Sustainability Aware Process Management using XML-Nets

Stefanie Betz[1]

Abstract

This paper gives a short overview about sustainability aware process management using XML-nets. Sustainability management is one of the upcoming movements in the 21st century. Communal and private organizations are interested in finding and using "sustainable" solutions and practices. But, there is a lack of available solutions and practices. In the 21st century also, software systems and their underlying business processes are ubiquitous and fundamental for most of the organizations of the industrial society. But, until now, sustainability is not sufficiently considered by business process engineering. Hence, to support the transition to sustainability, one must have sustainability (aspects) integrated into the business processes. Consequently, in this paper a holistic approach is presented to support sustainability aware business process management.

To realize such an approach, sustainability aspects must be integrated into the business processes life cycle. Thus, first to assist the stakeholder when modelling, designing, executing, and monitoring the business processes a process model is developed and explained. Second, sustainability aspects are conceptualized and integrated in a business process modelling language.

1. Introduction

Sustainability is an important part of society, politics and economics nowadays. Organizations have started to realize that not only cost savings can be reached with sustainability but even long-lasting business success. Thus, next to cost, time, and quality, also sustainability is a goal to reach. A business process is a set of activities that are executed according to certain rules to achieve a predefined business goal in an organization. Thus, if sustainability is not supported this may threaten the execution of business processes. So, when modelling, simulating, improving, and implementing business processes the additional dimension sustainability needs to be taken into account.

Nevertheless, a lot of organizations have problems to integrate sustainability into their daily business ([1,2]). Even when the companies are aware of the importance the additional effort needed to integrate sustainability management into their daily business seems to high. There exist a lot of frameworks regarding sustainability (e.g. Green Supply Chain Operations Reference (SCOR), Greenhouse Gas (GHG) protocol) and defined Key Performance Indicators (KPIs) (e.g. carbon footprint). But, the approaches so far bear the problem of being transparent, being analysable and (very important) comparable. One of the biggest challenges (next to getting the appropriate data of course) is to measure the sustainability of the specific products (e.g. emissions, water waste etc.) ([1,3]). One way to solve this resource allocation problem is to use business processes. There, the costs can be directly linked to the activities of the processes [4]. Thus, in order to facilitate the awareness and application of sustainability in daily business an integrated approach of sustainable aware process modelling and simulation approach should be used. The integration of sustainability on a business process level would create a lot of different possibilities

[1] Karlsruhe Institute of Technology, 76, 31 Karlsruhe Germany, stefanie.betz@kit.edu, Department of Applied Informatics and Formal Description Language

to understand and change the impact on environment, economies, and society on activity product as well as company level [1].

But, in traditional process management approaches sustainability and processes are not sufficiently integrated. Sustainability is usually not explicitly described in the relevant process models. In order to realize sustainability awareness in process management, one must have the process risks conceptualized and integrated into the complete process lifecycle process modelling, simulation, improvement, implementation, execution, and evaluation.

Thus, I present a methodology of sustainability aware process modelling, simulation, and improvement. To that end, in the following I firstly describe my understanding of sustainability and then I present related work. Next, my methodology for sustainability aware business process management is presented: An approach to facilitate the documentation, modelling, simulation, and evaluation of sustainability alongside a business process. Last, I present my suggestion for the extension of a business process modelling language.

2. Sustainability

To clarify my research objective I now explain how sustainability is defined in the given context, what aspects I am taking into account when working with sustainability, and which level of impact (positive and negative) it is referred to when including it in the approach.

In this paper I use one of the most cited definitions of sustainability, the definition of Brundtland from the Report of the World Commission on Environment and Development, saying that we should make sustainable use of our planet by maintaining its function to further fulfil human needs [5]. This definition is actually referring to sustainability as sustainable development and this is what I also refer to (as I am working on an engineering approach). But of course, no single product can be sustainable in the sense of sustainable development because this definition has a global scope (c.f. [6]). Therefore, I use sustainability indicators. Indicators are used to measure and thereby identify actions that are more beneficial to sustainability than others [6]. Indicators themselves are composed of metrics, which in turn are composed of measurements. In the given context sustainability is characterized by two different indicators[2] [6]:

- Resource oriented indicators: These indicators cover the environmental aspect of sustainability. The term footprint is somehow the common used metaphor for resource oriented sustainability indicators (e.g. carbon footprint).
- Well-being oriented indicators: These indicators cover the fulfillment of human needs aspect of sustainability. Here it is difficult to find appropriate metrics to measure the fulfillment of human needs.

