The Player-Interface method: a structured approach to support Product-Service Systems concept generation

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Abstract

For manufacturing companies, the integration of service elements to support product offering has become a key factor in gaining competitive advantage. Product-Service Systems (PSSs) are value offerings that combine tangible products and intangible services. To date, their design process is still critical. There are several aspects that designers need to consider, including (i) the variety of PSS elements, (ii) potential interactions between PSS players and (iii) lasting customer relationships. Considering these issues, this paper proposes a novel operative tool, herein named Player-Interface (PI) method, to support designers in the definition of new PSS concepts. The method helps designers to activate new service or product elements based on the analysis of the possible interactions between the PSS players. The description is supported by a case study in the manufacturing sector.

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*Keywords:*Product-Service System; Concept design; Manufacturing; Servitization; Player interaction; Prioritization.

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1. Introduction

For years, manufacturing companies have treated services as a cost and not as an opportunity (Pistoni and Songini, 2017). Services have been considered just add-ons to products to compensate for product failures and to increase product life span (Maussang et al., 2009). Nowadays, the scenario is radically different. An increasing number of manufacturing companies are evolving rapidly from their traditional focus on tangible goods and technologies to an innovative approach that combines products and services (Adrodegari et al., 2018; Mastrogiacomo et al., 2019, 2018). Services are becoming increasingly integrated with products and are acting as an essential driver for company growth in globalized and competitive markets (Bustinza et al., 2015). The term that has been conventionally used to describe this process is "servitization" (Vandermerwe and Rada, 1988). While servitization refers to the progressive transformation of manufacturing companies, the term Product-Service System (PSS) refers to company output (Beuren et al., 2013). PSSs are integrated bundles of products, services and supporting infrastructures which are jointly capable of fulfilling specific client demands (Ding et al., 2016; Goedkoop et al., 1999; Manzini and Vezzoli, 2003).

PSS are attracting increasing interest from researchers and practitioners. However, according to several authors, there remains a paucity of guidance and methodological approaches that can be used by manufacturing companies to support their servitization processes (Lightfoot et al., 2013; Song, 2017; Mastrogiacomo et al., 2018). According to Lightfoot et al. (2013) "the principal research need is to engineer tools or techniques that practitioners can apply in service design, organizational design and organizational transformation". In particular, more attention is needed on the development of engineering tools to support the generation of innovative PSS concepts (Beuren et al., 2013; Trevisan and Brissaud, 2016; Giuditta Pezzotta et al., 2018).

Several aspects need to be taken into account when a PSS concept is defined: (i) PSS are heterogeneous value offerings composed of both tangible and intangible elements; (ii) a multitude of players interact and co-create value; (iii) players are involved across different phases of the PSS lifecycle and (iv) users can customize functions and integrate different elements in the PSS (Song, 2017).

This paper proposes a new approach to support the conceptual design of a PSS, i.e. the design activities required during the first stages of the PSS lifecycle in order to define product functions, service elements and network of players (Shimomura et al., 2015; Wang et al., 2002). Relying on an analysis of the interactions between the PSS players, the method – herein named as Player-Interface (PI) method – was developed with the aim of addressing two research questions: (i) how to support designers in defining innovative PSS concepts, including new service components?; (ii) how to prioritize the design goals for the following phases of the PSS development?

The remainder of the paper is structured as follows. After a brief introduction to the literature concerning PSS concept design in Section 2, Section 3 analyzes the design components of a generic PSS. Section 4 discusses the approach adopted for developing the proposed PI method. The method is then presented in Section 5 and exemplified in Section 6. The concluding section summarizes the original contributions of the paper, focusing on the benefits, limitations and possible future developments.

2. Literature Review

The design process of a PSS is a complex set of strategic and tactical activities, from idea generation to realization, used to create the design of an offering that includes services, physical products and infrastructures (Alonso-Rasgado and Thompson, 2006). The following sections provide a discussion of relevant literature on PSS concept and summarize various PSS concept design methodologies.

2.1. PSS concept design

Traditionally, the design process can be divided into two main phases: the conceptual and the practical design, respectively defined by Muller et al. (2009) as “what should be offered to the customer” and “how to realize this offering”. While PSS practical design, concerning single products, infrastructures and services, can be supported by traditional design tools (Morelli, 2006), the same does not hold for PSS conceptual design, which requires ad-hoc approaches to manage the complexity and the heterogeneity of the designed object (Qu et al., 2016).

PSS concept design, i.e. the definition of product functions, service elements, and network of players, is particularly critical since the final system is developed accordingly (Shimomura et al., 2015). For this reason, it is important to start off on the right foot and to promptly and comprehensively identify all the physical elements, services, functions and infrastructure that, together with the network of players, will constitute the designed PSS (Bertoni et al., 2013). To this end, the integration of product functions and service activities should be taken into account from the early stages of PSS generation (Aurich et al., 2006a; Alonso-Rasgado and Thompson, 2006).

