Assessing the Environmental Impact: A Case of Business Process Analysis in the Automotive Industry

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***Abstract*— Sustainability management is has been in the focus of the enterprises for several years now. Communal and private organizations are interested in sustainable solutions and practices for their operations. Software systems and their underlying business processes are ubiquitous and fundamental for most of the organizations of our industrial society. Hence, sustainability aspects must be integrated into the information systems architecture and into the business process life cycle. Using the action research approach for the environmentally focused business analysis of an automotive supplier we provide insights on how measuring the environmental effect of a business process can affect its optimization. We also show how a more process aware software can generate enhance environmental indicators beyond its own resource use optimization. By including environmental indicators into the classic process performance measuring this approach allows researchers and practitioners integrating environmental performance goals into the processes and their analysis.**

Keywords- Measuring environmental impact; action research; business process management.

I. INTRODUCTION

The increasing awareness of customers and the general public for sustainability and environmental impact on the one hand and legislative requirements on the other hand motivate more and more organizations to keep track on their environmental impact [1]. Public and private organizations are interested in finding and using sustainable solutions and practices. Thus, sustainability needs to be considered on all organizational levels. To support the transition to sustainability, the organisation need to integrate aspects into the business processes and their management. Past research has indicated that, in order to become green, organizations need to embed sustainability-related targets at all levels of business, starting from the strategy level [2]. Consequently, business analysis needs to accommodate sustainability-related factors to be able to measure and control them. This step not only allows for controlling the accomplishment of sustainability-related targets, but also creates transparency and awareness [3].

Building on this reasoning, the research question here is: What insights can process analysis provide on sustainability-related optimization aspects? Being a research-in-progress, we focus on the environmental aspects of the general set of problems of sustainability. Furthermore, the effects of the derived management actions changed the environmental impact of the enterprise will be addressed in future studies.

In this paper we consider the environmental perspective of a business process and its contributions to achieving the environmental goals of an enterprise. Therefore, we define environmentally relevant process characteristics based on an online survey among environmental officers as well as on the literature review. Furthermore, we develop a list of indicators that includes the “classic” key performance indicators (KPI) as well as KPIs that measure the environmental impact of a business process. Using these indicators we assess a real-life processes from the automotive industry in regard to their environmental impact. Additionally, we suggest process optimization measures. Here, we use action research (AR) paradigm to provide insights on the environmental process assessment. The researchers are “participant observers” as required by Baskerville and Myers [4]. This paper presents the first two stages of the AR in Information Systems (IS) as described by [4]. We define the research problem and position our research in the domain of business analysis with theoretical background of design and action [5], here the soft system methodology [6]. As the second stage, an action needs to result from the research activities. The results of the analysed enterprise and business process were presented to the process owners and sustainability officer inducing the process re-engineering actions but also the social reasoning on the action and its results for the theoretical domain it was initiate from introducing stages three and four of AR. The pragmatic approach of AR provides the researcher with the method that helps explain why things work [4] and thus provides a valuable feedback to the theory the research question is grounded in.

This research contributes to a process-focused discussions between business and IT managers to enable a common understanding of processes and the resulting opportunities to make these processes and thus the organization more sustainable [7]. We focus on the process-oriented techniques, as this view allows leveraging the power of information systems for a transition to a more environmentally friendly process and organization [7]. The defined indicators can be applied by business process managers, sustainability officers, business process analysts as well as researchers in the area of green IS.

To present our research findings we review related work on assessment of environmental process indicators in section two. The research method is describe in section three, while section four describes the studies process and indicator structure followed by the process assessment results and the implications for change. The paper finishes with the discussion of the gained insights and outlook on our future work.

