Towards a methodology to engineer industrial product-service system – evidence from power and automation industry

Abstract

Manufacturing companies whose products have become increasingly commoditized are currently striving to identify innovative value propositions allowing them to re-position themselves in the market. This is gradually leading to a business shift from delivering traditional transaction-based, product-centric offering to the provision of integrated Product-Service Systems (PSS). However, the number of companies failing in successfully pursue such a transition is still increasing. Consequently, Service Engineering (SE), a discipline concerned with the systematic development and design of services and product-services, is gaining particular interest in both the scientific and practitioner communities. This paper contributes to these fields by proposing a complete overview of the applicability of the *SErvice Engineering Methodology* (*SEEM*) in an industrial context. The SEEM aims at supporting companies approaching the introduction of PSSs in their portfolio and suggests a structured decision-making process to (i) define the PSS offering most aligned with company product(s) and customer needs, (ii) (re-)engineer the (existing) service delivery processes, and (iii) balance the external performance (e.g. customer satisfaction, delivery time, service cycle time) with the internal performance (i.e. efficiency) of the service delivery process. The noteworthy benefits achievable through the SEEM are illustrated through a real case at the industrial partner ABB – a multinational company providing power and automation solutions. The implementation of all the SEEM steps is thoroughly described, and the advantages experienced along with the difficulties encountered are highlighted. Managerial implications and the main gaps to address in future research are also discussed.

1 Introduction

The recent economic crisis and the saturated and commoditized market have led manufacturing companies to rethink their traditional business and move beyond simply providing goods [1].

These global trends, together with increasing market saturation [2], make the companies aware about the strategic relevance of the provision of additional product-related services. This is perceived as a new source of value and competitive advantage by either reactively fulfilling explicit customers' requirements [3], or proactively providing them with new services or integrated Product-Service Systems (PSS) [4].

Therefore, these companies have to focus on services or service-oriented products to succeed in the market. Thus, they need to carry on with their traditional product design approach and to integrate it with proper service design as a mean to develop a marketable PSS. In addition, companies need suitable models, methods and tools for collecting, engineering and embedding in a solution (bundle of product and service) all the knowledge that meets or exceeds people's emotional needs and expectations [5] [6]. Up to now, manufacturing companies have focused their engineering capabilities on the pure physical product, neglecting the adoption of systematic engineering procedure for the development of the service components of an integrated solution. To this purpose, specific methods and models are required since, even if provided in conjunction with a product, services are characterized by high levels of intangibility, uncertainty and simultaneity [2]. In this context, Service Engineering (SE) has emerged as a discipline calling for the design and the development of product-related service offering adding value to customers.

In spite of the great success of the SE as an academic discipline, few of the methodologies available in literature can be directly adopted by companies for two main reasons. Firstly, most of the methodologies identified are too complex or too many methods are suggested (e.g. [7]). Secondly, the majority of them exclusively focuses their attention on designing solutions able to satisfy technically customer needs [8] [9] [10] [11] [12] [13] [14]. In any case, they do not consider company internal performance. Therefore, balancing the external performance (e.g. customer satisfaction, delivery time, service cycle time) with the internal performance (i.e. efficiency) during the delivery of a product-related service has been neglected in literature. To be sustainable in the long term, companies need a methodology able to overcome the previous mentioned gaps [15].

The *SErvice Engineering Methodology* (SEEM) has been introduced to fulfill this last challenge. *SEEM* proposes a set of methods that can be integrated with traditional product design and that can support companies in engineering and/or reengineering their offering. The SEEM structure supports in i) identifying new product-related service concepts fulfilling customers' needs and ii) identifying an efficient service delivery process balancing the company external performance and internal performance.

This paper aims at describing in detail the SEEM structure and at demonstrating its practical applicability through an implementation in a real industrial environment.

The paper is structured as follows: Section 2 presents a literature review on Service Engineering with a focus on the models and methods currently available. Section 3 describes the principal constructs of the methodology, while section 4 provides a full overview of the deployment of the methodology in a real industrial environment. Section 5 summarizes the most relevant managerial implications while section 6 concludes the paper and proposes further research prospects.

2 Service Engineering in the Product Service System context

Designing and developing a PSS is a complex task due to the long and unpredictable lifecycle and the number of interactions among the actors involved and the constituting components [16] [17] [18]. In fact, while in the area of product design a plethora of methods is widely accepted by the research community, in the area of pure service and product-related service design such robust and common approaches are not available. Consequently, when compared to physical products, services are generally under-designed and inefficiently developed [19]. The need of methods in the area of service design is increasingly being recognized as relevant by designers, engineers and managers to create a successful solution, even though the knowledge on how to develop a service and who should design it is still marginal [20]. This is the main motivation behind the continuous growth of Service Engineering (SE) as a technical discipline. Based on the definitions provided by Bullinger et al. [21] and Shimomura and Tomiyama [13], SE can be termed as a technical discipline concerned with the systematic development and design of services, aiming at increasing the value of physical artefacts. It is a rational and heuristic approach based upon the discussion of alternatives, goals, constraints and procedures, through the adoption of modelling and prototyping methods. Accordingly, the aim of SE is to increase the value of service offering by improving the service conception, service delivery and service consumption through the adoption of proper engineering methodologies. The development of a Service Engineering methodology implies the definition of *development process models*, describing the steps needed to engineer a service, and *concrete methods*, defining how to perform the model phases [21].

As stated by [22], several authors developed design methodologies for PSS under the Service engineering umbrella [23]; [13]; [24]; [25]; [26]. These researchers struggled with the definition of models and methods either to engineer the service component of a PSS or to integrate the traditional product design and the service design through the development of a solution.

By analyzing the most relevant works in PSS and SE fields [27] [28] [29] [30] [8] [9] [10] [11] [12] [13] [14] [7] [31] [32] [33] two gaps have been identified: i) they focus mainly on customer perspective and ii) they lack of critical and in depth evaluation of PSS performance in practice [34] [15]. Recently, some authors tried to overcome these gaps testing their methods in industrial setting [15] [34] [35] [36] [37] [38] [39] [40]. However, they all have a strong customer orientation in relation to the design of the PSS service components. Yoon, Kim and

Rhe [41] consider both the customer and the company perspective but their work is limited to the PSS evaluation without considering its design. Also Pezzotta, Pirola, et al. [42] identify a way to consider both the customer and the company perspective; however, the framework they proposed has not been validated in a real industrial environment.

To overcome the identified gaps, this paper proposes a methodology validated at industrial level balancing the company external performance with the long term business sustainability. For this purpose, a development process model and related concrete methods have been selected based on the literature analysis on both SE and PSS design.

Summarizing the most widespread models [9] [8] [7] [10] [11] [12] [13], four main common phases can be highlighted:

1) customer analysis: identification of customers' features and needs;

2) requirements analysis: definition of product or service requirements addressing customers' needs;

3) PSS design: identification and design of solution(s) satisfying customers;

4) PSS test and implementation: test the performance of the identified solution and implement it.

Concerning the methods, a wide range of authors has proposed alternative methods to carry out the above-mentioned phase. Table 1 lists these methods along with the phase where they have been adopted.

Table 1: Summary of available PSS design and SE methods

Phase	Methods	References
Customer analysis	• Persona Model	[43] [44] [45] [46]
	• Cost-benefit analysis	[47]
Requirements generation and analysis	• Quality Function Deployment (QFD)	[48] [17] [49] [50] [37]
	• Benchmarking	[17]
	• Functional Analysis / FAST - Function Analysis System Technique	[45] [51] [50] [37]
	• AHP	[52] [50]
	• Agent Based Simulation	[53]

PSS design	• Functional Analysis / Function Analysis System Technique (FAST)	[54] [14] [55]
	• Service Blueprinting	[56] [46] [31] [57] [58] [59] [50]
PSS evaluation and implementation	• Simulation (Discrete Event Simulation and continuous simulation)	[60] [61] [62] [63] [38] [39].
	• QFD	[64]
	• 3D visualization	[65]
	• Failure Mode and Effects Analysis (FMEA)	[66] [67]
	• ANP	[68] [69]
	• AHP	[70]

Most of the PSS design and SE literature highlights the relevance of deeply analyze the customer explicit or latent needs. However, only few methodologies in these fields clearly state how to collect, analyze and summarize those data. As reported in Table 1, the Persona Model results as the most adopted method due to its ability to summarize in a visual way the data collected thought market segmentation surveys or interviews.

