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A Service Engineering framework to design and assess an integrated product-service

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1 Introduction

The manufacturing sector has undergone tremendous changes in recent years. Manufacturing businesses that operate in today's competitive global economy – in which products are easily commoditized – are increasingly coerced to adopt strategies aimed at innovation and differentiation [1]. To withstand the sharp marked downfall, traditional firms need to extend their core manufacturing activities – focused primarily on purely physical products – with the provision of complementary services. This change in manufacturing companies, usually referred to as *servitization* [2], is largely motivated by a rising need to create new sources of value for customers, by either reactively fulfilling explicit requirements or proactively offering them new integrated solutions of product and service. [3]. From pure product orientation, businesses have thus evolved towards a Product-Service System (PSS) perspective, which refers to the whole cluster of products, services, supporting networks and infrastructures [4].

As repeatedly underlined in academic and managerial literature, mastering a servitization strategy can provide financial, strategic, marketing and environmental benefits [5,6]. However, although services are delivered to attain higher margins, most manufacturing companies find it quite difficult to perform the required transition successfully: a Bain and Co's survey revealed that only 21% of the sampled companies experienced lasting success with their service strategy[7]. When increasing their service offerings, companies sometimes incur higher costs and eventually fail to achieve the expected returns. [8,2]. Overcoming this hitch – referred to as the *servitization paradox* in the literature [9] – represents a major managerial challenge: companies need to re-design their organisational principles, structures, processes [8], capabilities [10], as well as the relationships with customers [11] and suppliers [12]. Indeed, the design and development of a PSS raise new issues; the service component introduces new requirements that are less (or not at all) relevant in a traditional, product-based business model. In particular, the substantial cultural shift, from a transaction-based approach to a long-term relationship with customers, needs to be thoroughly understood by companies, along with the acquisition of suitable models, methods and tools for collecting, engineering and embedding into a PSS all the knowledge that meets or exceeds people's emotional needs and expectations.

As reported by Cavalieri and Pezzotta [3] and Rapaccini et al. [13] a significant portion of the extant literature on PSS provided relevant contributions on methods and tools to manage the above-discussed aspects and address issues effectively. However, the majority of these approaches were developed in other fields (such as product and system engineering), and only subsequently adapted to the PSS field: indeed, to our best knowledge only a few methods and tools have so far been developed specifically for service and PSS design and engineering.

Because of this, Service Engineering (SE), a "technical discipline concerned with the systematic development and design of PSS using suitable models, methods, and tools" [14] has gained ascendance. SE is becoming a key approach for managing the complexity of a mechatronic PSS, meant as a combination of products, ICT (Information and Communication Technology) components and services, which demands a profound understanding of the system since its early stages of development.

However, despite the many advantages of SE amply attested in the literature [3,14], only a few authors have so far proposed tailored methodologies and tools that can easily be adopted by industrial companies, and these have in turn maintained a largely product-centric focus during PSS design. In other words, industrial companies still focus on engineering, the "tangible" part of their integrated solutions, adopting rather intuitive processes and methods to develop"intangible" elements. The achieved value therefore lacks optimisation, and appears as an unstructured mashup of "something methodologically and systematically approached" and "something rudimentarily developed" [3].

This paper endeavours to fill this gap by proposing a framework that integrates the design capabilities of a computer-aided modelling tool for Service Design (namely, the Service Explorer presented in [20]) with a simulation test-bench. The adoption of simulation is meant to enable comparison of alternative PSS configurations and an assessment of their technical, operational and economic performance. Within this framework, the central idea is to provide manufacturing companies with a valuable and user-friendly tool for designing PSSs methodically. Starting from a functional analysis and the definition of implicit (or context-related) and explicit customer needs, this framework envisages the adoption of simulation techniques for testing alternative scenarios and their impact on both customer and company needs. A preliminary version of the framework was presented in Pezzotta et al. (2013) [21] at the 11th IFAC Workshop on Intelligent Manufacturing Systems in São Paulo in 2013. The present paper provides a thorough description of a refined version of the framework, based on the feedback gathered from several applications in real-world industry cases. With a view to gaining an in-depth understanding of the developed framework and its related advantages, we will carry out a thorough analysis of the case study and of the results obtained. It should be stressed however that for the purpose of this paper, we focused exclusively on the engineering of PSS service elements, which include service content, provision process and related resources. To this end, we have laid out this paper as follows: a literature review on SE with a focus on design and simulation methods and tools nowadays available is presented in Section 2. Then, overviews on the Service CAD (Computer Aided Design) methodology, on the Service Explorer tool, and on Discrete Event Simulation (DES) are introduced in Sections 3 and 4.

Section 5provides a description of the framework through a sample case, while conclusions and further research developments are reported in the last section.

2 Product-service system engineering

The first definition of product-service appears in the literature in the '70s, in the words of Rathmell [22]: "Services may be an accompanying sale of a product". Although Rathmell's definition preserved a sharp distinction between product and service, it offered a new perspective for their mutual integration with the goal to improve customer satisfaction. Today, this concept has a new meaning. The basic idea behind the PSS concept originates from shifting the business focus from the design and provision of physical products to the design and provision of complete systems that consist of products, services, supporting networks and infrastructures [15,4] and also encompasses intelligent and mechatronic systems which group products, IT-components and services. These are jointly capable of fulfilling specific customer demands and needs.

The profit generation and the commercial success of a PSS critically depend on its conceptualisation, design and development, even though this notion has been largely ignored [14]. According to Baines et al. [15], the plethora of tools and methodologies available for designing PSS are typically a rearrangement of conventional processes. Therefore, they suffer a substantial lack of a critical and in-depth evaluation of their performance in practice. As highlighted in [23], when compared to physical products, services are generally under-designed and inefficiently developed.

This is the main factor behind the upsurge of SE as a technical discipline since the '90s and its prominence today. In the words of Bullinger et al. [14] and Shimomura and Tomiyama [24], SE may be termed as a technical discipline concerned with the systematic development and design of services aiming at increasing the value of artefacts. Through the adoption of a rational and heuristic approach based on modelling and prototyping methods, SE also aims at systematically integrating product and service contents, enhancing the functionalities and/or the quality of the physical product, and improving the service content and the provision channel. In particular, the provision of services and of enhanced functionalities in innovative and future products calls for the introduction of increased product smartness, such as the use of embedded mechatronics in product-service components [25,26]. This will necessitate a strong interconnection between product engineering and SE.