Please not that sustainability can only be gained by taking the two aspects into account: one need to fulfill human needs and take care of the global resources [6].

When talking about sustainability it is also important to explain the different levels of impact sustainability can have in connection with business processes. This leads to three levels of impacts: direct impact, indirect impact, and socio-economic impact (based on [6,7]):

- Direct impact: Direct impact refers to the life cycle impact. It includes any impact directly caused by the software system production and use (e.g. energy usage, e-waste production, emissions).

[2] I use indicators to be able to measure any impact (positive or negative).

- Indirect impact: Indirect impact refers to changes on a micro-level. It includes actions that are enabled by using software systems as well as by changes of software systems. These are for example process improvements, media substitution and behavioural or technological changes.
- Socio-economic impacts: A socio-economic impact refers to changes on a macro-level. It includes changes on economic structures and on institutional level.

These impacts are, of course, connected. More precise, indirect impacts are enabled on the basis of direct impacts and socio-economic impact emerges from indirect impact actions and, in turn, influences them. Following, these different levels of impact are discussed in more detail.

Most obvious are the direct level impacts. They refer to the environmental and social impacts caused by the production and the usage of software systems. They can be measured using performance requirements, network bandwidth etc. The direct environmental impact is quite often measured using the Life Cycle Assessment (LCA)3. The total impact could then be allocated to a functional unit during the use phase and can then be allocated to a functional unit [6]. Indirect impacts are already more complicated. They refer to actions that are enabled by changes of software systems on an organizational, behavioural or technical level. This might be for example industrial automation reducing (cost of) capital, energy, and information. Three types of changes are possible; all of them are based on resource substitution [6]:

- Process improvement: Here an immaterial resource substitutes a material resource.
- Media substitution: Here a material resource substitutes another material resource.
- Externalization of control: Here an immaterial resource substitutes another immaterial resource.

Last, the socio-economic impacts refer to changes that lead to substantial changes in the institutional structures such as new laws, politics, or social norms or economic structures such as the networked economy. The above-mentioned levels of impact are all echoed in the now presented model of sustainability aware software system engineering. But, they are enriched with additional connections between them through the explicit integration of business processes and their life cycle. Moreover, also impacts on sustainability triggered by any changes of the business processes are taken into account in the presented model. Thus, changes can be triggered by any level of impact and can have influence on any other level. At business process level, changes are made, of course, on an indirect level. The supporting IT is having a direct level impact and though the culture and strategy of an organization the socio-economic level is also impacting business processes. After having defined sustainability, in the given context, I will next describe the related work on sustainability aware business process management.

3. Related Work

The related work can be subdivided into four parts. The first part it focusing on sustainable indicators (e.g. [8,9,10]). In these work indicators (basically only environmental indicators named Environmental Performance Indicators or Key Ecological Indicators) are discussed and their importance to measure process improvements based on sustainability aspects is emphasized. The second group is focusing on how these indicators can possibly be integrated into business process management software systems (e.g. [11]). Here, the focus is especially on BPMN as the modelling

[3] LCA is a systematic analysis of the environmental impact of a product during its complete life cycle ("from cradle to grave").

language and on CO2-Emmissions and waste products (e.g. [12]). Another group is work related to the extension of business process management software systems with sustainability aspects and indicators (e.g. [13]). There the authors do not specifically explain how they plan to extend an existing modelling language and the software systems. The extensions are merely on an abstract conceptual level. Last, there is research work on process models on sustainability aware business processes management (e.g. [14]). But, most of the work is focusing on an one time reengineering approach base on Hammer and Champy [15] and not on continuous reengineering based on sustainability. Also, the presented work have found first solutions on sustainability aware business process management, none of the presented approaches is following a holistic approach including the different aspects of sustainability (environmental and well-being), a process model, and a modelling language to model to facilitate the documentation, modelling, simulation, and evaluation of sustainability in business processes.