The identification of the PSS that can really answer to customer needs is carried out in the second phase. Among the different methods, most of the methodologies adopts Quality Function Deployment (QFD), since it represents a structured approach to define customer needs and translate them into product-service functions [49], and Functional Analysis / FAST - Function Analysis System Technique, which allows to translate the functions expected by the customer into functionalities and the technical solutions [14].

The third phase deals with the PSS design. Here, service blueprinting is the most used method since it allows representing the service delivery process from the customer perspective highlighting the physical elements that can be perceived by the customer, and the activities where customer gets in touch with the service provider [58].

Lastly, in the PSS evaluation and implementation phase, the designed PSS is assessed and, if satisfactory, implemented. Despite the several methods suggested, the majority of methodologies in literature adopts simulation (both discrete event and continuous simulation) since it allows for the dynamic analysis of a system under different and future conditions and scenarios [63].

Starting from the models and the methods used in literature, in the next section the Service Engineering methodology (SEEM), developed in close collaboration with practitioners and involving industrial feedback since the beginning, is proposed. The main purpose of SEEM is to support companies in engineering and re-engineering their PSS offering, taking into consideration both company internal performance and customer needs.

3 SErvice Engineering Methodology Overview

As emerged in the literature review, one of the main gaps in the PSS design and SE is the absence of an industrial tested methodology focusing on both customer perspective and company's internal performance. This rather myopic view can lead to the development of services fulfilling customer needs completely, but that can potentially undermine the company economic sustainability in the long term, or vice versa.

To achieve this goal and to ensure its industrial applicability, SEEM has been developed starting from the theoretical background presented in previous section and has been refined adopting an iterative cycle of feedbacks and reviews collected during the application in several industrial cases. These applications have been carried out in collaboration with ABB, a leading company in power and automation technology. Continuous interaction and close collaboration with ABB scientists and service managers allowed to refine the methodology in terms of theoretical concepts, methods and terminology making it more appropriate for the industrial environment.

Hereafter the SEEM steps and methods are described.

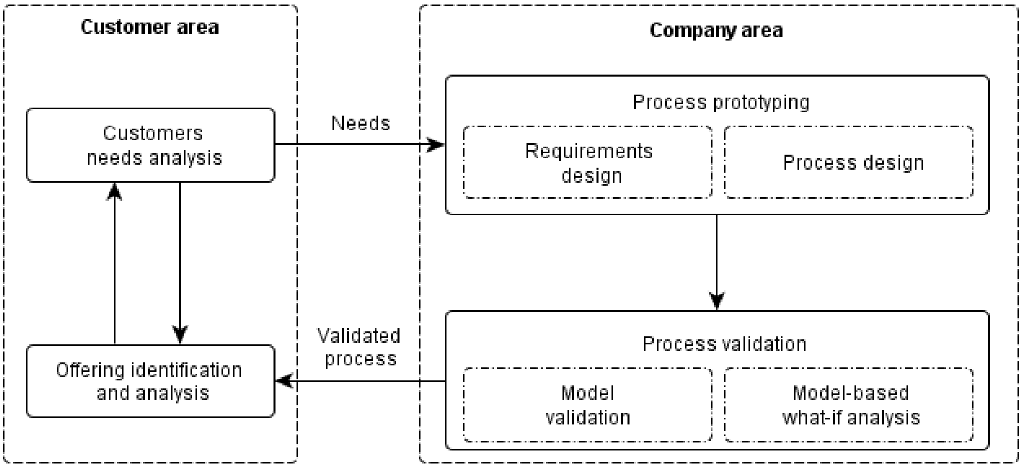

Figure 1: The SErvice Engineering Methodology (*SEEM*)

The *SEEM*, represented in Figure 1, is composed of two main areas: the customer area and the company area. The former addresses customer analysis while the latter aims at supporting the definition of a service delivering process considering both the company external and internal performance.

More in detail, the *SEEM* encompasses the most common phases in the SE models, namely: offering identification and analysis, customer needs analysis, process prototyping, and process validation. As shown in Figure 1, the first two phases belong to the customer area, while the remaining two belong to the company area. In addition, some of these phases are further decomposed into tasks and, for each of them, one or more methods have been suggested.

In the remainder of this section, an overview of the four phases is provided. Moreover, since industrial companies often need to re-engineer its offering SEEM has been created in order to be applicable also in this situation. Obviously, when it is applied to PSS re-engineering, the analysis starts from the comparison of the company offering and the customer needs in order to identify existing or potential gaps.

3.1 Customer area

The first two phases in (re)-engineering a PSS is the analysis of the customers' needs and of the current solution portfolio (if any). The aim is to identify the customer needs to be fulfilled by the PSS.

3.1.1 Offering identification and analysis

This phase of the *SEEM* refers to the analysis of the current offering of the company and/or generally of the market. The aim is to have a clear understanding of how the company is actually satisfying the customer needs.

3.1.2 Customer needs analysis

The purpose is to obtain a clear understanding of the customers' needs and requirements in terms of products, service, and expected performance. This analysis can also lead to the segmentation of customers in several, homogeneous classes in terms of main requirements and needs *[44]*. Even if a specific method to perform this analysis is not suggested, this step can be implemented in several ways, such as through market research, customers' interview, focus groups or expert panels.

3.2 Company area

Starting from the customer needs identified in the customer area, the PSSs able to satisfy such need(s) are identified and the product and service elements defined. Moreover, the service delivery process(es) are prototyped, validated and added to the company offering.

3.2.1 Process prototyping

The first phase of the company area is the process prototyping, which aims at identifying one or more PSSs and at designing the associated service delivery process(es). This phase is further decomposed in two tasks.

3.2.1.1 Requirements design

This task puts into evidence the main relationships between customers' need(s), PSS offering and the resources needed to deliver the PSS. For this purpose, the *Service Requirement Tree* (*SRT*) and a *Quality Function Deployment (QFD)* based analysis are proposed.

The SRT, is an "ad-hoc" method developed in the SEEM and it is based on the functional design domain knowledge. It is mainly drawn on the "Customer - Oriented FAST model" [54] and the "View Model" [71]. However, the concept of "function / functionality" behind these methods revealed complex to be understood by company representatives. Thinking about "what customer would like from the company" resulted more intuitive and approachable. Thus, the SRT has been developed as shown in Figure 2.

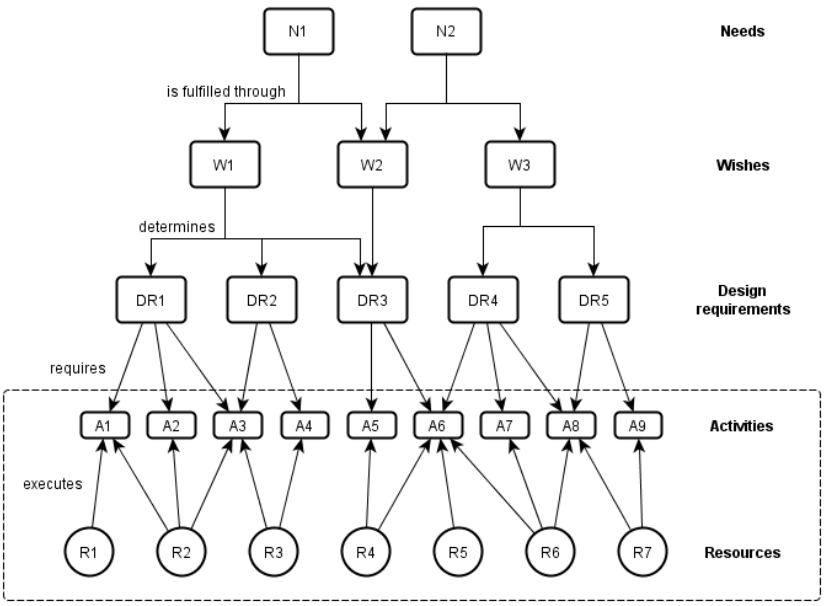

Figure 2: *Service Requirement Tree* (*SRT*)

a. *Needs* (N): needs express the customer necessities, in terms of results of the expected PSS and/or performance. These needs are identified in the first phase of the SEEM, through the customer analysis. An example can be “maximize the plant availability”.