II. RELATED WORK

The information systems (IS) domain addresses sustainability under the aspects of information technology (IT), software and business processes. Also, the notion of the Key environmental indicators (KEI) is gaining popularity in the domain of performance management. Reiter et al. [8] introduce a combined approach of IT and BPM for efficient energy use in a process. Cleven et al. [9] discuss the capabilities required to measure and manage sustainability performance on a process level by providing a capability maturity model (CMM) for green process performance management capabilities. Goldkuhl and Lind [10] address the process design phase by presenting an extended process modelling approach for capturing and documenting the greenhouse gas (GHG) emissions produced during the execution of a business process as well as an accordant analysis method. The calculation methods for the carbon footprint of a process already being explored by e.g. [11]–[15]. Betz [16] describes an approach for a sustainability aware business process management using XML-nets. Among these works, two general measurement approaches can be distinguished: Cooper and Fava (2006) suggest a bottom-up approach from the process analysis perspective, while Pan and Kraines (2001) describe a top-down perspective incorporated in the environmental input-output analysis. Heijungs and Suh (2006) combine the two approaches. Nowak et al. [17] present a methodology and architecture for green BPR, providing a starting point for green process analysis and re-design. Further methods for process analysis towards environmental potentials are presented in [18].

III. RESEARCH METHOD

Following Baskerville et al. [4] our research is based on the pragmatism premise. Thus, we first establish the purpose of the action research and its theoretical background. Given our research question of how and to what level to assess environmental effect of a business process, the theoretical background here is the soft systems methodology [6]. To assure that the problem setting includes practical action [4] we identified business units that are producing the highest environmental effect by distributing an online survey among environmental officers of the enterprises. The survey was sent to 87 enterprises and was designed to answer the question about which business division in the enterprise depending on the amount of greenhouse gas (GHG) emissions. A follow up question was, what business area the sustainability responsible considers to have the highest potential to reduce its environmental impact in future as required by German legislation on GHG emissions for enterprises. The final set consisted of 74 answered surveys.

To compose the evaluation system for environmental and business performance, the environmental indicators where collected from Eco-Management and Audit Scheme [19], an environmental management scheme based on EU-Regulation 1221/2009, as well as from German environmental legislation. They were filtered towards redundancy as well as the relevance and feasibility of process performance evaluation.

To assess the environmental effects, a real-life company, a testing company as automotive supplier, was contacted. The testing division, i.e. quality assurance unit, was chosen as an object analysis. For process identification and documentation interviews with process actors and owners were led. The process was modelled using BPMN and is shown in Fig. 1. The results of the process analysis where communicated back to the process owners and actors as well as the environmental officer. The discussion concerning their realization was initiated with the middle and upper management.

IV. RESULTS

The results of the online survey concerning the definition of the environmentally relevant business divisions resulted in 64% of the respondents identifying the manufacturing division as the business unit with the highest GHG emissions as well as the business area that will be affected by the legislation for emission reduction the most, according to 70% of the respondents. Facility management (11%) as well as logistics (10%) are seen as the business units with high environmental impact. Although, quality assurance was named as one of the emission intensive areas by only 8% of the respondents, 11% considered it to have a reduction potential concerning the future emissions.

A. Environmental Indicators

Based on literature review of sustainability indicators as well as on the environmental standard of EMAS III we identified environmental indicators that can be collected on the process level. Categories included into this KPI structure are listed in Table 1 as: biodiversity, mobility and employee information as well as classic indicators of process performance.

TABLE I. KPI STRUCTURE INCLUDING ENVIRONMENTAL INDICATORS

Category	Indicator (Example)
Energy efficiency	Total energy consumption p.a. in MWh Total energy consumption of renewable energy Percentage of renewable energy consumption on total energy consumption
Resource efficiency	p.a./ without energy and water in t
Water usage	p.a. in m3
Biodiversity	Usage of built-up area in m3
Waste	p.a.in t toxic waste p.a. in t
Emission	Of Green House Gas (GHG) in tCO_2 equivalent p.a.