4. Methodology for Sustainability Aware Processes

I present a methodology for sustainable process management (see Figure 1). The proposed methodology starts with a detailed process model, which is developed according to existing risk and compliance standards. Then the model is simulated and improved. At this step relevant sustainability factors (e.g. carbon footprint) are linked to the process activities. By linking the relevant sustainability factors to the process we seek to improve the planning of the process and make the process models comparable. Now, we built sub-processes with the different sustainability factors. These sub-processes can be used to evaluate process improvements by simulation. Finally, the improved process can be implemented and executed. Our methodology includes the following four steps: initial modelling of the original process; linking the process sustainability factors to the process activities; simulation and evaluation of process improvements; systematic selection and transformation of the original process model into an improved process model. In the following, I describe these four steps in detail.

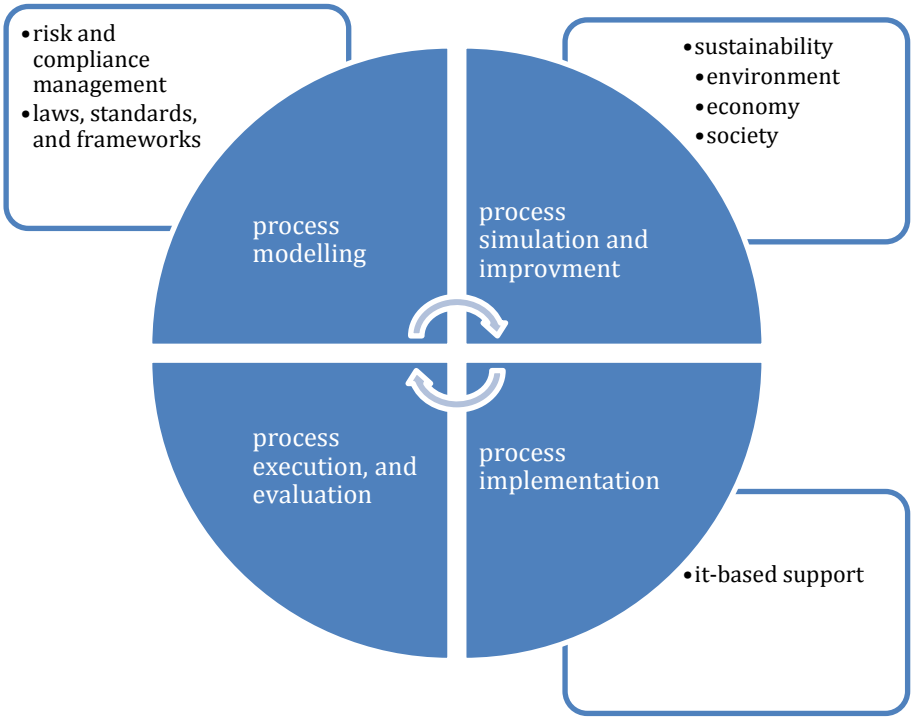

Figure 1: Sustainability Aware Process Management

4.1. Step1: Process Modelling

Basis for identifying sustainability indicators is a detailed process model because sustainability indicators are related to the elements of this model. Only a detailed specification of these elements can result in a complete identification of the related sustainability indicators. Figure 2 shows the UML conceptual model of a business process and sustainability. The process itself may be composed of various sub-processes. Eventually, processes are defined through a set of linked activities. Carrying out an activity needs various resources, which can be human (so-called actors), or non-human (hardware resources for instance). An artifact can be input or output of an activity. In this step the socio-economic level also influences the process model through the risk and compliance management as well as laws, standards, and frameworks. Also, in this phase, a strategy with regard to sustainability is defined and goals specifications are determined. For example a goal could be to improve the image of the organization using sustainability. The outcome of this step is the basis process.

