DISTRIBUTED M&S FOR PRODUCT SERVICE SYSTEM

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ABSTRACT
A challenge for many companies is to propose product service systems to foster customer loyalty and gain a competitive advantage. The objective can be reached under the condition that systems are designed regarding their usage to avoid waste and to increase the system provider profitability. Furthermore, services must be developed jointly with products to benefit from synergies between them and to reduce resource consumption. Even if these conditions of success are known, the way to do is not formalized and guided by a clear methodology. This paper proposes a service model in toys industry to be simulated with different service scenario before development to validate and satisfy both provider and client. A service-based modeling environment for service specification and simulation under distributed G-DEVS/HLA is presented. The interoperability required for simulation viability is addressed by complying with the distributed simulation standard HLA.

Keywords: Product service system, simulation, G-DEVS, HLA federation

1. INTRODUCTION

Sustainable production and consumption is an issue of current international concern. Many different approaches and concepts have been developed over the last decades to address environmental problems, such as cleaner production, cleaner technologies, waste minimization and recycling approaches, eco-design and design for sustainability (Maxwell, Sheate and Van der Vorst, 2006). The expectation that these strategies would solve the problems has not been realized, mainly because of increasing levels of consumption stimulated by continuous population growth and rising levels of affluence. Economic growth is seen as a driver of development and the sign of a healthy economy by major economic models. It is sustained by increased consumer demand and is usually measured in material terms. But, there is an apparent conflict between the goals of economic growth and the goal of preserving a clean environment.

The "Product-Service System" (PSS) or servicizing concept has been suggested as a way to reduce the conflict by exploring possibilities to sustain economic growth and consumer demand by creating more value without using more resources and causing more pollution. PSS challenge the traditional economy based on the sale of tangible goods and shift to use selling. The optimization of the functions provided by a product to its user is part of a new business strategy whose transactions must:

- Involve the use of a capital asset rather than its sale,
- Expect positive effects on sustainable development by reducing consumption of material and/or energy.

Despite, some companies have already shifted their business and gained a competitive advantage clearly assessing a reduced environmental impact, others are feebleness to follow this innovative way of generating profit and addressing environmental burden. The main reason is that the new business strategy requires managerial and organizational changes. New business models and business plan are to be developed; a close relationship with the customers is required to clearly understand its needs and use of products; networks of partnership are to be settled. Moreover, it is important to understand how the system for delivery of use value can be organized to ensure its environmental soundness in comparison to traditional business models of selling products. Practically, it is unclear that new business is low resource consumption than traditional one and scenario simulation can be interesting to compare the two strategies.

Although the research on PSS is abundant (Tukker and Tischner, 2006; Meier, Roy and Seliger, 2010) no research propose clear guidance for companies that are planning to shift from selling products to providing use value and there is no model to guarantee a high value offer. For instance, the research lacks a clear and commonly recognized methodology to support PSS design and realization fulfilling the environmental soundness and expected profit.

The purpose of this paper is to contribute to PSS design. As such, the paper proposes systematical customer-oriented PSS development process that enables companies to develop offers use and environment oriented. The idea is to propose service models to be simulated in services scenario before implementation. The simulation will permit to validate the desired properties and anticipate undesired effects. In other words, the simulation results will provide decision makers with a business decision support to guide their actions and know whether the development strategy where they tend to, is win-win.

The paper is organized as follows. First, we review the PSS specificities and problematic. Then, a PSS business model is presented. Focusing on the design phase, we propose a service-based modeling environment with a graphical language for modeling service specification and running distributed DEVS simulation before concluding.

2. PSS INS AND OUTS

Many PSS definitions exist in the literature assessing the difficulty to have a non-ambiguous idea of the coverage of the term (Goedkoop, van Halen, Riele and Rommens1999).

2.1. PSS concept

The accepted definition was proposed by Mont (2001) who defines a product-service system as "a system of products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models".

The definition emphasizes both the relationship with the customer and the environmental impact insinuating the socio-economic character of the PSS innovation. The innovation can take three different shapes: product-oriented, use-oriented and result-oriented and has accordingly, a specific impact on the environment and on the customer satisfaction (Kanda and Kakagami, 2006)

Despite the two pillars, the research on PSS mainly rests on the innovative relationship between provider and customer. The concept is not used to policy development as the measure of the load of the lifecycle of product and service is complex. Therefore, it is possible to avoid waste and provide a sustainable solution by comparing on the one hand, the user-product utilization to the user need and, on the other hand, the provider offer value (based on quantitative and qualitative criteria) to the resource consumption. Higher considerations on the environment should integrate reflections on resource consumption and effect for human being on the long term. Finally, a PSS requires to clearly defining the offer architecture and associated resources, the company position during value creation and the revenue model. These elements are constituent of a business model.

