Using BPMN-based Business Processes in Requirements Engineering: the Case Study of Sustainable Design

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Abstract - *Global economic challenges force companies to constantly seek alternatives to become more efficient in order to grow, or even survive. Process improvement has the potential to transform a company and lead to innovation while information technology is an enabler of business change. Both must evolve together to maximize the outcomes. This paper introduces the case study of a business process to support the sustainable design (SD) of products and services. The purpose is to illustrate how processes can be used to support eliciting and managing system requirements for highly complex domains, where both processes and requirements are difficult to define. The process was designed in Business Process Model and Notation (BPMN). The case study shows how information is gained during process mapping and how this information can be used in requirements engineering. Relevant SD knowledge and best practices are presented, making this process also very helpful for SD beginners.*

Keywords: Requirements engineering; Business process management (BPM); Business process model and notation (BPMN); Sustainable design.

1 Introduction

Business processes can be applied for mapping detailed information about a domain. They document and formalize best practices and the experts' knowledge about a subject, being a reliable guide to identify gaps and failures, extra work and improvements needed in informal/semi-formal processes present in most companies [7].

Business Process Management (BPM) comprises the activities of representing, analyzing and improving business processes in order to improve quality and efficiency, supporting innovation [5,7].

Business Process Model and Notation™ (BPMN™, in the following referred simply as BPMN) is a standard notation developed by OMG™ [9] for BPM, based on flowcharts. It was designed to be easily understandable by the main stakeholders of a process, such as business analysts, technical developers responsible for implementing the technology, and business people [5,9].

Requirements engineering (RE) is concerned with eliciting and managing requirements for the life cycle of software systems products. Business processes can be used to elicit and understand software system requirements due to the knowledge they summarize [7]. Keeping software systems aligned with business process is fundamental for companies to remain competitive nowadays. Therefore, business process are important assets to RE and must be perceived as such.

Business processes may also be helpful in other steps of systems development life cycle (SDLC). For example, they represent an important source of information for building software solutions based on services. Notorious examples are SaaS (Software as a Service)-based solutions and SOA (Service-Oriented Architectures) applications, where processes are very helpful to understand and identify service requirements, understand interoperability challenges and guide system integration [6,7].

A software package to design business processes in BPMN is usually known as Business Process Management System (BPMS). Different BPMSs incorporate different functionalities, such as performance evaluation, process analysis and execution. In this paper, the BPMS Bizagi Process Modeler™ [http://www.bizagi.com/] was chosen because it is compliant with the BPMN standard and it is a free, easy BPMS solution for modeling purposes. [6,7,9]

This paper presents a case study to illustrate how BPMN-based processes can be used to support requirements elicitation in highly complex domains, where both processes and requirements are difficult to understand and define.

The case study is focused on RE applied to the development of a software system to support sustainable design of products and services. It shows how information is gained during the design of a process and how this information simplifies RE. Results show how BPM can become a fundamental activity for RE and why it should be incorporated to SDLC, at least for complex systems.

The case study introduces relevant SD knowledge, techniques, challenges, pitfalls and best practices, which also makes the resulting process very helpful as a guide for SD beginners.

2 Sustainable design

Eco-efficiency studies the development of products and services to raise quality of life of populations worldwide while trying to reduce environmental impacts of the productive process and maintain competitive prices for products and services [1]. Clean production focuses on the continuous application of environmental strategies to raise eco-efficiency [http://www.uneptie.org/pc/cp/home.htm]. Product-Service System (PSS) is a system created to evaluate if either a product or a service should be chosen to address current needs, providing sustainability for both consumption and production [4]. Sustainable design (SD) is the activity of designing products and services to satisfy customer needs while reducing environmental impacts, providing eco-efficiency and clean production in a PSS scenario [3,4,8].

Life Cycle Assessment (LCA) is an ISO/IEC standard applied to evaluate environmental impacts associated with the production of goods [2]. LCA is essentially a quantitative method to measure emissions in each stage of the productive process, from raw material acquisition until the final destination of each product after usage. Considering only the relevant activities, LCA can be adapted to evaluate the corresponding impacts associated with the provision of services.

