tools developed in the FLEXINET European project and presented in this paper belongs to the Product Service Co-evolution and Management System (PSCoMS) package, aimed at supporting the early stages of PSS design (PSS Ideation and Design processes), also through the collaboration among several actors. The PSCoMS provides the four functionalities described below:

- PSS new idea generation: guiding users, external or internal to a company, in the creation of an information structure with a complete description of the PSSs ideas, to be further evaluated and completed in the following steps of company design process. This idea management support allows search for similar ideas into the company knowledge base and keeps track of the reasons why an idea is promoted or discarded;
- PSS re-design and co-evolution: collecting and making available all the documentation required in the different steps of the PSS design process;
- PSS preliminary technical check: supporting the design phase by analyzing the technical dependencies between the given product and the services to be provided to complement it in the new PSS offer; it also allows detection of possible incompatibilities between a product and a service, leveraging on the product-service relations formalized in the company knowledge base;

- Feedback assessment: providing the feedback analysis, through the description of user experience on the product, in order to check how the servitization of the project has been accepted by the market and how the PSS has been used.

These functionalities are able to support different PSLM phases, according to the explanation given by Figure 1. It shows the entire PSLM flow described in literature by [11], from PSS Ideation to PSS End-of-Life. The PSLM phases supported by the PSCoMS tools are the early ones (i.e. Product-Service Ideation, PSS co-design, Product-Service Integration) and the Figure 1 clearly explains what PSLM phase each tool functionality supports.

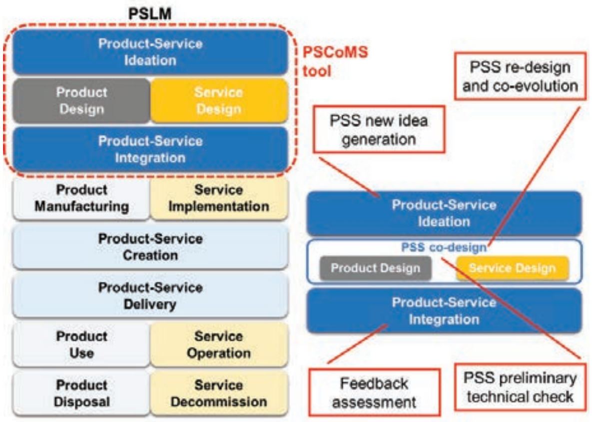

Fig. 1. How the PSCoMS functionalities support the PSLM flow

The PSCoMS design was driven by two main principles:

- collecting, analyzing and reusing the information that nowadays are most of the time implicit in the minds of different people. This kind of information is poorly structured to be analyzed with the support of IT technology;
- sharing and cooperating, to support brainstorming and decision making activities through virtual spaces where information and tools are shared among people from different physical locations.

According to these principles and to the main functionalities identified above, the PSCoMS package developed in FLEXINET is composed by four main applications:

- *Idea Manager* (IM), which supports the creation, collection, sharing and searching of information related to new PSS ideas. The application manages the Ideation process from the preliminary collection of roughly described ideas provided by internal and external people, to the complete definition of the first PSS virtual concept, that is used as the starting point for the detailed PSS co-design. The applications manages several roles, having different visibilities and rights of modifications of the PSS ideas .
- *Collaboration Environment* (CE), which can be used to support any kind of virtual cooperation meeting along the PSLM flow. Indeed, it provides the configuration of virtual spaces for brainstorming and decision making activities, with a high degree of flexibility and configurability.
- *Product-Service Configurator* (PSC), which supports the PSS design phase. Once the PSS virtual concept has been detailed through the Idea Manager application, PSC supports the technical team (composed by several people belonging to different departments) in the definition of Bill-Of-Material (BOM), the ICT architecture configuration (including the hardware and software components), the Business Model configuration, the Global Production Network description, the aesthetical model delineation, and so on. These elements are defined through the integration of the PSC with other tools (developed or not in FLEXINET project) to conduct the technical and business evaluation (e.g. sustainability assessment, risk assessment, technical and economic evaluation, etc.) and for the production network definition.
- User Experience Analyzer (UEA), which is able to collect and analyze data from customers' feedback, identifying what changes are feasible for the company. Indeed, after the PSS design, it is necessary to conduct the validation tests on the first prototype. The physical prototypes are offered to consumers for a short period during which they can use the PSS, and then provide their feedbacks. The evaluation is performed collecting both technical data (on the product behavior and on the usage of the services) and subjective comments from the end users..

4. Methodology development

4.1. PSCoMS architecture

The PSCoMS package consists of several services accessible by the end users as web-applications as represented in Fig. 2. Such the figure shows the architecture required because PSCoMS packages is able to work, which is composed by three main packages: End user application, PSCoMS package, Knowledge Management system. The services within the PSCoMS have their own interfaces that are offered to the end users, but can also be used as widgets within virtual rooms of the collaboration environment.

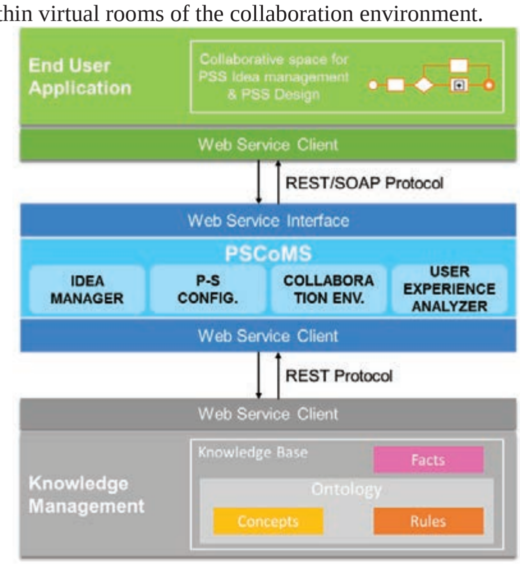

Fig. 2. PSCoMS integration architecture

The Knowledge Management system offers a REST interface through which the PSCoMS services can launch queries on a large repository of corporate information.The Knowledge Management systems contains not only the information extracted from legacy systems (e.g. product data, suppliers descriptions etc..), but also the definition of PSS concepts, business models, production networks, risk factors, rules and facts. Such the information support the FLEXINET stakeholders to take decisions about PSS ideas and concepts, and to create the knowledge required during the first phases of the PSLM. It is through the Knowledge Management system that the FLEXINET tools are integrate and exchange information.

