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Multi-criteria decision support based on iterative comparisons with reference points

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ABSTRACT

Small and medium sized enterprises have a wide influence in many economic sectors. They provide a substantial part of the jobs and goods while at the same time emitting huge amounts of pollutants. Existing research could prove that there is a lot of emission reduction potential available, but at the same time show that most enterprises do not implement cleaner production measures. One major obstacle is the absence of tools that provide easy to understand decision support for sustainability decisions in conjunction with corporate environmental management information systems, which also fit the requirements of small and medium sized enterprises. This article presents a multi-criteria decision support system and its integration into a corporate environmental management information system to overcome this barrier. The decision support approach is based on reference points, which makes it relatively easy to understand. Reference points may be adjusted by the decision maker in form of saturation levels to match his/her preferences more closely. To increase user acceptance the final results will be investigated with sensitivity analyses and an explanation system. This will enable decision makers in small and medium sized enterprises who have only a limited amount of time and are not familiar with the concept of multi-criteria decision making to implement the concept of cleaner production and examine whether the use of renewable resources or a cascade utilization of materials is beneficial.

1. Introduction

Small and medium sized companies (SMEs) are the backbone of most industrial societies. In OECD economies their share is between 96% and 99% of total enterprises (Klewitz and Hansen, 2014). They employ more than 60% of the European workforce and a large share of environmentally relevant production processes take place in SMEs (Granly and Welo, 2014). Their share of environmental pollution in the European Union (EU) is estimated to be roughly around 64% (European Commission, 2010). Nevertheless, only a few SMEs have yet integrated sustainability measures into their daily business (Granly and Welo, 2014). Companies who already sought to adopt cleaner production mostly focused on single aspects with so called "end-of-pipe technologies" (i.e. filters) which try to mitigate environmental pollution after their occurrence (Odenwald and Berg, 2014). Based on these technologies old products may still end up on landfills regardless whether they still contain valuable materials. To become even more environmental friendly and cost effective additional measures towards circular economies or cascade utilization are required. The goal of a circular economy is that old products and discarded outputs can be reclaimed and redirected back into the production process. Cascade utilization "describes a strategy for using raw materials or the products made from them in chronologically sequential steps as long, often, and efficiently as possible for materials and only to recover energy from them at the of the product life cycle" (Kosmol et al., 2012). Due to their characteristics SMEs usually cannot exploit economies of scale, however with their flat hierarchies they can act more agile and are able to adapt to new market developments much faster. One of these developments is the increasing existence of industrial networks using renewable resources. SMEs are important in that area because they can specialize on processes which enable cascade utilization. However, this requires "aggregated views allowing companies to optimize performance across suppliers, organizational entities, production lines and product categories in a scalable and effective manner" as well as effective decision making (Odenwald and Berg, 2014). These considerations show that the

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concept of cleaner production is recognized as one significant potential for cost effectiveness and environmental sustainability in firms, although the widespread application of said concept could not yet be proved for small and medium sized enterprises (van Hoof, 2014). One major obstacle can be seen in the lack of appropriate decision-support tools, geared towards the specific needs of SMEs.

Modern Corporate Environmental Management Information Systems (CEMIS) could provide companies with the necessary tools to increase their eco-efficiency and steer sustainable management of resource usage. Firms which claim corporate social responsibility or start voluntary corporate initiatives to enhance their reputation, preempt legal sanctions, and want to manage their risks, are dependent on such systems (Cruz, 2009). Additionally, more and more customers already include environmental aspects of products and services such as water consumption and carbon dioxide emissions into their buying decisions (Johnstone and Labonne, 2009). Companies which cannot offer such information might lose customers and will face decreasing market shares (Gonzáles-Benito et al., 2011). This challenge is especially decisive for SMEs, as their economic future is strongly dependent on successful customer relations. CEMIS can provide companies with the required environmental related information on the basis of material and energy flows and forward them to various stakeholders (Gasbarro et al., 2013). The UN Global Compact Accenture CEO Study on Sustainability 2013 states that direct business benefits for individual organizations emphasizing sustainability is limited and demands new innovative systems, markets, structures, and a new commitment to collaboration beyond individual organizations (Odenwald and Berg, 2014). Modern CEMIS should be able to deliver that functionality to support the development of circular economies and cascade utilization business networks. However, currently available CEMIS usually offer only an operational perspective on the business processes. They focus solely on the current enquiry period and lack a strategic point of view (Teuteberg and Marx Gómez, 2010). Odenwald and Berg (2014) argue that "there is a strong need to expand existing business software solutions to help address social and environmental goals. Addressing sustainability challenges while maintaining economic growth and improving quality of life is one of the fundamental challenges of the 21st century". Newly developed CEMIS have to address this need for a strategic forecast and are required to make a real progress towards more sustainable production and logistics processes in SMEs. Besides the representation of Best Available Techniques for application in SMEs, suitable approaches for decision making are needed. Many tools for decision making and especially multi-criteria decision making have been developed and described in literature, also in combination with process models, such as flowsheeting programs (Spengler et al., 1998) or mass and energy flow models (Geldermann and Rentz, 2004a), or with life cycle assessment (LCA) tools (Hermann et al., 2007).