2.2. Overview of PSS concept design methodologies

A variety of methodologies addressing different issues of PSS concept design have been suggested (Barravecchia et al., 2019; Qu et al., 2016; Vasantha et al., 2012).

Shimomura and colleagues defined a methodology to maximize customer value by considering the mutual effects of synergy, alternatives, and complementarity (Shimomura et al., 2015). Morelli developed a methodological tool, to support designers in the generation of innovative solutions including products and services (Morelli, 2009). Lim et al. presented a structured tool called "PSS Board" to visualize the PSS development process and to support the PSS design (Lim et al., 2012). The "PSS board" consists of a matrix where the customer activities, state of the products, services, dedicated infrastructures, and partners are placed in rows, and the general PSS process steps are placed in columns. Pezzotta et al. (2012) discussed a spiral process model to engineer a PSS that takes into account the iteration process and the customer involvement with a comprehensive lifecycle perspective. Carreira et al. (2013) extended the Kansei engineering method including the analysis of the different players that collaborate within the PSS.

Different authors have proposed methods to evaluate PSS concepts in early design phases: (i) Kimita et al. (2009) proposed a method for the estimation of customer satisfaction at the conceptual stage of the PSS design; (ii) an evaluation method aimed at increasing the likelihood of success and reducing risk of a PSS solution was proposed by Yoon et al. (2012), the method considers the perspectives of service providers as well as customers, to evaluate innovative PSS concepts not yet applied in the real market; (iii) Lee et al. (2015) elaborated a method for assessing the acceptability of PSS concepts by customers; (iv) Barravecchia et al. (2018) developed the Service Relationship Deployment (SRD), a practical tool which aims at evaluating the impact on perceived quality resulting from the combined offering of different services.

Despite the variety of proposals found in the literature about PSS concept design, a design tool that simultaneously takes into account the distinctive characteristics of PSS is still needed (Song, 2017). Through a structured analysis of the elements of a generic PSS, this paper aims at filling this gap by proposing a novel approach for supporting the generation of PSS concepts in the early stages of PSS development. The Player-Interface (PI) method is based on the systematic definition of the PSS concept considering all the possible interactions across the different points of contact, namely interfaces, among PSS players.

3. PSS design components

The definition of a PSS concept requires the understanding of the PSS design components and their possible relationships (Aurich et al., 2006a, 2006b). This section provides a description of the basic PSS components to be considered during the PSS concept design process: PSS value elements, PSS interfaces and PSS service typologies.

3.1. PSS value elements

In general, a PSS can be considered as a system composed of four basic elements: products, services, players and infrastructure (Goedkoop et al., 1999; Beuren et al., 2013), where:

- *Products:* are tangible elements of a PSS. Their peculiarity is that their production can be achieved without any interaction between producer and customer.
- *Services:* are the intangible elements of a PSS. Services are characterized by activities performed at the interface between the provider and the customer. Dominant outcomes of a service are generally intangible.
- *Players:* are the people or organizations that contribute to the creation of the PSS value through their mutual interactions.
- *Infrastructures:* are tangible elements of a PSS. Infrastructures are the underlying bases or foundations of PSS. They may include the basic facilities, networks and installations needed for the proper functioning of the system.

Products, players and infrastructures interact and co-create value acting either as customers or providers of the service elements of a PSS, where *customers* are the elements that could or does receive a service and *providers* are the elements that provide a service (Rese et al., 2013; International Organization for Standardization, 2015; Mastrogiacomo et al., 2016). As an example of the double role of a PSS player, consider the case of the provider of technical support services which can be seen either as a provider when offering the service or as a customer when buying spare parts from the producer company.

3.2. PSS interfaces

We define as PSS interface the place at which customers and providers of a PSS meet, act or communicate with each other. According to Manzini and Vezzoli (2003), PSS interface design should represent the starting point in the development of a novel PSS concept. The possible interfaces at which the different players may interact by exchanging services are classified into two categories:

- *Product-Embedded Interface:* provider and customer interact through the tangible elements of a PSS. Using its own resources, the provider offers services to the customer through the use of the product. The product represents the physical platform through which services are delivered (Lay et al., 2010). As an example of Product-Embedded Interface, consider a smartphone that acts as interface between different players and serves as platform for the delivery of a variety services.
- *Product-Related Interface:* customer and provider interact directly, without the filter of the physical product. However, the interactions between the two players would not take place without the presence of the physical product. As an example of Product-Related Interface, consider the interaction between a manufacturer and a customer during the provision of a technical support service.