SD is a very complex activity [4]. It must consider social and economic impacts of introducing new or replacing products or services. Legal and human aspects that can interfere in the productive process or product/service adoption have to be taken into account. Evaluating potential consumption increases is also mandatory in SD, as well as evaluating rebound-effects (increase of environmental impacts in unexpected areas, such as people printing emails and several copies of the same documents in the early days of email adoption), as tthey may worsen the overall environmental impacts, even when a so-called "green" product is conceived [3,8].

In [8], a reference process for SD was proposed. The process is presented in Figure 1. In this process, six main steps for SD were identified: 1) functionality conception; 2)

Steps	PSS Aspects	LCA Aspects	Social Aspects	Economic Aspects	Other Aspects
1. Functionality conception	• Define the functionality (market demand) to be attended and the steps to achieve it • Identify options for PSS and evaluate environmental impacts of both products and services, to choose the best alternative • Carefullly study the consumer before replacing a product by a service	• Verify safe and health in product regular usage • Evaluate the complete life-cycle, inputs/outputs and environmental impacts of a PSS	• Evaluate quality of physical and social life • Verify the social impacts to replace a product for a service and vice-versa • Evaluate dynamic (time) approach	• Verify if the PSS is cost effective • Verify the cost of the PSS when compared to a competing versions of a product or a service able to attend the same requirements • Consider the environmental external costs (e.g. end of life recovery, reuse, treatment, disposal) • Apply this reasoning for all phasis of the product design process • Evaluate distributed economic model, with local resource supply (creative communities /cooperative networks)	•Verify legal aspects to the product introduction • Innovation of the life cycle basis • Platforms to implement PSS
2. Raw material aquisition	• Minimize the volume of materials used • Substitution of none/less hazardous raw materials • Analize the extraction and processing • Minimize energy, water , emissions, wastes and eliminate toxic components • Evaluate/reduce transport impact • Eliminate or reduce non-renewables usage	• Verify and reduce impacts in environmental management • Quantification of greenhouse gas emission • Evaluate environmental burden of the activity • Quantitative results	• Verify where and how do the raw materials are extracted/processed • Verify the ownership rights • Verify if the trading arrangements are equitable		• Stakeholder reconfiguration • Identification of new research areas and professional competence • Compliance with legal and technical specifications • Evaluate quality aspects • Obtain data to evaluate environmental burden
3. Manufacturing	• Optimise production technology • Minimize energy, water , emissions to air, wastes, and effluents • Eliminate /minimize toxic components and non-biodegradable substances • Maximize ecology efficience	• Perform periodic greenhouse analysis • Evaluate environmental burden of the activity • Priorize quantitative results	• Analyze employee conditions of work (at company or subcontracted companies) and impacts on local community • Analyse local investments and adverse impacts for local and global community • Evaluate local initiatives		
4. Trade and delivery	• Evaluate/reduce transport impact for both products and services • Evaluate volume and nature of transport, and the type of fuel usage • Eliminate/reduce emissions to air / waste				• Stakeholder reconfiguration • Get data to evaluate environmental burden
5. Use / Maintenance	• Minimize energy, water , emissions to air, wastes (product and packing), and effluents • Eliminate non-biodegradable substances • Maximize durability	• Reason for PSS choice • Perform periodic greenhouse analysis • Evaluate environmental burden of the regular use	• Analyze adverse health/safety impacts for the local and the global community		• Evaluate rebound effects • Prevent colateral effects to PSS introduction
6. Re-use / recycling / energy recovery / disposal	• Apply strategias to extend the product life cycle • Design for repair and modular design • Simplify recovery of components for reuse and for recycling or waste treatment/disposal	• Perform periodic greenhouse analysis • Evaluate environmental burden of the activity	• Adverse adeverse health/safety impacts for the local and the global community		• Get data to evaluate environmental burden

Figure 1 – A reference process to design information systems for sustainable design based on LCA, PSS, social and economic aspects proposed in Santana et al. (2010) [8].

raw material acquisition; 3) manufacturing; 4) trade and delivery; 5) use/maintenance; and 6) reuse/recycling/energy recovery/disposal. PSS, LCA, social, economic, legal and other relevant aspects were identified. The main concerns and issues related to SD were also extensively discussed, leading to a complete understanding of SD while identifying major challenges and best practices for this activity.

