Product-Service Systems across Life Cycle

SErvice Engineering Methodology and Energy Services: applicability analysis and case study

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Abstract

In recent years, the economic and financial crises have been slowing down the growth of international markets. The resulting necessity to increase competitiveness has forced manufacturing industries to rethink their offer portfolio, also implementing servitization strategies. In particular, given the dramatic raise of customers' awareness as regards environmental and energy problems, the energy industry is also considering the provision of Product-Service System (PSS) solutions (i.e. the bundle of energy services to energy efficiency related products) as a profitable alternative. However, the design of PSS and in particular of the service content of the offer is a challenging activity, mainly due to the fact that services are by definition characterized by high level of intangibility and perishability, and to the fact that standard tools and methodologies for service engineering are not available. The SErvice Engineering Methodology (SEEM) [1] aims at supporting companies in these design and implementation phases. The methodology is in its development phase and its applicability in industry has been mainly tested in one specific context. This paper deals with the application of SEEM in the context of Energy Services (ESs) where the design phase can be much more complex than in other areas due to the variety of industries offering this kind of services and to the number of stakeholders involved during the service provision. In particular, this paper refers to a specific ES (the provision of data elaboration and analysis to energy consumption monitoring and control purposes) marketed together with energy meters. The general aim of this work is to provide a first analysis and a general understanding of the applicability of this existing methodology to the ES field by the mean of a real case study. In the paper, main steps of the application of the SEEM to the case study are described and discussed, to highlight main criticalities. In the end, a critical analysis is provided in order to put the basis to generalize the insights of this work to additional Energy Services.

Keywords: Service Engineering; PSS Design; Energy Services

1. Introduction

During the last decades, the spread of Energy Services (ESs) [2] and Energy Service Companies (ESCos) [3,4] has gradually changed the way energy is provided to manufacturing companies [5], increasing the amount and enhancing the quality of services offered, generally resulting in the adoption of more sustainable and resource-efficient practices [6,7]. The continuous quest for new sources of revenues [8] that has recently caused many product based companies to shift toward service provision [9,10] has also entailed an increase in the attractiveness of this new business for many companies producing and selling energy-related products. As a result, energy-related Product-Service Systems (PSS) (i.e. the bundle of ESs to energy efficiency related products) [11] are nowadays offered by many companies, afferent to different industries, in different forms and with different types of contracts [12]. Such fragmented servitization scenario prevented the development and the diffusion of a standard and wide recognized framework and/or methodology to support companies systematically

engineering and re-engineering their energy service offering. In the PSSs context, some proposals for methodologies with practical mechanisms allowing an easy and effective design and development of a solution are available (such as MEPSS [13], Service CAD [14], SEEM [1,15] and those proposed by Aurich et al. [16], Alix [17], Maussang et al. [18],Trevisan et al. [19] and Pezzotta et al [20]). Among them, no one has been designed or even just applied to ESs, apart from [19]. Therefore, the goal of this paper is to analyze and discuss the applicability of the SEEM [1] to energy-related PSSs through its implementation in a real industrial case. The PSS under investigation relates to the provision of data elaboration and analysis to energy consumption monitoring and control purposes (service), marketed together with energy meters (product) and data analysis software (infrastructure). This energy-related PSS business area has been selected because it presents several peculiar features which might be the most challenging to be implemented with a PSS design methodology. In particular:

- it is usually offered by companies with very different core businesses;
- customers' needs and the service delivery process are highly dependent from the customers' segment and their maturity level in energy management [21];
- the PSS provider might or might not directly own the manufacturing of the product;
- the service delivery process involves many partners and external stakeholders and its results are highly affected by their performance as well as by external factors;
- the engineering and provision of this service requires the cooperation of several functions within the customer's company (energy management, maintenance, production planning, etc.)

The case study has been carried out in collaboration with a company whose name and data will not appear in the paper for privacy reasons, and that will be called ABC in the rest of the paper. The company ABC has been selected mainly because of its long experience in the business, the variety of customers it deals with and its strong commitment in satisfying their needs. Furthermore, the ES analyzed is particularly relevant for ABC because the revenues related to its provision are the major percentage of total income which also drives ABC to further expand in the near future in this business area.

The remainder of this paper is structured as follows. In the next section, the theoretical concepts of the SEEM methodology are briefly recalled. The third section illustrates the implementation of the methodology in the case study. In the final part of the paper, a critical analysis of the case study is conducted, highlighting issues raised concerning the applicability of the methodology to the ES analyzed.