3.3. PSS service typologies

This section proposes a taxonomy of the intangible elements of a PSS with the aim of introducing and clarifying the notation that will be used in the rest of the paper. This taxonomy is presented with respect to the types of player and interface introduced in the previous sections:

- *Functions*: the kind of action or activity that the tangible element (product or infrastructure) is designed to provide autonomously, without direct interaction with external players (Muffatto and Roveda, 2002; Ulrich, 1995). By definition, functions are provided at the product-embedded interface. As an explanatory example, consider the brake pads of a vehicle. Their function is to exert a braking action on the discs and consequently on the vehicle.
- *Product-embedded services*: services provided through the tangible elements of a PSS, thus at the product-embedded interface (Abramovici and Filos, 2011). A provider uses the product as a means of delivering and distributing services to its customers. An example is the service of real-time traffic information provided through the car navigation system (product) to the driver.
- *Product-related services*: services in which the interface is product-related. The provider therefore delivers and distributes services without directly exploiting products that are part of the PSS (Aurich et al., 2006a). Providers and customers interact directly without using PSS products as a medium. In this kind of services, the provider can use products to provide the services, but products are not core to value delivery. As an example, if considering a car, product-related services are all the support services ranging from technical assistance to assurance or financing services.

  In this paper, the generic term "service" will be used in its broadest sense to refer to either functions or product-embedded services or product-related services, whenever a distinction between them is unnecessary.

4. Methodology development

The proposed PI method has been developed considering both insights and requirements from industrial partners and literature gaps. Following previous studies (Peffers et al., 2012; Grenha Teixeira et al., 2017; Hevner et al., 2004), the key activities carried out during the development of the PI method can be listed as follows:

1. *Identification of the problem and motivation*: the review of the literature on the available methods to support the PSS concept design and the collection of insights

from industrial partners provided the basis for the development of the PI Method. Section 2 provides an updated overview of the literature concerning the topics.

2. *Definition of objectives*: the PI method objective is to support a design team in the definition of a PSS concept. Based on a structured analysis that merges customer and designer perspectives, the PI method integrates two steps of the development process of a PSS: the concept generation and the prioritization of the design goals for the following phases of the PSS development.
3. *Design and development*: the combination of the theoretical foundation presented in the literature review (see Section 2) and the analysis of the interacting PSS design components (see Section 3) served as inputs for the development of the PI Method.
4. *Demonstration*: a series of applications in distinct manufacturing sectors were analysed, showing how the PI method can support PSS concept design. Section 6 proposes an excerpt of application.

5. The Player-Interface method

This section describes a structured approach for the definition of a PSS concept and the prioritisation of the composing service and function elements. For PSS, a "heterogeneous team, possessing divergent expertise, must collaborate in early development to nourish both a service and a product perspective" (Ericson and Larsson, 2009). The design team should be able to take into account all the stages of a PSS lifecycle and to interface with the future PSS users in order to understand their needs (Aurich et al., 2006b).

The Player-Interface (PI) method leads the design team in the identification of the services and functions (see Section 3.3) exchanged between the elements of the PSS (see Sections 3.1), depending on the interface types (Section 3.2). The method is based on the use of a set of different matrices that are meant to be applicable in different contexts: either when all the elements of the PSS must be defined or when a part is already existing. For this reason, not all the entries are required to be filled. The different matrices guide the activity of the design team by stimulating the analysis of all the possible combinations of elements and interfaces of the PSS so as to consider all the relevant dimensions of the concept. More specifically, the Player-Interface method can be structured into three phases (see Figure 1): (i) the preliminary analysis; (ii) the PSS concept generation and (iii) the PSS concept prioritization.

In the following sections, the operative steps of the method are presented. The application of the method is shown in Section 6 where a case study is discussed.