One of the salient features of SE is its orientation to the design and development of product-service offerings which take into account the internal perspectives of both customer and company. Despite that, existing SE models[13,15–19] focus mainly on designing solutions able to satisfy customer needs from a functional point of view, and largely neglect the equally crucial aspect of operational excellence in the delivery phase of the service solution.

Consideration of the literature on SE shows that a significant number of contributions focuses on how to carry out the SE process through the adoption of suitable practices, methods and tools. However, only a limited number of methods have been developed specifically for service and PSS design, development and engineering. In fact, most available SE models, methods and tools derive from the adaptation of traditional engineering, business and computer science approaches to Service System (SS) or PSS [3,27,28].

In addition, some of the available methods were proposed as a part of a broader methodology to support the SE process and all the related activities and tasks. These include the Methodology for Product-Service System (MePSS) [17]and the Service CAD [29], a modelling methodology created to describe and develop customer value and its ground, the relationship between customer value and service contents, and the service contents delivered by products and/or services [30,31]. These methodologies marked the need to support theoretical research by creating a specific IT tool which aims at translating theoretical knowledge into viable industrial applications [3].

Among the different authors approaching SE, Arai and Shimomura [29], Hara et al. [30] and Sakao and Shimomura [20] focused their attention on two main outputs: the establishment of a new discipline called Service/Product Engineering (SPE), and the development of the Service CAD. The focus of the SPE is close to the SE, but it puts more emphasis on customer value creation, which must be accomplished not only through the provision of products, but also with all the service activities, a relevant feature concurring in the creation of customer value. In SPE, product and service activities are designed in parallel according to the value provided to the final customer.

Based on the Service CAD methodology, the “Service Explorer” – a software design tool conceived to engineer and to improve the quality of services –was developed by the same authors [20,30,29]. An analysis of relevant literature shows that the Service Explorer is the only software tool available nowadays with these features. [3,32]. In particular, Service Explorer supports the designer in the definition of PSSs with a customer-oriented perspective, and provides a ranking of the relevance of the various functions and attributes of a PSS based on a Quality Function Deployment (QFD) analysis [30,31].

Even though the development of an ICT tool to support companies is a key issue in the SE field, until now the focus of academic contributions has been on PSS conceptualisation and on the adoption and tailoring of product engineering methods to the service context [32]. SE’s conjectural focus is mainly due to the fact that development of SE as a discipline is still in its infancy stage [3,33].

3 Service CAD and Service Explorer

The main concept behind SE and the definition of the Service CAD is to incorporate PSSs into a proper design environment, which in manufacturing industries has traditionally been dominated by physical products. Service CAD methodology defines a design procedure, which is the methodological base for the development of a computerized CAD system, namely the "Service Explorer".

3.1 Basic features of the Service CAD methodology

In accordance with Service CAD methodology, a PSS aims at changing the state of a service receiver [34]. In particular, as shown in Fig. 1, a provider delivers value to a receiver through a service content by changing his/her state into a desired one. The service channel is used to transfer, amplify and control the service contents. Both content and channel are meant to satisfy the customer thanks to the delivery of product-services [34].

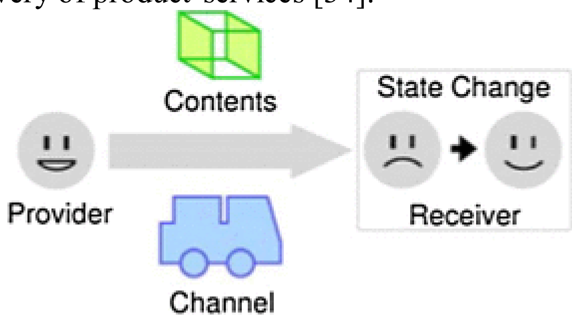

Fig. 1 Service definition in SPE [25–27].

In more detail, the receiver is described by a set of Receiver State Parameters (RSPs) whose aim it is to represent customer value [29]. Both service content and provision channel can influence RSPs.

The concept of "Persona" is adopted to describe the receiver's lifestyle and behaviour, his/her personal characteristics, his/her type of job and his/her social position. It is also used to specify RSPs. In other words, it is used to provide a complete picture of a customer.

Moreover, the Service CAD provides the following sub-models for representing a functional service structure [29–31]:

(1) The *Flow model* represents the relationships among the various agents/stakeholders of a value chain, from the original providers to the final receivers. This model is needed in order to allow designers to consider how different agents are involved in service delivery and in value creation.

(2) The *View model* defines how customer value, represented by an RSP, and actual entities (human resources, supporting products) are related. In particular, as shown in Fig. 2, it makes use of a functional tree structure to describe the mutual relationships between an RSP and its related contents, as well as between contents and channels. An RSP is directly influenced by the contents of the service received. Conversely, service channels do not directly influence an RSP but they influence service contents. Each content and channel is represented by a Function– describing what the content and the channel have to do in order to satisfy the customer needs – and by one or more Parameters – that measure the performance of content and channel. At the lowest level of a View model, the entities and their attributes are introduced. An entity represents an element, hardware and humanware, involved in the delivery of the final solution to the customer (such as physical products, facilities, employees, and information systems, etc…). An attribute, instead, marks a specific feature of an entity. An entity may have several attributes, but an attribute refers to a single entity. Using a View model, designers can perform a static evaluation of customer satisfaction based on these entities and their attributes.

(3)

The *Scope model* describes the real activities taking place between a receiver and a service provider. The scope model deals with all the RSPs of all the actors involved in the service provision process, handling multiple view models (namely, multiple RSPs). The aim of this model is to help designers understand the activities between provider and receiver.

