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Empirical study on integration of environmental aspects into product development: processes, requirements and the use of tools in vehicle manufacturing companies in Sweden

Sofia Poulikidou [a, b, *], Anna Björklund [a], Sara Tyskeng [c]

[a] KTH Royal Institute of Technology, Division of Environmental Strategies Research, Drottning Kristinas v. 30, 100 44 Stockholm, Sweden
[b] KTH Royal Institute of Technology, Centre for ECO² Vehicle Design, Teknikringen 8, 100 44 Stockholm, Sweden
[c] The Royal Swedish Academy of Sciences, Lilla Frescati v. 4 A, 114 18 Stockholm, Sweden

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ABSTRACT

An empirical study was conducted on integration of environmental aspects and requirements into four vehicle manufacturing companies in Sweden. The aim was to gain insights into how Design for Environment (DfE) is organised in these companies and, thus help bridge the gap between methodological development and practice. The processes for identifying and integrating environmental aspects into product development, the type of environmental requirements considered and the use of different types of DfE tools were investigated through semi-structured interviews. Despite similarities regarding the type of environmental requirements considered and the major drivers for these, the companies studied have adopted different ways to identify and integrate environmental requirements into their product development process and use DfE tools to differing extents. Such variations reflect differences in the success and maturity levels of the DfE practices adopted. When compared to success factors mentioned in the existing literature, the study concluded that some components needed for efficient integration of environmental aspects into the product development process of all participating companies are lacking. Some of the companies had a greater need for measures that would increase systematic integration of environmental requirements during design decisions. Others first need to establish the processes (in terms of people and use of supporting tools) that could enable such integration.

1. Introduction

Transforming market opportunities into technical and commercial solutions is a core objective of product development. Products are designed to meet customer needs, but at the same time a significant number of aspects and requirements need to be considered and fulfilled. Traditionally, such requirements covered functional and non-functional properties of the product related to quality, cost or performance. Calls for improvement of the environmental performance of products have increased as a result of legislation and customer demands, creating a need for incorporation of environmental aspects into the product development process. In other words, product designers still need to satisfy all functional and non-functional requirements, while also providing customers with an environmentally improved product.

Environmental impacts arise at different stages during the life cycle of a product, ranging from raw material extraction through manufacturing and use to final disposal. Most of these impacts are introduced, at least to some extent, when product properties and specifications are defined, since they determine not only the materials and manufacturing process of the product, but also for instance its use phase performance and recyclability. Product development is therefore considered a strategic area for the environmental adaptation of products (Ritzén, 2000). From an engineering design perspective, early integration offers more opportunities for modifications and improvements, as constraints on time and cost are lower (Luttropp and Lagerstedt, 2006).

Based on these principles, the concepts of Design for Environment (DfE) and Ecodesign[1] have been developed to promote the systematic consideration of environmental aspects during all stages of product design and development. DfE is defined as "a process,

* Corresponding author. KTH Royal Institute of Technology, Division of Environmental Strategies Research, Drottning Kristinas v. 30, 100 44 Stockholm, Sweden. Tel.: +46 8 790 86 33.
E-mail address: sofiapo@kth.se (S. Poulikidou).

[1] Design for Environment (DfE) and Ecodesign are often used as interchangeable terms. In this paper the term DfE is used.

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integrated within design and development that aims to reduce environmental impacts and continually improve the environmental performance of products, throughout their life cycle" (ISO 14006, 2011).

Research concerning DfE is broad and constantly evolving. A significant proportion of publications focus on how DfE can be implemented, by providing an introduction to the framework and describing the principles behind it. Models and guidelines have been suggested by numerous authors (Brezet and Hemel, 1997; Handfield et al., 2001; Wimmer et al., 2004) and institutions (ISO TR/14062, 2002). Another substantial proportion of publications focuses on factors influencing the implementation of the DfE approach and successful integration of environmental aspects into the product development process. A state of the art summary by Johansson (2002) lists different factors for successful integration, including management commitment, early consideration of environmental aspects, selection of company-specific environmental principles, use of supporting tools, competence development, and support from environmental specialists. Tingström (2007) subsequently devised a conceptual model for facilitating integration of environmental aspects into product development. This model classifies success factors into four interlinked areas, namely management support, the product development process, DfE mindset, and DfE tools.