2. SEEM description

SEEM aims at supporting companies in making the shift to a service-dominant logic as well as re-engineering an already servitized business. In particular, SEEM focuses on supporting
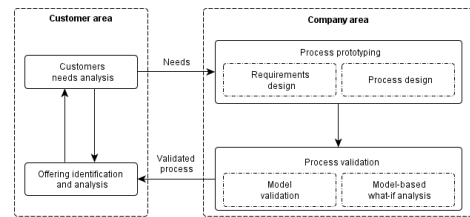

Figure 1 SEEM framework [1]

PSS re-engineering while balancing the value perceived by customers with the internal efficiency and productivity of the service delivery processes. To this purpose, as represented in Figure 1 SEEM is divided in two main areas.

- Customer area that aims at collecting customer's needs and at comparing them to the existing company service portfolio. On this side, SEEM foresees the adoption of methods such as market research, customer's interviews or focus group to collect information.

- Company area that, starting from the need identified in customer area, suggest the design of a PSS solution and of an efficient service provision process associated to it. In this area SEEM includes the following methods:
  - Service Requirement Tree (SRT), a functional analysis that, starting from an identified need(s) allows the identification of i) Wish (how the customer wish to satisfy its needs); ii) Design Requirements" (DR) (how the company can satisfy customer needs and whishes) that are possible PSS solutions capable of satisfying customer's needs and ii) "Design Specifications" (DS), representing the main activities and resources associated to each DR.
  - Quality Function Deployment (QFD) [1] to define the importance of each solution (DR) and connected activities and resources (DS) in satisfying customer needs. This is supposed to put prioritization among DRs and DSs.
  - Blueprint [22] is adopted to represent the service provision process of the selected alternative. In order to understand how much the process is able to satisfy the customer's need, the connection between the DSs of the SRT and the activities of the blueprint is also included.
  - Business process simulation is used as a final step to validate the proposed process and to identify additional and more efficient configurations.

For further details on the methodology please refer to [1].

In the next section, the application of SEEM in energy services is described in deeper details. It is important to highlight that currently only the first steps of the SEEM have been implemented in the industrial case (i.e. the process has been mapped in the blueprint but it has not been simulated). The implementation of these steps has been useful to make first qualitative considerations concerning the SEEM applicability to ESs. Future works will complete the applicability analysis

with process simulation and analysis of the service process mapped.

3. Industrial case

This section presents the company ABC and describes the systematic application of the SEEM for the re-engineering of the selected service.

3.1. The company

ABC is a small information technology enterprise that started its business in the early 90s. It is composed of two main business units corresponding to their two main products: a maintenance planning software and an energy consumption monitoring and control software. The latter (to which we will refer in the rest of the paper) is generally marketed together with energy meters that are partly assembled and customized by ABC. These energy meters are connected to the internet, and measured data are automatically read, elaborated and saved on a cloud and then they are ready to be analyzed by a software. The hardware is manufactured by third companies, while the software is entirely developed, customized and maintained by ABC. Due to the particular nature of its products that require specific knowledge to be used, ABC has also provided training services since the beginning. Only in recent years, as the demand for this kind of products increased and the number of customers proliferated (including less mature companies), ABC has also started to provide consultancy services. In this way it helps customers to take the best out of its products, assuring the constant control of the energy efficiency of their assets over time.

3.2. SEEM application to ABC

Due to the fact that a re-engineering case was considered, the implementation of the SEEM in ABC started with the analysis of the existing service portfolio and its comparison with customer needs. The following paragraphs describe in detail all the steps and the results obtained in the case application. Each step was conducted through interviews and meetings with the ABC general manager, and the outputs (SRT and blueprinting) were drawn by the authors and validated by ABC general manager.

3.2.1. Customer area: customer needs analysis and company service portfolio

As a first step, main customer needs have been identified and the company service portfolio has been analyzed. Different segments of customers have been considered in this phase:

- Segment I: customers trusting ABC's capabilities to monitor and control the energy efficiency of their assets and also commissioning to the PSS provider the mediation with external technical operators. They are not interested in developing any knowledge at all regarding the monitoring and control processes and only care about the results.

