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A QFD-based methodology to support Product-Service design in manufacturing industry

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Abstract — Recently manufacturing enterprises are challenged by the transition from product-centered solutions to the new concept of Product-Service System (PSS). However, designing a new PSS implies the definition of new specifications and the integration of the necessary assets to create a coherent system. This paper presents a QFD-based methodology to support manufacturing companies moving from products to services by focusing on product-service design. It starts from the analysis of the target market and customer needs, and correlates them with the functionalities and with the assets offered by the company ecosystem. The method is validated on a real case study where a white goods producer wants to innovate its business by service-based solution. Assets are virtualized and selected with the final scope to design a highly sustainable PSS. The case study considers the design of a predictive maintenance service for dryers, which includes the product enhanced with advanced HW and SW components, a remote service for product monitoring and data elaboration, and a web / mobile application for customer interaction and service provisioning.

Keywords — *Product-Service System (PSS); Product-Service design; Sustainability; Ecosystem assets analysis; Industrial case study.*

I. INTRODUCTION

Product-service design actually represents a new way towards responsible innovation for industry. In particular, the product-service concept consists of proposing a mix of tangible products and intangible services designed and combined to optimize the product use and performances [1]. As a consequence, it offers an easy way to reuse and restyle the company products by adding services and a proper infrastructure with the final scope to increase the value for customers and create value through an extended business network. The product-service idea starts from the concept of extended product [2]: it indicates the tangible product as the core of a service shell, where a set of intangible services is incorporated to support or differentiate the product use by adding new functionalities. In particular, the term Product-Service System (PSS) refers to the mix of the tangible product, the related services, the enterprise network and the infrastructures needed [3].

In the context of product innovation PSS can bring numerous advantages to manufacturing companies: on one hand they support the product use and interaction with the customers during the operation stage by offering new features and interfaces [4]; on the other hand they can be added to

product with low impact for manufacturers and they can be realized at low-cost [5]. Furthermore, they can benefit on global sustainability by reducing consumption and emissions during the lifecycle as well as reducing global operating costs, thanks to a more controlled and conscious use of the product itself [6].

However, designing and producing a PSS opens new issues for manufacturing companies: a new PSS cannot be realized by simply adding services to the traditional product, but requires a deep analysis of the functionalities to be created and the assets needed in order to define the new design specifications, involve the right partners and define the successful business model. Furthermore, the product-service idea overcomes the traditional product models and the boundaries of the single company, so companies require new methods to work together, to properly design the new solution, and to manage the activities along the product-service lifecycle. As a result, if traditional product-based solutions could be designed and managed by the manufacturer company and its supply chain, PSS design and management requires new methods and tools. In particular, design is the most strategic phase and requires the virtualization of the assets and their definition from a more complex scenario. Such a scenario is a new ecosystem dedicated to PSS, which replaces the single enterprise and takes over the lifetime responsibilities for the new PSS.

In this context, the paper proposes a structured methodology to identify the product-service functionalities starting from a new PSS idea, and select those tangible and intangible assets needed to realize it. It is based on Quality Functional Deployment (QFD) technique [7]; it correlates the customer needs with the new design functionalities and the necessary assets, and finally select the assets according to the global sustainability achieved. The paper also provides an example of its application to an industrial case study: it describes the main results and highlights the main advantages connected with the method application for manufacturing companies.

II. PRODUCT-SERVICE IN MANUFACTURING INDUSTRY

A. Service innovation for manufacturing companies

In the modern industrial scenario, numerous manufacturing enterprises are moving from a product-oriented business model to a new extended service-oriented one, that consists of adding a wide range of services [8] in order to increase the product value perceived by the customers. In literature this shifting is defined in several ways [9]: one of the most representatives is

based on the concept of Product Service System (PSS), that brings to a novel understanding consisting of integrated product and service shares. It represents a new trend for industries to innovate their artefacts and create fresh business opportunities. Its development within the manufacturing industry can be realized through the implementation of servitization process.