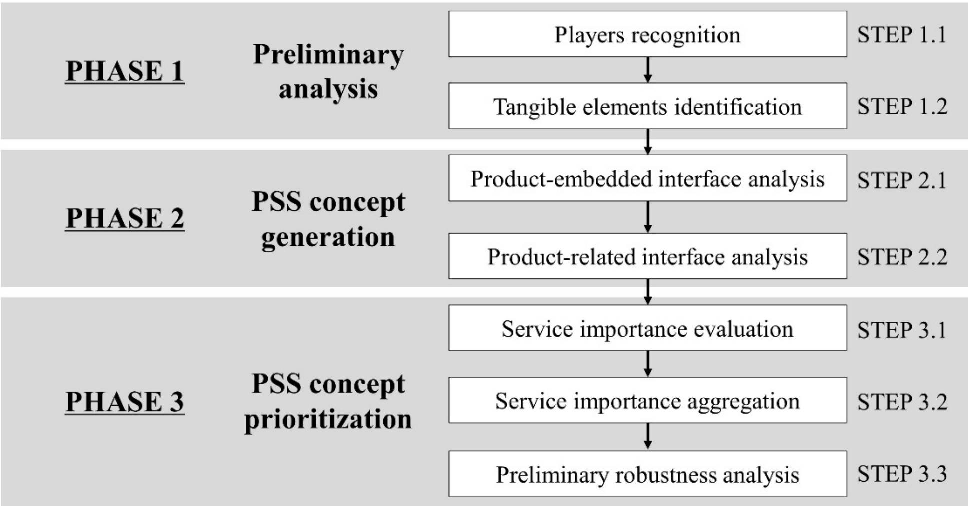

Figure 1. Flowchart description of the PI method

5.1. Phase 1: Preliminary analysis

To properly generate an innovative PSS concept, the design team should provide some fundamental inputs. The preliminary analysis aims at identifying key contextual elements that will be used to generate the novel PSS concept. This phase can be divided in two steps:

- *STEP 1.1 – Players recognition*: the network of players interacting within the PSS should be defined. When developing a new PSS, it is necessary to identify the network of players early in the project, since they are considered as inputs for the development of the entire system (Maussang et al., 2009).
- *STEP 1.2- Tangible elements identification*: the tangible elements of the designed PSS need to be identified. The analysis of interfaces (see Section 3.2) highlighted the need for physical systems (product and infrastructures) to link players, distribute functions and deliver services. In this step it is, therefore, necessary to identify which types of products will constitute the PSS and which infrastructures, existing or to be designed, will support the designed PSS.

5.2. Phase 2: PSS concept generation

The second phase aims at defining the services and the functions of the PSS. With the purpose of supporting this process, a visualization tool, called Player-Interface (PI) Matrix, is proposed (see Figure 2). The use of matrices is thought to help the design team to clarify and rationally analyse all the opportunities to enable new value exchange between PSS elements. Each element (S^{i}_{pcj}) of the PI matrices defines a specific service exchanged within the PSS, where:

- *i-th* is the interface at which the service is provided; *i* ∈ *{product-embedded interface; product-related interface}*;
- *p-th* is the PSS element that provides the service; *p* ∈ *{product, infrastructure, service}*;
- *c-th* is the customer of the service; *c* ∈ *{product, infrastructure, service}*;
- *j-th* is a generic service; *j* ∈ *{1,…,m}*;
- *m* is the number of different services within a specific cell of a Player-Interface Matrix

In the following two steps the design team is responsible for the filling of the PI matrices respectively related to the Product-Embedded and the Product-Related interfaces:

- *STEP 2.1 - Product-embedded interface analysis*: this step is aimed at the identification of the intangible elements exchanged between players, product and infrastructure at the Product-embedded interface (see Figure 2(A)). These services are generally referred to as function or product-embedded services.

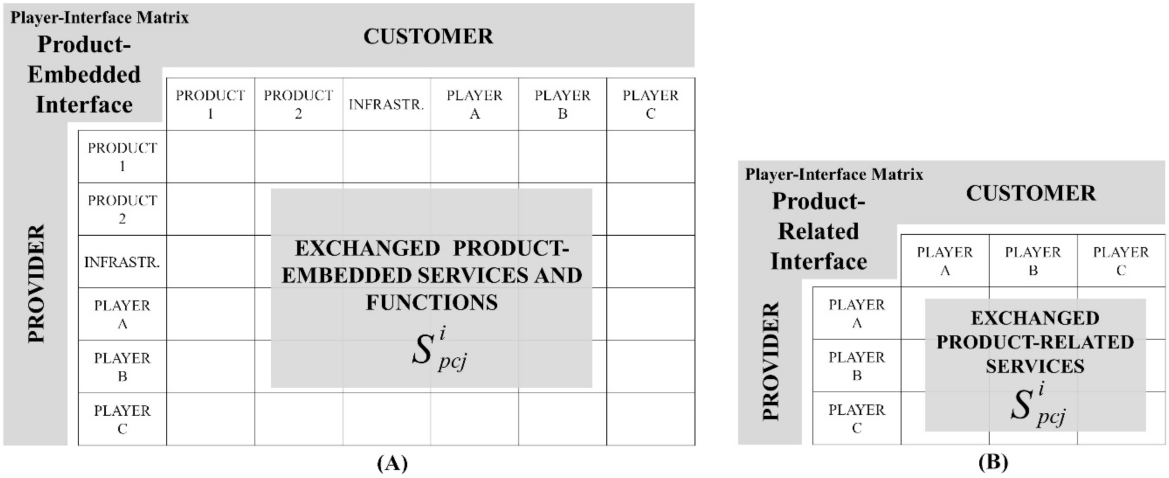

Figure 2. (A) Generic PI matrix related to the product-embedded interface. (B) Generic PI matrix related to the product-related interface (products and infrastructures are not herein considered since they cannot provide any service at the product-related interface)

- *STEP 2.2 - Product-related interface analysis*: this step is aimed at the identification of the service elements of a PSS exchanged by the players at the product-related interfaces (see Figure 2(B)), i.e. when the players directly interact with each other. These services are generally referred to as product-related services.