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Mobility	p.a. in km: transport, business fleet, business travel per person in flight/train, fuel consumption, parking space for cars/bikes per employee
Employee information	Number of sustainability workshops; number of suggested and realized sustainability related improvements
Realization of the Environmental Management System (EMS)	Number of EMS related workshops, number of days and costs related to EMS maintenance
Time	Response, processing, cycle time, set-up time
Cost	Failure, overall. Resources
Quality	Usability, accuracy, life expectancy, reliability
Capacity	Bottle-necks, machine efficiency, throughput
Flexibility	Temporal, structural, volume
Integration	Degree of automation, information flow, information: transparency, granularity, accessibility
Complexity	Degree of: standardization, structure; organizational and process interfaces

B. *Studied Process*

The process chosen for the environmental analysis is situated in the quality assurance domain. The considered enterprise is a service provider for testing of automotive products. Thus, the analysed testing process is a core process for the service provider and is modelled in Fig. 1. The company is situated in several locations, thus for some of the tests the tested object needs to be transported between different locations.

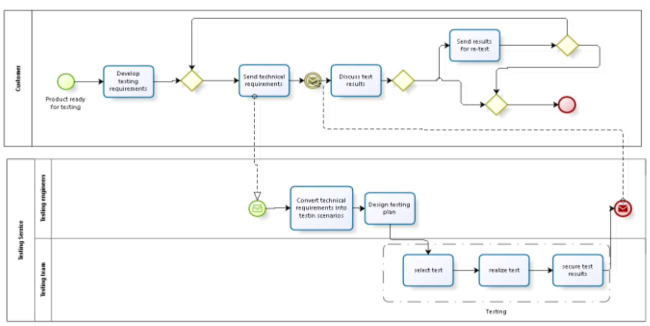

Figure 1. Testing process

The testing process is initiated by the customer. The customer describes the product and the characteristics that need to be tested. According to these requirements, testing scenario/s are chosen and specified in a testing plan by an engineer. The testing team performs the tests using the support of a specific software. Testing engineer and testing manager supervise the tests and communicate with the customer who can change the technical requirements according to the test results. For the process analysis we consider the sub- processes, i.e. the tests: Static/Dynamic Performance Tests (SPT, DPT), the most frequently executed test, Powered Thermal Cycle (PTC), the most energy intensive test, and Running Noise (RN). The testing process is coordination intensive as it implies several decisions being made by different parties. Some of the tests might also require transportation between the locations of the service provider or in case of external testing between a third-party service provider.

C. *Process Assessment Results*

We used the integrated analysis approach for assessing process productivity and environmental effects. Several of the suggested KPIs such as mobility could not be measured in our setting on the process level. Others, indicate possible improvements that can be realized on the process level or location-wide. Table 2 shows an excerpt from the process analysis results.

TABLE II. RESULTS OF PROCESS PERFORMANCE ANALYSIS

Indicator/Process	SPT	DPT	PTC	RN
Power Consumption (in MWh)	0.3	0.43	10.09	0.31
Percentage of energy from renewable sources	24	24	24	24
Emissions (p.a. in tCO_2)	0.17	0.24	5.75	0.16
Built-up area	105	105	175	250
Handling time (in min)	62	62	140	80
Processing time (in min)	62	62	14675	80
Idle time (in min)	0	0	14535	0
Set-up time (in min)	17	17	60	30

Representing the quality assurance domain, the main resources used during the execution of the tests are energy and space. The PTC test uses the highest amount of energy (10.09 kWh per cycle) that is mostly needed for the heating of the testing room, while the RN-test process requires the highest space usage ($250m^3$). The three testing processes generated 6.32 tons of CO_2 per year due to their execution. The exact mobility patterns related to the tests were hard to deduce during the analysis. Also the water usage as well as employee information indicators could not be sufficiently assessed during the process analysis.

D. *Implications for Change*

Being a measurement process, the tests mostly involve the usage of energy and space. Besides using the energy for the IT support of the process the PTC process involves working with high temperatures. Thus, a closer look at the performance number of the PTC process provides optimization potentials. Beside the idle period as well as the set-up time of the testing appliances that can be reduced using a scheduling software that is provided with the exact process description including cycle times and device usage, further potential for change lies in the heterogeneous expertise of the testing team. Since the testing knowledge is not symmetric within the team, tests are scheduled according to their feasibility and not according to the optimal resource usage. Homogenous knowledge level would also result in reduced error rates, leading to less test re-runs requiring resource usage.