The introduction of PSS in manufacturing firms opens new scenarios exploiting services. On one hand they can bring new business opportunities and gain new market shares; on the other hand they force product-centric firms to consider also the service dimension into their strategic analysis [10] and evolving such processes that affected by services. For instance, optimizing the delivery process as well as creating new customer interface and new buyer-seller relationship [11] represents the core of service innovation and is fundamental for service implementation. However, compared to product innovation, there is a limited understanding about service and service innovation so far, especially in manufacturing industry [12-13].

In order to implement service innovation within a manufacturing company, three different approaches have been defined. The first one considers service innovation as an extension of product innovation and service is managed similarly to the product. The second way considers service innovation as separated from product innovation, where product activities relate to all tangible goods and service activities refer to the intangible ones; as a consequence, the two flows usually run in parallel. The last approach is the most recent and considers service innovation and product innovation as interrelated processes, whose activities are strongly linked and sometimes synchronized, so that we have a real Product-Service co-creation [14]. Such co-evolution is hard to realize and requires tailored methods and tools. Contrarily the analysis of the commercial tools available for industry highlighted the lack of dedicated methods for product-service co-evolution and PSS-supporting tools. That is the reason why product-service design and management are still highly problematic.

B. Tangible and intangible assets for product-service

The product-service concept has its foundations on the combination of tangible and intangible assets. Basically, tangible assets refer to material resources and generally are whatever kind of physical objects with economic value [15]. They are distinguished into manufacturing assets and product assets; manufacturing assets include machines, tools, material, work place equipment, material flow components, control systems, storage systems, and the manufacturing environment (building, air conditioning, cleaning); whereas product assets are the physical product components. Contrarily, intangible assets are defined as the essence of knowledge, and whose nature can be defined and recorded as immaterial resources like human capitals or relationships capitals [16]. They can be divided into intellectual property (those assets for which the organization has property rights) and knowledge assets (those assets for which the organization does not have property rights), such as accounting, strategy, human resource management, information systems, knowledge management [17]. In order to create a PSS, intangible assets play a

fundamental role in the value creation process. Furthermore, it is important to note that tangible and intangible assets have a lot of mutual interactions within the manufacturing ecosystem; for instance, a drilling station provides “holes per hour” and often operates in combination with relevant expertise and knowledge. Assets may be classified according to their entity (i.e. tangible or intangible) or to their use, as proposed to the market (i.e. owned or serviced). In this way interrelations between tangible and intangible assets can be represented by four entities: products, extended products, hybrid products, and pure services. The servitization process leads the way lower to upper level, thus replacing the general meaning of possession of an object by using a function.

In order to describe and represent assets in servitization, several languages have been adopted. The first developments of service languages concerns Service-Oriented Architectures (SOA) and XML is the common representation of web service languages over the years. After that, different standard bodies have specified many languages, but the most prominent language to describe services is the USDL, i.e. Unified Service Description Language [18]. USDL has been built and assessed in a collaborative and interdisciplinary way by the contribution of researchers such as computer scientists, security and SLA experts, business economists, and legal scientists from different countries. It starts from modeling passing to identification of knowledge of bodies and methodologies, finishing with rules to efficiently manage the virtualization process. It allows representing both tangible and intangible assets within a manufacturing environment and it has been successfully adopted for similar purposes in manufacturing ecosystems also by recent research works [19]. It has two main advantages: it allows representing into a unique framework tangible and intangible assets and it fits the requirements of a complex ecosystem (not only of a company).

For these reasons, USDL can be used to virtualize the ecosystem assets and to compose them “on the fly” in order to create a product-service solution and the relative PSS. However, the authors believe that such a composition must be properly driven by market needs and design functionalities to be valuable, and assets virtualization and selection must follow the market requirements and design constraints. Contrarily, researched cared about assets classification and representation but lacks in properly driving such virtualization and selection according to the design purposes.

C. Sustainability assessment of tangible and intangible assets

Services are predicted to provide great advantages on sustainability according to all the three dimensions considered by the modern sustainability thinking: environment, economics and social wellbeing [20]. Indeed, from the economical viewpoint, services can create higher profit margins and contribute to higher productivity by means of reduced investment costs along the lifetime as well as reduced operating costs for the final users [21]; from an ecological viewpoint, product-services can be more efficient thanks to a more conscious product usage, increased resource productivity and a close loop-chain manufacturing [22]; finally, services are able to realize a socially advanced scenario by ensuring knowledge intensive jobs and contributing to a more

geographically balanced wellbeing distribution [23]. As a consequence, potentially services can achieve such benefits, but their effective achievement depends on the final PSS arranged. As the feasibility of a certain solution and the market perception is recently strongly influenced by its sustainability, assessing sustainability becomes a key factor in comparing design alternatives and choosing the most promising solution to be realized.