However, the reference process presented in [8] was not in an ideal format to support RE nor it deeply studied the complexities inherent to each step. Deepening the reference process while designing the corresponding detailed process in BPMN provides the resources for a complete and realistic evaluation of the environmental impacts caused by introducing a new product or service, adequately guiding the construction of software systems to support SD. Functional requirements and quality attributes can be easily identified during the process mapping phase and from the BPMN-based business process for SD.

3 The BPMN-based business process for SD

The BMPN-based business process for SD starts with raw material acquisition and ends with residues disposal. With the exception of prototype development, the process must be executed before any product is manufactured or any service is implemented to ensure the proper application of SD principles.

The BPMN-based process can be applied to products or services under PSS. However, if a service is chosen, the required products to have it provided must be considered for SD, as well as additional requirements that may arise. For example, if having clean clothes is the SD need, a washing machine could be the product to be compared with laundry services but evaluating the latter should include transportation and labor. An overall evaluation should consider having a reduced number of washing machines worldwide vs. service-associated costs.

The main process for SD is presented in Figure 2. In BPMN, rectangles represent activities while diamonds are gateways to control the process flow. Rectangles with a plus ("+") symbol are macro-processes and thus must be detailed. Circles represent beginning and end of the process.

Raw material acquisition if followed by the "Resource Type" macro-process. In "Resource Type", the raw material "greenness" is evaluated to encourage the adoption of renewable or recyclable resources. "Resource Type" is presented in Figure 3.

Next step is to analyze pollutants emission caused by the product/service to be designed. This is described in the macro-process "Pollutants Emission" presented in Figure 4. Pollutants are classified as low, medium or high. Chemistry analysis and environmental laws will define specific values for low, medium and high. Classification depends mainly on products/services being designed, industry sector (e.g., plastics and chemical) and raw material usage (type and quantity). Unless minimum quantities of pollutants are being generated, optimization/redesign is required. Environmental contamination risks must be carefully evaluated. As every product or service always will generate at least a minimum amount of pollutants, the option "null" is disregarded in the "Resource Type" macro-process.

Transportation, the following step of the process, is one of the most important aspects to be evaluated when assessing products/services under SD. Transportation can, by itself, compromise completely a product/service "greenness", being local development always recommended but hardly adopted. Having manufactured products being developed locally is unlikely in the current global market. However, there are means of transportation that may reduce significantly environmental impacts. Therefore, global investments in efficient transportation networks are mandatory. Meanwhile, the adoption of products that can be transported via the available efficient networks must be prioritized.

The production process is evaluated in the next step of the BPMN-based business process for SD. The macro-process