b. *Wishes* (W): they express how the customer wants to satisfy his/her needs. For example, considering the need “maximize plant availability”, the wishes can be “reduce breakdown time” and “increase plant lifecycle”.

c. *Design Requirements* (DR): they represent how the company can satisfy customer’s wishes. In other words, they represent the PSS(s) the company can offer to achieve customers’ wishes and, to fulfil accordingly their needs. For example, to fulfill the customer wish “reduce breakdown time”, possible design requirements can be “preventive maintenance” or “remote monitoring based maintenance”.

d. *Activities (As) and Resources (Rs)*: they represent how the company provides a specific design requirement to customers. Its aim is to give explicit information to the process design in terms of main service delivery process activities (As) and resources that can be both product components and human resources (Rs). In case of product components, their design is left to traditional product design methods used in the company while for service-related activities and resources they are discussed in the next steps of the methodology.

These four levels are hierarchically related in the SRT, as depicted in Figure 2. Considering the literature findings, a method based on the Quality Function Deployment (QFD) approach has been adopted to identify the most relevant elements (DRs, Activities and Resources) in fulfilling customer wishes and needs. Besides being the most widespread method in literature, QFD has been selected because the way in which weights are set and how the assessment of the tree elements is carried out, are readily understandable by industrial people.

The QFD-based approach developed in the SEEM is articulated in four main steps. A weight is assigned by the people involved in the PSS design (e.g. customers, service managers, sales people) to each branch of the SRT in order to quantify the importance of the lower level element in satisfying the linked upper level element. The possible weights are:

- "9": the lower level element is fundamental to fulfill the upper level element
- "3": the lower level element is important but not fundamental to fulfill the upper level element
- "1": the lower level element is not essential to fulfill the upper level element

For each step, assuming a set $\boldsymbol{N}$ of needs and a set $\boldsymbol{W}$ of wishes with cardinality η and ω, respectively, a matrix is built a follows:

- The first step evaluates the relation between needs $i \in \boldsymbol{N}$ and wishes $j \in \boldsymbol{W}$, by measuring to what extent each wish is important to satisfy the need. Such value is represented by a weight I_{ji} that can assume the values 1, 3 and 9 as previously illustrated. For each wish, an importance measure WI_j is defined and expressed as:

$$WI_j = \sum_{i \in \boldsymbol{N}} NI_i \cdot I_{ji} \qquad \forall j \in \boldsymbol{W} \qquad [1]$$

where NI_i is the weight assigned to i-th need. Similarly, the importance can be expressed as a percentage value as follows:

$$WI\%_j = \frac{WI_j}{\sum_{\hat{\jmath} \in \boldsymbol{W}} WI_{\hat{\jmath}}} \qquad \forall j \in \boldsymbol{W} \qquad [2]$$

Table 2 shows the QFD based matrix linking needs and wishes.

Table 2: QFD based matrix: needs vs. wishes

Needs / Wishes	*Need 1*	*Need 2*	⋮	*Need η*	***W*** importance	***W*** importance %
Wish 1	I_{11}			$I_{1\eta}$	WI_1	$WI\%_1$
Wish 2					WI_2	$WI\%_2$
…			I_{ji}		…	…

Wish ω	$I_{\omega 1}$			$I_{\omega\eta}$	WI_{ω}	$WI\%_{\omega}$
Needs weights	NI_1	NI_2	…	NI_{η}		

- The second step analyses the relation between the set of wishes ***W*** and the set of design requirements ***DR*** of cardinality *δ*, highlighting what the company should provide to reach the customer wishes. Also here, a weight I_{kj} is assigned to each couple $j \in \boldsymbol{W}$ and $k \in \boldsymbol{DR}$, expressing the relative importance of the *k*-th design requirement in satisfying the *j*-th wish, while the weights WI_j are those obtained at the previous step, as reported in Table 3.

Table 3: QFD based matrix: wishes vs. DRs

Wishes / Design Requirements	*Wish 1*	*Wish 2*	…	*Wish ω*	***DR*** importance	***DR*** importance %
DR 1	I_{11}			$I_{1\omega}$	DRI_1	$DRI\%_1$
DR 2					DRI_2	$DRI\%_2$
…			I_{kj}		…	…
DR δ	$I_{\delta 1}$			$I_{\delta\omega}$	DRI_{δ}	$DRI\%_{\delta}$
Wishes weights	WI_1	WI_2	…	WI_{ω}		

The design requirement importance is calculated as follow:

$$DRI_k = \sum_{j \in \boldsymbol{W}} WI_j \cdot I_{kj} \qquad \forall k \in \boldsymbol{DR} \qquad [3]$$

$$DRI\%_k = \frac{DR_k}{\sum_{\hat{k} \in \boldsymbol{DR}} DR_{\hat{k}}} \qquad \forall k \in \boldsymbol{DR} \qquad [4]$$

The QFD based matrixes linking design requirements ***DR*** - activities ***A***, and activities ***A*** - resources ***R***, are based on exactly the same logic and allows the calculation of activities (AI and AI%) and resources (RI and RI%) relevance.

The QFD based analysis supports the decision-making process since it displays important information in terms of relative importance among design requirements, resources and process activities in relation to the main customer need(s). In other words, QFD helps define the activities and resources the company should focus on to properly fulfill customer needs.

In conclusion, the SRT allows to identify new or updated PSS(s) highlighting the service delivery process activities and resources, and the enabling product components. The SEEM does not tackle the design and engineering of the product components, identified as resources in the last level of the SRT, but it relies on traditional and widespread product design methods and tools.

3.2.1.2 Process design

This task involves the definition and representation of alternative service delivery processes of one or more design requirement(s). As previously stated, this phase of SEEM, as well as the following ones, focuses only on engineering (or re-engineering) the service component of a PSS (i.e. the service delivery process).

In the *SEEM*, the Service Blueprinting [57] [58] [59] technique is used for simultaneously depicting the service delivery process, the points of customer contact, and the physical evidence of the service delivery from the customer's point of view. In particular, the activities composing the process are classified into 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). In case of re-engineering, this phase entails the mapping of the current service delivery process(es) (*as-is*) as well as the identification of possible alternative and improved delivery process(es).

Furthermore, in the blueprinting model the parts of the process corresponding to the activities identified through the SRT are highlighted. This link allows for the identification of the most relevant performance to be monitored in order to answer to customer needs. In fact, internal and external performance are measured at both single activity level and the entire service delivery process level.

3.2.2 Process validation

The result of the previous phase consists in the definition of one or more alternative service delivery processes. Nonetheless, this is a static result: nothing can be inferred about the performance of the process(es) from internal and external point of view. Therefore, the aim of the third phase of the *SEEM* involves the validation and assessment of the prototyped process(es), as well as the identification of the most suitable configuration of the process activities and resources. To this end, the *SEEM* adopts a process simulation approach, since it allows for the dynamic analysis of a system (the service delivery process in this case) under different conditions and scenarios. Considering that service delivery processes are fairly well defined discrete processes [72] [73] [74] [38] [39], the methodology suggests the adoption of Discrete Event Simulation (DES). DES has a great potential as a means of describing, analyzing, and optimizing service delivery processes [75] and supports their systematic and optimized engineer. DES can be run with a wide range of software available in the market [61].

