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A system modelling approach to collaborative PSS design

Martha Orellano^{a,*}, Khaled Medini^b, Christine Lambey-Checchin^c, Gilles Neubert^d

^aMines Saint-Etienne, Univ Lyon, Univ Jean Moulin, Univ Lumire, Univ Jean Monnet, ENTPE, INSA Lyon, ENS Lyon, CNRS, UMR 5600 EVS, Institut Henri Fayol, F-42023, Saint-Etienne, France

^bMines Saint-Etienne, Univ Clermont Auvergne, CNRS, UMR 6158 LIMOS, Institut Henri Fayol, F 42023, Saint-Etienne, France

^cUniversit Clermont Auvergne, EA3849 CleRMA, F-63008, Clermont-Ferrand, France

^demlyon business school, CNRS, UMR 5600 EVS, F-42009, Saint-Etienne, France

* Corresponding author. E-mail address: martha.orellano@emse.fr

Abstract

An adequate design of PSS-oriented business models (PSS BM) should illustrate the link between the strategic objectives of the stakeholders and the operational development of the offer. The literature on PSS explains the content of a business model mostly from the provider's perspective with a clear operational positioning. This paper considers the strategic positioning of stakeholders in the early stage of the process of value co-creation. More precisely, this paper aims at providing a comprehensive conceptual model that integrates both strategic and operational perspectives of a business model, which is considered here as a system of value co-creation. A system modelling approach, by coupling two modelling methodologies, is proposed. Goal Modelling (GM) is used for the strategic perspective, and Model-Based System Engineering (MBSE) for the operational one. GM allows modelling high-level objectives that stakeholders expect from a given system, whereas MBSE supports formal modelling of the engineering process. Combining both modelling frameworks makes it possible to visualize the entire system from strategic and operational perspectives as a unique socio-technical system. The aim of this work is to support the value co-creation process in the early stages of PSS design through the visualization of its key elements (e.g., actors, goals, PSS offers, activities, among others). The implementation of the modelling framework is illustrated through a real example of a French company with respect to the provision of safety clothing for its employees.

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Keywords: Product-Service Systems, Value co-creation, System modelling, Goal Modelling, MBSE

1. Introduction

Manufacturing industry is shifting towards more serviced offerings as a way of responding to recent society needs. Customized solutions, sustainability, and collaboration between several actors (e.g. industrial partners, consumers) are some of the needs that an adequate business model (BM) should address nowadays. In this context, Product-Service Systems (PSS) represent an alternative to enable such BMs. Adopting PSS requires to identify the organizational elements to be taken into account for creating and capturing high value. For instance, collaboration between key actors is essential to achieve higher value, becoming a key driver for successful PSS BMs [1]. Designing collaborative BMs for PSS needs the alignment between the strategic objectives of the stakeholders and the operational development of the offer itself. However, the literature on PSS explains the content of a business model from an operational perspective, centered in the offer development. In contrast, the strategic perspective, which implies stakeholders' objectives in early phases of the value

creation process, is undervalued. Solaimani et al. [2] highlight the importance of the conceptualization of value in terms of "value expectations" from a strategic reasoning of the key actors, as the main principle to design feasible offers. The aim of the proposed modelling approach is to support the value co-creation process for PSS design, through the visualization of its various elements (e.g. goals, PSS offers, activities) from strategic and operational perspectives. The research questions guiding this research are:

- *How to model the collaborative process of PSS design?*
- *What are the elements of value creation concerning both strategic and operational perspectives?*

To answer these questions, this study is based on the implementation of two modelling frameworks, Goal Modelling (GM) and Model-Based System Engineering (MBSE), developed in the field of system engineering and applied to requirement engineering in collaborative contexts [3–5]. The interest of using GM resides on the definition of high-level

objectives that stakeholders expect from the system in the early phases of the design process. Besides, MBSE complements the GM framework, since it consists in using formal modelling to support the engineering process of the system development. In this paper, the application of those frameworks are complemented by a conceptualization effort associated to the literature of PSS and value co-creation, allowing to determine the specific elements related to the collaborative development of PSS.