We highlight that the described method is intended to be iterative: it can happen that the identification of a product-related service requires specific product functions or infrastructures that the design team must indicate in the related form of the method (iteration between step 2.2 and step 2.1), if not previously planned.

5.3. Phase 3: PSS Concept prioritization

The last phase of the proposed methodology aims at prioritizing design goals. This phase can be described again in two steps:

STEP 3.1 – Service importance evaluation: for each element (S_{pcj}^{i}) of the PI matrices, the design team must gather the importance (I_{pcj}^{i}) of each service or function by customers. The importance I_{pcj}^{i} can be defined as the importance given to each S_{pcj}^{i} by the c-*th* customer. In detail, the importances I_{pcj}^{i} are obtained by a sample of potential customers. Different choices of assessment scale are possible, however, in the early development phases, customers are usually unable to provide detailed assessments, so customer preferences are gathered on a simple ordinal scale (Barravecchia et al., 2018).

In this view, we followed symbolic notations used in QFD model (Franceschini and Rossetto, 1998). The importance is codified on a 3-level ordinal scale: strong (⊙), moderate (○) and weak (△).

In order to obtain specific evaluations, potential customers are supported by a summary table of the assessment criteria (see Table 1) and are informed by the design team about the prioritization method.

As illustrated in the matrix in Figure 3, all the PSS services and functions need to be associated with a symbolic evaluation of importance.

Table 1. Importance evaluation criteria

Symbolic evaluation	Label	Importance criteria	Assigned numerical value
⊙	Strong importance	The function or service is of primary importance for the customer. OR It will be useful in many of the activities related to the use of the PSS.	9
○	Moderate importance	The function or service is of secondary importance for the customer. OR It will be useful in some of the activities related to the use of the PSS.	3
△	Weak importance	The function or service is of marginal importance for the customer. OR It will be useful in a few of the activities related to the use of the PSS.	1

Different aggregation methods can be used to process information about service importance (Marichal and Mesiar, 2009). If, for example, the evaluations of all respondents are considered equally important, the mode or median of their distribution can be used.

- *STEP 3.2 – Service importance aggregation*: the symbolic evaluations of importance (given in Step 3.1) are aggregated in this step. Given the double role played by PSS elements (i.e. customer and provider), a pair of indicators are defined to drive the future decision of the design team:

- *Customer Importance Rating (CIR_c):* it is defined as the ratio between the importances of services and functions received by a PSS element (i.e. the sum of the importances in the columns of the PI matrices associated to a specific PSS element) and the overall sum of importances contained in all the PI matrices. It can be calculated as follows:

$$CIR_c = \frac{\sum_i \sum_p AI_{pc}^i}{I_{TOT}} \quad , \tag{1}$$

being AI_{pc}^i the sum of the importances of all the services provided at the *i-th* interface by the *p-th* provider to the *c-th* customer (the sum of the importances of all the services contained in a cell of a PI matrix) and I_{TOT} the total amount of the importances (the sum of the importances of all the services contained in all the PI matrices):

$$AI_{pc}^i = \sum_j I_{pcj}^i \tag{2}$$

$$I_{TOT} = \sum_i \sum_p \sum_c AI_{pc}^i \tag{3}$$

The CIR_c represents the priority to be given to the *c-th* PSS customer by the design team in the development process. Since the CIR_c represents the aggregated importance of the services and functions exploited by a specific PSS element, the higher the value of CIR_c, the higher the weight of the PSS element must have in the definition of the PSS requirements. Requirements and needs of the PSS elements with high CIR_c must have a greater influence on the design choices compared to those with low CIR_c.

- *Provider Importance Rating (*PIR_p*):* it is defined as to the ratio between the importances of services and functions provided by a PSS element and I_{TOT}. It can be calculated as follows:

$$PIR_p = \frac{\sum_i \sum_c AI_{pc}^i}{I_{TOT}} \tag{4}$$

The PIR_p represents the priority to be given to the development of services or functions provided by the *p-th* PSS elements. It may be linked to the priority in the allocation of resources. PSS elements with a high PIR_p contribute to prove services and functions with higher aggregate importance and consequently deserve more resources and attentions for their development.