- Segment II: customers trusting ABC's capabilities to monitor and control the energy efficiency of their assets; they are not interested in developing any knowledge as in the previous case but they also wish to maintain the control over a certain number of processes (e.g. maintenance and maintenance planning processes).
- Segment III: customers who seek ABC's help in the ramp up phase of the monitoring and control system, but then directly take care of their assets' efficiency monitoring and control, and only resort to ABC's support for complex service jobs and retrofits; they mainly aim at developing knowledge during the ramp up phase of the monitoring system.
- Segment IV: customers who directly take care of their assets' efficiency monitoring and control, and only resort to ABC's support for complex service jobs and product retrofits. They already possess the necessary knowledge to run the monitoring and control system and only ask the provider for research and development activities.

It is possible to notice that, ranging from the first to the fourth customer's typology identified, the number of stakeholders directly interfacing with ABC decreases, and so does the complexity of communication management and planning activities. In addition, the "scope" of the offered ES, as defined by Sorrell [2], is gradually reduced and the PSS provider has lower and lower control over customer's activities (the results of the service highly depend on the customer's performances, and the risk assumed by the PSS provider is higher [2,5]).

The four customer's segments share the same need, which is *"the maximization of the energy efficiency"* of their assets, but have very different wishes. Thus, only one of the four categories will be analyzed in the followings so as to make the critical analysis more effective and easier to understand. Customer's segment *number II* has been chosen as it is definitely the most common for ABC. As stated before, the ES business unit analyzed is *the provision of data elaboration and analysis to energy consumption monitoring and control purposes.*

3.2.2. Company area: process prototyping

Customer's need identified in the previous step has then been used to start identifying the main requirements of the process and then defining the service delivery process. Starting from the main customer's need (to maximize the energy efficiency of its assets) the three levels of the SRT have been deployed through the definition of the wishes, the design requirements (DRs) and design specifications (DSs) and their dependencies and connections. At the end, the single initial need allowed the deployment of two wishes, four DRs, sixteen DSs also including four different resources roles. An extract of the SRT is depicted in Fig. 2. According to the SRT only one DR has been selected for further analysis. Differently to what the SEEM suggests, that is the QFD calculation to identify the most relevant from the company perspective, one DR has been defined as the priority, the one that make more revenues for the ABC company: the identification and correction of anomalies. The second step related to the process prototyping is the

process design by the means of the blueprinting methodology [22].

The service delivery blueprint has been drawn; the set of activities identified (about seventy) are performed by either the customer or by ABC resources (e.g. IT specialists, data analysts, technicians working as front-end or backstage, additional resources handling support processes).
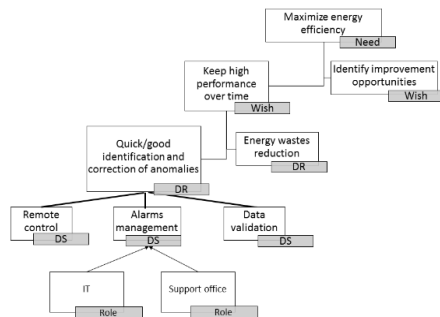

Figure 2. Short extract of ABC SRT.

A brief description of the general service delivery at ABC is:

- *Handle query/alarm*: the automatic control system generates alarms if an anomaly is verified; the alarm is received by the support office, that contacts data analysts and the technical office to determine the causes of the alarm;

- *Identify possible causes*: data analysts and technical office together apply problem solving techniques in order to identify possible causes;

- *Assign service job*: on the basis of the results of problem solving and hypotheses testing activities, the management of the alarm is assigned to data analysts, technicians or meters' maintenance team;

- *Customer's validation*: in this phase the customer is involved in the troubleshooting activity; to be sure to identify the right cause of the anomaly, the team that was assigned to the job visits the customer's site; this activity ends with the final identification of the anomaly cause;

- *Generate solutions*: in this phase possible solutions to solve the verified problem are generated and at first evaluated (in terms of economic and technical feasibility) by ABC in back office;

- *Validate and choose solution*: a report is given to the customer. A list of all identified solutions and details about their evaluation are reported in the report; the customer selects the solution to be implemented;

- *Plan solution implementation*: this phase strictly refers to the case the solution can be directly implemented by ABC (problems related either to the software or the meters); ABC support office and the team to which the job was assigned define a detailed plan to implement the identified solution; resources and materials to execute the job are defined as well as the quotation of this activity;

- *Mobilize and plan*: this phase strictly refers to the case of intervention at the customer's plant. ABC and the customer would agree on a date to perform the service;

- *Perform service job*: in the case of onsite intervention, technicians go to the customer whereas in the other cases they perform the service job in back office;

Complete service job: the effectiveness of the implemented solution is verified (this activity is performed also in case the solution has not been directly implemented by ABC and an interface with a third company is therefore needed here); possible modifications to the software and/or to the statistical models are evaluated and implemented and a report is sent to the customer.