The structure of the paper is as follows. Section 2 presents briefly the theoretical background of value co-creation in the context of PSS, and provides an overview of existent methodologies implemented on PSS design. Section 3 introduces the model proposal for designing collaborative PSS. Section 4 discusses an illustration of the model proposal through a real example, modelling the provision of safety clothing of a French energy company. Finally, the conclusions and research perspectives are discussed in Section 5.

2. Conceptual background

2.1. Value co-creation in PSS

According to Xing and Ness [6], the success of a PSS depends on the design of proper business models. In general, a business model is defined as the logic by which a company creates and captures value for its stakeholders [7,8]. One of the most known works among industrial and academic is the Business Model Canvas (BMC) proposed by Osterwalder and Pigneur [9], which is based on the definition of the value proposition. As in the BMC, the nature of value creation is commonly studied from the provider perspective, pointing out the maximization of profits while achieving customer satisfaction. However, some recent studies have started to investigate the design of collaborative business models, expanding the boundaries of a single company, and integrating customers and other actors (e.g., suppliers, competitors, community) to co-create higher value [10–12].

In the context of PSS, the integration of the customer in the process of value creation is a crucial factor to have a successful business model [13]. For instance, Tran and Park [1] highlight the concept of value co-creation as the fact of involving the customer from the early phases of the offer development. Furthermore, the process of value co-creation aims at aligning the objectives of the customer with the offer of the provider [10]. Indeed, the objective of the value co-creation process is to achieve the trade-off between the accomplishment of customer's value expectations and the development of feasible value propositions according to the capabilities of the providers' network. In this sense, Ballantyne et al. [14] define a value proposition as the "promise of value" between actors, materialized through products and services; while value expectations are the benefits that strategic actors expect to get through the business activity. This logic allows us to analyze the business model as two-fold model of value creation as shown in Fig. 1. A strategic perspective with a high-level abstraction related to global objectives and expectations [2,8]; and an operational perspective, with a low-level abstraction in terms of activities, resources, and actors for the development of value propositions [6]. The collaborative development of

PSS suggests that both the customer and the provider network are involved in the two perspectives of the model of value co-creation.

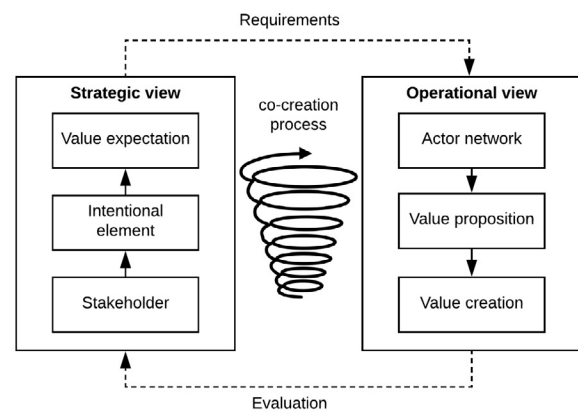


Fig. 1. Generic model for collaborative PSS design.

2.2. PSS design

There is an extensive literature about the techniques for the design of PSS offers. Regarding literature, we can group the existing works into three general categories: the engineering approaches, the organizational approaches, and the holistic approaches.

The main part of the works refers to the engineering approaches [15–18], combining techniques from new product and new service development. The contributions about the offer engineering cover several points. For instance, the integration of products and services along the life cycle, increasing offer variety, reducing costs, and reducing environmental impacts, among others.

On the other hand, a few amount of works on organizational approaches have been proposed recently. Xing and Ness [6] propose an improvement of the BMC by adopting the principles of the service-dominant logic (SDL), which is translated into collaborative practices between customers and providers. Most of the contributions in this category are based on the PSS typology proposed by Tukker [19] (i.e., product-oriented, used-oriented and result-oriented). Some authors analyze each type of PSS through the lens of BMC as exposed by Barquet et al. [20], getting specific business model properties for PSS.

Finally, holistic approaches group the works related to system modelling for supporting the offer development. For instance, Idrissi et al. [21] elaborate a generic meta-model for the support of PSS design. The work in [22] builds also a meta-model based on a socio-technical perspective of PSS offer development. Both contributions combine aspects of offer engineering with organizational modelling, providing integrated frameworks for the development of PSS. Nevertheless, the three categories of the PSS design adopt a provider perspective and an operational orientation.