(4) The *Extended Service Blueprinting*. Even though the View model represents customer value, it includes limited information about the service provision process and about how entities are connected with sub-processes and functions. The details of the relationships between functions and entities are depicted in a service blueprint. The Service CAD adopts an extended service blueprint, based on the Business Process Modelling Notation (BPMN), to include product behaviour and its relationship with service activities, as well as the relationship between activities/behaviours and customer requirements [35]. Therefore, by connecting the View model and the Extended Service Blueprinting, designers can clarify the influence of the service process on customer through functions.

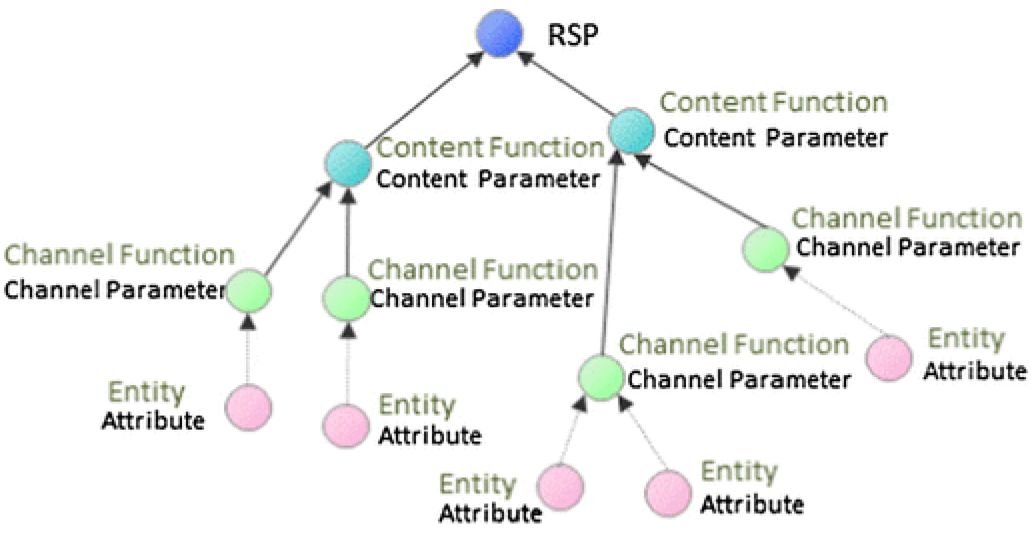

Fig. 2 The View model.

3.2 Service Explorer

Based on the aforementioned modelling methods, a prototype CAD system called Service Explorer was developed, as discussed in [20]. The aim of Service Explorer is to support service designers in describing customer needs and their mutual relationships, providing a design environment which allows for customer analyses as well as entities construction. The Service Explorer is aimed to support both the review of existing services and the design a new service. Fig. 3 depicts the conceptual scheme of the Service Explorer.

(1) *Design workspace*: in this area, designers can model services using the Service CAD methodology through six editors, each connected to a specific model: the Scenario Builder, the Flow Editor, the Scope Editor, the View Editor, the Extended Service Blueprinting Editor (composed by the Activity Blueprinting Editor and the Behaviour Blueprinting Editor).

(2) *Service design organizer*: it is an evaluation module to assess a service design solution [20]. Assessment is mainly devoted to determining the relative importance of each Content Parameter (CoP) and Channel Parameter (ChP), through a weighted-scored approach based on the QFD method.

(3) *Library space*: consists of several databases of elements to store information which comes from existing service cases.

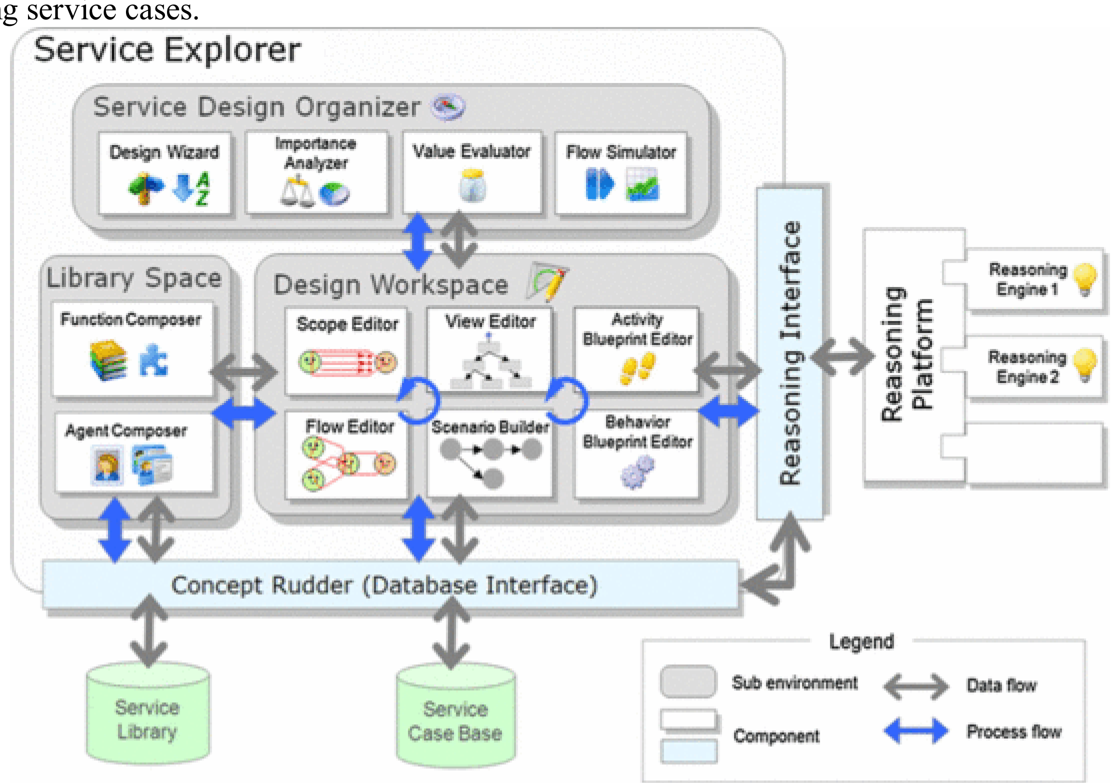

Fig. 3 The conceptual scheme underlying Service Explorer [25–27].