However, their practical usage in SMEs is hampered by several factors. Decision making tools which are intended to be used in large companies do not fit the requirements of SMEs due to their restricted knowledge, human, and financial resources. Usually, SMEs do not have the personnel that are familiar with decision making methods nor have capacities to hire external consultants. Lanteigne and Laforest (2007) describe the situation as follows: "the human resource constraints found in SMEs commonly lead to time related issues: the workload is often heavy to fulfill for the staff so that environmental matters are usually set aside in order to address 'more pressing' affairs". To overcome these difficulties, the integration of a suitable decision support system into a CEMIS should allow for an immediate collection of decision relevant data and data interchange with existing information systems such as enterprise resource planning (ERP) software. Additionally, due to the aforementioned restrictions decision makers may not be able to deal with more sophisticated decision making methods that require various subjective inputs and their dependencies onto the final result. On the other hand, solutions identified by decision making methods which rely solely on objective inputs, and are thus fairly easy to use, may lack acceptance. Therefore, available information should be automatically preprocessed as much as possible and integrated into the decision process in order to reduce the complexity for the decision maker while offering comprehensive decision support. Interactive features allow modeling of the decision problem according to the decision maker's perceptions while at the same enabling the software to react to inconsistent information and hereby increase the trust in the final solution.

The aim of the article is to present a decision making approach which is suitable for SMEs to help them to facilitate cleaner production while using existing advantages of CEMIS. SMEs of the industrial sector with substantial environmental pollution activities and rather old machineries will have the most benefit of the presented software tool. Typical decision problems are the replacement of old machineries, the adoption of new technologies or the substitution of currently used input materials by renewable resources. Therefore following research questions need to be answered: How should a decision support approach look like to be user-friendly and easy to understand? How can this decision making approach be integrated into a CEMIS to benefit from their strengths and improve them so SMEs become more environmental friendly.

The paper is organized as follows: Section 2 gives a brief overview on CEMIS including their general purposes and current limits. Section 3 presents the interactive decision support tool in detail followed by an illustrative example. Section 5 explains the benefits of combining both aspects into one system, before section 6 gives a short conclusion and summary.

2. Corporate environmental management information systems

Environmental Management Systems such as ISO 14000 series and the Eco-Management and Audit Scheme (EMAS) play an important role in either improving environmental performance and compliance or comparing environmental impacts of various enterprises with each other (Neugebauer, 2012; Potoski and Prakash, 2005; Zhang et al., 2014). These tasks are supported by CEMIS and depend on the availability and accessibility of correct and current information (Frysinger, 2001). Hence, the term CEMIS subsumes computer programs which support executives in collecting, documenting and evaluating environmental relevant data (Page and Wohlgemuth, 2010). However, many companies which dealt with environmental information solely did so, because they were obliged to fulfill governmental regulations. Traditional CEMIS that assess material and energy flows and report environmental impacts to the appropriate institutions supported them. Nowadays more and more stakeholders (e.g., clients and investors) are also interested in this information. Although traditional systems produce huge quantities of data every second, they frequently lack the relevant and actionable data points to respond to simple questions people have about what products are made of and how they are made (Odenwald and Berg, 2014). The existing software tools cannot fulfill the increased requirements which necessitate a new kind of CEMIS.

Currently available CEMIS based on material and energy flows like Umberto, SimaPro, GaBi, etc., provide product life cycle assessments (LCA) based on ISO 14040 or inventory analyses which aggregate environmental impacts of business processes. However,