Journal of Cleaner Production 39 (2013) 117–128

Contents lists available at SciVerse ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Eco-design practice in the context of a structured design process: an interdisciplinary empirical study of UK manufacturers

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ARTICLE INFO

Article history:
Received 24 June 2011
Received in revised form
24 August 2012
Accepted 27 August 2012
Available online 5 September 2012

Keywords:
Eco-design
Functional requirement
Regulation
Design space
Product design
UK

ABSTRACT

Environmental design (eco-design) has been identified in both academic and policy circles as a point of intervention in the product lifecycle to promote environmental performance. The benefit of eco-design would be enhanced by rooting it firmly within theoretical design principles and establishing 'sustainability' as a functional requirement within a regulatory framework. Formulating such an innovative approach requires first understanding current practices of eco-design in industry. This paper, therefore, addresses three questions: 1) To what extent is the design process structured in practice as suggested by design theory? 2) What, if any, environmental issues do designers consider to be relevant to their products? and 3) To what extent are environmental issues incorporated into product design? Targeting primarily large UK based companies, the authors conducted open ended interviews in conjunction with a postal survey of a sample of manufacturing companies incorporating a wide range of industrial sectors. Critically, many designers are not following good design practice, which limits the possibilities for radical environmental innovation. The environmental design behaviour of companies reflects a complex balance of designers' understanding of environmental issues and the extent of the design space, influenced by legal requirements, economic and supply chain constraints. A more effective regulatory strategy informed by good design practice is required to assist companies in achieving an effective implementation of eco-design.

1. Introduction

The design stage of a product has been identified as determining its environmental impact over its lifecycle (e.g., Baumann et al., 2002) and so provides an intervention point to implement environmental goals (Graedel and Allenby, 1998; Pongrácz, 2009). Designing "products with the environment in mind and to assume some responsibility for the product's environmental consequences as they relate to specific decisions and actions executed during the design process" is known as eco-design, or design for the environment (Lewis et al., 2001; 16). There are many examples in the literature of eco-design initiatives relating to specific products (e.g., electronic products; Yung et al., 2012) or developing tools for eco-design (Negny et al., 2012 looking at the chemical industry).

Whilst sustainability is recognised as incorporating environmental, social and economic considerations (WCED, 1987), the balance and precise definition of these is politically contingent. Furthermore, the design priority varies between products (Bovea and Pérez-Belis, 2012). The present authors, therefore, are not proscribing specific considerations for designers (e.g., recyclability, or content of post-consumer material). Rather it is proposed that for eco-design to become more effective, sustainability needs to be established as a formal functional requirement within a structured design process for all products (Deutz et al., 2010).

As in so much relating to sustainable development, there is a significant implementation gap between the theory and practice of eco-design (Baumann et al., 2002; Knight and Jenkins, 2009). This may, in part, reflect a lack of familiarity of companies with the implications of sustainability and/or how the available initiatives link both to each other and to company practice (Tingström and Karlsson, 2006; Bovea and Pérez-Belis, 2012; Lozano, 2012).

Regulations are a major driver for eco-design where it does happen (Boks, 2006), but they need to be framed in a manner cognisant of the practices of product designers (Tsai and Chang, 2012).

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http://dx.doi.org/10.1016/j.jclepro.2012.08.035

There is however, a lack of a broad based study providing a characterisation of eco-design practices in industry. Previous work typically presents detailed case studies of a very small number of companies, often selected as examples of good practice and commonly analysing the experience of implementing a specific approach (Lofthouse, 2006; Knight and Jenkins, 2009; Arana-Landin and Heras-Saizarbitoria, 2011). Significantly, eco-design needs to reach beyond niche markets to achieve a significant environmental impact. In addition, the existing eco-design literature is largely silent on design theory, which is potentially a critical oversight.

This paper aims therefore to gauge design practice and eco-design engagement across a range of industries. Drawing on engineering and social science expertise, this paper addresses three research questions: 1) To what extent is the design process structured in practice as suggested by design theory? 2) What, if any, environmental issues do designers consider to be relevant to their products? and 3) To what extent are environmental issues incorporated into product design? Accordingly, a survey of a broad spectrum of UK manufacturing industry was undertaken by questionnaire and through interviews. This paper first outlines the structured approach to design advocated by design theory, and reviews previous studies of eco-design in practice. It then outlines the methods used, followed by an analysis of results, and presents conclusions which provide a framework for future work and practice.