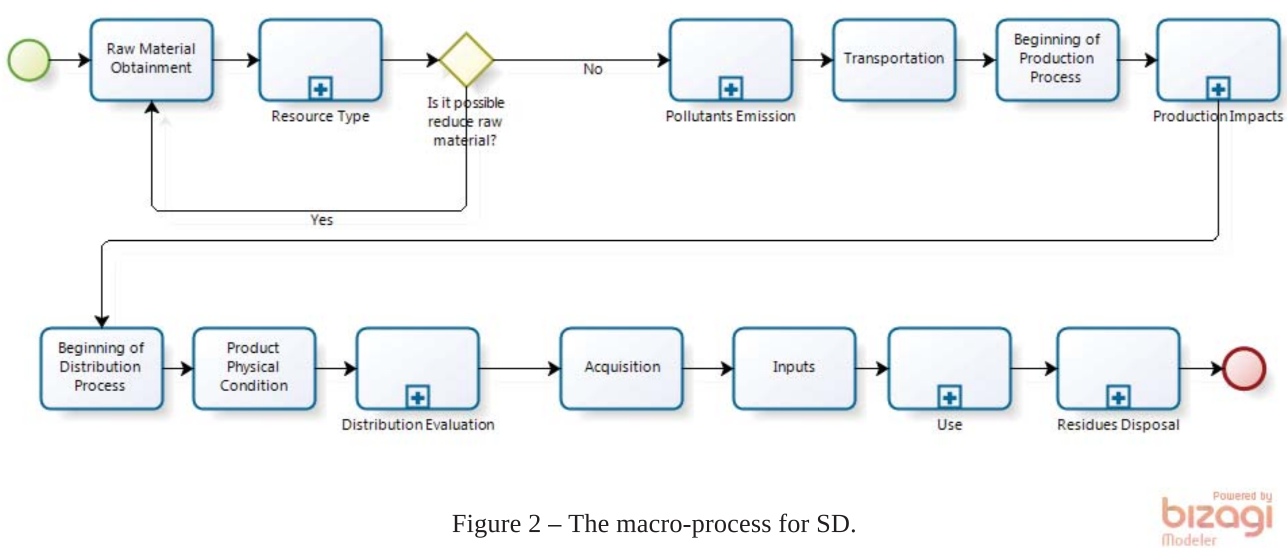

Figure 2 – The macro-process for SD.

"Production Impacts" is presented in Figure 5. This process evaluates the whole impact of manufacturing, considering energy expenditure, equipment wear and pollutants' emission by the manufacturer. Specific issues must be considered for each one of them, such as plant modernization and residues treatment.

Quality control and calculating waste are also important to ensure SD principles are being properly addressed in the "Production Impacts" macro-process. For example, environmental impacts caused by production rejects that cannot be recycled must be properly assessed, as well as associated costs for recycling whenever applicable.

Figure 6 presents the macro-process "Distribution Evaluation," which is the next step of the main process for SD. In this step, priority must be given to the analyses of possible distribution processes and scenarios. Transportation networks and risks attributed to transportation must be considered. This step is followed by product acquisition and inputs, where the assessment must be made from the manufacturer point of view. Environmental impacts caused by resellers should also be assessed when the producer has any control over the process.

Next step in the main process for SD is "Use", detailed in Figure 7. In this step, the designer must consider all

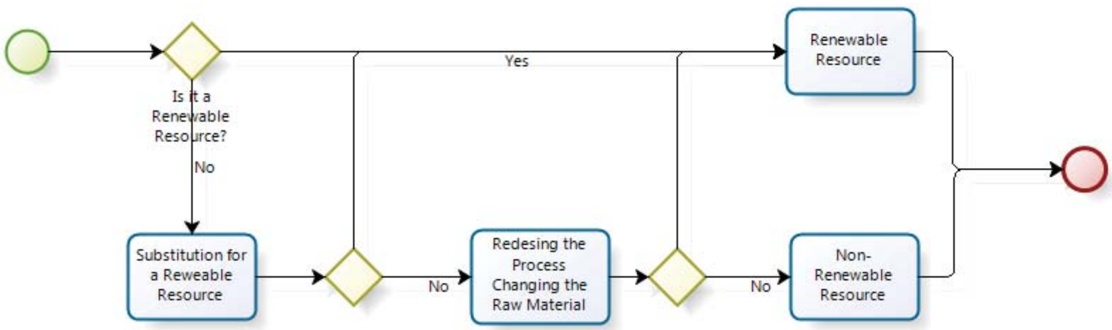

Figure 3 – The "Resource Type" macro-process.