The purpose of the simulation is to: i) assess the performance of a service delivery process under different conditions (*what-if* analysis), ii) evaluate the effectiveness of possible process changes, iii) support the selection of the process configuration with the best trade-off between internal and external performance, and iv) provide insights about the service delivery process dynamics and bottlenecks.

The following table reports the validation procedure, highlighting the difference between the engineering and the re-engineering case.

Table 4: Validation procedure

	Engineering case	***Re-engineering case***
Check the solidity of the prototyped process:	Once the process is simulated, the performance obtained (in terms of number of jobs performed, lead-time …) are compared with the desired performance. The simulation model is refined until it is possible to assert that the model is realistic and fits the desirable performance.	Once the process is simulated, the performance obtained (in terms of number of jobs performed, lead-time …) are compared with the actual performance. The simulation model is refined until it is possible to assert that the model fits the industrial reality.
Define the as-is future target scenario	n.a.	The as-is service delivery process model, refined in the previous step, is simulated setting future company conditions (such as forecasted service demand, updated service portfolio, and so on) in order to understand how the actual company service delivery process would perform under the forecasted changes (as-is future target scenario).
Perform the what-if analysis	Alternative service delivery processes are created, simulated and compared in order to define the *best process configuration*, namely the one maximizing the trade-off between internal and external performance	Starting from the as-is future target scenario, alternative service delivery processes are identified, simulated and compared in order to define the best process configuration, namely the one maximizing the trade-off between internal and external performance.

Considering the main purpose of the *SEEM*, related to the identification of a proper balance between external performance (*Customer satisfaction based on cycle time*) and internal company performance (*Company internal measures*), two categories of KPIs are assessed in the validation phase. They are:

1. *Company internal measures* that can be set considering the company's strategy and goals. The typical indicators belonging to this category are activities' duration, waiting times, resources utilization, costs and so. Usually, these indicators can be measured directly through the simulation.
2. *Customer satisfaction based on cycle time*. This indicator takes into account the total service cycle time that is defined as the total time elapsed from when a customer expresses a need to when that need is satisfied [76]. Service cycle time indicator is obtained through the simulation results. The main concept behind this indicator is that the lower is the cycle time the higher is the customer satisfaction in relation to the selected service [77] [78]. Furthermore, the higher is the relevance of the activity in satisfying customer needs (emerging from the QFD-based approach), the higher is the benefit of having low cycle time. For this reason, the indicator considers the cycle time with respect to the activity and the importance of the activity in satisfying the need (I_{hk}).

Therefore, the customer satisfaction based on cycle time related to each activity $h \in \boldsymbol{A}$ and to each design requirement $k \in \boldsymbol{DR}$ (SA_{hk}) has been defined as follows:

$$SA_{hk} = \frac{Ttarget_A(h)}{T_A(h)} \cdot \frac{I_{hk}}{\sum_{\hat{h}} I_{\hat{h}k}} \qquad \forall h \in \boldsymbol{A}, k \in \boldsymbol{DR} \qquad [5]$$

Where

$T_A(h)$ is the average duration of activity $h \in \boldsymbol{A}$

$Ttarget_A(h)$ is the target duration to carry out the activity $h \in \boldsymbol{A}$. Target duration can be either fixed by the company or fixed as the minimum time obtained during the simulation of the as-is process configuration. In both cases the $Ttarget_A(h)$ is not the lowest possible, however it can be considered as a good target.

I_{hk} is the importance of the activity h with respect to the design requirement k as indicated in the QFD structure.

Fixing the values I_{hk}, the lower is the ratio between $Ttarget_A(h)$ and $T_A(h)$, the lower is SA_{hk}, indicating a lower customer satisfaction based on cycle time for the activity h on the design requirement k. When $T_A(h) \rightarrow 0$, SA_{hk} is closed to the target value and indicates a higher customer satisfaction based on cycle time.

The overall customer satisfaction based on cycle time indicator, *S*, is calculated as the sum of the SA_{hk} related to all the activities and design requirements previously identified:

$$S = \sum_{k \in \boldsymbol{DR}} \sum_{h \in \boldsymbol{G_k}} SA_{hk} \cdot DRI\%_k \qquad [6]$$

where G_k is the set of activities that are involved in the design requirement k (e.g. with reference to the SRT in Figure 2, it is possible to write $G_{DR1} = \{A1, A2, A3\}$).

By construction, when $S \rightarrow 0$ customers are less satisfied with relation the service cycle time, whereas when $S \rightarrow 1$ customers result more satisfied. When the duration of each activity is equal to the target one, *S* is equal to 1. S can result higher than 1, in the case DR_k duration is lower than the target one. This last situation is not common because the target value is a good goal to achieve by definition.

Thus, considering the company internal measures and the customer satisfaction based on cycle time indicators, simulation is 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.

In the next section, the implementation of the methodology in an industrial case of PSS re-engineering is presented and discussed.

4 SEEM on practice - Industrial case at ABB

This section illustrates the application of SEEM in an industrial context. The aim is to provide insights on how the methodology has been used to re-engineer the ABB service portfolio.

4.1 The company

ABB is a global leader in power and automation technologies. The company is divided in five divisions that are, in turn, organized in specific business units in relation to the customers and industries they serve. The ABB product portfolio is composed of complex offerings such as medium and high voltage power products, power systems, solutions for industrial processes optimization, discrete automation products, and low voltage products for electrical application. As it could be seen, this diversified product portfolio needs different service requirements, i.e. features, price and lifecycle intervention. The ABB service organization provides to its customers 11 service categories ranging from traditional corrective maintenance to system performance management. Such an extensive product-related service offering and heterogeneous product portfolio make the sharing of best practices among the business units a daunting task. The adoption of a systematic service engineering methodology along all the business units is crucial to properly identify and engineer PSS leading to increase service revenues and fulfil customer needs. This motivated the implementation of the SEEM at ABB.

4.2 SEEM application at ABB

The SEEM application in ABB deals with the re-engineering of the actual product-related service portfolio of one specific business unit. The rationale behind this decision is threefold. Firstly, this business unit is composed of more than fifty service-related employees, making difficult for the service manager to assess quickly how balanced is its business. Secondly, the product-related service portfolio is complex and with some efficiency issues. Finally, the customer segments are highly diversified.

The following paragraphs describe in details all the steps and the results obtained during the industrial application. For each step, several meetings with ABB managers and employees, involved in the service design and delivery, have been held to understand the customer needs, analyze the current offering and processes and to collect all the data. This allowed the research team to avoid misunderstanding and to triangulate the data collected. Those meetings have been also useful to keep the company involved in the research, collect feedback, update and modify the methods adopted, and early transfer the results to the business unit.

4.2.1 Customer area: Offering identification and analysis and customer needs analysis

As previously mentioned, the methodology started with the analysis of the current service portfolio. Currently, the 90% of the total service revenues of the business unit is derived from the following offering:

- *Preventive and corrective maintenance*. It refers to all the activities performed on the customer's product in order to make it functioning as efficiently as possible or, in case of corrective, to recondition it to proper functioning. In the analyzed case, maintenance can be performed at the customer site or at the ABB plant.
- *Replacement.* It consists in the provision of products currently out of production. A limited amount of these products is still produced for customer with plant's specific needs.
- *Retrofit.* ABB provides specific kits to adapt a new product to the fixed part of an old one. This helps in adding functionalities to an aged product.
- *Spare parts provision*. ABB provides to its distributors and end-customers a set of spare parts that could be ordered and shipped to the final destination.

The identification of the main customer needs is the second step of the SEEM application to the service portfolio re-engineering. Customer needs have been drawn out from marketing and customer's data already available in ABB, and segmented by using cluster analysis. The obtained segments have been described by using the persona model [44]. Among the key learning from this marketing-oriented analysis, there is the evidence that ABB has to deal with heterogeneous types of customers with different needs and expectations from ABB service. For the current analysis, two categories with distinctive features have been taken into account:

- *Customers type I:* these customers do not have internal capabilities to manage their maintenance activities and they completely rely on ABB to maintain their installed base in a good operating condition;
- *Customers type II*: these customers are usually large companies with an internal team dedicated to maintenance. They directly take care of their installed base, and resort to ABB support only for complex service jobs and for critical spare parts.