In industry product sustainability can be accomplished by adopting lifecycle design approaches and techniques, such as LifeCycle Assessment (LCA) [24], LifeCycle Costing (LCC) [25] and Social LifeCycle Assessment (SLCA) [26]. However, the application of such techniques generally refers to physical products and adopts the perspectives of a single company. In the context of assets evaluation, such techniques can be adopted to assess tangible assets as they refer to product-related items.

Moreover a recent study applies the above-mentioned lifecycle methods for sustainability assessment of PSS [27]. This study paves the way to intangible assets evaluation: in particular it proposed modelling the service features and PSS item and assessing them conspiring the impact in terms of consequence for human health, money spent and quality of life. However in the proposed study such analyses are carried out at the end of the designed stage and have never been applied for assets evaluation and weighting. Furthermore, the company's ecosystem has never been considered nor the related partners' impact investigated. In this context it could be interesting adopting a similar approach for a preliminary assessment of single PSS items independently from the specific application, in order to objectivize their impacts and use them for a preventive estimation during the design stage.

III. METHODOLOGY TO SUPPORT PSS DESIGN BY ASSETS SELECTION

A. The research approach

This paper aims to support product-center firms in PSS design by a structured methodology able to select the required functionalities, choose the tangible and intangible assets necessary for the PSS co-creation, create design alternative solutions, and compare them by sustainability assessment. Such an approach allows filling the gap about PSS co-creation tools in the modern industrial scenario. Indeed, evaluating the PSS assets during the design stage can provide useful design guidelines and anticipate their impact in advance to choose the best design solution.

From a practical point of view, tangible and intangible assets come from modelling the company and its ecosystem. Such modelling is hard to realize since interrelations between products and non-physical services are complex and require managing new relationships between different stakeholders of the ecosystem in order to create the tailored network able to develop the conceptual PSS. Such relationships are fundamental as they provide new skills, competences and assets to the companies, which are necessary to realize the PSS. In this context, sustainability is a driving principle as it is widely recognize to have a direct effect on markets as well as on the industrial performance evaluation. Furthermore,

assessing sustainability allows understanding the benefits connected these assets and the effective advantages of the PSS in respect with traditional products. However, a reliable analysis can be achieved only by considering a new integrated lifecycle and the ecosystem as a whole.

In order to achieve a complete, clear and valid sustainability assessment of all tangible and intangible assets in a complex PSS ecosystem, it is necessary to identify a structured methodology to follow a rational workflow. First of all, an integrated Product-Service Lifecycle considering all the activities related to product and service realization, from PSS ideation and design until PSS disposal and decommission, has to be defined. Then, the main stakeholders involved in the PSS supply chain during the lifetime must be identified (i.e. the ecosystem and assets definition) and the relationships between each stakeholder and the PSS lifecycle phases are modelled. Successively, reliable measuring techniques must be adopted to assess sustainability in the ecosystem. Finally, the sustainability value related each involved asset is measured.

B. The methodology for supporting PSS design and evaluation

The present research proposes a structured methodology to support companies in facing service innovation and designing sustainable product-service solutions by selecting the most suitable assets from the company ecosystem on the basis of sustainability indicators. In this context, the main research challenges are:

- a) the identification of the most relevant product-service functionalities to satisfy the customer needs;
- b) the selection of the tangible and intangible assets necessary to realize the new PSS from the company ecosystem;
- c) the optimization of the assets selection according to the sustainability performance.