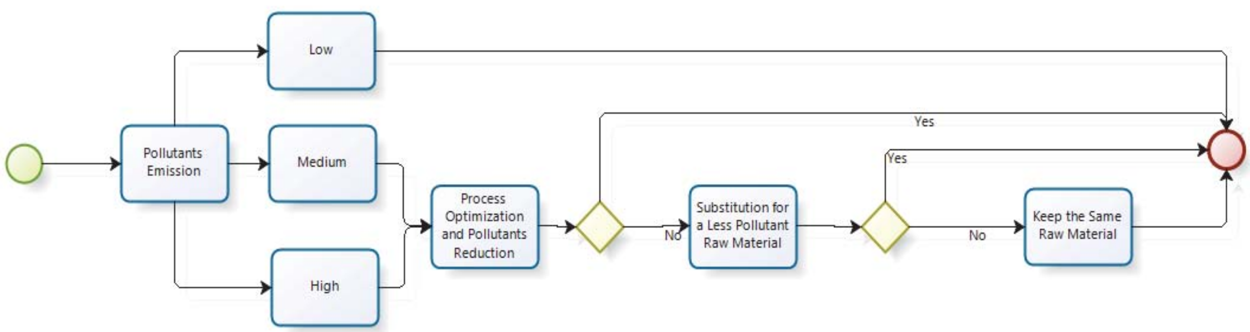

Figure 4 – The "Pollutants Emission" macro-process.

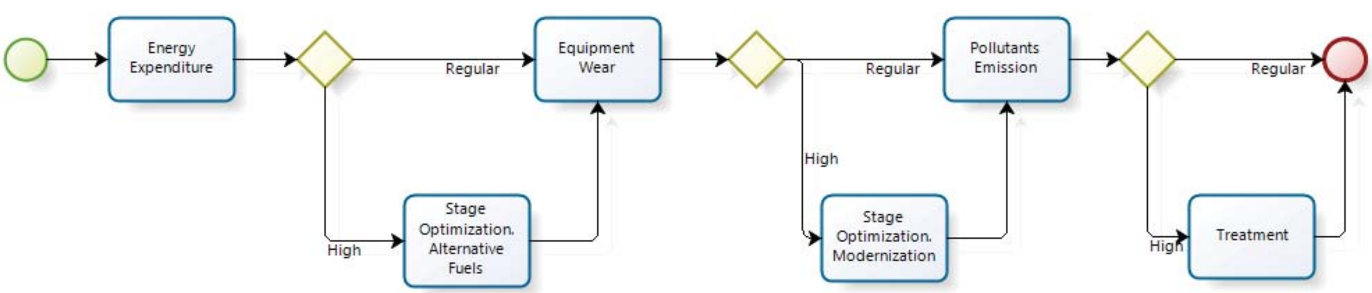

Figure 5 – The macro-process "Production Impacts"

different uses/destinations that can be given by users to products/services, including incorrect use. Producer/provider's responsibilities are usually restricted to the specifications provided in the manual/contract that accompanies each product/service, but environmental impacts must still be assessed under SD rules to predict and minimize undesirable results (e.g., rebound-effect).

Last step of the BPMN-based business process for SD is "Residues Disposal", presented in Figure 8. In this macro-process, different forms of product discard must be considered, such as recycling, reuse and additional treatments to reduce environmental impacts.

Finally, the PSS system is presented in the Figure 9. It compares SD for products and services from the supply chain management point of view. Simplified LCA is performed in the beginning to help the designer to start, but afterwards a complete assessment is provided and it includes all relevant steps of the main process, such as production, distribution, use and residues disposal.

4 Discussion

Defining the BPMN-based business process for SD was essential to understand this complex activity and define the problem domain, representing a valuable contribution for RE.

The process covered all technical aspects related to PSS and satisfaction of consumer's needs. The main functional requirements for designing a software system to support SD may be easily gathered by using a systematic approach to analyze the process step-by-step.