2.2. PSS business model fundamental

The fundamental of a model business adapted to servicising would be the following ones:

- the value proposition which is offered to the market: product / service combination;
- the customer interface management:
  - The customers segments concerned by the value proposition: similar in a combination product / services, different in a formal logic of "serviticising" (Vandermerwe and Rada, on 1988);
  - The communication and the distribution channels used to reach the customers and offer them the value proposition: this mix can strongly change since the offer leans on intangible elements.
- The management infrastructure: this element is central to the division of the structures responsible for the product manufacturing and service delivery:
  - The skills and the fundamental resources making the model business feasible;
  - The key activities necessary for the model business realization.
- The financial aspects:
  - The cash flows generated by the business model;
  - The costs of structure for the business model functioning;
  - The business model control methods and tools.

That view of the fundamentals of a PSS business model is aligned with Muller-Stewens and Lechner business model proposition. The authors defined a PSS Business Model composed of five sub-models (Muller-Stewens, and Lechner, 2005) in (Aurich, Mannweiler and Schweitzer, 2010). Despite objectives of each sub-models are described, the design and realisation phase of the PSS life cycle are given less attention. The next sub-section presents a general overview of a PSS life cycle-oriented business model.

3. PSS DEVELOPMENT METHODOLOGY

The proposed business model leans on a project process and thus follows the different phases of the project life cycle (Figure 1).

3.1. Global overview

In that specific case, the project aims at proposing a high value system composed of physical and non physical elements to a customer. As such, the design and realisation of the PSS are the main concerns. The project process is divided into four main phases: a definition, design, realization and closing phase. We do not specifically focus on the PSS use phase as it is another process, orthogonal to the project realization. Considerations on client-PSS use are obtained during: (i) the definition phase that stems from a marketing analysis and a customer-system utilization analysis and, (ii) the closing phase allowing a feedback on the solutions proposal (lacks and advantages). During each phase, operational and support activities are performed.

Operating activities are activities that make the PSS evolve from the status of "idea" to the status of system "delivered" and "evaluated" " by a client. These activities ensure that the functional requirements of the PSS are met according to the customer need, the business environment influence and the company itself.

Support activities allow the business process control. During these activities costs, time and risks are controlled to ensure the delivery on time of the solution and anticipate problems; knowledge and communication management enables to control the proposition value. Finally, the organization management tasks are equivalent to the management infrastructure abovementioned. Main aspects of the support activities concern are illustrated in Figure 1.

3.2. Detailed business model

Each phase of the business model is detailed hereafter.

3.2.1. Definition phase

The first step of the methodology consists in a strategic analysis whose aim is to list the less risky and most profitable PSS innovations a company can propose. To make the list, the company will compare the customer needs, refined regarding product utilization, to the results of an internal and an external analysis. The internal analysis focuses on the company market position, organization, skills, knowledge, resources and ability to mobilize the resources. The external analysis is based on the macro-environment analysis (PESTEL model) and on the microenvironment analysis (Porter, 1985). Environmental incentives can be taken into account during that phase thanks to the PESTEL model.

A list of approximately forty criteria aggregated into ten factors is proposed to make that internal and external analysis. The quantification of the criteria allows their positioning into strengths or weaknesses, opportunities and threats according to their nature (internal or external, positive or negative). Two types of aggregators are considered: the "average" aggregator and the "weighted average" aggregator. The list of criteria and factors may be increased or decreased depending on their relevance to the case studied. It is possible to represent these quantified factors in a SWOT matrix chart and to compare, regarding the different charts, the PSS innovations against each other on a common basis in order to retain only the most advantageous. The different charts make it possible for a strategist to choose between several scenarios by analyzing the potential of the company, the environment and the customer demand (Alix and Vallespir, 2010a).

3.2.2. Design phase

The second step is an engineering phase that allows the determination of the PSS to design regarding the value of the system for any stakeholder. Currently, only the customer and the provider of the system are considered. Based on the value engineering approach, the determination rests on the distribution of the costs necessary to realize the PSS over the functions expressed as benefits expected for the provider and expressed as needs to satisfy for the customer (Goyhenetche, 1999).