The research conducted highlighted that both these customers' types share the same need, which is to maximize the availability of their installed base ("maximize availability" in short hereafter). This need has been the starting point for building the Service Requirement Tree (SRT).

4.2.2 Company area: Process prototyping

Requirements design is the first task of the "process prototyping" phase. It entails the development of the SRT to identify the design requirements, and the implementation of the QFD logic to weigh the activities and resources relevance in fulfilling customer needs. Once the PSS(s) has been identified, the second task is the designing the associated service delivery process(es).

4.2.2.1 Requirements design: definition of the SRT

The Service Requirement Tree (SRT) has been built for both the two types of customer starting from the common need "maximize availability". It is important to highlight the effort spent by ABB managers to define both the existing and hypothetical design requirements (DRs), activities (As) and resources (Rs). The single initial need allowed the identification of three main wishes (optimize plant, reduce downtime and extend equipment lifetime), and 13 DRs. 20 different activities have been identified (e.g. manage order, handle customer request). All the resources involved in delivering the services to the customers have been listed including humans (such as order handler or sales people), IT resources (such as ERP systems), and product components.

An extract of the SRT is depicted in Figure 3.

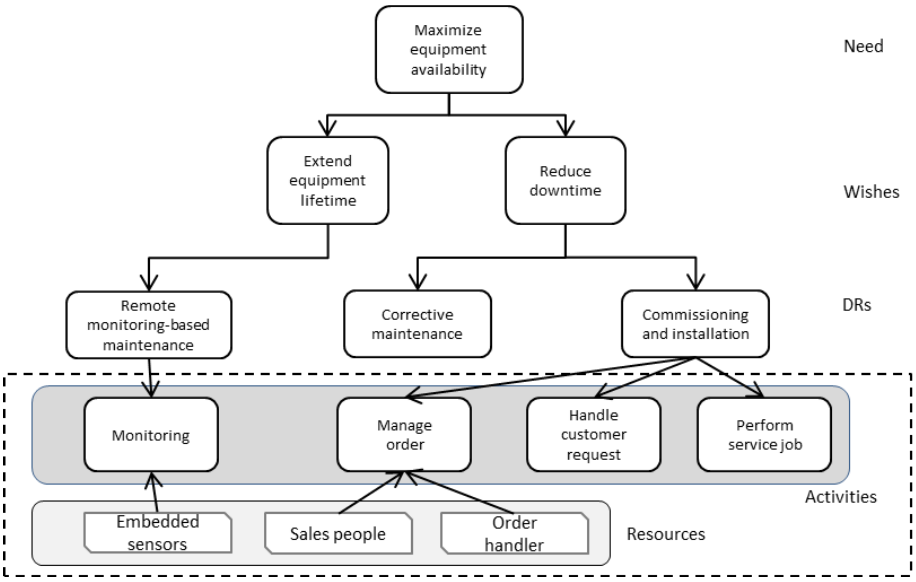

Figure 3: Excerpt from the ABB SRT

The above figure shows the deployment of the need through the wish "reduce downtime". The company can support the customer in achieving this goal through, for example, the provision of proper installation, remote monitoring-based maintenance and commissioning (DRs). To offer these services, the activities that should be performed are "manage order", "handle customer request" and "perform service job" (As). For a good order processing activity, the "sales people" and the "order handler" are the relevant resources that should be employed. The DR "remote monitoring-based maintenance" is connected to a "monitoring" activity and to a product component (i.e. the sensors). As previously stated, the design of product components is left to traditional methods and tools which are already implemented in the company.

4.2.2.2 Requirements design: QFD based analysis

After the definition of the SRT, a QFD based analysis has been carried out. To this purpose, a weight (1, 3 or 9) has been assigned to each branch of the SRT in order to define the most critical activities and the associated resources in complying with customer's need. Theoretically, this activity should be "co-developed" with the customer. However, obtaining customers availability is complex and takes a lot of time and effort. Therefore, the evaluation has been carried out by service managers and sales and marketing people. The weights have been assigned considering both the personal expertise and internal customer analysis data (e.g. "Net Promoter Score"). Then, for each level of the SRT, the following QFD matrixes have been developed: i) need-wishes, ii) wishes-DRs, iii) DRs-activities, iv) activities-resources. Table shows an excerpt of the wishes-DRs matrix for one kind of customer.

Table 5: Excerpt of the ABB wishes-DRs matrix

Wishes / Design Requirements	*Reduce downtime*	*Extended equipment lifetime*	***DR*** importance	***DR*** importance %
Corrective maintenance	*3*	-	*27*	*4%*
Commissioning and installation	*3*	-	*27*	*4%*
Remote monitoring-based maintenance	*9*	*3*	*108*	*17%*
Wishes weights	*9*	*3*		

Following the procedure reported in section 2, the resources' relevance in *maximizing equipment availability* for both types of customers resulting from the QFD based analysis is summarized in Figure 4. This chart shows the resources to which ABB should pay particular attention while engineering and re-engineering its service delivery processes in order to satisfy the needs of the two different kind of customers. In fact, it is fundamental to select the resources with the right skills and avoid over utilization of such resources since they have to manage the relation with the customer.

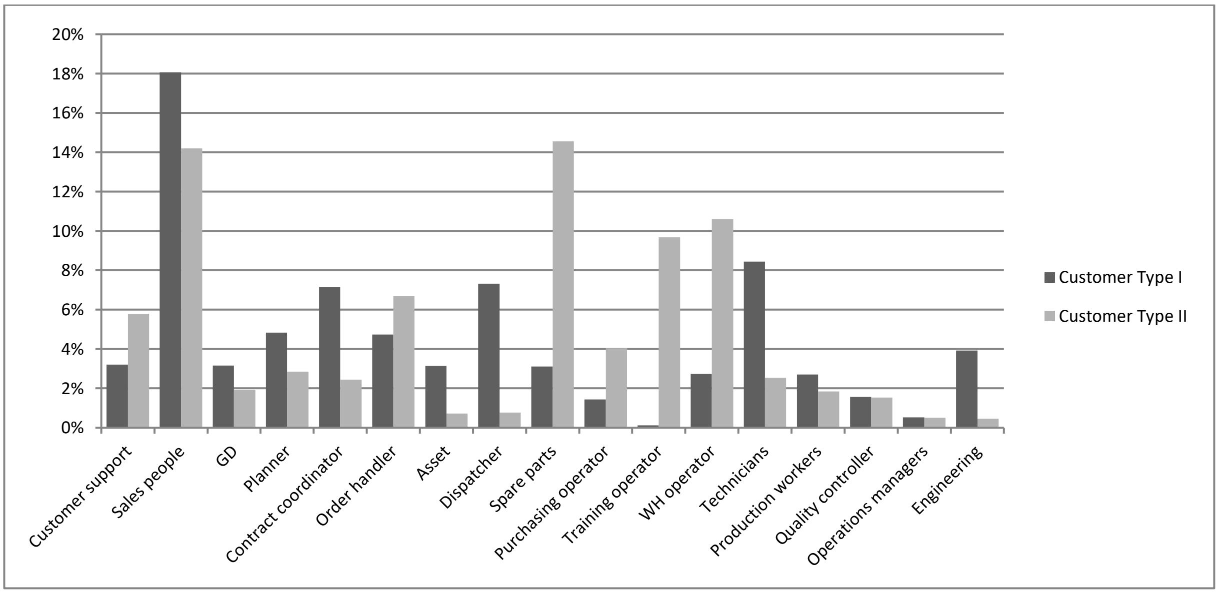

Figure 4: Resources relevance for the two customer types in *maximizing equipment availability*

According to the QFD based analysis, the most important resources to satisfy customer type II are "sales people", "training operators", "spare parts" and "warehouse operators". This result is in agreement with the definition of the customer type II: if he/she wants to perform the maintenance activities on his/her own, he/she would definitely need a good training and a fast spare parts delivery service for which the "warehouse operator" and the "sales people" are key players. On the other hand, to satisfy customer type I, who completely relies on ABB, the most critical resources are the "sales people" who defines the contract terms and conditions, and the “technicians” who perform the service job. These results about resources’ relevance have been the key levers to identify possible process improvement, keeping a high focus on customer needs.