The use of DfE tools is frequently mentioned as an essential part of the DfE approach (Johansson, 2002; Lindahl, 2005; Tingström, 2007). The term "tool" in this context is defined in a broad sense as any type of systematised aid to incorporating environmental aspects into the product design and development process. DfE tools aim to provide methodological support to design engineers and increase understanding of the aspects that influence the environmental performance of products (Hallstedt, 2008). DfE tools may vary from generic manuals and simplified guidelines to more sophisticated analytical tools (Baumann et al., 2002). They can be qualitative or quantitative and can be found in various forms and structures, for example lists, matrices, computer-based tools or radar graphs (Poulikidou, 2012). Byggeth and Hochschorner (2006) classified DfE tools into prescriptive, comparative and analytical based on their objectives and the support provided to product designers, i.e. to provide design guidelines, to compare product alternatives and to assess the environmental performance of a product under a specific or multiple impact categories. In addition to these, tools that can be used to generate design strategies are available (Bovea and Perez-Belis, 2012), as well as benchmarking tools or tools that investigate customer environmental needs (Lindahl and Ekermann, 2013). Based on their purpose and their data and time requirements, different tools can be used at different stages during the product development process, from early planning to detailed design stages.

The maturity of the DfE framework and tools in the academic world is clearly apparent. However systematic adoption of DfE strategies in industries and in product development processes is generally reported to be low. Tukker et al. (2001) performed an extensive study on the maturity of DfE in Europe in which EU member states were assessed in relation to method development, dissemination, education and practical implementation of DfE principles and tools. Among the conclusions of the study was that even countries that scored highly as regards development of methods and tools, education and dissemination (for instance Scandinavian and central European countries) had significantly lower scores as regards maturity in practical implementation. Around the same time, an empirical study performed by Handfield et al. (2001) tested a number of theoretical foundations for DfE with the practices adopted in ten firms. The results demonstrated gaps between theory and practice and the study concluded that the firms did not incorporate environmental aspects as part of their product innovation process or use DfE tools to any great extent. A few years later, Lindahl (2005) specifically investigated the use and diffusion of DfE methods and tools among different Swedish enterprises and found limited and often not very systematic use of DfE tools.

In more recent studies, the implementation gap remains evident. Deutz et al. (2013) studied firms of various sizes and sectors in the UK and found variations in environmental awareness among the different companies studied. This led those authors to conclude that integrating environmental aspects into design processes is "far from a standard practice". Similarly, Jönbrink et al. (2013) performed a survey on DfE implementation among Swedish enterprises and, concluded that although environmental and sustainability issues are increasing in importance in industry (compared with previous years), a holistic approach has not yet been adopted. Significant variations were observed among the different companies, although the majority continue to work on "single issues", e.g. energy efficiency improvements or restrictions on certain materials and chemicals.

If DfE is to be integrated effectively on a regular basis into product design and development, there is a need to bridge the gap between theory and practice. To this end, empirical studies of the integration of DfE into companies are needed in order to increase understanding about the drivers and barriers to implementation. The study presented in this paper is part of a research project on the integration of environmental aspects during vehicle design and development, with the aim of developing a comprehensive approach in material selection processes. Empirical data on existing processes and tools for this sector are therefore needed in order to increase understanding of the needs and challenges faced by companies within this specific product category. As Boks and McAloone (2009) point out, "it is very likely that company specific factors determine the appropriateness and acceptance of ecodesign strategies". Thus studies on such factors are essential and may "prove to be instrumental in furthering the implementation of sustainable product innovation practices, and as such, constitute a next transition in this field" (ibid.). The authors found limited information in the literature relating specifically to vehicle design. Most existing studies, including those discussed above, consider companies in different sectors simultaneously. This of course increases the diversity, but may limit the possibilities to provide comparable results due to differences in product complexity or the challenges that the sectors need to address.

1.1. Aim of the study

An empirical study was conducted on the diffusion and implementation of the DfE framework and tools among four vehicle manufacturing companies in Sweden. Through interviews with the staff involved, directly or indirectly, in product design and development, the aim was to describe and gain insights into how DfE is organised in the selected companies. Specific objectives were to:

- Obtain a general overview of the product design and development process in the different companies, and determine where and in what way in that process, environmental aspects are integrated and monitored in terms of organisational units, staff, product specifications and requirements
- Identify and describe the main DfE tools used by the selected companies and the purpose of using those tools
- Discuss drivers and barriers in relation to DfE organisation and tools as experienced in the companies studied

The scope of the study was limited to the physical products manufactured by the companies and not the entire organisation;