4.2. Step 2: Process simulation and improvement

In this step we assess sustainability. The objective of sustainability assessment is to identify the sustainability indicators and link the to the organizational goals as well as to the business process activities, for example the CO2-Emission or the e-waste of activities. In general sustainability assessment practices are manifold. Possible are analytical methods like for example LCA, checklists, and questionnaires as well as creative methods like brainstorming and expert interviews. We are conducting sustainability assessment in three steps: First, we are identifying the sustainability indicators and then we link them to the business process. Third, we develop process improvements to increase (positive) sustainability impact.

As stated above in a business process reduce the negative impact one can either substitute an immaterial resource substitutes a material resource (process improvement) or a material resource substitutes another material resource (media substitution), or immaterial resource substitutes another immaterial resource (externalisation of control). Thus, the cause of a sustainability impact "the resource" either needs to be substituted or the resource needs to be improved or externalized. For example in case of a non-human resource the hardware needs to be upgraded or the software updated or changed. Each possible process improvement is modeled explicitly by sub-processes and the actual process model will be refined. The basic process and the refined process models have to be simulated to determine the process Key Performance Indicators (KPI) such as flow time (duration) and costs for each sustainability improvement in order to analyze and possibly reorganize the actual process. As stated in [16] this is usually be done by simulation.

To run a simulation the input parameters need to be initialized and the model needs to be tailored to the organization [17]. The data to parameterize the process model must be provided by the organization. We are aware that accurate data is not always available but as stated in [17] useful strategies to overcome these problems are available. But this goes beyond the focus of this paper. All possible process improvements need to be considered. For this reason, different process variants concerning a certain sustainability indicators can be developed. For each of these process variants the values of the KPIs are determined. Therefore we need a quantification of improvement that is related to a sustainability reduction treatment.

4.3. Step 3: Process Implementation

In this step the most satisfying process variant in terms of stakeholder preferences needs to be chosen and implemented. This could be an improved one with a sustainability impact improvement included or the basic process. Only the acceptable process variants determined in step 2 are considered. If the stakeholder is able to specify his preferences for increasing cost and flow time by

weights then using a weighting function is possible. Also, for further sustainability control, the sustainability indicators need to be directly implemented in the process.

4.4. Step 4: Process execution and evaluation

Here, it is important to continuously monitor and further control the process, also additional adapting and further improvement of the processes with regard to the sustainability impact needs to be conducted. Step two to four can literately be repeated. Next we discuss shortly a possible extension of a business process modelling language.

5. Suggested extension

A business process is defined as a set of manual, partially automated or automated business activities, executed according to given rules with respect to certain business goals [16]. During execution business process activities need to be coordinated such that the given rules are observed and the business goals are met. Additionally, resources needed for execution of activities have to be provided (see Figure 2). The process itself may be composed of various sub-processes. Eventually, processes are defined through a set of linked activities. Carrying out an activity needs various resources, which can be human (so-called actors), or non-human (hardware resources for instance). An artefact can be input or output of an activity.

The basis of techniques and tools for analysis and simulation of business processes are business process models. There exist several modelling languages for business processes like UML Activity Diagrams, EPC, BPMN and Petri nets. As stated earlier I use XML nets, a variant of high-level Petri nets [18]. Petri nets combine the advantages of a graphical representation of business processes with formal semantics and a mathematical foundation. Numerous Petri net variants have been proposed, which can be subsumed in elementary or high-level Petri nets. In elementary Petri nets, places contain tokens (black dots), which represent anonymous objects, whereas the flow of the tokens simulates the process flow. A transition box inscribed with two vertical bars indicates that the respective transition is refined by another Petri net. Repeated refinement of transitions leads to a hierarchical representation of a process. In high-level Petri nets tokens represent identifiable objects. In XML nets [18], a place is typified by an XML schema. Thus places can be interpreted as containers for XML documents representing process-relevant objects like invoice or sustainability indicators. The edges are labeled with filter schemas and thereby describe the process objects that are relevant for the following transitions or places and the way these objects are manipulated. A transition can be inscribed by a logical expression of the variables that appear in the labels of the adjacent edges. The expression can be evaluated either to true or false for a given instantiation of the variables. The flow of an XML document is defined by the occurrence rule of transitions. A transition is activated if every place in the pre-set of the transition contains at least a valid XML document which observes both of the conditions specified in the filter schema of the adjacent edge and in the logical expression of the transition. Additionally, the generated new XML document cannot already exist in the post-set-places. Then the transition can fire and the generated new XML document will be assigned to places in the post-set of the transition. Simulation of a business process enables process modelers to evaluate the impact of process changes prior to their implementation in real environment. By evaluating dynamic process parameters like throughput, costs, cycle times or resource utilization simulation enhances process performance analysis and provides decision support for realizing process changes. Also, using simulation possible impact of sustainability indicators can be evaluated.