To answer these questions, QFD techniques and HoQ (House of Quality) correlation are adopted to objectify the results at each stage (*a*, *b*, and *c*) and correlate the output from each step to the input of the following one. The method approach is reported in Fig.1. Each step contributes to fulfill the related HoQ by using data and resources as indicated in the figure; the process moves on by exploiting the obtained results in the next houses until the final House that allows estimating the sustainability performance of the selected assets and choose the most sustainable design solution among the possible ones. The proposed method can be summarized into five steps as follows:

Step 1) *Identification of the customer needs according to the context of use*: it starts from the analysis of the target market with regards to the conceptual product-service idea to elicit the customer needs, and defines the importance of each need for the specific application scenario according to a 5-point scale (1 = low importance, 5 = high importance). 1-5 point evaluation follows the Likert scale method and is widely used for measuring subjective impressions and judgments [28];

Step 2) *Correlation between the customer needs and the product-service functionalities*: it analyzes the product-service idea and extracts the main functionalities to be mapped with the market needs. Matrix correlation (Matrix 1) defines the relations between system functions and customers needs according to a 0-3-9 scale (0 = no correlation, 9 = high correlation). 0-3-9 evaluation are used in QFD approach to expressing the relation between items belonging to two different class in a two-entry matrix [7];

Step 3) *Identification of the most relevant product-service functionalities*: the selected functionalities are evaluated according to the elicited needs; in particular, the needs are weighted according to their relative importance as defined in step 1, and the functionalities are ranged in order to define how they satisfy the market needs. Finally, the highest ranked functions are selected to be realized;

Step 4) *Assets virtualization and sustainability assessment*: the tangible and intangible assets related to the specific ecosystem are analyzed, virtualized and evaluated according to their impact on sustainability, which considers economic, environmental and social aspects. For each asset a unique value is obtained and normalized according to a 1-5 point scale expressing the sustainability level. Likert scale is adopted also in this case to measure objective impressions [28];

Step 5) *Mapping of the ecosystem assets and assets selection*: the assets are mapped with the selected functionalities to identify the necessary assets in Matrix 2. The roof of Matrix 2 allows highlighting assets' integration and compatibility, which are crucial aspects in PSS design. The central part of Matrix 2 relates the functionalities and the assets requires according to a 0-3-9 scale (0 = no correlation, 9 = high correlation) [7]. Finally, a double-weighted correlation is carried out in Matrix 2: functionalities are weighted according to the rank (normalized) and assets are weighted according to the sustainability level, and the relative importance for each considered asset is calculated. At the end the selected assets are highlighted on the basis of the highest values obtained.

Such a method allows easily define the product-service functionalities able to satisfy the needs of the target customers and to map the available assets in order to define the best PSS design solution and optimize sustainability. Assets can belong to the company as well as its partners as the whole company ecosystem is considered.

Such a method is general since it can be applied to every industrial sector and every product field. Of course the market analysis and the needs weighting highly depends on the specific context of use.