The Service CAD and the Service Explorer may provide substantial help in designing and developing new PSSs. However, the main limitation of the discussed methodology is its static nature when it comes to assess overall performance: solutions designed with Service Explorer are evaluated solely from a static perspective (i.e. the evolution and provision of any given solution over time is not taken into account). Moreover, it only considers the value provided to the customer, to all intents and purposes neglecting company performance (i.e. resource utilization, costs, lead-time, etc.). In this sense, the integration of the Service CAD and Service Explorer with a simulation tool allows for a comparison of different configurations of designed PSS with a view to evaluating both customer and product-service provider performance. To this end, we briefly introduce the DES paradigm, and illustrate its possible integration with the Service CAD.

4 Discrete event simulation in Service Engineering

Simulation is “a technique for constructing a model that describes the behaviour of a real world system, and the resulting model can then be used to test how the performance of a proposed system alters over differing operating conditions” [36]. Simulation allows for the accounting of variability and randomness; therefore, it is usually a robust choice when it comes to dealing with uncertainty and dynamic systems.

Traditionally, simulation focused mainly on production and manufacturing processes; however, over the last few years the adoption of simulation in service and PSS field has gained momentum due to the increasing scale of operations and to the complexity and the nature of connected operations [37,38]. By definition, a good service encompasses performance considerations of quality and timeliness. The identification and clear description of service productivity require the use of novel methods, which go beyond a static description of work processes, such as the one found in SE models, methods and available tools. In particular, the representation of the underlying dynamics and uncertainties of a work organization should enable service managers to generate valid service scenarios [39]. In this sense, simulation can contribute to the design of the service provision process and the evaluation of different systems created under different what-if scenarios. In particular, the adoption of DES as a tool for SE can offer great potential as a mean for describing, analysing, and optimising the service provision process of many types [38]. It also supports their systematic and optimised engineering. In addition, DES can provide support to the assessment of service provision processes, analysing the balance between the excellence in the value channelled to the customer and a high efficiency and productivity of the service processes.

Following our discussion about the need to integrate a simulation approach in a SE framework, in the next section we are going to outline our proposal through a sample case developed in a service company.

5 The proposed framework

This section illustrates the framework that was developed by the authors to support the engineering of innovative PSSs through the definition of the most suitable and complete service for a customer in terms of content and provision channels. As depicted in Fig. 4, the framework is based on five different areas, each referring to a specific phase of the Product-Service Engineering process.

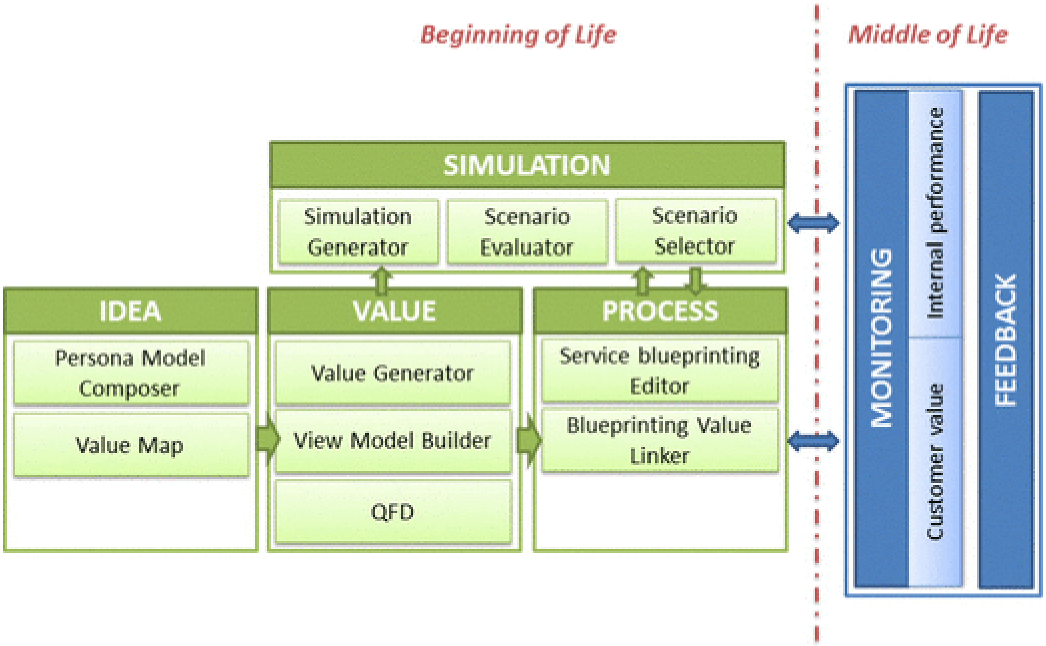

Fig. 4 The framework for product-service engineering.

Each phase is presented in the following. The description includes a general discussion and an empirical application, derived from a sample case developed to test the logical robustness and applicability of the framework. The case is based on real data, collected during an action research carried out in the repair workshop of a truck company.

With regard to the sample case, the main aim of the company we analysed was to understand which service was best from among a set of possible alternatives, to introduce it in its portfolio and to see how such service could be engineered. For the sake of the example, we will assume that only one new service may be implemented in the company, but the methodology applies just as effectively to cases where more than one service needs to be implemented. In particular, due to the economic downturn and the high volatility of the automotive sector at the time when research was conducted, the company aimed at introducing a service that could be seen as valuable for customers and, at the same time, had low economic impact in terms of cost.

Phase 1 – IDEA – Theoretical discussion: The definition of a new product-service starts from the analysis of the different customer segments, described through the *Persona model*. This analysis allows the company to understand the main requirements customers are willing to satisfy with the new product-service, and to express them in terms of value. Thus, value represents how customers intend to improve their context-specific experience Value items to consider may include timeliness of service, low price, high quality level, etc. Besides customer values, the company has to identify the list of values satisfied by potential services. These potential services may be: (i) services already offered by the company, (ii) services available in the market, but not provided by the company, (iii) completely new services. By matching customer values with those satisfied by potential services, companies will identify the most compelling services for further analysis.