According to this overview, this work is placed in the holistic category, and it aims at putting the attention on the strategic perspective within the early phase of the value co-creation process. In the next section, the model proposal is explained.

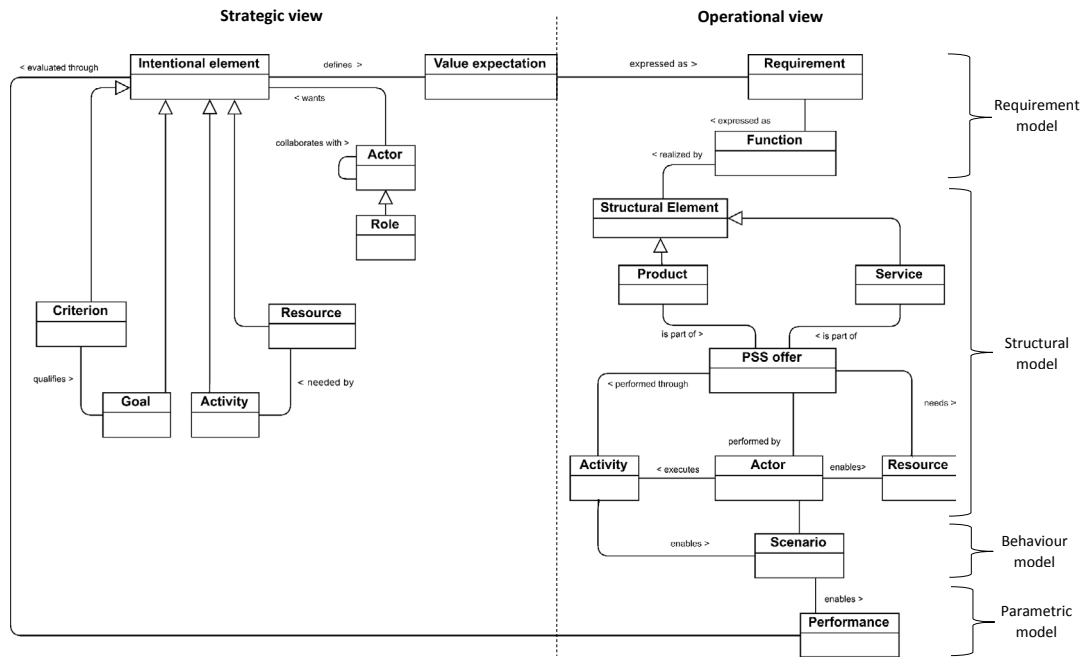


Fig. 2. System modelling for collaborative PSS design.

3. Coupling Goal-MBSE modelling for collaborative PSS design

3.1. Background of Model-Based Systems Engineering (MBSE) and Goal Modelling (GM) approaches

Our model proposal is based on the conceptual model shown in Fig. 2. The model is operational through the application of two modelling approaches called GM and MBSE, applied to the context of PSS in this research work. GM is executed by using i^* modelling language [5], whereas MBSE by using SysML [3]. there are two main views of our model: strategic and operational. Firstly, for the strategic view, GM is applied. This approach is concerned with the intends and expectations of the stakeholders regarding the system to be designed. The main idea of GM is to get functional and non-functional requirements to be included in the offer design, aiming at satisfying strategic intends of the actors involved [4]. In GM the central element is the actor, and each actor determines its own expectations according to its needs. Such value expectations contain goals to be achieved, criteria to qualify the goals, activities to be performed, and resources to be used for the offer development [5].

Secondly, for the operational view of the model, MBSE is implemented. This approach is a formal application of modelling methodologies for developing integrated, consistent and coherent system models, aiming at representing any aspect of the reality [3]. MBSE is structured in four model views: requirement, structural, behaviour, and parametric views [3]. The requirement view is related to the concrete specifications of the stakeholders involved in the system. The structural view represents the primary elements constituting the entire system and it is the base of all the other views. The behaviour view explains the dynamics of the system in relationship with the actors, and represents the system states throughout its life time. Finally, the parametric view is supported by an evaluation

model that allows assessing the performance of the system and facilitates decision-making.