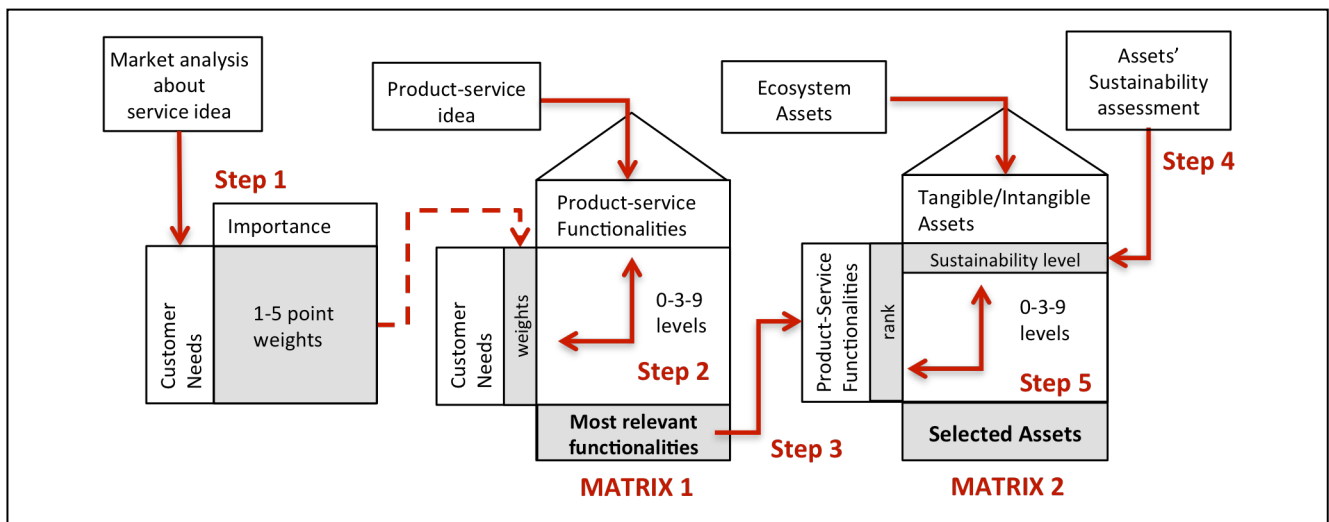


Fig. 1. QFD-based methodology to support product-service design and assets selection

C. Analysis of the product-service functionalities according to the customer needs

This section details the early three steps of the proposed methodology and explains how to define Matrix 1 in practice. The first step is the identification of the customers' needs that is carried out involving the marketing offices of the ecosystem companies: the market is explored and the target customers are identified by means of questionnaires or surveys with the final aim to elicit the target customers' expectations and needs (i.e. aesthetical features, service functions, service cost, technical features, etc.). In particular, target customers are divided into segments, and each of them has specific requirements.

Moreover, the customers' needs are weighted in respect with the PSS idea proposed by the companies, according to their answers on the questionnaires, on the basis of the questionnaires results.

Subsequently, the selected needs (N_i) are collected and elaborated by the internal departments (mainly marketing and technical depts.) by brainstorming sessions and focus groups in order to identify a list of functionalities and characteristics of new product-service solution. Such a result is used by the marketing staff to depict a set of business models where the value proposition is related to the target customers in details. At the same time, the technical staff identifies the product-

service features and its functionalities are related to the requirements analysis, specification and engineering, used to determine the ecosystem activities necessary for the development of product-service solution. The first stage is the *Requirements Analysis* that specifies “what” the PSS should do, without specifying how. After that, the *Requirements Specification* defines “how” the elicited requirements can be implemented into system specifications. At this stage it is recommended using a tool able to model the product-service system in terms of company processes, involved activities involved and the related input and output as well as the needed resources (e.g. human, material or IT) and the involved competences and skills, and the control unit (e.g. company’s departments, process’s managers). The next activities is *Requirements Engineering* that models the service system in terms of concept and its representation (e.g. service and product relationship, service value, service PIs, resources needed and provided, etc.); this construct can be used to specify concrete system requirements for service system engineering from the user requirements documented in the requirements lists. The specific product-service functionalities (F_j) are derived by the requirements analysis and engineering described above.

The next step is identifying the relation between the market needs and product-service functionalities, which is carried out by the technical staff. It expresses how much a certain need (N_i) can be satisfied by the specific function (F_j) and is defined according to a 0-3-9 scale, where 0 identifies no relation, 3 means low relation, and 9 represents a high correlation. Relations are elicited for all needs and functions defined by the previous analyses. Finally, for each functionality, the relation value (0-3-9) is multiplied for the need weight (w_i) and summed each other in order to obtain a final importance value (FI_j) for all the identified functionalities, as indicated by equation (1). Finally, the more relevant functionalities are defined according to the higher values obtained.

$$FI_j = \sum_i N_i * w_i \quad (1)$$

D. Assets’ sustainability evaluation and selection

This section deepens Matrix 2 and aims at mapping the involved assets and selecting them according to sustainability performance. The process starts from mapping both tangible assets (i.e. machines, materials, devices, sensors) and intangible assets (e.g. competences, skills, knowledge, relations among tangible components needed to realize another product functionality) through detailed questionnaires. Questions cover different aspects of the value creation process (e.g. value proposition, key partners), and each of them is directly linked to a specific key business activity or resource identified in the company business model. Assets identification is based on the correlation between the PSS assets (e.g. appliance, software system, communication module) and the company ecosystem. In fact, the PSS idea is defined by a new set of tangible and intangible assets, coming from the specific competences and skills of the ecosystem partners. The mapping consists of tracing the network relations among the ecosystem partners, in terms of who has that knowledge, who provides that components, who realizes that software application, who produces the product, who implements the service, etc. In this