Phase 1 – Application example: In the sample case, interviews involving workshop workers and managers made it possible to identify the main"*Persona*" (customers segments) and related potential services. As for customers, two different segments were identified: (i) customers with an un-overloaded fleet (in this case if a truck is out of service, a substitute truck is available) and (ii) customers with an overloaded fleet (in this case if the truck is out of service, no substitute trucks are available). As shown in Table 1, each customer segment presented a different rank of values. The most important values for customers with a fleet with substitute truck were quality and technical competence, followed by price, timeliness, punctuality and transparency; for the other segment, instead, the most important value was timeliness, followed by punctuality, quality and technical competence, price and transparency.

Table 1 Customer values per segment.

Un-overloaded fleet		Overloaded fleet	
Rank of value	Weight	Rank of value	Weight
Quality and technical competence	5	Timeliness	5
Price	4	Punctuality	4
Timeliness	3	Quality and technical competence	3
Punctuality	2	Price	2
Transparency	1	Transparency	1

Concerning the potential services deemed as relevant, and thus considered in the analysis, we identified two alternative solutions, which can be readily implemented:

(i) *Quick maintenance service*: in order to implement this type of service and make preventive maintenance quicker than conventional maintenance, maintenance activities are carried out by two workers in tandem instead of one, as commonly done. Since preventive maintenance in the truck workshop is based on a predefined list of activities, having two parallel workers allows for a decrease in the overall duration of the intervention, thereby reducing customer lead time.

(ii) *Long-term maintenance program*: in this case, the customer signs a contract and pays a fixed amount in advance; in return, the customer benefits from periodic maintenance interventions (i.e. scheduled every 6 months, in general with no additional cost) directly managed by the workshop. In order to implement this type of service, new commercial skills for the employees in the front office are needed and a new employee managing the long-term maintenance contract and relationship is required.

Therefore, each identified solution requires specific changes in the service provision process both in terms of activities and in terms of resources.

Table 2 reports the list of values satisfied by these two services, along with relevant weights.

Table 2 Values satisfied by the potential customers.

Quick maintenance		Maintenance contract	
List of value	Weight	List of value	Weight
Timeliness	4	Price	4
Punctuality	3	Transparency	3
Quality and technical competence	2	Quality and technical competence	2
Transparency	1	Availability (data and time flexibility)	1

By matching and weighting customer values and the values satisfied by potential services, we assessed the impact of each service alternative on different customer segments. The results reported in Table 3 show that quick maintenance was the service that can potentially provide the highest satisfaction of both the customer segments. Therefore, the company decided to engineer this service only. The analysis that follows refers to this service.

Table 3 Service idea selection.

Customer segments	Quick maintenance	Maintenance contract
Fleet with substitute truck	29	29
Fleet without substitute truck	39	17
Average weight	34	23

Phase 2 – VALUE – Theoretical discussion: During phase 1 the company develops a high-level idea of the service to be engineered. In particular, the company must define which customer values should be satisfied, and which are the general contents and the main functionalities of the solution idea. After this first task, it is crucial to expand on the service idea, defining the precise content of this new offering and selecting the most suitable provision process. For this purpose, in accordance with the view model, the target values (RSPs) are broken down into detailed functionalities, until a definition of the tangible entities (human resources, supporting products, ICT) involved in the implementation of various functionalities is achieved. Thus, the objective of this phase is to define the detailed functionalities characterizing the new product service, and to identify the entities that the company can leverage in order to optimise its provision process. Furthermore, given the hierarchical link between resources and customer values in the view model, it is necessary to define the impact of each resource on each content and channel function. That would make it possible to identify the key area to address in order to fulfill customer needs. Among the available approaches suitable for assessing the impact of resources, the QFD approach was selected.

Phase 2 – Application example: With reference to the case, since timeliness was the most important value addressed by a quick maintenance service, and it was one of the most relevant values from the customers' point of view, the related "ensure low cycle time" functionality was chosen as the main RSP. Thus, the view model was used to break down the identified RSP in detail, into content functions and parameters, channel functions and parameters, and entities, as shown in Fig. 5.

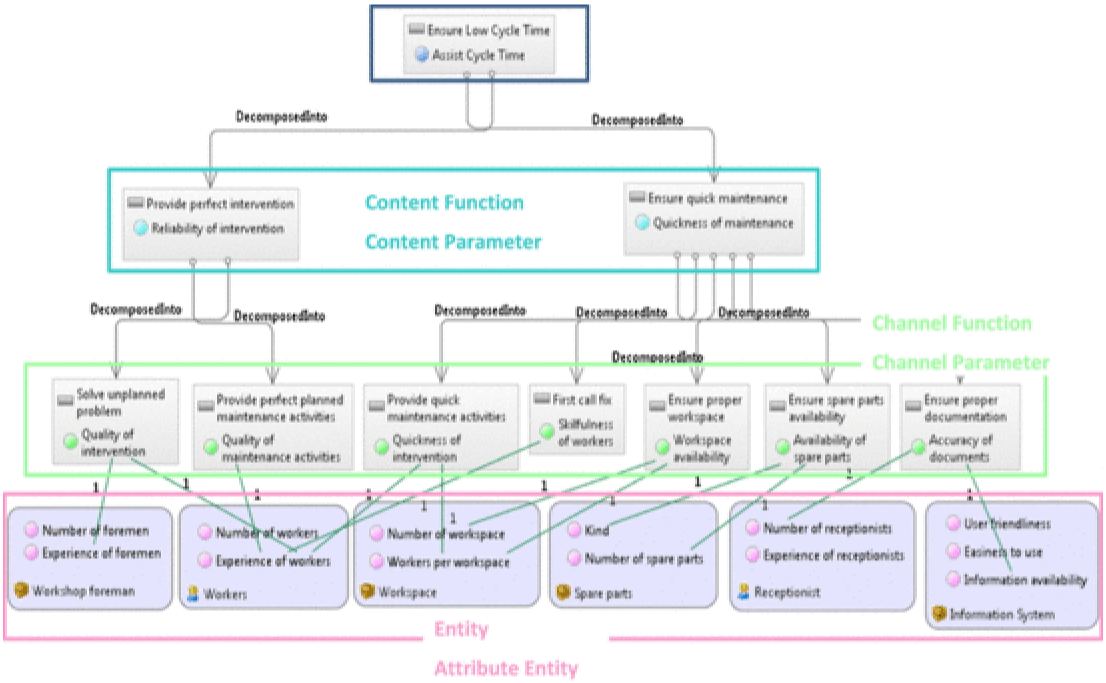

Fig. 5 Application of the View model in the sample case.