3.2. The model proposal

Our proposal is a two-fold model which establishes the link between actors' strategic objectives expressed as value expectations, and operational capabilities of the provider network to develop suitable value propositions. Fig. 2 shows the detailed model, by using the notation of GM and MBSE. The left side of the model is designated as "goal model" and shows the strategic view of the value co-creation process. It is composed by three elements: value expectation, intentional element, and actor. The element value expectation represents the benefits that each actor aims to get from the PSS. The intentional element is the abstract representation of activities, goals, criteria and resources that stakeholders consider necessary to the development of the PSS. Finally, the element actor represents all the the strategic actors that motivate the offer development based on their needs. The output of the goal model are the value expectations. This view of the model is based on the i^* meta-model proposed in [5], which is a goal-oriented modelling framework developed to model socio-technical problems. i^* allows modelling actors, their intentions and their relationships. In the following, we explain the objects contained in the model.

- Actor: strategic stakeholders involved in the goal model and their relationships. An actor could be a natural person or an organization, and it has a corresponding role.
- Role: the behaviour of an actor according to its specialized domain of competencies.
- Goal: high-level intentions of strategic actors. What they want to achieve through the design of the offer.
- Criterion: evaluates the level of accomplishment of a goal.
- Activity: actions that an actor wants to be executed in

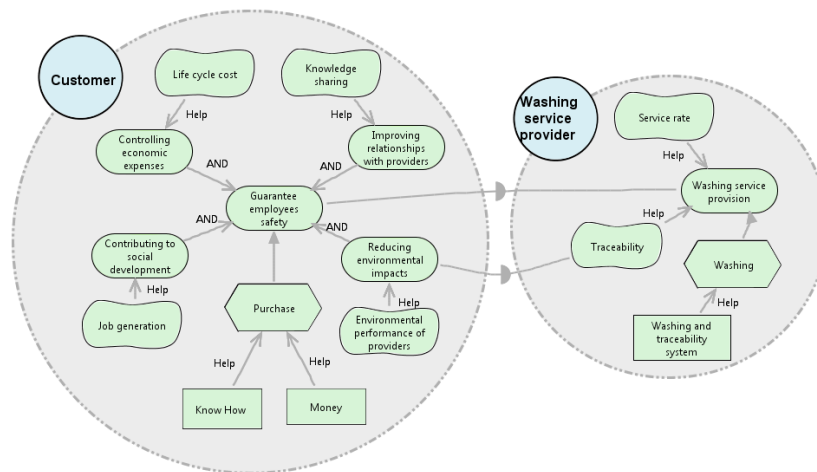


Fig. 3. Goal model extract based on the example of company 'C'.

order to achieve the set of goals.

- **Resource:** physical or informational elements required to perform an activity.
- **Value expectation:** benefits that the stakeholders aim to get from the system. It is the output of the goal model.

The right side of the model is detailed on Fig. 2, which represents the operational view of the process of value co-creation. It is based on the generic PSS meta-model proposed in [21]. The output of the operational view is the value created.

Now, we present the concepts of the model in a simplified way, structured by the framework of MBSE.

Requirement model. It corresponds to the first step of the PSS modelling from the operational view. It allows to represent the functional and non-functional requirements of stakeholders, and draws out the set of functions needed to achieve them. Functions could be performed by products or by services.

Structural model. It refers to the set of primary elements on the system, products, services, actors, resources and activities involved in the required processes to develop the PSS offer, as well as the set of relationships between them.

- **Product:** physical or tangible part of the PSS offer. It integrates the technical specifications to accomplish the functions that fit the best actors' requirements.
- **Service:** intangible part of the PSS offer. It needs a set of activities co-developed between the actors.
- **PSS offer:** content of the value proposition. The PSS is a bundle of products and services that fit together in order to respond to complex customer needs. Several types of PSS can take place as defined by [19], grouped into three main categories: product-oriented, use-oriented, and result-oriented.
- **Actor:** set of actors involved in the process of value creation from an operational point of view. The key actors are partners, suppliers and customers. Each actor has a role, which depends on their competencies.
- **Activity:** set of activities needed to perform the products and services contained in the PSS offer and depends on the role of each actor.

- **Resource:** set of assets, knowledge, people and technology that an actor deploys to support the process of value creation.