way different types of resources are identified and extracted in order to populate the ontologies according to the USLD language. After that, the measurement of a sustainability value for each asset and each ecosystem partners is defined; it is a performance indicator that identifies the asset performance from an environmental, economic and social viewpoint. In particular, lifecycle analyses are separately conducted for each identified asset and for each identified ecosystem partner to have a sustainability value, according to [29]. In fact, for each asset LCA, LCCA and SLCA are coupled to obtain a unique sustainability index via proper data normalization. The environmental impact, originally expressed in EI-99 pt., can be translated into PDFm²yr (Potentially Disappeared Fraction of species per square meter per year) and MJ (MegaJoule), and then normalized. The social impact, originally expressed in QALYs, can be multiplied for the estimate cost for year according to recent European data, and finally the three monetary values (in euro) are summed to obtain a unique SA value per asset. Sustainability level is defined after normalization (0-1 value).

In order to populate Matrix 2, the product-service functionalities (F_j) are associated to their normalized ranks from Matrix 1 (r_j) and related to the identified assets (A_z) with their own normalized sustainability indicators (s_z) expressing the sustainability level. After that, the correlation is defined through a 0-3-9 scale, where 0 identifies no relation, 3 means low relation, and 9 represents a high correlation. Finally, for each assets, the relation value (0-3-9) is multiplied for the normalized rank (r_j) and summed each other in order to obtain the asset relevance (AR_z), after considering the assets sustainability weight (s_z), as indicated by equation (2).

$$AR_z = \sum_z (F_j * r_i) * s_z \quad (2)$$

IV. THE INDUSTRIAL CASE STUDY

A. Preventive Maintenance service for dryers

The case study has been realized in collaboration with an Italian company producing household appliances and home care device. Its processes are structured as in traditional manufacturing firms, and are actually organized within a product-oriented supply chain. It works in a centric ecosystem, where there is one leader and limited cooperation with partners. The company wants to design a new PSS idea, based on providing connected devices and on-line assistance for predictive maintenance. In particular, the case study focuses on dryers. The main tangible assets required are: connected devices, auxiliary sensors (i.e. machine sensors, zigbee module, router WiFi), new software components (i.e. web services, web data storage, SW applications for data mining and elaboration, web/mobile application) and an infrastructure able to connect the product-service in a network, allowing to monitor the appliances running and usage.

B. PSS design and assets selection

Starting from the PSS idea of Predictive Maintenance for Dryers, the market needs have been investigated by questionnaires involving sample 40 users and organized with the support of the marketing staff (4 people) of the involved companies. At the same time, technical staff (4 people) defined the system functionalities. These needs represent the

market desiderata and indicate the target features for the future solution. Matrix 1 mapped the relations between the elicited needs and the identified functionalities according to the proposed method. Finally, for each of the selected functionalities, the importance *FI* is calculated according to equation (1).

Table 1 shows an extraction of the case study matrix, which presents the most relevant functions identified in the case study.

Table 1. Correlation between customer needs and Product-Service functionalities (Matrix 1)

CUSTOMER NEEDS	WEIGHT	PRODUCT-SERVICE FUNCTIONALITIES						
		Appliance connection	Appliance monitoring	Best practices proposal	Marketing offers	Coaching actions	Preventive maintenance	Ubiquitous service
Appliance control	5	3	9	0	0	3	9	9
High machine performances	4	0	9	9	0	9	9	0
High quality of components	2	0	0	9	3	9	3	0
Reliability and Durability	2	3	3	0	0	0	9	9
Energy efficiency	5	3	9	9	0	9	3	9
Other resources efficiency	3	3	9	9	0	9	3	9
Easy to use	4	9	0	9	0	9	3	9
Safety and security	3	9	3	0	0	0	9	3
Sustainability	4	3	0	9	3	9	9	9
Function personalization	5	3	9	9	9	9	3	9
Functionality Importance (FI)	135	213	243	63	258	219	261	

Matrix 1 supported the definition of the main features of the service case study. For the target markets the most important needs are (weight = 5): having the appliance control, guaranteeing energy efficiency and personalizing the service functions. At the same time, also having high machine performances, creating an easy to use application and maximizing sustainability are relevant needs (weight = 4). Among the functionalities, providing an ubiquitous service as well as personalized coaching actions and best practices are perceived as fundamental to succeed in the target market. After that, providing a secure monitoring of the device and carrying out preventive maintenance is good. Connection is not perceived less important (even if technicians know that it is necessary to support the other functions). However the analysis reveals that connection is not important by itself.