Collected environmental indicators imply that changes towards more sustainability will induce changes on the enterprise level or at least location level. Most efficient changes can be achieved by changing the energy provider to enhance the energy mix from currently 24% being from

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renewable energy sources to a higher percentage. An alternative for a more sustainable energy acquisition can be a construction of an on-site energy generator such as photovoltaic facility that could, e.g. cover the parking lot or is located on the roof of the building to provide a renewable energy source for heating. These alternatives would result in a reduction of GHG emissions as well as provide other advantages in terms of employee satisfaction and benefits for facility management. Another large scale action would be the enforcement of commuting of employees by train between locations rather than by cars. A back-of-the-envelope calculation on the change in transportation for the location and testing team in question showed a difference of GHG emission of 18t per year.

Potential for process enhancement bears the focus on test specific equipment. The PTC test uses a climate chamber that needs to be pre-heated for three hours before the test. Thus, the heater runs during the night, resulting in about nine hours of excrescent heating. Furthermore, the heater generates rejected heat that stimulates the air conditioning (AC) to balancing the temperature. A solution would be to position the AC machines in a separate room, making the room temperature gradually adjustable as well as reducing the noise in the testing room. A more efficient planning software would also contribute to a higher energy efficiency by providing the exact times for the optimal room tempering for the tests and automated heater management. These actions would result in a higher energy efficiency and GHG emission reduction of 2.8t per year given the averaged historical data on process execution.

Hence, our assessment of the environmental process performance revealed sustainability potentials on all of the three levels: Enterprise-wide such as the change of the energy provider; location-wide such as instalment of a photovoltaic facility; process-wide such as re-assessing the software features towards planning and facility automation and re-thinking the process tools usage. While the enterprise-wide changes might be difficult to realize due to the complex decision structure, location and process-wide changes can be targeted for short-time realization. Thus, we suggest that the company launches processes to support the environmental officer in realization of location- and process-wide programs to support the environmental thinking and realize the otherwise lost potentials as well as to encourage employees in their awareness of environmentally effective process improvements.

V. Discussion and Outlook

In this paper we presented insights gained from an action research based approach to sustainability assessment on process level by including environmental indicators within the classic process performance measures. The chosen research paradigm of action research allowed us to observe the reactions on the topic of environmental problems in general within the enterprise on different organizational levels as well as the reaction on the suggested optimization measures in particular.

Since the considered enterprise does have an environmental officer, there have already been actions taken to provide more sustainable operations. These have mostly concerned the facility management domain, e.g. automatic light sensors, routine maintenance of the heating, etc. for efficient energy use. These actions are consistent with other research findings of the effects and toeholds of enterprise-wide sustainability initiatives [20].

The performed process analysis revealed a close connection between classic process optimization and enhancement of environmental indicators. Focusing on sustainability additionally allows the process analysis to look deeper not only into the workflows but also into surroundings in which the process is situated. Hence, the results suggest a need for a process analysis framework that includes environmental aspects. The potential effects will be continuous process improvement (CPI) that result in a more efficient technology use and work schedules. Hence, the suggested improvement of the testing software would not only result in a more efficient workflow but would also positively affect the energy use and employee satisfaction. Similar to the classic CPI approach, process owners or managers should encourage process actors to pay attention to more efficient resource usage as well as the exploration of occurring synergies. While big changes towards sustainability can be realized on the enterprise level, gradual improvement as well as personal awareness needs to take place on the process-level in the enterprise. To achieve this goal, enterprises need to invest into supporting education of the workers not only on the CPI techniques but also in environmental topics.

Our future work will focus on development of the sustainable performance management framework that that includes the structuring of enterprise wide aspects, locally changeable issues as well as process wide issues. Furthermore, a process analysis method based on the KPIs described above will be developed to include the potential interdependencies of the performance and environmental indicators. Furthermore, the KPI structure presented here needs to include further indicators of sustainability that go beyond environmental concern. We intend to provide sustainability managers with an evaluated tool that encourages change, incorporates suggestions from process actions and shows the results of their implementation.

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