If needed, the QFD based analysis can be adopted to support the classification of DRs and activities according to their relevance for customers. Thus, it would help in defining company’s strategy.

4.2.2.3 Process design

The second task of the process prototyping is process design using the blueprinting technique [59] [57]. Considering the focus of the case, four different service delivery processes have been analysed and drawn in a blueprint map using MS Visio. In these maps, all the activities have been represented, putting into evidence the resources performing them and their relation with the customer process. About 120 activities have been identified for each service delivery process performed by the customers, ABB front-end resources (e.g. sales people, onsite technicians), ABB backstage resources (order handlers, workshop technicians), and support processes employees (e.g. logistics, administration). The service delivery processes of the ABB service offering are characterized by a common structure that is described hereafter and represented in Figure 5:

- *Handle customer request*. The process starts with a service request from the customer. The sales people receive these requests, analyze the customer reliability and define a quotation for the selected service.
- *Confirm capability*. The customer reviews the ABB offer and determines whether it fits its requirements. Then, the customer sends a service order to ABB.
- *Manage order*. Once the service order is received, it is compared to the offer to check its alignment, and then uploaded in the ABB’s ERP system with all the related information.
- *Mobilize and plan*. This phase strictly refers to the case of intervention at the customer’s plant. ABB and the customer agree on a date to perform the service and set all the

documentation needed before the intervention. The “dispatcher”, responsible for this task, also selects the technician(s) to perform the service job according to staff availability and to failure criticality.

- *Prepare service job*. In this phase, the technicians define the spare parts and the material needed for the intervention. In the case of workshop maintenance, the customer sends the product to ABB’s premise.
- *Perform service job*. In the case of onsite maintenance, the “technician(s)” go(es) to the customer, whereas in the other case the “production workers” perform the service job, or assemble the retrofitting kit or the spare parts at the ABB facility.
- *Complete service job*. The final part of the process entails the shipment of the materials to the customer (in case of workshop maintenance) and the collection of all the documents. Finally, the invoice is sent to the customer.

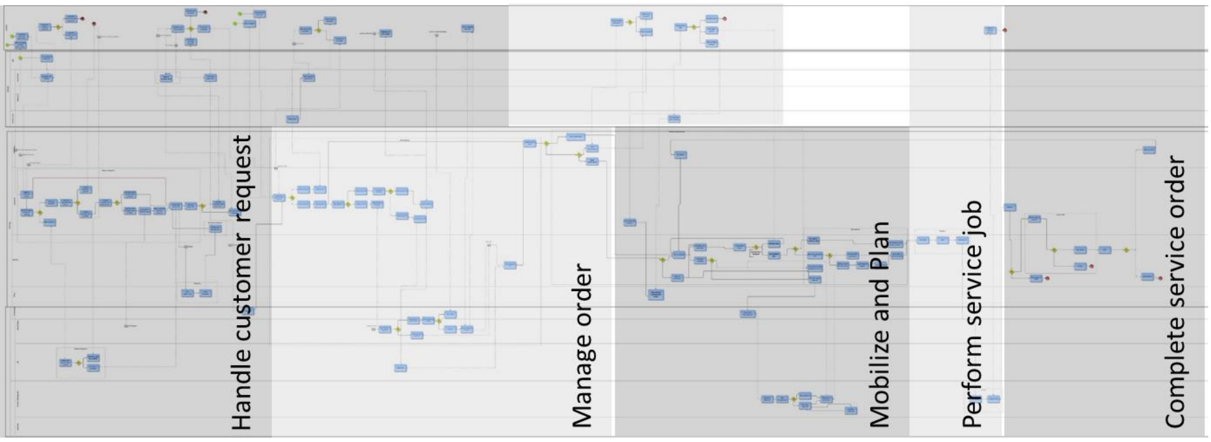

Figure 5: ABB Service Blueprinting map

The next section focuses on the validation of the service delivery process devised on the blueprint.

4.2.3 Company area: Process validation

In a re-engineering case, the main goal of the process validation step is the assessment of the current processes' performance and the identification of the resource configuration that better balance the external performance (i.e. customer satisfaction based on cycle time) and internal efficiency.

Considering the mid and long term ABB strategies and targets for the service business, the *as-is future target* scenario has been defined and the *what-if* analysis has been carried out in order to evaluate the performance of current organization. Based on these results, the best solution has been identified among the different scenarios ensuring a balance between the external performance, evaluated through the customer satisfaction based on cycle time, and the internal performance. For this purpose, the Discrete Event Simulation (DES) approach has been adopted. The blueprinting maps represented in Microsoft Visio have then been translated into a simulation model with ProModel Process Simulation software.

The simulation model has been developed considering the *entities* as the customer requests of the different services and the *events* as the service delivery process activities. The entry distributions of the entities have been inferred from ABB historical data by calculating the best fitting distribution.

With regard to activities' duration, a distribution function has been specified, according to the available data or to ABB employee's experience. The majority of them have been set as a triangular distribution with a minimum, a maximum and a mode. Furthermore, a resource or a group of resources has been assigned to each activity. Additionally, for each human resource, the working schedule has been appointed to define the amount of their time dedicated to the service process under investigation. In total, 55 different resources have been modelled.

Once validated, the simulation has been run over a period of three years for ten replications to ensure consistency and variability of the results. Moreover, since the system at time zero has been assumed empty, a warm-up time of six months has been set.

At the end of the simulation, the results have been collected and compared with real data to check the robustness of the model. The main KPIs, belonging to the two above-mentioned categories, have been the following:

1. *Company internal measures:*
   - *Number of completed service jobs per year*. For each kind of service, the number of requests yearly received, together with those completed have been identified. The number of entities still in the system or exiting from the system is automatically shown by the simulation software;
   - *Time to complete a service job.* The time for processing each kind of service request has been measured with a "ad hoc" function monitoring the time laps between the request arrival and its conclusion;
   - *Resource utilization.* It represents the utilization of the human resources based on the time they dedicate to the process activities. Resource utilization is a standard output of the simulator;
   - *Queues*: it has been measured as the waiting time to perform an activity and it is a standard output of the simulation software. The queue lengths along with the resource utilization have been used to identify the bottlenecks in the system.
2. *Customer satisfaction based on cycle time*. This performance has been measured through the indicator proposed by the SEEM and presented in section 3.2.2. The data used as input to calculate this indicator are standard output of the simulation software.

Following the validation procedure for the re-engineering case, the model, simulating the current process, has been run (*as-is* scenario) and refined until the company has confirmed its alignment with the reality.

The ABB forecasts (not reported for privacy reasons) have been set into the model to define the *as-is future target* scenario. The *as-is future target* analysis showed how ABB would face the forecasted changes with the current organization. In particular, in the *as-is future target* data related to the introduction of new product-related services and the increase and decrease of the demand for some services have been evaluated. As expected, those changes affect all the process parameters and in particular the service cycle time and the resource utilization.

The *as-is future target* simulation results showed three main bottlenecks (in terms of long queues and high resource utilization): i) handle customer request (performed by the "sales people"), ii) mobilize and plan, referred to the service jobs performed at the customer site ("dispatcher"), and iii) performing service job ("technicians").

The results obtained in terms of bottlenecks, resource utilization, customer satisfaction based on cycle time and some input from the ABB future strategy have been considered as the starting point to develop the scenarios of the *what-if* analysis.

In particular, the scenarios of the *what-if* analysis have been identified combining the factors predominantly influencing the process performance. One of the main influencing factors is represented by the capacity of the "sales people", the "dispatcher" and the "technicians", which have been revealed critical in the *as-is future target* and significant in the QFD based analysis for the customer. In addition, with regard to the bottlenecks identified in the "handling customer request" and "manage order" activities, the automation of such activities through the introduction of IT systems has been identified as a further factor influencing the overall process performance.