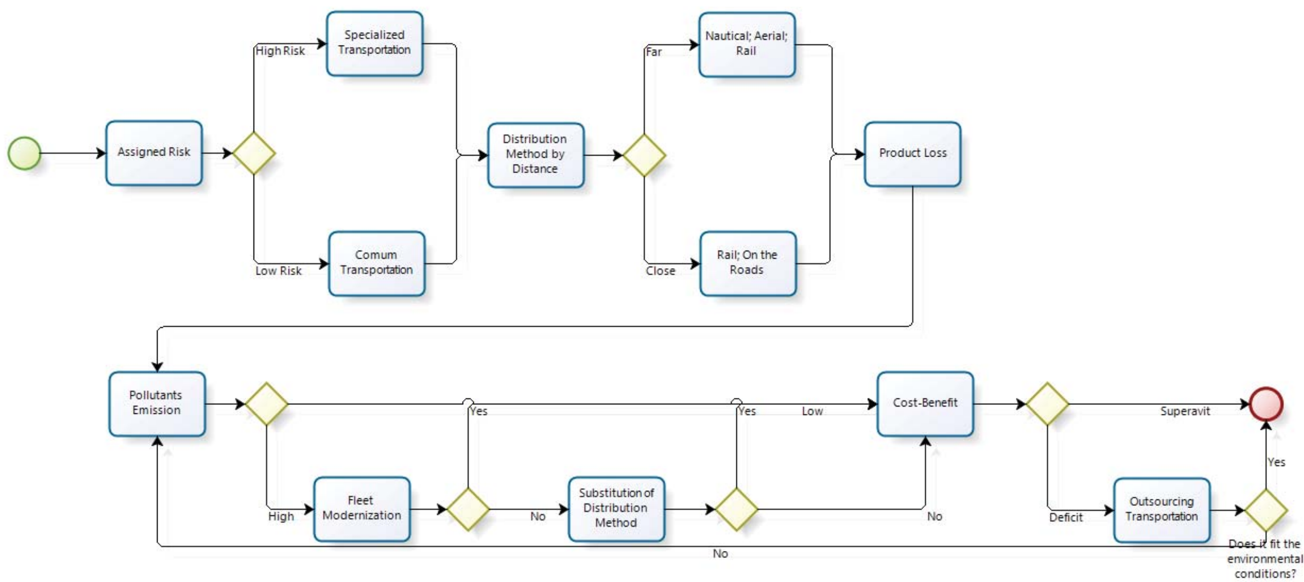

Figure 6 – The macro-process "Distribution Evaluation"

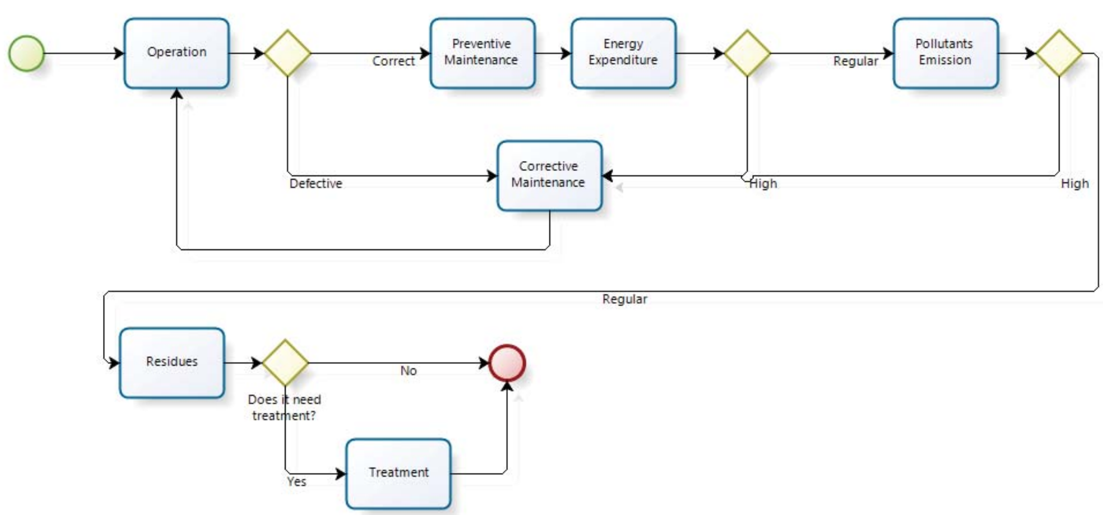

Figure 7 – The macro-process "Use".