Among the benefits are included :(i) the construction of a customer loyalty, (ii) the search for differentiation, (iii) the increase and stabilizing of firms' turnover, (iv) the corporate image reinforcement, (v) the occupation of an existing or new market, (vi) the possibility to create alliance with service providers and to share risks, (vii) the possibility to increase the quickness of a design or production process using product-service based on information and communication technologies, (viii) the possibility to shorten sales delay or negotiation phase using financial services and (ix) the search for a product-service system that is designed to have a lower environmental impact than traditional business models.

The needs of the customer include implicit and explicit needs get from a consumer panel. It also takes into account user-product utilization.

Costs are divided in direct and indirect costs. They encompass component costs, labour cost, and overheads. The value engineering analysis is done for both stakeholders and thus, two ratios are obtained. The first one represents the value of the PSS for the provider while the other represents the value of the PSS for the customer.

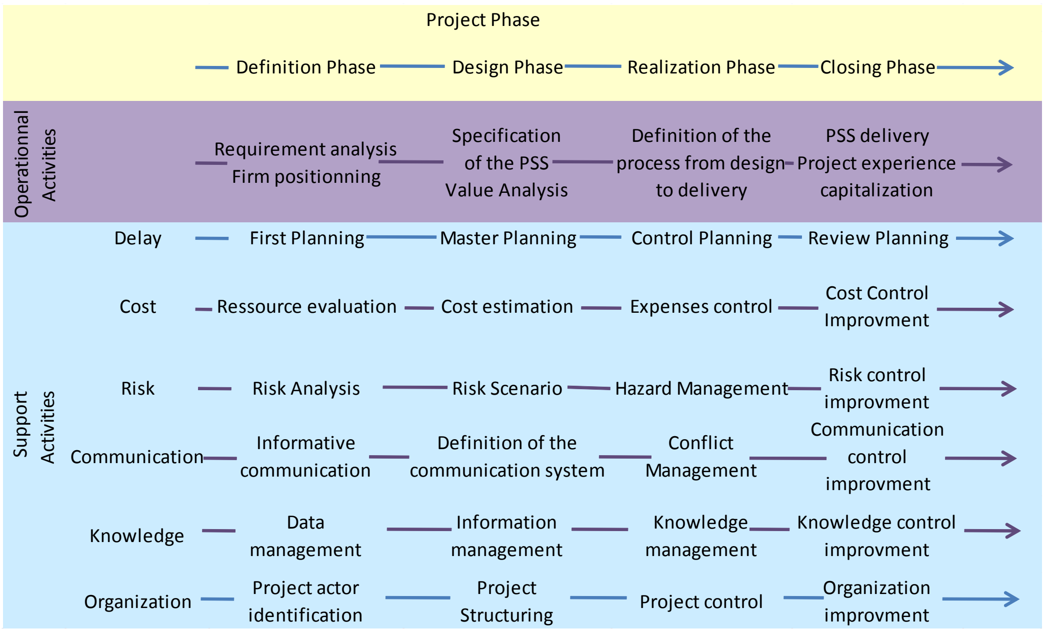

Figure 1: Business model of a PSS based on a project life cycle

The two values represented in a square matrix enables to analyze the relevance of a PSS innovation against the costs of design, implementation, delivery and mercantile strategy of the company before realization (Alix and Vallespir, 2010b).

The value analysis can be performed at a macroscopic level or at a more microscopic level considering that the system is made of elementary subsets whose value can be analyzed separately. The underlying idea is to simulate the process of coupling these components to see the combinations that increase the system value for both the customer and the provider. Modeling methods such BPMN, SADT/IDEF0 (Morelli, 2006), or blueprints (Chekitan and Schultz, 2005) can be used to represent the activities and their sequence. Work on validation of distributed simulation models coupling product-service are detailed in the following section.

3.2.3. Realization and closing phase

The realization phase aims to operationalize the solution defined in the previous phase. The production and delivery processes will be set up during the phase; the availability of material and human resources required will be checked as well as the competence of the human resources. The closing phase is the PSS assessment phase during which user-product utilization will be capitalized for future low consumption development. Possible subset coupling could merge from that feedback leading to the possibility for new development to benefit from past experience and thus minimizing expenses.