As a preliminary approach, for the calculation of CIR_c and PIR_p indicators, we suggest the adoption of a simple scoring method in which symbols are converted into numerical values (as reported in Table 1: Weak = 1, Moderate = 3, Strong = 9). It should be emphasized that the process of converting ordinal assessments into cardinal assessments, in general, is an arbitrary operation. Ordinal scales establish a priority order among objects without providing any indication of their distance in the ranking (Franceschini, 2002). However, considering that the goal of the PI method is to provide a preliminary outline of the PSS concept, such operation can be tolerated. Finally, it is important to point out that other techniques, such as the Analytic Hierarchy Process method, may be applied to prioritize services/functions, as alternatives to the proposed approach (Saaty, 1986, 2008).

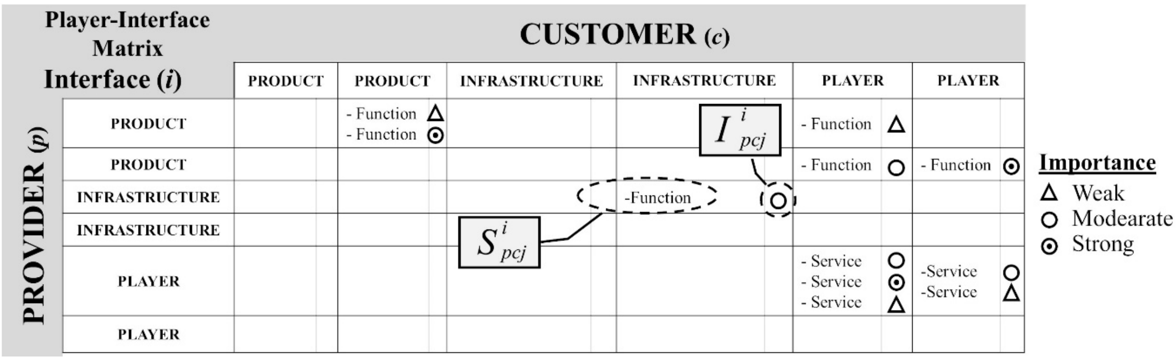

Figure 3. PI Matrix for PSS concept prioritization. The importance assigned by the customer is reported next to the related service or function. Importances of services and functions are codified by the following ordinal scale: Strong importance (⊙), moderate importance (○), weak importance (△).

- *STEP 3.3 – Preliminary robustness analysis:* in this step, we propose a preliminary discussion of the robustness of the CIR_c and PIR_p indicators. In line with QFD literature, we adopt a robustness analysis based on the approach suggested by Ghiya et al. (1999). We propose to use four different options in the numerical conversion of the symbolic ordinal assessments of importance (see Table 1), replacing the conventional 1-3-9, with: (i) 1-3-7 (decrease of the strong importance); (ii) 1-3-5 (further decrease the strong importance); (iii) 0-3-9 (decrease of the weak importance) and (iv) 1-2-4 (changing the base of the exponential scale from 3 to 2) (Ghiya et al., 1999).

  The sensitivity of the PIR_p indicator can be evaluated by means of the Root Mean Square (RMS) deviation in the obtained results, calculated as follows:

$$RMS\ deviation\ (PIR_p) = \sqrt{\frac{1}{4}\sum_{i=1}^{4}\left[PIR_p(original) - PIR_p(replacement\ _i)\right]^2}, \qquad (5)$$

where $PIR_p(original)$ represent the PIR_p indicator calculated using the conventional conversion 1-3-9, while $PIR_p(replacement\ _i)$ represent the PIR_p indicator calculated using the four alternatives numerical conversions (1-3-7; 1-3-5; 0-9-3 and 1-2-4).

In a similar way, the sensitivity of the CIR_c indicator can be evaluated as follows:

$$RMS\ deviation\ (CIR_c) = \sqrt{\frac{1}{4}\sum_{i=1}^{4}[CIR_c(original) - CIR_c(replacement\ _i)]^2}. \qquad (6)$$

6. Application case

This section proposes an application of the PI method to the development of a new PSS concept. The case study is a simplified excerpt of a more complex application analysed by the authors. Specifically, the analysis refers to the development of an industrial-PSS including collaborative robotics systems (cobot). The company aims at developing an innovative PSS where the product is supported by a variety of services in order to compete against bigger competitors in the quickly evolving cobot industry.

6.1. Phase 1: Preliminary analysis

The first phase of the PI method entails all the activities aimed at defining the network of players and the tangible elements (products and infrastructures) of the PSS. This phase is described in the following two steps:

- *STEP 1.1 – Players recognition:* the design team defines the different players that will interact in the PSS (see Table 2). Four player categories are defined: producer company, national distributors, operators and specialized technicians. Other possible players could have been taken into account, such as programmers or owner companies but, given the pedagogical aim of the proposed application and their minor role, they are not herein considered.