In case the last phase gives negative results, the delivery process is repeated from the second phase on.

Once the service blueprinting maps were complete, a good static overview of the processes was available. In order to be able to assess the performance of the delivery process towards satisfying the customer's need, the identified DSs have been linked to the blueprint activities. Such a link allowed for a formal check to verify whether there exists any activity in the blueprint not assigned to any DS and vice versa. In the case analyzed all the blueprinting activities were linked to DSs, but some of the DSs were not represented in the blueprinting by any activity. The missing DSs are related to the possibility of having an automatic troubleshooting and first diagnosis when an anomaly occurs (in order to make the solution identification process faster and therefore to have a quicker diagnosis). Thus, that could be a possible improvement of the delivery process and a feasibility study will follow this work in order to evaluate possible paths to introduce some specification in the represented process, as the use of an Artificial Neural Network based system (similar to the one described in [23]).

4. Critical analysis of the SEEM applicability to ESs

After the implementation of the SEEM in the case study some conclusions and comments about SEEM applicability to the ESs have been collected and are illustrated hereafter.

4.1.1. The identification of customers' needs

First of all, defining customers' needs is not trivial. The perception and consciousness that customers have of their needs varies according to their maturity level in the energy management field [21], and even for customers of the same segment, the maturity may be slightly different. SEEM suggests to identify one or more need(s) for each customer segment but does not take into account the variation of needs during time. A possible improvement can be the distinction among basic needs, performance needs and excitement needs, by applying the model created by Kano in the 80s [24] to analyze customer's needs. This might be useful to have a clearer picture of the needs and their relation with customer satisfaction. In turn, the classification of needs would imply changes in the DRs and DSs to put in the SRT, in the QFD analysis and an initial prioritization of the solution(s) to be implemented. A basic need indeed can be defined as "must satisfy" and during the identification of a solution, a company can decide to start implementing solutions whose aim is the satisfaction of a basic need, then it can decide whether to focus on performance needs or on excitement needs. In ABC, for example, for customers of the second segment with a high level

of maturity the need "increasing the availability of assets" might be a performance need, while for customers of the second segment with a lower level of maturity it might be an excitement need. Since the need can be fulfilled by the service "monitoring energy efficiency", the selection of its implementation can be related to the categorization of such a need and to the fact that the maturity level changes over time for a single customer. Therefore, the adoption of Kano's model might be useful to take into account future scenarios and possible evolutions of customer's needs (as they can migrate from one group to another while the maturity level increases).

4.1.2. The analysis of different PSS providers and possible partnerships

Another particular aspect of ES (and energy-related PSS) is that they can be offered by different providers, afferent to different industries. Therefore, providers have to properly design their value proposition and to attract customers who can recognize and pay for their core activities. In case they need additional capabilities, they have to create valuable networks and partnerships with other companies. For example, ABC, that is basically a software development company, is very good at monitoring performance over time and quickly individuating anomalies, and might take advantage from partnerships with ESCos offering engineering services and monitoring products to individuate anomalies' causes and possible solutions. SEEM, as it is, supports the PSS design and process selection merely from a provider perspective. It does not take into account the design of possible partnership or network. Thus, it might be very useful to insert in the process prototyping phase of the SEEM a method to evaluate possible weaknesses of the provider and suggest what relationships to start with partners whose core activities are complementary to those of the service provider. Considering possible methods to evaluate weaknesses, SWOT analysis is a well-known method also mentioned in the area of PSS [17], whereas for the analysis of network, Kimita et al. [25] analyzed the PSS from the network viewpoint. The need to include such methods, risen in ES context can be also generalized to every PSS since they are characterized by different elements among which the infrastructure and the network [11].