In the following I am describing the conceptual model showing my understanding of sustainability and the connection to business processes as well as the surrounding relevant context (see Figure 2). Sustainability is divided into ecological and well-being aspects and are measured using indicators.

Indicators are linked to process activities. Organizational culture and strategy are influencing the goals with respect to sustainability. Additionally, Sustainability has different levels of impact. The processes are executed by software systems.

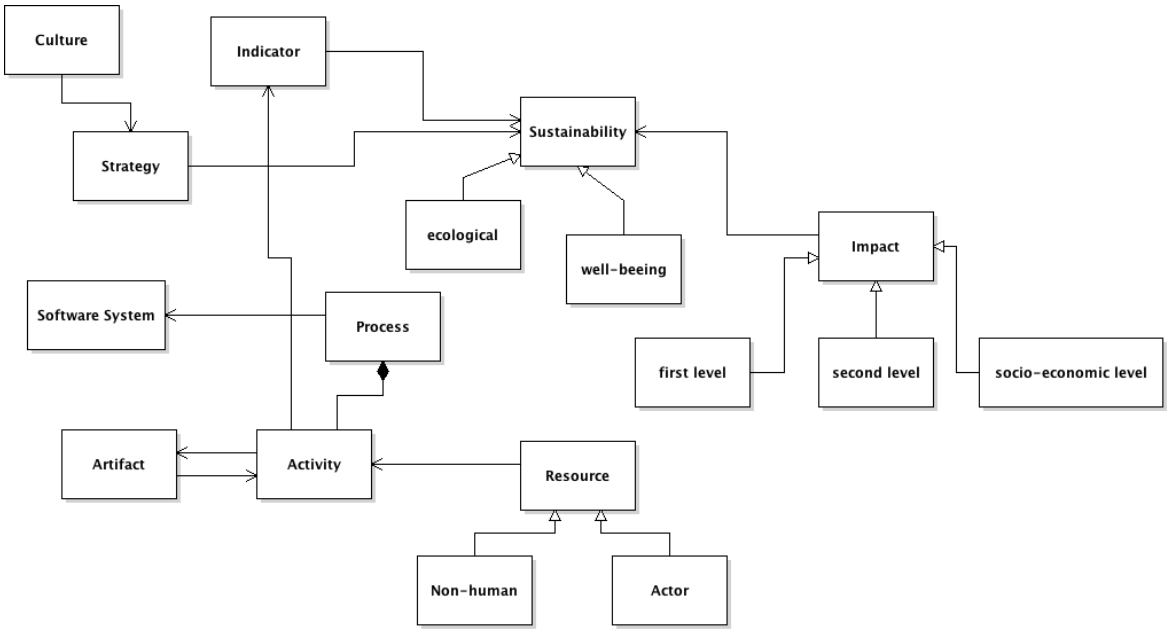

Figure 2: Conceptual Model of Sustainability and Business Processes

To reduce the possible sustainability impacts, the sustainability factors need to be managed. To manage them, the context-specific characteristics in respect to the situation, where an (negative) impact occurs and how reduce them, need to be analyzed. Hence sustainability impact reduction during business process execution is directly coupled to the business process and the sustainability indicators. For this reason we suggest an approach based on modelling the business process and the associated sustainability indicators.