In order to "ensure low cycle time" the two functionalities identified were"to provide perfect intervention" and "to ensure quick maintenance". These represented the content functions, while the related content parameters (i.e. the performance indicator) were represented by the reliability of the intervention and quickness of maintenance, respectively. Going down the tree, the content function "to provide perfect intervention" was broken down into the channel functions "to solve unplanned problem" and "to provide perfect planned maintenance activities". Instead, the content function "to ensure quick maintenance" was broken down into the channel functions "to provide quick maintenance activities", "first call fix", "to ensure proper workspace", "to ensure spare parts availability" and "to ensure proper documentation". At the lowest level of the tree, we identified the entities that were needed to carry out the functionalities along with their attributes, namely workshop foreman (whose attributes are number and experience), workers (number and experience), workspace (number and workers per workspace), spare parts (typology and number), receptionist (number and experience) and information system (user friendliness, easiness of use, information availability).

In order to identify the resources that mostly affect RSP fulfilment, the QFD approach was applied. Consequently, each tree branch was assigned a weight; Fig. 6 shows the result: the experience of the workers and the worker per number of workspace turned out to be the two most relevant entity attributes in order to ensure low cycle time to customers.

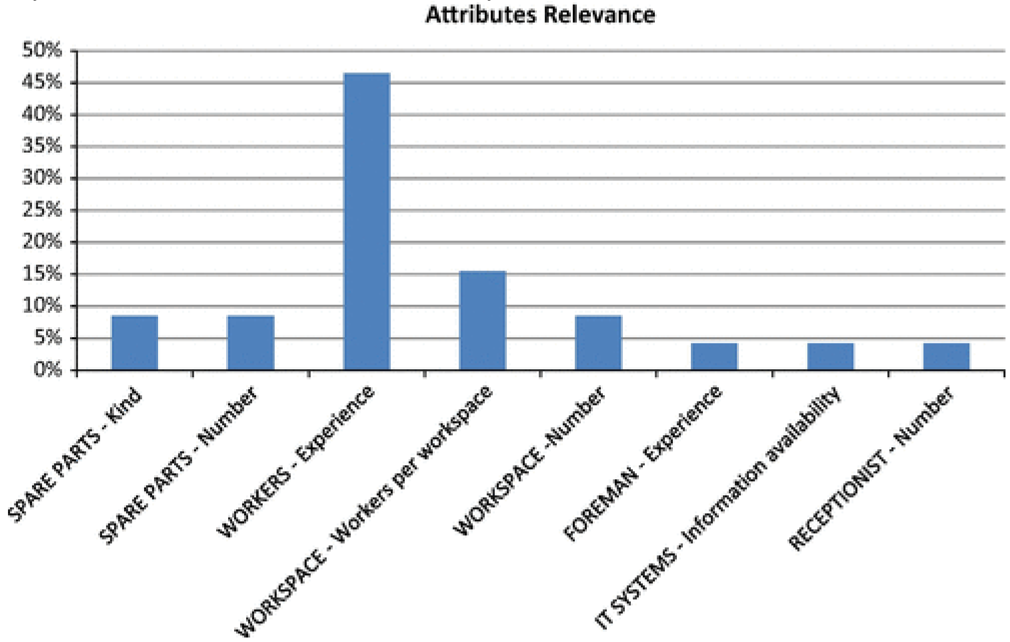

Fig. 6 QFD results on entities attributes.

Phase 3 – PROCESS – Theoretical discussion: In this phase, alternative service provision processes are defined and modelled with the *service blueprinting methodology* [40,41]. The activities that underlie the process comprise four categories: (i) *customer's activities* (performed by the customer), (ii) *front-end activities* (performed by the company interacting with the customer), (iii) *back-end activities* (performed by the company, but hidden from customer view), and (iv) *support activities* (general management activities performed by the company to support several processes).

Since the processes to be engineered must provide most of the functionalities identified in the previous phase to satisfy customer needs, the activities represented in the blueprinting model are connected to the tree channel functions. These links allow for the following check of the process:

- Activities that are not connected to any channel function are not contributing to customer value creation directly, and they should be analysed to understand whether they must be kept as they are, changed, or removed from the process;
- Channel functions that are not modelled in the blueprinting reduce the fulfilment of the RSP and, therefore, the customer value could not be optimised.

Phase 3 – Application example: the Service Blueprinting of a potential quick maintenance service provision process and the links with the channel functions are reported in Fig. 7. This process starts with the customer going to the dealer. The dealer's receptionist receives the customer, verifies the customer request and, in case of intervention acceptance, he/she prints the intervention documentation and quotation. Then, the maintenance intervention starts with the assignment of the workspace and workers to the truck and ends, after the maintenance intervention activities performed by the workers, with the final check of the truck performed by the workshop supervisor. The process finishes with the customer that comes back to the workshop, takes his truck back, pays and leaves the workshop.