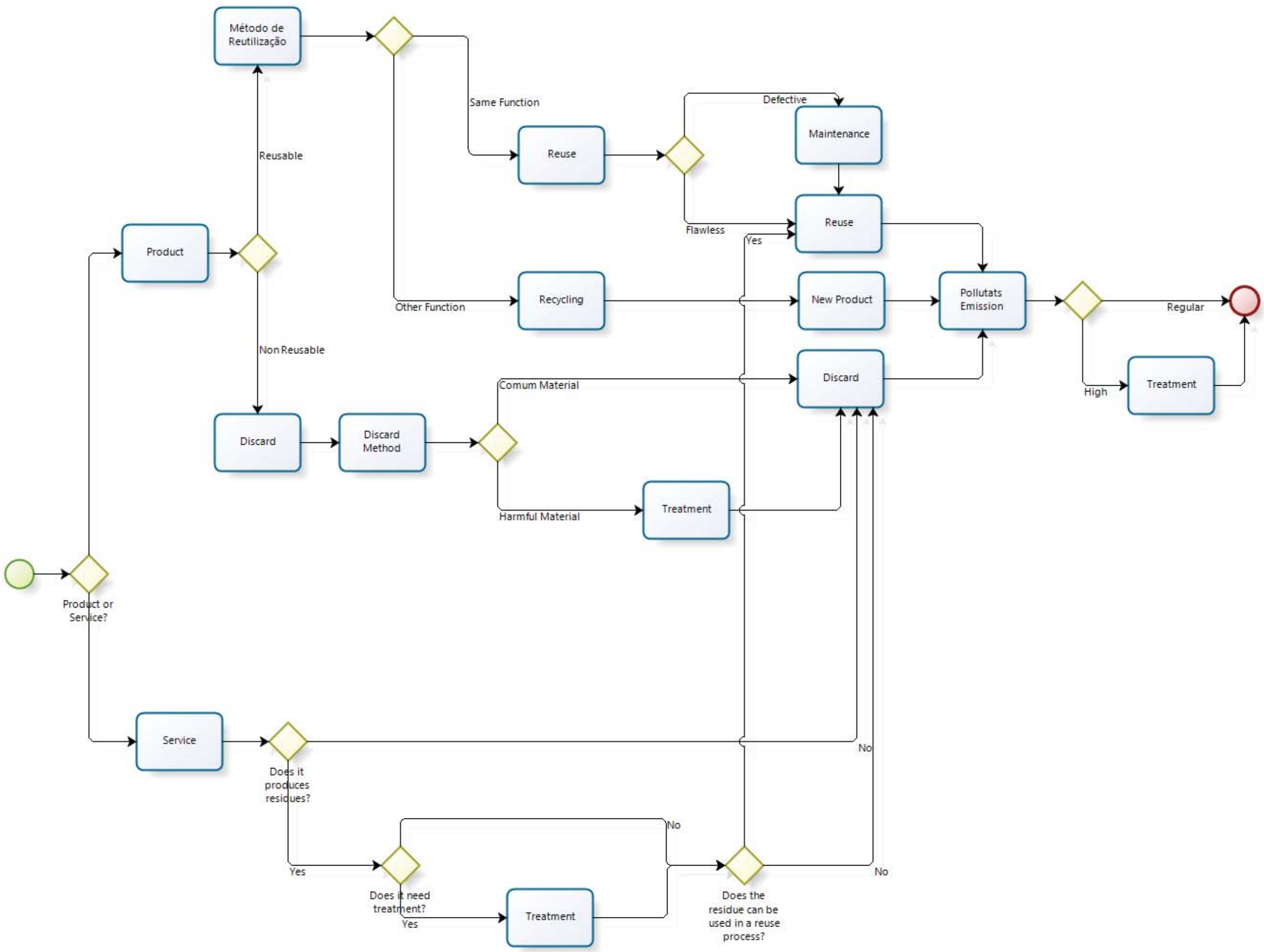

Figure 8 – The macro-process “Residues Disposal”

