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An Analytic Network Process approach for the environmental aspect selection problem — A case study for a hand blender

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ABSTRACT

Life Cycle Assessment is a tool to assess, in a systematic way, the environmental aspects and its potential environmental impacts and resources used throughout a product's life cycle. It is widely accepted and considered as one of the most powerful tools to support decision-making processes used in ecodesign and sustainable production in order to learn about the most problematic parts and life cycle phases of a product and to have a projection for future improvements. However, since Life Cycle Assessment is a cost and time intensive method, companies do not intend to carry out a full version of it, except for large corporate ones. Especially for small and medium sized enterprises, which do not have enough budget for and knowledge on sustainable production and ecodesign approaches, focusing only on the most important possible environmental aspect is unavoidable. In this direction, finding the right environmental aspect to work on is crucial for the companies. In this study, a multi-criteria decision-making methodology, Analytic Network Process is proposed to select the most relevant environmental aspect. The proposed methodology aims at providing a simplified environmental assessment to producers. It is applied for a hand blender, which is a member of the Electrical and Electronic Equipment family. The decision criteria for the environmental aspects and relations of dependence are defined. The evaluation is made by the Analytic Network Process in order to create a realistic approach to inter-dependencies among the criteria. The results are computed via the Super Decisions software. Finally, it is observed that the procedure is completed in less time, with less data, with less cost and in a less subjective way than conventional approaches.

1. Introduction

Since the last twenty years, environmental concepts (such as sustainable production, environmental assessment, and ecodesign) are getting more and more attention both in the literature and in mass media due to the alarming situation of the nature and significant damages provoked by human actions (Byggeth and Hochschorner, 2006). Although there is legislation (Directives 2000/53/EC, 2002/95/EC, 2002/96/EC, 2005/32/EC), which forces manufacturers to take the responsibility of their products, environmental methods and tools are not commonly used among the companies yet (Ernzer et al., 2003; Knight and Jenkins, 2009).

Many methods, tools and indicators for assessing and benchmarking environmental impacts have been developed to improve the environmental performance of different systems and products. Examples include Life Cycle Assessment (LCA), Strategic Environmental Assessment (SEA), Environmental Impact Assessment (EIA), Environmental Risk Assessment (ERA), Cost-Benefit Analysis (CBA), Material Flow Analysis (MFA), and Ecological Footprint (Wanyama et al., 2003; Karlsson and Luttropp, 2006; Finnveden et al., 2009; Pigosso et al., 2010).

Life Cycle Assessment is one of the most powerful methods which models and environmentally assesses all life cycle stages of a product from cradle to grave for the implementation of ecodesign (ISO 14040, 2006; Finnveden et al., 2009). However conducting a full LCA poses an additional workload and cost on manufacturers' shoulders. Experiences with the industry have shown that this additional workload and cost is one reason for the denial of the use of such tools, and the incompatibility of some tools with the design and product development process is another reason (Knight and Jenkins, 2009). Lack of knowledge in the sustainable production field stands also as a remarkable reason especially among small and medium sized enterprises (SMEs) (Masoni et al., 2004).

The aim of this study is to develop a framework for helping SMEs and/or beginners in environmental assessment, who cannot afford a complete LCA in their business. The proposed methodology will contribute to the existing literature by providing a simplification in LCA through the evaluation and selection of environmental aspects.

An Analytic Network Process (ANP) (Saaty, 1996) technique is proposed in this paper to evaluate and select the most important environmental aspect of a product. ANP, which has interdependencies between its alternatives and criteria, is well suited to deal with decision

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problems. Since the environmental aspects and impacts, which are respectively the alternatives and the criteria of the case study in this paper, usually have such interdependencies, ANP is chosen as the most appropriate technique to use. Its use is common in production, supply chain management and waste management, also combined with a fuzzy approach (Chung et al., 2005; Mohanty et al., 2005; Bayazit and Karpak, 2007; Promentilla et al., 2008; Ravi et al., 2008; Tuzkaya et al., 2008; Aragonés-Beltrán et al., 2010; Lee et al., 2010; De Felice et al., 2013). Nevertheless, none of those studies had in their focus the environmental assessment of a product. The originality of this paper lies at the use of the ANP technique in ecodesign with the purpose of simplifying the assessment procedure.

To apply the proposed methodology in a case study, the product *hand blender* is chosen. A hand blender is a small household appliance and a member of the Electrical and Electronic Equipment (EEE) family. This type of product family stands as one of the major environmental problems of our time. Their fast expansion driven by technological developments and consumerism generates an increased amount of wastes and they have already begun to accumulate at garbage dumps. This accumulation comes along with significant negative impact on the environment and the human health (Widmer et al., 2005; Tsydenova and Bengtsson, 2011). The negative aspects of EEE occurring during its whole life cycle and the necessity to analyze its environmental performance lead us to choose this type of products as the main application field for this study.

The outline of the paper is as follows: Life Cycle Assessment is briefly defined, the challenge for SMEs and beginners, which is the main motivation of this study is stated, and the existing studies in the field are reviewed in Section 2. In Section 3, the proposed methodology is discussed. In Section 4, the environmental aspects and impacts, the selection problem, and the results are presented. Conclusions driven from the research are finally provided in Section 5.