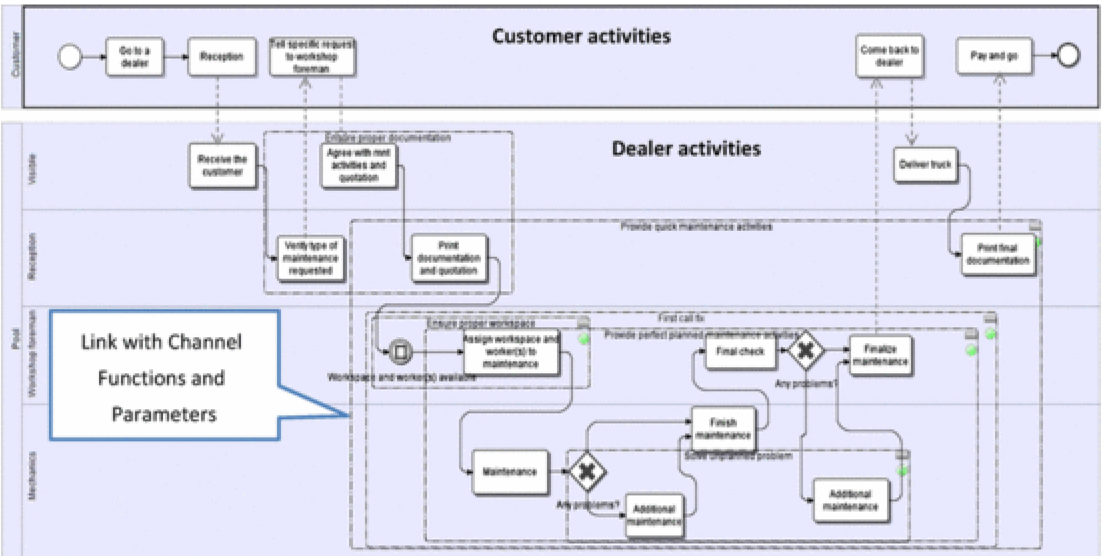

Fig. 7 Application of the service blueprinting in the sample case.

As reported in Fig. 7, all the channel functions discussed above were linked to a part of the process. Instead, a number of activities were not linked. These were kept in the process because even though they did not affect the fulfilment of the RSP directly, they were important for ensuring complete execution of the process.

Phase 4 – SIMULATION – Theoretical discussion: The results of the previous stage made it possible to assess whether all the functions are addressed by the activities composing the service provision process. Nonetheless, this is a rather static result: nothing can be inferred about the performance of the process, both for the AS-IS processes and the TO-BE proposals. In addition, since a company can design different product services, and for each of them alternative provision processes can be identified, it is important to find the best solution for maximizing expected performance, in terms of both company value (internal performance) and customer value (customer satisfaction).

Therefore, this phase aims at validating and assessing the performance of the process, as well as at identifying the most suitable configuration of the process. To this end, the presented methodology adopts DES, as discussed in Section 4.

Simulation is used: (i) to assess the performance of a service provision process under different conditions (what-if analysis), (ii) to evaluate the effectiveness of possible changes in the service organization, (iii) to support the selection of the process configuration with the best trade-off between internal performance and value for customer, and (iv) to provide insights into the SS dynamics and its possible bottlenecks. Simulation can thus be used as a decision-making tool to test different, alternative scenarios and process configurations, as well as to identify the best one according to the pre-specified key performance measures.

The first step in using the simulation is transposition of the service blueprinting model into the DES environment, according to the notation of the selected tool. In this step, the information defining each single process is established on the base of the elements designed with the view model. In order to ensure proper transposition of the service blueprinting into the simulation tool, a tool with a graphical interface and based on pre-defined building blocks is more advisable.

At a later stage, different scenarios are created, simulated and compared in order to identify the best alternative. Each scenario is derived from the analysis of the results of previous simulations, starting from the simulation of the AS-IS process, when available. In general terms, new scenarios are generated aimed at(i) removing the main bottlenecks emerged from the previous simulation(s) and(ii) reducing cost and increasing performance, usually by adding/changing resources by number and skills, or changing the service provision process logic. The scenario definition process is performed iteratively until designers deem the results satisfactory (i.e. when the results meet company goal). Although some elements of this process can be automated, in our framework the definition of new scenarios remains prevalently a trial-and-error task, in which the role of the designers and the decision makers is pivotal.

Phase 4 – Application example: With regard to a real-life sample case, the maintenance activities performed by a single worker (AS-IS) scenario was tested against the alternative service solution: quick maintenance service performed by two workers in parallel (TO-BE). In the simulation, we used real data gathered directly from the field, and we followed general guidelines for the execution of the simulation runs (i.e. duration, warm-up period, replications…)[42]. In this case, the simulation was carried out using Arena Simulation Software (Rockwell Automation) due to its flexibility, suitability with respect to the analysed case, and the experience the authors have with it (Fig. 8). Although other platforms are available on the market, Arena Simulation Software seemed better-suited for our purposes: its graphical interface allows for an intuitive and hands-on understanding of the process flow from company employees who participate in the process analysis and its simulation features and capabilities are excellent. Nonetheless, it should be stressed that the proposed framework is not bound to the Arena Simulation Software package.

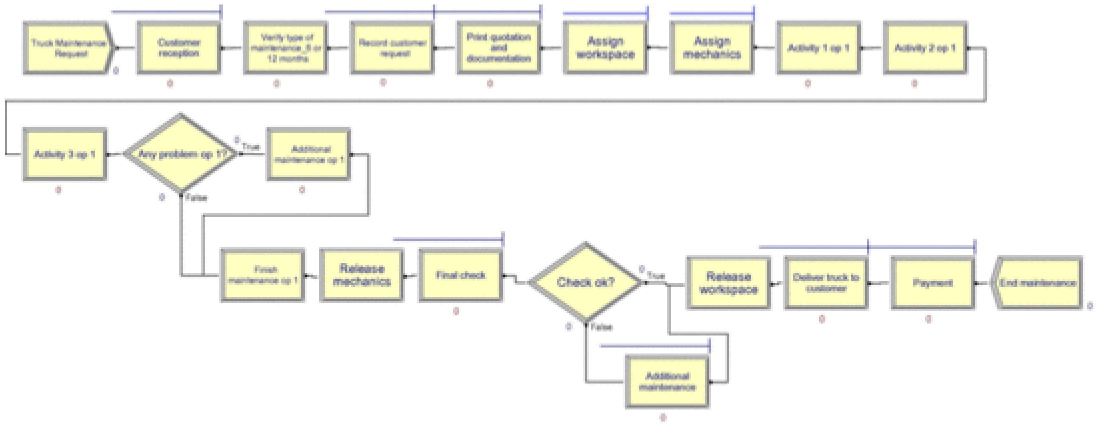

Fig. 8 Example of the simulation model.