Behaviour model. It corresponds to the different configurations that the system could have throughout its life time. Each configuration is known as "scenario", and it is the result of combining the elements of the structural model: products, services, actors, resources, and activities. A scenario defines the responsibilities of the PSS actors to deliver the value proposition to the customer. Each scenario entails a different level of fitness between the value expectations and the value proposition, and then different level of value is created. Multiple scenarios could take place depending on the degree of knowledge and maturity of the actors and the quality of their relationships.

Parametric model. It allows the evaluation of the global performance of the system. In the context of business models, the parametric model provides the basis for assessing the value created in each different scenario. In PSS, the value is a multidimensional element, expressing economic, environmental, social, relational and functional values created through the business model from the point of view of each actor. The parametric model allows evaluating the global value created by the system and facilitates decision-making. This can be done by qualitative or quantitative indicators.

4. Illustrative example

The illustrative example is inspired by a real case company in France, which will be denoted as 'C' for confidentiality reasons. C main activity consists in the production and distribution of energy. One of the most important support activities of the company is the provision of safety clothing to the employees. Currently, the safety clothing belong to the employees (users), who are fully responsible for their usage, maintenance and recycling. This process limits the leverage of C regarding the management of the safety clothing through its life cycle. The company decided to launch an innovation project to transform the current offer, going from a product purchasing-based offer towards a PSS-based offer.

The development of the PSS offer needs the collaboration between several actors from inside and outside the boundaries of the company (i.e., actors from the entire value chain). In this context, *C* as a customer, needs to mobilize all the key actors in the value chain to meet its specific needs regarding the safety clothing offer: textile manufacturers, logistics providers, washing service providers, and service providers at the end of life. The application of the proposed model, described in Section 3.2, helps *C* to structure its problem and illustrates the collaborative process for the development of the PSS offer. In this section, the elements of the conceptual model presented in Fig. 2 will be instantiated using *C* context.

The first main step consists in defining the goal model. This requires the definition of the strategic actors participating in the definition of the value expectations, including their roles, goals, criteria of evaluation, and required activities and resources. Fig. 3 shows an extract of the goal model instantiated for *C* case. It is possible to observe the relationship between *C* (the customer) and the washing service provider. Each actor has a boundary space and a shared space of interaction. *C* main objective is the guarantee of employees safety, which is associated to secondary objectives as reducing environmental impacts, contributing to social development, controlling economic expenses, and improving relationships with providers. The accomplishment of these objectives should be evaluated through the definition of strategic criteria (e.g., level of knowledge sharing, job generation, environmental performance of providers, among others). Besides, the main objective of the washing service provider is providing high-quality washing service to create profit. Two of the criteria to evaluate the main objective are the service rate and the efficiency of the traceability system. Here it is possible to identify the relationships of dependency between both actors, which is represented by an arrow. In this case guarantying *C* employees safety depends on the provision of the washing service. Some other dependencies could be modeled, for instance, the reduction of the environmental impacts is linked to the efficiency of the traceability system.

The second main step corresponds to the development of the operational view of the model, starting with the requirement model Fig. 4. Requirements are categorized into five dimensions of value (defined in the goal model in relation with the strategic objectives): functional, environmental, social, economic and relational values. For instance, improvement of mechanic resistance, reduction of water consumption, variety of styles of the safety clothing, controlling economic expenses, and improving corporate image are some examples of requirements in each dimension of value. Once the requirements are clearly described, the elements of the structural model can be defined. Products, services, corresponding activities and resources are defined in the structural model (Fig. 5). The main product in this case is safety clothing, which can be made with ecological fibers, with integrated systems for traceability, recycling-oriented design, among others characteristics. Services include real-time data transfer (tracking), integral maintenance, training for efficient usability, re-manufacturing, among others. Different combinations of the structural elements lead to feasible scenarios, which are represented in the behaviour

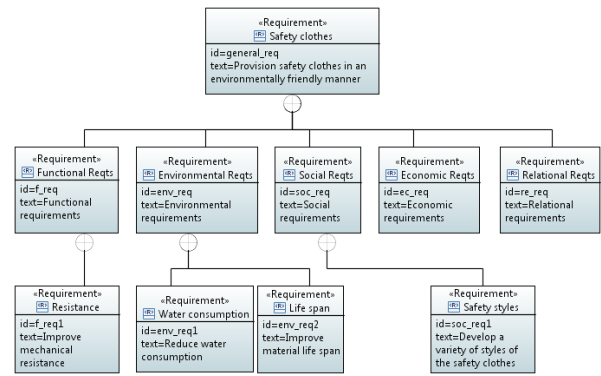


Fig. 4. Requirement model based on the example of company 'C'.