2. Structured approach to product design

A structured design process commonly includes problem definition, generation of concepts, selection and refinement of potential design solutions (Gagnon et al., 2010). It begins with a 'design brief' outlining the task at hand. From this, designers, in consultation with the client/customer for the product, derive the functional requirements. A functional requirement of a product is an inherent property that is fundamental to accomplishing the task for which it is intended. It should not be confused with either design parameters, i.e. potential solutions to a functional requirement, or design criteria, e.g. cost (Suh, 1990). Design criteria are also referred to as non-functional requirements or attributes (Otto and Wood, 2001). Defining sustainability as a functional requirement extends the ordinary definition of 'functional' from the operation of the product during its lifespan to encompass its entire lifecycle.

The next phase in the design process is conceptual design, i.e., the generation of ideas, or concepts, that meet the underlying functional requirements (Lipson and Shpitalni, 2000). From a theoretical perspective, these ideas form an intellectual design space enveloping all potential solutions to a design problem; the greater the divergence of the design space, the greater the probability that the 'best' solution will be found (Dym and Little, 2004). Sustainability needs to be recognised as a functional requirement before concept generation otherwise there is the danger of its being merely a design criterion (a consideration in selecting the preferred solution) rather than a fundamental proposition inherent in the generation of potential design solutions (Deutz et al., 2010).

Despite, or because of, the intellectual rigour of the theoretical design approaches, implementing them is challenging. Even a relatively simple product can have a design space comprising thousands of concepts. Convergent thinking is needed to focus on the 'best' alternatives in order to 'converge' to a solution within known limits. Therefore, designers often introduce design constraints at early stages in the design process, thereby reducing complexity by excluding potential solutions (Scaravetti and Sebastian, 2007).

Once the potential design solutions have been identified, design proceeds to the embodiment stage. This is an iterative process of determining the likely shape, materials and production processes for the product, which should incorporate consultation between designer and customer in order to best meet the functional requirements in the light of financial and/or technological constraints (Pahl and Beitz, 1996). The incorporation of environmental issues into design can create an additional area on which customer input is required, or offered (e.g., Kivimaa, 2008). Understanding how consumers make decisions about the replacement of products, for example, is an important consideration in designing products to last longer (van Nes and Cramer, 2005). However, this form of consultation is not beyond the scope of acitivities which ideally should be occurring (i.e., close co-operation between designer and client/customer).

Finally, detailed design is the process of determining the precise product and production specifications. By this stage, most of the original design space is beyond consideration. Issues such as safety and the environment are germain to decision making at embodiment and detail stages (Pahl and Beitz, 1996), but optimal solutions will not be found at this stage, if they have not been identified at the earlier design stages.

3. Eco-design in practice

Notwithstanding the potential of eco-design to contribute to product sustainability, previous research implies that eco-design is in actuality largely confined to maintaining the minimum legal requirements (Akermark, 1999; Boks, 2006). Tukker et al. (2001), in an EU scale study, found little evidence for eco-design in practice. However, they did note a degree of engagement in sectors such as automotive and electronics, which were influenced by EU Directives such as End of Life Vehicles and Waste Electronic and Electrical Equipment (WEEE). Nevertheless, Gottberg et al.'s (2006) study of 8 firms in the EU lighting sector found little impact of the WEEE regulations on design. Similarly, Handfield et al. (2001) studied eco-design practices of 12 companies (all seen as eco-design leaders in the US). They were found to be simply complying with what they understood to be requirements. Rather than incorporating environmental considerations into their process of product innovation, the environment was seen as a constraint on decision making. Furthermore, the regulation-driven nature of eco-design results in an emphasis on design for recycling (Akermark, 1999; Handfield et al., 2001), rather than a broader consideration of the sustainability priority of a given product. Designers were not trained as environmental scientists – likely with no more than a lay person's understanding of environmental issues, how to respond to them, or the potential impact of their products (Akermark, 1999). Projects working closely with individual companies indicate that both guidance and information are required to bring environmental issues to the design table (Lofthouse, 2006; Johansson and Magnusson, 2006), with stakeholder engagement a potentially important source of environmental information (Aschehoug et al., 2012).

Product design is a complicated process involving several company departments (e.g., production, marketing, purchasing) in addition to design. There are several company scale studies that make an important contribution to understanding how firms engage with environmental issues, but by virtue of their broad scope, have not engaged in detail with the design process (e.g., Pujari et al., 2003; Donnelly et al., 2006). These studies suggest that voluntary initiatives such as environmental management systems are not sufficient to overcome barriers to eco-design. Regulatory and customer requirements are paramount. Arana-Landin and Heras-Saizarbitoria's (2011) detailed study of four