Thus, for each influencing factor, possible alternatives (Value) have been identified with the ABB service managers and are reported in Table together with the notation that will be used

(Set of value notation). For example, in relation to the “handle customer request” factor, two alternatives have been identified:

- introduction of new IT tools and related procedures to automate some process activities;
- keeping the process unchanged.

Table 6: Factors and response value for the development of the scenarios

Factors	**Type of value**	**Value**	**Set of value notation**
Handle customer request (*hcr*)	Qualitative	$hcr=s$: Automated process (referred to as hcr^s in the following) $hcr=n$: Non automated process (hcr^n)	$\boldsymbol{HCR}$
Manage Order (*mo*)	Qualitative	$mo=s$: Automated process (mo^s in the following) $mo=n$: Non automated process (mo^n)	$\boldsymbol{MO}$
Sales people Capacity change (*pc*)	Quantitative	$pc=0$: current capacity of the sales people (pc_0) $pc=12$: +12h sales people (pc_{12}) $pc=16$: +16h sales people (pc_{16})	$\boldsymbol{PC}$
Dispatcher Capacity change (*dc*)	Quantitative	$dc=2$: +2h Dispatcher (dc_2) $dc=4$: +4h Dispatcher (dc_4) $dc=6$:+6h Dispatcher (dc_6)	$\boldsymbol{DC}$
Technicians Capacity change (*tc*)	Quantitative	$tc=24$: +24h Technicians (tc_{24}) $tc=32$: +32h Technicians (tc_{32})	$\boldsymbol{TC}$

Each scenario is a combination of the factor values, and can be written as:

$$SC_t = (hcr, mo, pc, dc, tc) \quad \forall t \in T \tag{7}$$

where T is the set of all the scenarios. Considering the five factors and their possible value, 72 scenarios to be experimented can be identified, that is:

$$|T| = |\boldsymbol{HCR}| \cdot |\boldsymbol{MO}| \cdot |\boldsymbol{PC}| \cdot |\boldsymbol{DC}| \cdot |\boldsymbol{TC}| = 72\ T \tag{8}$$

where the operator $|X|$ returns the cardinality of the set X.

All the 72 identified scenarios have been qualitatively analyzed by the researchers and the ABB managers. Among them, 16 scenarios have been considered feasible and representative of the reality. In this paper, only the two most significant scenarios are reported for brevity, referred to as scenario A and B. Table reports the values assumed by each factor in the two selected scenarios along with the data describing the changes made to the processes. For example, in

Scenario A, the automation of the process activities causes a 50% reduction of the time to define a standard offer and a 25% reduction of the development time of a complex offer.

Table 7: Description of analyzed scenarios

	SCENARIO A $SC_A = (hcr^s, mo^s, pc_0, dc_2, tc_{24})$	**SCENARIO B** $SC_B = (hcr^n, mo^n, pc_{12}, dc_6, tc_{32})$
Change in the process		
Change in the proposal process	Automated process (hcr^s) involving: - 50% reduction of the time to define a standard offer - 25% reduction of the development time of a complex offer	Non automated process (hcr^n)
Change in the analysis of the order	Automated process (mo^s) involving: - Reduction of 50% of the time to check order coherence with the proposal	Non automated process (mo^n)
Change in the capacity of resource (working hours)		
Sales people Capacity	pc_0 – No change	pc_{12} – Increase of 12 working hours per day
Dispatcher Capacity	dc_2 – Increase of 2 working hours per day	dc_6 – Increase of 6 working hours per day
Technicians Capacity	tc_{24} – Increase of 24 working hours per day	tc_{32} – Increase of 32 working hours per day

These two scenarios have been selected since they allow performance improvement both from internal and external point of view. For each kind of product-related service under analysis, the improvement actions suggested in these scenarios helped to achieve acceptable total duration (aligned with the actual one), proper resource utilization (lower than 80%) and an adequate customer satisfaction based on cycle time (comparable or higher than the current one).

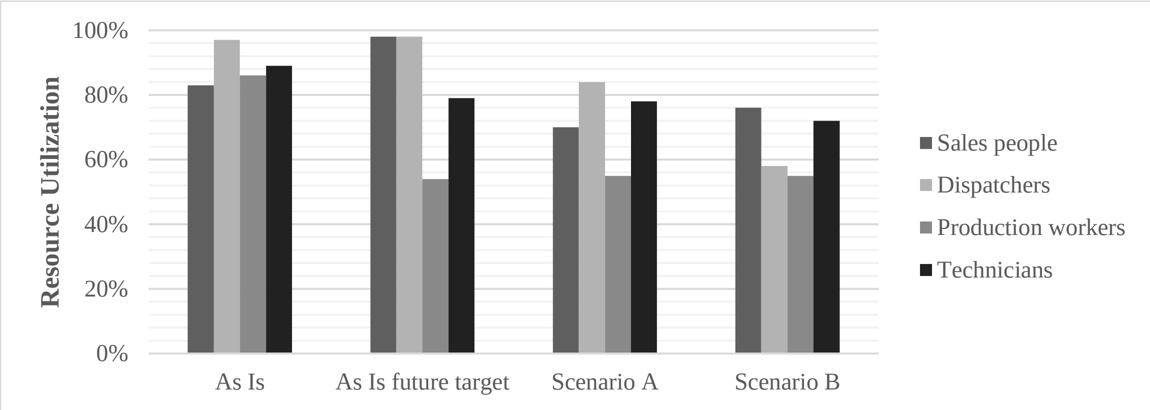

Figure 6: Scheduled utilization of Resources

In Figure 6, the average utilization of the most relevant groups of resources is depicted. As it is possible to observe, in the *as-is future target*, the sales people and the dispatcher reach a 100% utilization that is not feasible, in reality, for human being. With the changes proposed in the scenarios A and B, the utilization does not exceed the 80% threshold. This threshold is feasible considering possible extra working hours that have not been set in the resource scheduling in the simulation model.

Furthermore, the *what-if* analysis is relevant to see how changes in the service portfolio affect the company organization. In fact, the “production workers” utilization from the *as-is* to the *as-is future target* scenario drastically decreases due to the removal of one service from the offer. Based on this result, the company should define substitutive activities for this kind of human resource.

Regarding service cycle time, the time needed to handle customer requests and to perform the service job has been thoroughly analyzed since they were the bottlenecks of the process. Figure 7 reports the results of the *what-if* analysis. It emerged that, in the *as-is future target*, the total service cycle time increases significantly. However, in scenario A and B this time is lowered to the actual level (for privacy reason, the values on the Y-axis cannot be reported).