4. SERVICE MODELLING AND SIMULATION

Service design and development are more than ever a key challenge for enterprises. However, the development of new service activities is not fully formalized and is not guided by a clear or commonly recognized methodology. These facts may cause a drawback from the definitions to the practical implementation of services that can penalize the enterprise, especially when finding lately the defects in the services development. The idea presented in (Zacharewicz, Alix and Vallespir, 2009) was to model and simulate the services associated with the products before they real implementation in order to validate the desired properties and anticipate a wrong behavior of services. However, the authors identified a limit to this proposal: the complexity of a full product-service system (actors, software, machines) excluded from catching this whole complex behavior into the model. The idea is to offer physical or software actors to act in the loop simulation for validation. In consequence, the simulation requires interacting and synchronizing with heterogeneous actors and distributed service. To meet these considerations, the authors proposed a Service M&S environment based on a graphical language for modeling service selecting the essential concepts from (Bell, 2008) service models and reusing the G-DEVS/HLA distributed simulation (Zacharewicz, Frydman and Giambiasi, 2008). The G-DEVS formalism (Giambiasi, Escude and Ghosh, 2000) was chosen for its formal properties. This previous works also described a method for transforming service specification models to simulation models. The interoperability of simulation models with human-machine interfaces was addressed by complying with the HLA standard for distributed simulation that got the thirty years of experience in the distributed simulation. Finally, the modeling environment of distributed services and interfaces proposed service models with other actors in a compatible HLA federation, propose to validate some desired properties of service-couples before their course into production (realization). These previous works on service modeling have been extended to cover PSS specification; they are detailed in the following sections.

4.1. Modeling

As mentioned earlier, the Product Service System Modeling is a recent domain that has not adopted yet a unique and/or common standard for developing frameworks to manage services processes. The complexity of PSS Modeling specification comes from PSS may involve different software and / or actors components which are essential to its execution but heterogeneously specified. The literature reports several standards specification, the authors have chosen the graphical definition of the Service-Oriented Modeling Framework (SOMF) (Bell, 2008). The reasons are mainly the fine coverage of the domain and the user friendly design of the language. In detail, the service modeling does not require expertise on service specification and language coding (execution code can be eventually generated from a graphical specification). Nevertheless, the missing piece is the correctness checking or the scenario evaluation of the couple product-service models. Concretely, this field is demanding verification and validation methods; the authors believe that simulation can give projecting information on the correctness of the models. In more detail, one identified lack is the SOMF does not define an explicit simulation semantics associated to the Service Modeling. This fact may lead to difficulties to determine if simulation result errors have to be imputed to a wrong model or to an incorrect implementation of the Service Modeling engine.

Having selected the essential concepts from SOMF in the elaboration of PSS Modeling, the authors have defined a PSS Modeling process to represent the components involved in PSS. The authors added to this description the notion of Resource that is key issue to represent the PSS. The Resource will be part of the model if possible, if not, thanks to interoperability (introduced next section), it will be involved in the loop human or external machine or software. To sum up the approach, a XML PSS Modeling process model is composed of sub service components that treat in-progress service and controllers components that route in-progress service information between sub services. In-progress services pass over a sequence of these components.

Then, the SOMF models are using a XSLT based method to transform XML PSS Modeling specifications into G-DEVS simulation models. The work is based on a previously introduced methodology to transform Service models to Simulation models (Zacharewicz, Frydman and Giambiasi, 2008). In depth, the PSS model is transformed into a coupled G-DEVS model by coupling G-DEVS atomic models representing Service Modeling basic components. This G-DEVS model takes advantage of formal properties and can be simulated.

4.2. Distributed Simulation HLA based

Based on the experience of distributed simulation, the authors proposed to address the interoperability by conforming to the distributed simulation standard High Level Architecture (HLA). For a short recall, HLA is a software architecture specification that defines a common understanding to create a global simulation composed of distributed simulations (or other software components). In HLA, every participating simulation is called federate. A federate interacts with other federates within an HLA federation, which is in fact a group of distributed federates. The HLA set of definitions brought about the creation of Standard 1.3 in 1996, which then evolved into HLA 1516 in 2000 and HLA 1516 Evolved in 2010 (IEEE, 2010).

Finally, they defined a distributed PSS Modeling Environment (detailed in § 5.3) that interfaces components (implementation of subsets) of the PSS Models and others actors in HLA compliant Federation.