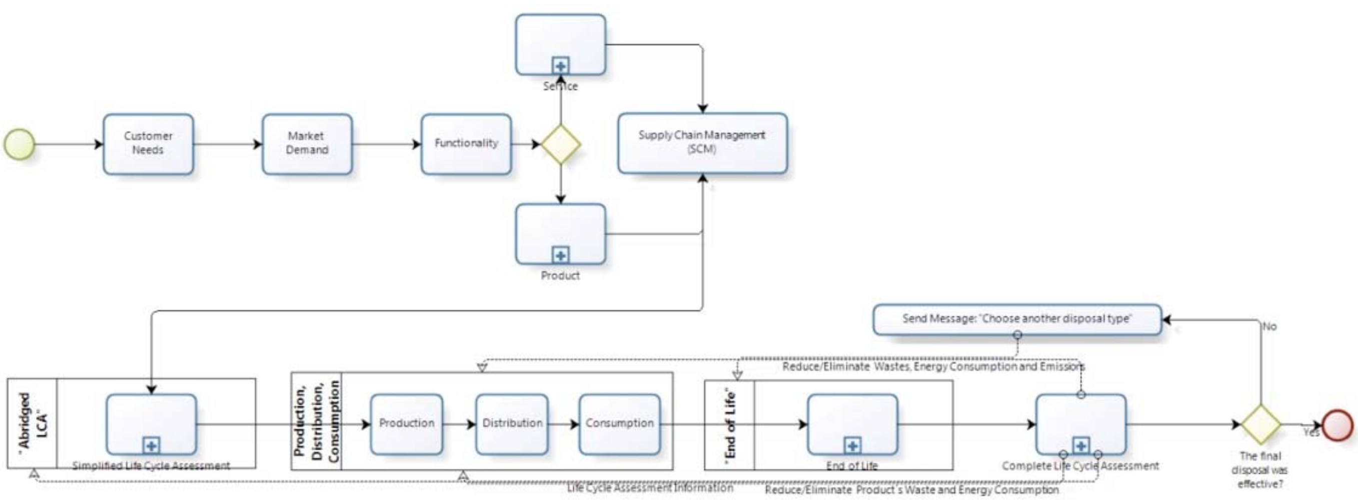

Figure 9 – Product Service System

Non-functional requirements may also be inferred, such as integrability and interoperability, as external information will be necessary for SD (e.g., information provided by transportation companies).

For example, the “Transportation” step showed that calculating distance between suppliers, manufacturers and distributors is an important requirement for SD. The same for incorporating recommendations and rules on pollutants' emissions according to classifications provided by industry or application field, identified in the “Pollutants Emission” macro-process (e.g., energy consumption is important for fridges manufacturers while other factors have more relevance for furniture and plastic manufacturers, such as quantity and type of raw material used).

Requirements on product disposal also could be identified, being treatment one of most important of them. For example, disposal issues caused by coffee machines designed to work with capsules has led some companies to create special disposal programs for collecting and recycling the capsules themselves. Had the SD process being followed since the beginning, those recycling programs could have been proactive instead of reactive.

Requirements must be well defined and quantifiable whenever possible, so words like “minimize” and “reduce” as presented in the process must, during the requirements elicitation phase, be replaced by numeric criteria or at least by intervals of confidence. Otherwise, applying LCA to measure and classify environmental impacts according to well-accepted international standards will not be possible.

The process presented in the case study is also a very reliable, detailed source of knowledge on SD. Thus, it can be used for training purposes, helping the designer to understand the inherent complexity of this activity, as well as the main challenges, pitfalls and best practices required to design clean products/services.

Finally, the business process presented in this work can be used as a reference guide to SD, independent of the development of a corresponding software system. As this process introduces a global analysis of environmental impacts instead of localized actions, unexpected synergies may occur, resulting in more appropriated, real “green” products that can also bring consumer satisfaction, profitability, competitiveness and environmental benefits.

5 Conclusions

This paper presented a BPMN-based business process to illustrate how they could support RE in highly complex domains, where gathering requirements was inherently difficult. Results showed that BPM was fundamental for mastering the complexity and defining the problem domain.

The case study was focused on RE applied to the development of a software system to support SD. The purpose was to show how information could be gained during the design of a process to simplify RE. As relevant SD knowledge and best practices were presented, this process can also be used for training purposes, being very helpful to introduce SD beginners to this complex activity.

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