After this analysis, the design team defined the PSS project. It will focus on a smart appliance (i.e. dryer) and a web/mobile service for final users, who receives coaching activities and advices for properly managing the appliance's faults. Data are monitored by specific sensors and gathered in a database for data storage; here, a set of algorithms analyzes data according to the two service policies: coaching and fault management. In both cases the system monitors some appliance's parameters (i.e. energy consumed, temperature, speed, etc.) and detect when they overcome pre-defined thresholds or achieve some critical values. In the first case, the system gives to the customer a list of personalized suggestions according to his/her usage of the appliance (e.g. programs, selected options, most frequently configurations) to take care about the product; in the second case, the system send a

message to solve some problems or to train the user in performing the checking actions required for the specific case.

The second stage selected those assets that are necessary to realize the PSS project as defined in the first stage. In particular, the assets have been classified by USDL and mapped. Each asset has been assessed by LCA, LCCA and SLCA and weighted according to their sustainability level. Matrix 2 allowed defined the most important assets and which partner can offer each of them. Table 2 shows a synthesis of the analysis: on the rows the selected functionalities are shown and its rank has been normalized in order to have a weighting value; on the columns the selected assets are listed and its sustainability level is indicated. The matrix has been populated by four experts in product and service engineering from the company ecosystem. The asset relevance (*AR*) indicates which assets are crucial for the PSS detailed design and following implementation. It can be stated that having elaboration software (27 pt.) and a web/mobile application (25,03 pt.) are essential and can be realized with low impact on sustainability. Furthermore, also monitoring sensors (13,08 pt.) and data storage (13,00 pt.) are important assets. In the case study different alternatives offered by different partners have been evaluated and the more sustainable ones have been selected. Results about skills and competences are not included as they are still in elaboration.

Table 2. Correlation between Product-Service functionalities and T/I assets (Matrix 2)

PRODUCT-SERVICE functionalities	T/I ASSET & related SUSTAINABILITY level							
	Normalized RANK	Appliance	Monitoring sensors	Mechanical components	Hydraulic components	Communication (Zigbee, WiFi)	Data storage	SW elaboration system
Sustainability LEVEL	0,5	0,8	0,7	0,4	0,8	0,9	1	1
Appliance connection	0,52	3	0	0	0	9	0	0
Appliance monitoring	0,82	9	9	3	3	3	0	0
Best practices pr.	0,93	0	3	3	3	0	3	9
Marketing offers	0,24	0	3	9	9	0	3	9
Coaching actions	0,99	3	3	3	3	0	3	9
Preventive maintenance	0,84	9	3	9	9	3	3	9
Ubiquitous service	1,00	0	0	0	0	3	3	0
Asset Relevance (AR)	9,71	13,08	12,55	7,17	10,10	13,00	27,00	25,03

V. CONCLUSIONS

The present paper proposed a structured methodology to support PSS design and provide design guidelines to manufacturing companies that wants to innovate their products by creating product-service solutions. It is based on QFD techniques and uses two main Houses of Quality to identify those product-service functionalities that satisfying the market needs, and to select those tangible and intangible assets by considering the functions development and the sustainability impact. It overcomes the main limitations of the actual design

methods and tools that are still strongly product-oriented and poorly support PSS design.

The methodology is applied and tested on an industrial case study focused on a new productive maintenance service for household appliances, with a particular application for dryers. The method allows correlating technical functions and customer needs in order to define the most significant functions to offer to the market. After that, the method support assets analysis and correlation with the desired functions. The case study is still in development and further results will be added in future works. Up to now it demonstrated how the proposed method supports the team in the preliminary design activities. Assets investigation will be improved and detailed by a precise mapping of the selected tangible and intangible assets for the specific case of application.

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