We developed and tested the TO-BE scenario against the AS-IS one, to understand the effectiveness of the new quick maintenance service. For the sake of brevity, we will only be addressing a comparison between two of the analysed scenarios based on two Key Performance Indicators (KPIs): (i) the *customer value*, defined in terms of the Cycle Time (total time spent by the truck in the workshop), Operational Time (value-added time, during which the employees perform activities related to the truck) and waiting time; and (ii) the *service provision efficiency*, evaluated in terms of cost (both busy and idle costs) and resource utilization. The main results of the simulated scenarios are reported in Table 4.

Table 4 Performance evaluation.

Scenario	Average time	Busy cost (€)	Idle cost (€)	Resource utilization
One worker maintenance	Cycle time: 2201 min (min: 340 – max: 4352) Total operations time: 349 min Wait time: 1853 min	Total: 17.664 € Workers: 12.974 € Receptionist: 2.135 € Foreman: 2.554 €	Total: 21.140 € Workers: 17.025 € Receptionist: 4.114 €	Workers: 43.2% Workspace: 93.3% Receptionist: 34.2% Workshop foreman: 25.5%
Two workers maintenance (quick maintenance)	Cycle time: 279 min (min: 174 – max: 376) Total operations time: 353 min Wait time: 66 min	Total: 18.585 € Workers: 13.882 € Receptionist: 2.130 € Foreman: 2.573 €	Total: 20.150 € Workers: 16.029 € Receptionist: 4.119 €	Workers: 46.5% Workspace: 53.7% Receptionist: 34% Workshop foreman: 25.7%

The simulation proved that quick maintenance entailed no additional fixed cost for the company, but substantially improved the value perceived by the final customer. At the same time, quick maintenance can significantly reduce cycle time by curtailing waiting time. Maintenance cycle time after the introduction of the quick maintenance service was reduced from an average of

2201 min to 279 min. This time reduction was achieved thanks to a substantial decrease of waiting time from 1853 min to 66 min. The introduction of quick maintenance also allowed an appreciable decrease of operational time: without considering queues, average operational time in the one-worker-maintenance setting was 348 min (2201–1853 min) while in the quick-maintenance setting was 213 min (279–66 min). In the case of one-worker maintenance, this time corresponds to the total operation time reported in Table 4, while for the quick maintenance scenario the total operations time reported is higher because it is the sum of the operation times of the two workers. Because of the long queue, in the first case workspace utilization is close to 100% while in the quick maintenance is nearly 50%. In both cases, workers utilization was about 45%. This means that with quick maintenance a higher maintenance demand may be managed without substantially affecting workshop performance and, hence customer satisfaction.

Phase 5 – MONITORING – Theoretical discussion: In order to evaluate the solution after its implementation and during delivery to the customers, it is fundamental to define a structured system of KPIs supporting the monitoring of the service which delivers performance. As a starting point, the KPIs to be monitored can be the ones selected among a wider range of alternatives in the simulation phase. In particular, due to the focus of the framework, internal and external KPIs must be identified in order to seamlessly evaluate customer and company needs. Identification of the main customer KPIs should make it possible to adequately assess the impact of the solution on customer needs. Therefore, it should be based on the View Model parameters previously defined, which ensures a clear assessment of how effectively the delivered process contributes to the customer experience.

Phase 5 – Application example: From the application example standpoint, monitoring involves a continuous evaluation of the performance of the implemented process. That is achieved by constantly gathering data and feedback from the field and comparing them against a properly defined target.

6 Conclusions

This paper introduces a framework to support the (re)engineering of a PSS as well as to allow the definition of the most suitable PSS for a customer in terms of content and provision channels. Built around five different phases, the framework extends the logic of Service CAD methodology by introducing an assessment phase based on DES in order to support the economical and risk assessment of the most suitable service provision process.

The sample case presented in the paper provides a detailed overview of the possible actual advantages to be derived from the adoption of an SE approach in a company's servitization process. Among these:

(i) Adoption of a systematic procedure to rethink existing services and/or to develop new services in existent products or in new intelligent and smarter products can provide substantial benefits by guiding design and development processes through a sequence of clear and self-contained steps, thus reducing time waste in the service design phase. In this sense, a systematic procedure can also ensure reduction of the time needed to introduce new product-service into the market.

(ii) The methodology presented here promotes *improvement of the service process performance* by pinpointing actual issues that affect customer needs and satisfaction. The framework provides support to effectively address customer needs (both expressed and unexpressed) and to translate these needs into product-service functionalities. This will guarantee the implementation of product-services tailored to answer real market expectations and customers' needs.

(iii) The adoption of an economic and risk assessment tool (such as simulation) makes it possible to monitor expenditure by preventing the adoption of a service that is ineffective (from the customer's perspective) and shows substandard performance (from the point of view of the company's profitability). In fact, the power of modelling and simulation tools rests with their ability to describe and imitate the behaviour of an actual system, which allows for a better comprehension of the system's dynamic and facilitates discussion around it.

(iv) The process changes needed to accurately manage an increase of demand and revenues are defined and assessed more thoroughly. In this sense, by simulating alternative service provision processes, managers will be able to estimate their cost, service level, time, and quality, minimizing risks by incorporating multiple considerations into the early phases of the PSS design, where the flexibility to pursue alternatives still exists.

Despite all these advantages, the framework is still at an early stage of maturity, and further developments and applications are needed. Only a limited number of framework applications have been completed so far and, even if the advantages of the approach are momentous, its implementation in an actual environment with a complete PSS is still challenging. Moreover, development of the simulation process model requires knowledge that is not always readily available within companies. In particular, simulation of a service provision process requires simulation of the customer process in its interaction with the company, but such interaction is hard to model due to the uncertainty inherent in human behaviour.

In order to verify the efficacy, solidity and inventiveness of this approach we need to carry out more tests; we need to adopt it extensively in the design and implementation of new PSSs and we must bring it to bear upon future intelligent solutions, such as smarter services in smarter products. The approach we propose here will have a significant impact on the definition of new intelligent solving procedures based on mechatronics system, aiming at satisfying customer needs not solely via traditional products but thanks to the provision of highly efficient solutions.

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