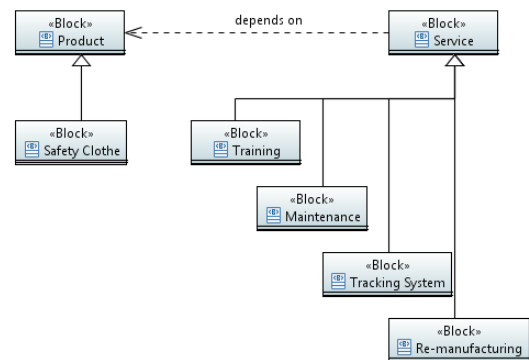


Fig. 5. Structural model based on the example of company 'C'.

model. In this paper, we represent an extract of the behaviour model in Fig. 6, assigning actors to specific functions according to their skills. Finally, once the feasible scenarios are defined, they could be assessed through the parametric model, using quantitative or qualitative data. This model provides the basis for evaluating the performance of each scenario. A simplified overview of this model is provided in Fig. 7. A more detailed description of each of all the operational views should be developed during the next stages of the project development.

The modelling framework helped to visualize the information coming from the different actors in early steps of the PSS design. This visualization is of interest to decision-makers involved in the development process of PSS, or any system at large, as it supports more informed decisions and facilitates the collaboration between them. In this sense, the proposed model framework could be used as a starting point for collaboratively outlining requirement specifications by a given customer working with several suppliers.

5. Conclusions and future research

One of the major challenges for designing PSS business models lies in enabling the interaction between several stakeholders, and aligning their value expectations with the developing of feasible offers. We proposed a two-fold model that helps to reconcile the strategic objectives of the stakeholders with the operational development of PSS offers. The illustration of the proposed model through a real case company witnesses the added-value of the model, particularly by supporting organizational design and offer development

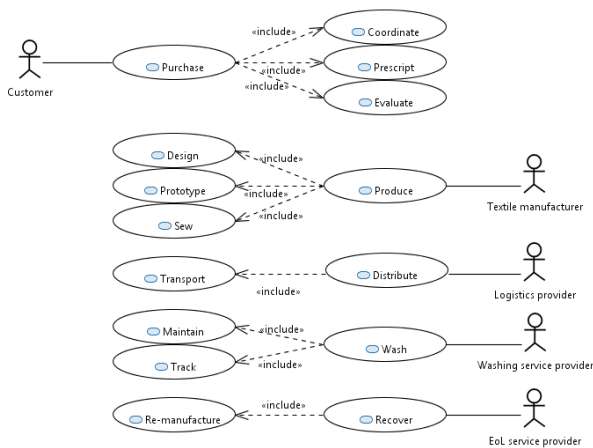


Fig. 6. Behaviour model based on the example of company 'C'.

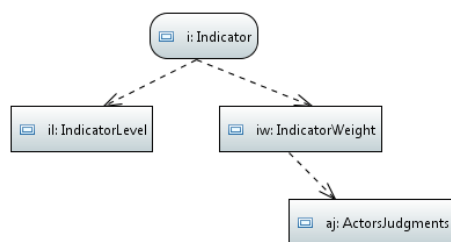


Fig. 7. Parametric model based on the example of company 'C'.

through a step-wise process coupling GM and MBSE. This systemic vision facilitates collaboration and decision-making in a context of multiple stakeholders. Moreover, the paper contributes to the decision support of disruptive innovation as the case of PSS, in relation with the early design phases. This decision support is particularly valuable, since it corresponds to early stages of offer development, where data is scarce. Certainly, deeper research is needed to develop the model in all its views. Although the effort made in this work for modelling the relation between strategic and operational perspectives, we consider that deeper research is needed for the model generalization. Furthermore, the application in other contexts is necessary for further validation of the model.

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