4.2. PSCoMS development

The approach adopted in FLEXINET is based on a common repository for the knowledge represented as facts generated by a set of ontologies and rules. By using this approach, data created by the various FLEXINET tools are injected into the common and unique Knowledge database, avoiding data spreading and possible duplication within local databases managed by the single applications.

The knowledge management system (KMS) contains different types of knowledge, represented as instances of ontologies. The concepts that are more relevant for the PSCoMS tools are: “Idea”, “Concept” and “Prototype”, which are needed to support idea generation and management. These concepts are related to “Product”, “Service”, “Component” as well as “Department”, “Requirement” and thus “Customer” together with the “Business Model”. For checking the Product-Service architectures, the concept of “Product” is created and it is related to “Component List” and “Component” by way of “Bill of Material”.

The Idea Manager tool creates new instances of “Idea” in the KMS; these instances are elaborated and used to create new “concepts”, which are evaluated within the Collaboration Environment and possibly promoted to become “Prototypes”. The Product Service Configuration tool extracts descriptions of Prototypes from the Knowledge repository and sets up a workflow-like environment where different stakeholders can contribute to the complete definition of a PSS prototype, completing different types of “what-if” analysis (e.g. risk assessment, business models evaluation, technology maturity assessment, etc.) through the other FLEXINET tools. Results are returned and combined in the PSC interface, where all the accumulated knowledge is traced and shared.

5. PSCoMS tool exploitation

The exploitation of the PSCoMS tools that have been presented in this paper involves the main FLEXINET end-user interested in PSS Ideation and Design. It is a big Italian branch of a company operating in the whitegoods production field, having the mission of continuously innovating its business through a wider offer of services. Recently, it started working on product connectivity solutions and actually is proposing a set of connected devices (e.g. washing machines, dryers, fridges, etc.) addressing the smart home concept. However, it is still producing and selling products while services are almost commercial add-ons. In this context, the PSCoMS tools want to support the company design process to move in this direction.

The PSCoMS applications (i.e. IM, PSC, CE, UEA) delivers the following functionalities:

- IM has been developed to support the Open Innovation approach, where new ideas come from different actors, managing different accounts. New ideas can be submitted to the company by filling in a simple online form. Ideas that have been approved by a moderator can be shared with other users that can comment and/or vote upon them. Ideas should pass different evaluation steps and refinement phases, where the initial description is enriched with technical, economic and marketing details (through the lick to PSC), before being promoted to become a new PSS in the company’s portfolio. When several ideas describe a similar concept, they can be grouped together defining a “concept”. However, it is important to explain that to fully support the Open Innovation approach, the IM should be used in tight connection with the CE and PSC.
- CE allows the creation of virtual rooms (Obeyas) having specific participants, each with different access rights. The CE supports concurrent and asynchronous work in the same virtual rooms, and collaboration with team members both in the same physical place and at a distance. Within each room, many applications can be integrated to provide a wide set of services. In addition, web-based tools provided by third parties can be embedded into virtual rooms that are set up and thus made available to teams of people to support collaborative brainstorming and decision-making. Its key feature is the implementation of visual management, which is a clear, simple and effective way of organizing and presenting work.
- The P-S Configurator offers a set of functionalities to select and configure the PSS elements during the design phase. The descriptions of the PSS ideas are created in the Idea Manager as a result of an Open Innovation initiative. Therefore, integration with this application was envisaged, to describe more in deep the approved ideas. A process-driven approach guides the usage of PSC along the main steps that have to be accomplished to provide a complete configuration of the PSS generated by innovative ideas. The application generates a warning in case any step is not properly completed.
- The UEA supports users to create, complete and analyze the feedback from the customers, managing: feedback form design (questionnaire to collect feedback from users), feedback collection (questionnaire/forms available on-line), feedback analysis (user friendly graphical format to do feasibility analysis and the identify the requests that can be adopted).

5. Conclusions

The present paper shows how an Open Innovation based approach can be used to support the early stages of PSS design. In fact, the methodology described in the previous sections aims to support the processes involved in the ideation and design of a new PSS solutions thus going beyond the methodology focused only on the design of the final physical product, which will be delivered to customers.

Such methodology links the concepts of Open Innovation with the PSS design, where the PSS involves also the implementation of IoT to create a new value proposition. Indeed, the tools developed according to this methodology are applied in a real use case, involving an Italian manufacturing company that wants to develop new connected appliances exploiting the IoT principles.

The focus of this paper was to propose a new design approach for supporting the transition from a product-oriented approach to the creation of an innovative PSS solution. Therefore, the scope of this work is give an overview about how to approach the PSS design issue through the application of the PSCoMS tools developed within the FLEXINET project.

The PSCoMS has proved as an interesting set of tools, easy to use into an industrial company, even if it requires to build a structured knowledge base. It might be seen as a limitation, but this knowledge base, after a first input by the company, can be populated directly through the specific applications delivered by the PSCoMS (i.e. IM, CE, PSC, UEA. This makes such the tool more flexible to changes, which are properly of the industrial world.

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