- *STEP 1.2 - Tangible elements identification:* the cobot are the main product components considered. Cobots are robots intended to physically interact with humans in a shared workspace, that can be easily integrated into existing production contexts. The market in which the company plans to establish its presence is that of single arm cobots with payloads up to 5 kg. The design team also included as infrastructure a web platform that enables a series of e-services.

Table 2. Applicative example – PSS players

Player category	Description
Producer company	Producer company develops and produces cobots, also providing some complimentary services.
National distributors	PSS is sold and distributed worldwide through a network of national distributors.
Operators	Operators collaborate with cobots in production or service delivery environments
Specialized technicians	National distributors hire a network of independent specialized technicians to provide technical support to customers.

6.2. Phase 2: PSS concept generation

Once the general PSS framework (players, products and infrastructures) is defined, the design team can proceed with the definition of PSS intangible elements (functions and services):

- *STEP 2.1- Product-embedded interface analysis*: the PI matrix supports the design team in identifying a whole range of services and function that PSS elements can exchange though the cobots and the web platform (see Figure 4).
  More in detail, in addition to the features that cobots provide to the operators (e.g. quick set-up and removal or the capability of connecting universal add-ons and end effector to the robotic arm) additional features have been developed for the other players of the PSS. In particular, specific functionalities for distributors (e.g. demonstrations of the operational potential of the cobot) and technicians (e.g. ease of repair and replacement of components) have been introduced. The PI matrix also supported the design team in identifying a whole range of services that players can receive and provide through the

web platform. For example, the producer can provide e-learning courses to operators and specialized technicians with the objective of improving their performance and optimizing the use of cobots and human-machine interaction. Through the web platform, operators will be able to visualize statistics and insights on the functioning of cobots in order to improve their efficiency. Specialized technicians can receive real-time notifications about problems or malfunctions in order to ensure prompt intervention and avoid production interruptions.

- *STEP 2.2- Product-related interface analysis*: Figure 5 presents the PI matrix developed for the case study. A variety of product-related services have been taken into account, ranging from technical to training and advisory services. By way of illustration, the PSS concept includes spare parts delivery services, technical support services, development of customized solutions and 24/7 hotline with experts always ready. The producer company and national distributors can also offer a series of courses and tutoring activities in order to improve the implementation of the new technology in the customers' production systems. Given their proximity to the market, specialized technicians can offer many services to meet the needs of end customers, such as on-site services, programming of cobots and production cells, development of ad-hoc software, preventive maintenance, refurbishment and modernization of the installed robotic systems.

Player-Interface Matrix — Product-Embedded interface

PROVIDER \ CUSTOMER	Cobot	Web platform	Producer company	National distributors	Operators	Specialized technicians
Cobot		- Transmission of data and performance statistics ○		- Keep human operators safe ⊙ - Easy programming by hand-guiding △ - Demonstrative task and activities of manufacturing applications ○	- Quick Set-up and removal ○ - Easy programming by hand-guiding △ - Universal add-ons and end effector ○ - Plug+play ○ - Keep human operators safe ⊙ - Real-time data to monitor, troubleshoot and improve production performance △ - Adaptable for different uses ○ - Assist operators in tasks or processes ⊙ - Connectivity with industrial control systems ○	- Wear sensors △ - Easy to repair ⊙ - Keep human operators safe ○ - Easy replacement of wear parts ⊙
Web Platform	- Connection to manufacturer systems ⊙		- Data collection on cobot operation ⊙ - Collecting reports and feedback from players ○		- Real-time reporting of malfunctions and maintenance requests ○	- Real-time reporting of malfunctions and maintenance requests ○
Producer company					- Software upgrades ○ - Online seminar ○ - Technical documentation △	- Software upgrades ○ - Online seminar ○ - Technical documentation ⊙
National distributors						
Operators						
Specialized technicians						

Figure 4. Applicative example – PSS Cobot: PI Matrix related to the **product-embedded interface**. Importances of services and functions are codified by the following ordinal scale: Strong importance (⊙), moderate importance (○), weak importance (△).

Player-Interface Matrix — Product-Related interface

PROVIDER \ CUSTOMER	Producer company	National distributors	Operators	Specialized technicians
Producer company		- Supply of spare parts ⊙	- 27/7 technical hotline ⊙ - Courses and tutoring activities ○ - Development of customized solutions ○ - Technology consulting △	- Courses and tutoring activities ⊙ - Supply of spare parts ○
National distributors	- Usage statistics ○		- 3D offline simulation ○ - Process and system optimization △ - Supply of spare parts ○ - Courses and tutoring activities △	
Operators	- Usage statistics ○			
Specialized technicians	- Usage statistics ○ - Warranty services to end customers ⊙		- On-site service ⊙ - Robot and system programming ⊙ - Ad-hoc software development ○ - Preventive maintenance ○ - Maintenance agreement △ - Refurbishment and modernization △ - Supply of spare parts ⊙ - Risk analysis △ - Warranty ⊙	

Figure 5. Applicative example – PSS Cobot: PI Matrix related to the **product-related interface.** Importances of services and functions are codified by the following ordinal scale: Strong importance (⊙), moderate importance (○), weak importance (△).