2. Motivation

The aim of the environmental assessment in ecodesign is to determine the most problematic features of a product according to its impact and aspects, thus to help in developing the possible environmental improvement strategies for the examined product. Life Cycle Assessment is an effective tool promising to reach that aim.

In ISO 14040 (2006) Life Cycle Assessment is defined as the “compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle”. The full methodology of LCA consists of four main steps to be completed: *Goal and Scope*, *Life Cycle Inventory Analysis (LCI)*, *Life Cycle Impact Assessment (LCIA)*, and *Interpretation*.

2.1. The challenge for SMEs and beginners

The previous studies in the literature show that conducting a complete LCA is mostly time and cost consuming for companies (Rebitzer et al., 2004; Le Pochat, 2005; Collado-Ruiz and Ostad-Ahmad-Ghorabi, 2010). Especially for SMEs, any kind of environmental assessment is accepted to be a significant additional load on the company's shoulders since they have limited resources. Therefore they tend to ignore environmental concerns in their product development management except for some obligatory requirements of regulations (Hauschild et al., 2005).

LCI, by data collection and compilation (Rebitzer et al., 2004), and LCIA, by associating specific environmental impact categories and category indicators (Finnveden et al., 2009), generate most of the difficulties in LCA. Another obstacles standing in front of applying LCA and ecodesign techniques in the product development process are the lack of knowledge, scarcity of data, lack of awareness, restrictions in specific resources for environmental issues, and low levels of training (Masoni et al., 2004; Finnveden et al., 2009).

As stated in ISO 14040 (2006), the matter of subjectivity, such as choice, modeling and evaluation of impact categories, is also a critical issue in LCIA and its interpretation. Manufacturers may choose several or only one impact category to assess their product's environmental profile according to their personal and/or corporate preference. Thus, a decision-making problem should be modeled to select the right environmental aspect and/or impact.

2.2. Background

The interest on exploring new ways to simplify the existing LCA methodology has increased among researchers in the last decade. The studies are mostly in the direction of simplification for data inventory (Fleischer et al., 2001; Mourad et al., 2007; Valkama and Keskinen, 2008; Zah et al., 2009; Ostad-Ahmad-Ghorabi and Collado-Ruiz, 2011; Bersimis and Georgakellos, 2013), for impact categories and indicators (Kaebernick et al., 2003; Valkama and Keskinen, 2008; Bala et al., 2010; Gangolells et al., 2014), for aspects (Hur et al., 2005), and for the systematic implementation of environmental assessment (Zabalza et al., 2009; Kellenberger and Althaus, 2009; Malmqvist et al., 2011; Poudelet et al., 2012; Pigosso et al., 2013; Zhang et al., 2013).

Bereketli and Erol Genevois (2013) proposed a multi-aspect Quality Function Deployment for Environment (QFDE) approach to identify the ecodesign improvement strategies. Their approach is suitable for use in the early design phase, since it does not require detailed information about the product. In this perspective it is also considered as a simplification attempt in environmental assessment. Nevertheless it is necessary to be applied in parallel to a complementary decision-making methodology in order to define well the frame of the possible ecodesign improvement strategies.

There also exist in the literature some studies concentrating on multi-criteria decision-making for a simplified environmental assessment by fuzzy logic methods (Gonzales et al., 2002), for ranking the impact categories by using AHP with the regional scale point of view (Hermann et al., 2007), for weighting them by using a panel approach and a Multi-Criteria Decision Aid (MCDA) (Soares et al., 2006), for developing ecodesign at the conceptual design phase by integrating ANP and distance to target (DT) method (Kengpol and Boonkanit, 2011), for comparing environmental product footprint by proposing a modified AHP method (De Felice et al., 2014), and for the evaluation of ecodesigns (Chan et al., 2013; Ng and Chuah, 2013; Wang et al., 2013).

All these studies and arguments point the need of the companies, especially SMEs, for a simplified way to do an environmental assessment. There is clearly a need for a rapid decision or a rough first overview of a system's aspects and/or impacts in order to decide on further investigations and improvement strategies (Rebitzer et al., 2004). Especially considering the lack of data to conduct an LCA, focusing on only one environmental aspect will help manufacturers to reduce inventory requirements and work with less data.

In this paper, a new approach will be presented to find out the most important environmental aspect causing the most significant environmental impacts by using a coherent decision-making method, thus to eliminate the less significant ones from the assessment study, which will decrease the complexity and time consumed for the assessment especially in LCI and LCIA phases, and to reduce the subjectivity of the latter phase.

3. Methodology: Analytic Network Process

The Analytic Network Process (ANP) is a multi-criteria decision-making tool considered to be an extension of the Analytic Hierarchy Process (AHP) (Saaty, 1981). Whereas AHP models a decision-making framework using a unidirectional hierarchical relationship among decision levels, ANP allows for more complex interrelationships among the decision levels and components (Sarkis, 1998). In many real life decision problems, the hierarchy becomes more like a network. Therefore,