5. PSS M&S CASE STUDY

In this study, the authors modeled a PSS oriented Service where service is more important than material property. The example study is dedicated to the baby toys market. The targets of this market are parents of child from 0 to 1 year. The authors proposed a G-DEVS coupled model of different market approaches (buying versus renting toys). This model has been formalized according to several data reports from CRIOC realized in Belgium (Vandercammen, Warrant and Meirsman, 2010).The study describes Service Models in a formal approach and validates these models by simulation.

5.1. PSS Toys industry G-DEVS Models

This section details the PSS G-DEVS model for toy renting systems.

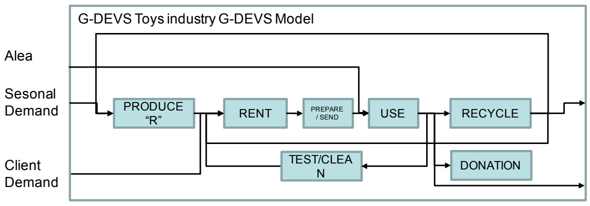

Figure 2: G-DEVS model PSS Service oriented

In figure 2, the G-DEVS coupled model is describing a PSS oriented service where the toy is rented instead of being sell. This model is also starting from a production phase that has been differentiated from a "classical" production on the fact it is supposed to integrate more environmental care in the choice of the raw materials, processes and recycling concerns. The second sub model is the renting model it takes into account the demands from clients based on seasonal demands. Once the toy is rented it is prepared and expedited to the client. The use model of the toy is based on stochastic input on toys duration and child interest in the toy. In case the product is destroyed or damaged by the child, three solutions are envisaged. Fist, if too much damaged or destroyed the product is recycled as raw materials input for new production. Second, in case the product has been used more than a fixed amount of time or has been decided too much old-fashioned regarding criteria it is donated to charity organizations. Last, in case the toy is still functional and not degraded after a rent duration it is tested, cleaned and proposed again for renting.

5.2. Other components

A random event generator has been created, based on Excel stochastic function to generate a file that schedules events to feed the toy breaking incidents, the toy interest for a child and old-fashioned. This file is charged in a scheduler for G-DEVS models in "alea" (hazard) input of the use model. The seasonal toy market selling and client demands have been elaborated in an Excel file to transpose the results from CRIOC to events planned as inputs of the PSS G-DEVS models (Client / Seasonal Demand input of Produce and Rent models).

5.3. Distributed Simulation Architecture

The architecture presented in figure 3 has retained the HLA standard to solve interoperability problems between heterogeneous components introduced.

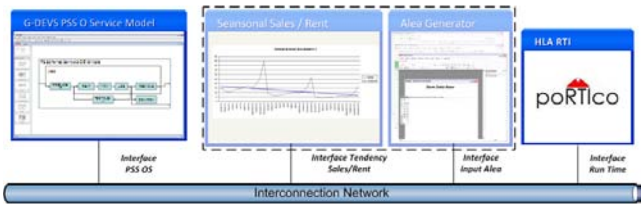

Figure 3: PSS M&S Distributed Architecture

The open source Run Time Infrastructure poRTIco takes in charge the distributed execution and message synchronized delivery. This architecture is based on previous works to handle message passing synchronization consideration (Zacharewicz, Frydman and Giambiasi, 2008; Tu, Zacharewicz and Chen, 2010). The simulation has been run on several scenarios.

One simulation scenario has leaded to compare from the client point of view the best valuable option regarding buying and renting toys for under one year child. The results conclude on the necessity of a fine tuning of the renting duration (2 months or 3 months for 5 toys dedicated to an under one year child) and price regarding buying (less than 30 €). The second measurement was about the impact on the environment, the study has shown that renting can divide by three the impact by reusing the toys regarding the age of the child, the interest duration to a toy from a child and toys non breaking duration.

6. CONCLUSION

The study has envisaged that profitability can be obtained under the condition PSS design and realization consider simultaneously the design of products and services, taking care of the use of the system and of its impact on the environment. A special attention has been paid to simulate PSS behaviour regarding classical selling systems to be sure that the realized PSS meets customer needs. This paper has presented premise of a Product-Service Modelling & Distributed Simulation Environment based on G-DEVS / HLA. Therefore, a toys industry innovative PSS scenario has been simulated and tested regarding specific criteria allowing a decision maker to choose an innovation baby toys distribution win/win strategy. Future research will include testing other scenarios and integration of other criteria for the PSS solution choice.

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