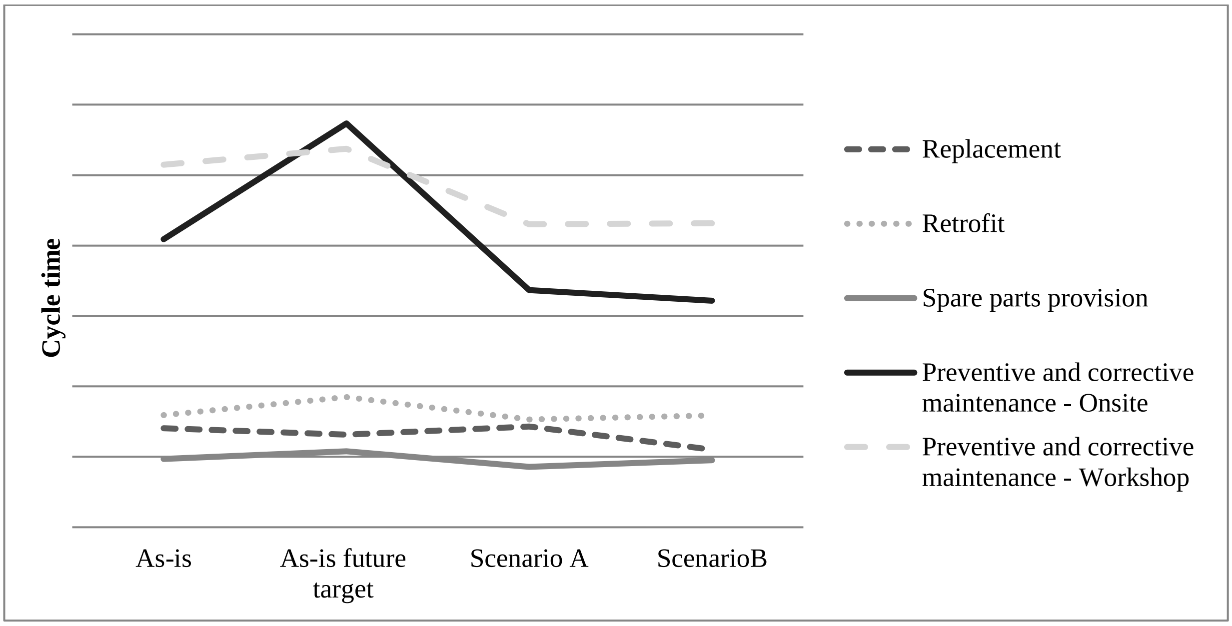

Figure 7: Average total cycle time for design requirements

In addition, the results related to customer satisfaction based on cycle time have been analyzed. The indicators SA_{hk} have been calculated for each activity and design requirement as described in section 3.2.2. $Ttarget_A(h)$ has been fixed the minimum activity duration obtained during the *as-is* simulation, since the company does not have fixed ad-hoc target duration for each activity. Concerning the customer satisfaction based on cycle time (Table), the overall indicator (S) related to customer type I segment is 85,46% in the *as-is* model, then it decreases to 79,48% in the *as-is future target* model and finally it increases to 91% in scenarios A and B. The same trend is observed in the customer type II segment case, where S is equal to 95,90% in the *as-is* model, to 94,80% in the *as-is future target* model and to 96,99% (Scenario A) and 97,16% (Scenario B). These trends are due to changes of the activity duration since the activities importance rates have been kept unchanged. Therefore, as expected, it is possible to argue that reducing the total service cycle time, the overall customer satisfaction based on cycle time increases. This phenomenon is observed in the case of the improved scenarios A and B, where the total service cycle time is significantly reduced and, consequently, the increase of the overall customer satisfaction based on cycle time, as considered in the SEEM, is respectively 6% for customer's type I and 1% for customer's type II.

Table 8: Customer satisfaction based on cycle time indicators

Activities	Customer satisfaction based on cycle time indicators *S*							
	As-is		As-is future target		SCENARIO A		SCENARIO B	
	Customer type I	Customer type II	Customer type I	Customer type II	Customer type I	Customer type II	Customer type I	Customer type II
S	85,46%	95,90%	79,48%	94,80%	91.14%	96.99%	91,96%	97,16%

The customer satisfaction based on cycle time indicator could help the company in defining and selecting the best possible process configuration. A cross analysis considering the number of resources involved, their utilization and S could be a good way to balance the external with the internal performance. For example, the selection between scenario A and scenario B can be the strategic choice between a slightly higher customer satisfaction based on cycle time achievable in B and better resource utilization in scenario A. The company could decide whether to focus on the customer satisfaction based on cycle time while another one can believe that for such a small increase in the customer satisfaction based on cycle time, a lower resource utilization, and the related increase in terms of cost, is not justified.

Summarizing, the *what-if* analysis provides some suggestions that should be taken into account when the company is planning to change its product-related service offering or the customer requests are expected to change. The results emerged represent just a possible way to solve future issues related to services, and they would be used as hints to balance the service organization to the future needs.

5 Discussion

The test case presented in the previous section demonstrated the robustness of the SEEM in being applied to an industrial case. In particular, the step by step methodology can support company managers to: i) guide the identification of customer needs, ii) identify possible PSSs fulfilling such needs, iii) identify the company activities and resources to implement such PSSs and iv) re-engineer the service delivery process providing a useful support while making decision. More in detail, according to the case presented and to other applications in different

ABB business units, the SEEM has been used to set PSSs in terms of service delivery process capable of balancing internal and external performance through:

a) a systematic evaluation of internal and external performance of the as-is process;
b) the analysis of possible balance between internal and external performance;
c) the comparison of a variety of service delivery configurations.

In terms of management implication, the test case demonstrates the validity of the SEEM in supporting all that phases of PSS engineering with a deeper focus on the service delivery process. According to managers' feedback, the adoption of such approach created shared awareness about current processes and inefficiencies. In addition, it supported the definition of a new process characterized by a better resources planning and a higher efficiency in dealing with customer requests. Moreover, the joint analysis of resources utilization and customer satisfaction based on cycle time make managers capable of taking structured and justified decisions.

For what regards the methodology itself, the process validation phase revealed as the most time consuming phase due to the following differences between the static and the dynamic maps:

- *Unique simulation model.* Since the different service processes analyzed share several resources, such as sales people, technicians and order handlers, a single simulation model is required. The amount of time that each resource dedicates to a specific service could not be defined a priori, since it depends on many factors such as the period of the year, the priority of each request and the specific intervention.
- *Level of detail.* The service blueprinting maps present the processes in a very detailed way. In the simulation model, such a detailed representation may be a problem, since the duration and time variability must be included when setting the process parameters. Setting the time for many detailed activities increases significantly the variability at levels that do not reflect reality. In order to avoid this problem, it is crucial to group together some activities that are

sequential and logically linked and that, together, can become a macro-process in the final model.

- *Hierarchical structure.* The simulation model, due to the huge number of activities involved, required a lot of time to be set. To facilitate the sharing and the comprehensiveness of the model, it has been represented with a two level hierarchical structure. The two levels have been designed according to [79] to obtain a suitable overview of the company and customer performance. The first level provides the sequence of the main activities (A), identified in the SRT, while in the second level a breakdown in terms of sub-activities is detailed.

6 Conclusions

Industrial companies are facing the need of tools and methods to design and assess their PSS offering and the related service delivery processes. This study presents the SEEM methodology that assists companies in balancing the company internal and external performance while (re)-engineering its PSS offering. The methodology, which is composed of two main areas (company and customer), has been applied also to an industrial case to illustrate its applicability. The use case, focused on the re-engineering of service portfolio at ABB business unit, demonstrates the complex definition of a PSS solution and the critical capability planning (i.e. resources, tools and spare parts) in service delivery.

The industrial case showed its appropriateness and robustness to identify possible PSS solutions and to address the complexity of assessing the performance of the service delivery of PSS offerings.

In particular, the main benefits of this methodology, demonstrated with the application on ABB, are: i) the adoption of a systematic procedure to analyze the existing portfolio; ii) the improvement of the delivery performance by the identification of resources or service activities directly affecting customer needs, iii) a better definition of the process changes in order to properly manage an increase/decrease of demand or changes in service portfolio, and iv) the definition of a possible service delivery process able to create at the same time value for the customer and profitability for the company.

In parallel to the benefits, the application to a case shed the light on possible improvement of it.

The main limitation of the methodology is related to the customer satisfaction based on cycle time indicator. The main assumption behind this application is that the minimum cycle time of the current service delivery process is the optimal one. However, to improve the methodology it could be useful to identify an optimal time interval for both customer and company sides in order to achieve a more meaningful measure. The definition of this interval could help organizations to distinguish those activities that have low levels of customer satisfaction based on cycle time indicator and that have to be improved.

In addition, so far the second step of the methodology focuses only on the service part of the PSS and the design of product components are left to traditional product design methods. The methodology could be improved with a better integration of product design also during the second step of the framework.

Future works will be related to the adoption of the methodology in other cases and in other industries in order to test extensively its applicability and to further generalize the SEEM. Indeed, having a more generalized and mature theoretical framework would finally help in developing proper integrated tools.

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