6. Conclusion

Of course, I am not the first to examine business processes and environmental sustainability. But, business process approaches so far have only concentrated on green aspects and they have not developed a holistic approach. So far only single solutions for example for carbon emissions [1] have been developed and none of the approaches is able to simulate possible different scenarios with the help of a modelling language like petri-nets. In addition, the presented approach can help to improve sustainability in business processes and therefore the organizational performance. Also, the presented approach can even be used for environmental accounting and sustainability reporting as well as environmental risk-assessment.

7. References

[1] Recker, J., vom Brocke J, and Seidel, S. *Green Business Process Management*. Berlin Heidelberg: Springer, 2012.

[2] Gadatsch, A. “Kommentar zu Green IT: Ein Thema für die Wirtschaftsinformatik?," *Wirtschaftsinformatik*, vol. 53, no. 6, pp. 391-391, 2011.

[3] Schmidt, M. "Von der Material- und Energiefussanalyse zum Carbon Footprint - Anleihen aus der Kostenrechnung," *Chemie Ingenieur Technik*, vol. 83, no. 10, pp. 1541-1552, Oktober 2011.

[4] Bromwich, M. and Hong, C. "Activity-based costing systems and incremental costs," *Management Accounting Research*, vol. 10, no. 1, pp. 39-60, 1999.

[5] Brundtland, G. H. " World Commission on environment and development our common future," Oxford University Press, United Nations, 1987.

[6] Hilty, L. M., and Aebischer, B. "ICT for Sustainability: An Emerging Research Field," in *ICT Innovations for Sustainbility, Advances in Intelligent Systems and Computing* , L. M. and Aebischer, B. Hilty, Ed.: Springer International Publishing, 2014, vol. 310, in press.

[7] Hertin, F., and Berkhout, J. "Impacts of information and communication technologies on environmental sustainability: Speculations and evidence," Report to the OECD, Brighton, 21, 2001.

[8] Alemayehu, W and vom Brocke, J. "Sustainability Performance Measurement - The Case of Ethopian Airlines," in Business Process Management Workshops, *Lecture Notes in Business Informatics*, 2011, pp. 468-478.

[9] Isaksson, R., and Gavare, R."Measuring Sustainable Development using Process Models," *Managerial Auditing Journal*, vol. 18, no. 8, pp. 649-656, 2003.

[10] Recker, J., Rosemann, M. and Gohar, E. R. "Measuring the Carbon Footprint of Business Processes," in *Business process management workshops*, Springer, 2011, pp. 511-520.

[11] Houy, C. et al., "Advancing Business Process Technology for Humanity - Oppertunities and Challenges of Green BPM for Sustainable Business Activities," in *Green BPM - Towards Environmentally Sustainable Enterprise*, J vom Brocke and S Seidel, Eds. Heidelberg: Springer, 2011.

[12] Hoesch-Klohe, K., and Ghose, A. "Carbon-Aware Business Process Design in Abnoba," in Service-Oriented Computing, *Lecture Notes in Computer Science*, 2010, pp. 551-556.

[13] Keller, G. and Teufel, T. *SAP R/3 prozessoreintiert anwenden, Iteratives Prozeß-Prototyping zur Bildung von Wertschöpfungsketten*. Bonn: Addison-Wesley, 1998.

[14] Nowak, A., Leymann, F., and Mietzner, R."Towards Green Business Process Reenginering," in Service-Oriented Computing, *Lecture Notes on Computer Science*, 2011, pp. 187-192.

[15] Hammer, M., and Champy, J. *Reenginering in Cooperation: A Manifesto for Business Revolution*. New York: Haper Collins, 1993.

[16] Oberweis, A. "An Integrated Approach for the Specification of Processes and Related Complex Structured Objects in Business Applications," *Decision Support Systems*, vol. 17, pp. 31-53, 1996.

[17] Neu, H., Hanne, T., Münch, J., Wirsen, S., and Nickel, A. "Simulation-Based Risk reduction for Planning Inspections," in *International Conference on Product Focused Software (PROFES)*, 2002, pp. 78-93.

[18] Lenz, K, and A. Oberweis, "Inter-organizational Business Process Management with XML Nets," in *Petri Net Technology for Communication-Based Systems,Advances in Petri Nets*, vol. 2472, 2003, pp. 243-263.