4.1.3. The evaluation of external factors' influence

A most remarkable consideration is that the results of the delivery process of an ES (and in particular of the ES here analyzed) and the fulfillment of customers' needs highly depend on factors and variables that are not under the direct control of the provider, and therefore do not only depend on the provider's performance. In the case presented in this paper, for example, the maximization of energy efficiency of the

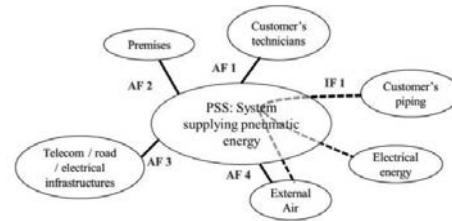customers' assets is strictly related to customers' performance

Figure 3 External functional analysis example [15]

in implementing and maintaining the chosen solution and/or on the performance of the third company that has to implement the solution, as well as on the commitment of the customer to the results. In addition, the energy efficiency of some of the assets might depend on external variables' fluctuation (for example, the efficiency of a chiller is directly dependent on the external temperature), and this shall be taken into account particularly in the process validation and evaluation phase. In other words, the wider the scope of the service offered is, the lower will be the responsibility of the provider on poor results. It has to be highlighted that in the present work the maximization of energy efficiency has been taken as customer's need; otherwise, if the minimization of energy cost was considered, also market fluctuation would have affected provider's capability to fulfill customers' needs. Thus, the case sheds the light on the necessity to include external factors affecting PSS and its performance. According to the case, analysis of external factors could be useful both in the service prototyping and validation phases. The PSS design methodology adopted by Trevisan et al. in [15] might be taken as a reference to modify the SEEM. In fact, it envisages the analysis of all possible functions (Interaction or Adaptation functions) linking the PSS to external factors and takes them into account to define the blueprinting and to evaluate the service delivery process.
In addition, it also adopts Functional Bloc Diagrams to understand the physical organization of the product's component that might be useful to individuate and validate these links.

4.1.4. Stakeholders' identification and management
The need to i) consider partnerships and to include networks in the design process and ii) to analyze the impact of external factors on performances, stresses the high complexity for the energy-related PSSs, and the involvement of a huge number of stakeholders to be managed, informed and satisfied.
Among stakeholders, in addition, it is possible to recognize the environment and the society. In particular, energy services can
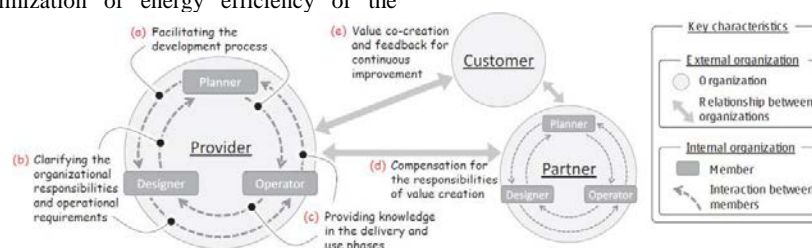

Figure 4 An organizational framework for PSS development [26]

have a high impact on social and environmental sustainability and therefore cannot be ignored nor omitted in the design phase. Thus, having a broader picture highlighting at least the majority of the stakeholders involved, could be useful. The proposal of Kimita et al. [26] of a methodology to build an organizational framework for PSS development (represented in Figure 4) could be taken into account as a possible way to integrate SEEM.

As the service analysed might follow in the category of Internet of Things (IoT) enabled services, it would be also interesting to consider the work of Wang et al. [27], who introduced an agent-based model to improve the coordination of the IoT and third party service providers by the means of web interfaces optimization.

5. Conclusions

The present paper was aimed at analyzing the applicability of the SEEM to the design of an energy-related PSS. Such analysis has been conducted starting from the implementation of the methodology in a real case study and then generalizing issues raised and conclusions to all ESs. Main identified barriers to overcome for the application of SEEM to ESs are:

- The clear definition of customers' needs in a dynamic scenario where customers' energy management maturity level is always evolving;
- The wide range of and differences among ESs providers, affecting a precise definition of DRs' importance;
- The influence of external factors on the results of service delivery process;
- The difficulties raised by a complex stakeholder's management.

For all of these issues a possible solution has been proposed. Next steps of this research will be to simulate the service delivery process here described in order to complete the applicability analyses in all the steps of the SEEM. After that, the initial analysis proposed in this paper will be validated. After additional tests and additional research on other existing methods, SEEM will be completed in order to accomplish all the issues raised.

Concerning the case study, possible process improvements will be evaluated as suggested before in order to include all the identified DSs in the existing service process.

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