6.3. Phase 3: PSS concept prioritization

The last phase of the PI method concerns the prioritization of the design goals:

- *STEP 3.1– Service importance evaluation*: Figure 4 and Figure 5 show the evaluation of service and function importances. This assessment is done by customer interviews (focus-groups). For example, operators considered "safety" strongly important, while "real-time monitoring" weakly important. Similar assessments were made for all services and functions in the PI matrix.

- *STEP 3.2 – Service importance aggregation*: importances (I_{pcj}^{i}) are combined in order to calculate the CIR_c and PIR_p indicators (see Eq.1 and Eq.4). For example, the CIR indicator related to the player category "Specialized technicians" is calculated as the ratio between the sum of the importances of the functions and services received by specialized technicians and the sum of all the importances attributed to all the functions and services of the PSS (see Figure 4 and Figure 5):

$$CIR_{Specialized\ technicians} = \frac{\sum_i \sum_p AI_{pc}^{i}}{I_{TOT}} =$$

$$= \frac{(1+9+3+9)+(3)+(3+3+9)+(9+3)}{230} = 0.23$$

Table 3 reports the final results of this analysis. Given their high values of CIR_c, operators and specialized technicians resulted to be the most important customer categories. An in-depth consultation of their needs and requirements is critical for the success of the PSS development. On the other hand, from the Provider point of view (PIR_p), a greater priority should be given to the development of: (i) functions performed by the product cobot; (ii) service delivery processes managed by the producer company and (iii) services provided by specialized technicians.

- *STEP 3.3 – Preliminary robustness analysis:* for each of the CIR_c and PIR_p indicators, a measurement of result robustness has been quantified according to Eqs. 5 and 6. Table 3 shows the values of $RMS\ deviation\ (CIR_c)$ and $RMS\ deviation\ (PIR_p)$. This preliminary analysis proves that, for this specific case, the deviations derived from the numerical conversion does not have substantial effects on the outcomes.

Table 3. Applicative example – CIR_c and PIR_p - $RMS\ deviation\ (CIR_c)$ and $RMS\ deviation\ (PIR_p)$.

	Cobot	Web platform	Producer company	National distributors	Operators	Specialized technicians	TOTAL
$\boldsymbol{CIR_c}$	0.04	0.01	0.13	0.10	0.50	0.23	1
$RMS\ deviation\ (CIR_c)$	0.006	0.003	0.004	0.007	0.019	0.008	
$\boldsymbol{PIR_p}$	0.32	0.12	0.26	0.05	0.01	0.25	1
$RMS\ deviation\ (PIR_p)$	0.002	0.004	0.002	0.013	0.003	0.015	

7. Conclusion

Although extensive research has been carried out on PSS, relatively little attention has been paid to the definition of methodologies and practical approaches to support PSS concept design. Nowadays, a design tool that simultaneously takes into account the distinctive characteristics of PSS is still needed (Song, 2017; Trevisan and Brissaud, 2016; Giuditta Pezzotta et al., 2018).

Trying to overcome this gap, the paper presents the PI method, a structured approach to assist the design of a PSS in its early development phases. The PI method stimulates PSS designer in the systematic development of the PSS concept and in the complete and exhaustive definition of a PSS concept in the form of a list of functions and services the PSS should include and provide. The method assists the design team in a structured analysis of all the combinations of players, products, infrastructures and PSS interfaces. Moreover, the PI method supports the prioritization of the design goals for the following phases of the PSS development.

This paper also proposes an excerpt of application of the PI method to a real case study. The application evidences the effectiveness of the method in supporting the design team in developing complex PSSs involving a variety of service elements provided by different players.

The method can be applied to: (i) identify the service elements of a PSS when products and infrastructures already exist, (ii) systematically design the services and product elements when the infrastructure is available or (iii) produce a concurrent design of all the elements of a PSS.

Furthermore, it can be integrated with tools capable of: (i) translating the PSS concept into services and product technical specifications and (ii) comparing different PSS alternatives considering many benchmarking criteria, such as customer satisfaction and cost-effectiveness.

The method can be enriched with a preliminary technical and economic analysis of feasibility of the proposed solution which will be the object of further developments.

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