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TO WHAT EXTENT ARE DFX PRINCIPLES REALLY USED WHEN DEVELOPING ENVIRONMENTALLY SENSITIVE PRODUCTS?

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ABSTRACT

Research shows that over the past five years, industry has improved its understanding of the need to consider the environmental impacts of its products As a result companies are now beginning to incorporate environmental decisions into their design processes. It has been observed that companies follow a general pattern of change in order to continuously improve their eco-design capabilities. Many methods can be used to ensure that environmental considerations are included in the design process, some which may be complimentary to the existing process of design, and some which may contradict existing design practices. This paper explores the use of DFX principles during eco-design. Literature describing the use of DFX principles in eco-design is reviewed and used to investigate empirical evidence from designers in the electrical/electronics industry.

KEYWORDS

DFX, eco-design, environment, product development

INTRODUCTION

The increased demand to consider environmental issues when designing products has set industry and academia on the road to looking for eco-design tools and techniques. In its infancy eco-design addressed single-issue environmental problems such as disassembly, recycling, or parts identification. However, as the understanding of the subject has widened to considerations such as whole product life-cycles, multi-product lives, and de-materialised products, so must the tools and techniques become more sophisticated to deal with these issues.

Design For X is a term that is used to represent a variety of considerations that must be made whilst designing a product. Olesen describes DFX as:

> *"a tool in which a long series of relationships between design characteristics have been formulated, together with their dispositional effects, measured in relation to the universal virtues. In this way the designer is given dispositional insight into the technical areas in which he does not naturally belong."* [1]

The need for DFX tools arises from the fact that designers cannot be expected to be subject experts on every factor that arises during the design process. With DFA, for example, issues such as parts orientation; fastening techniques; parts-minimisation; and feeding techniques are addressed to make one specific stage of the product's life more effective [2]. Design For Disassembly (DFD) is a technique that aids the designer in considering how to do the opposite of DFA at another specific point in the product's life - the end. The point here is that DFX considerations relate to specific stages in the design process. One problem faced by designers with environmental constraints to consider is that the constraints occur at every stage of the product's life. By studying the literature describing DFX in eco-design and considering this next to the results of an empirical study, we shall gain insight into the use of DFX techniques in eco-design.

DFX AND THE ENVIRONMENT – A BRIEF REVIEW

In addition to his above description of DFX, Olesen [1] also views eco-design considerations as falling under the DFX umbrella. This raises the question of whether eco-design is an extension of DFX, in that existing DFX principles and methods are applicable and sufficient. For issues that occur at specific stages in design, (such as DFD and DFR), DFX may indeed be sufficient. (This is typical of the earlier notion that companies have evolved along the chain of: "recycle → reuse → reduce" [3, 4].) However let us consider some other facets of eco-design. Reduction of materials; reuse of components over multiple product life-cycles; energy efficiency in design and manufacture; or the moral implications of designing the product all affect every stage of the product's life and not merely one specific point in the design process. This paints a more complex picture of eco-design. Many companies have reached a stage where the designer cannot any longer be expected to consider every environmental consideration in a simple step manner, but as an integral part of every stage in the design process [5].

In an attempt to find a way in which to integrate environmental impact considerations into the product design process, Thurston and Blair [6] consider the use of DFX and concurrent engineering. They conclude that DFX does not integrate environmental considerations explicitly enough that the designer can use the technique to significantly improve the environmental profile of a product.

Van Hemel and Keldmann [7], however, argue that, to an extent, eco-design (or 'DFE' as they term it) is indeed a part of the DFX family - mainly due to the systematic way in which environmental considerations can be dealt with by the use of tools and techniques. However, eco-design is much more than the systematic application of tools and techniques at set stages in the product development process. Van Hemel and Keldmann recognise this difference and point out eight main ways in which eco-design does not fit into the DFX pattern:

1.	*"there is no DFE without morals and ethics"* - meaning that eco-design causes the designer to think about moral and ethical issues that do not occur in other DFX elements;
2.	*"the mindset is the fundament"* - meaning that the way in which the designer thinks has a profound effect on eco-design, and this mindset is created by the designer themself (through personal experiences - daily occurrences, following the media etc.) Furthermore the company's corporate environmental mindset affects the designer's eco-design;
3.	*"setting the right goals is complicated"* - meaning that other DFX's have clear and tangible targets, whereas eco-design's target is to contribute to sustainable development - a term which no-one seems able to quantify;
4.	*"DFE results are difficult to measure and communicate"* - meaning that quantitative measures such as LCA produce results that are still under discussion, and qualitative measures are hard to attribute to environmental improvements;
5.	*"both product and life-cycle are synthesised"* - meaning that eco-design encourages the designer to think about the environmental performance of the whole product life-cycle system and not simply the environmental performance of the single product;
6.	*"external relations are essential in DFE"* - meaning that because eco-design considers the whole life-cycle of the product, all of the stakeholders of this whole life-cycle must be consulted, from the materials supplier to the manufacturing engineers to the actual users;
7.	*"the stakeholder gallery is expanded"* - meaning that eco-design opens the product up to a wider group of people who will have an opinion about the environmental design of that product, including the recycling industry and consumer associations;
8.	*"legislation and regulation play important roles"* - meaning that legislation has a major affect on eco-design - companies will not encourage their designers to make long-term environmental improvements if they feel that future legislation may not support them or, worse still may oppose these improvements.

Figure 1 - How eco-design differs from DFX (After van Hemel and Keldmann [7])

Taking the understanding from Olesen, Thurston and Blair, that DFX focuses on single areas of performance as being the appropriate design drivers, we can consider DFX and eco-design from a different viewpoint. Figure 2 illustrates the way in which the *eco2*[1] school [8] views the contribution of single DFX issues to the whole issue of eco-design and sustainable design. The kernel of the figure represents where DFX considerations are made to improve the environmental criteria of products. A collection of environmental DFX's is considered here to be 'green design'. The further out from the centre of the diagram one travels, the more philosophical the environmental goal is. 'Eco-design' is defined by *eco2* as approaching environmental issues from a holistic viewpoint, where the issue of, say recycling cannot be considered in an isolated DFX-manner, but with respect to the whole life-cycle; each environmental decision has a knock-on effect to another issue later in the product's life.

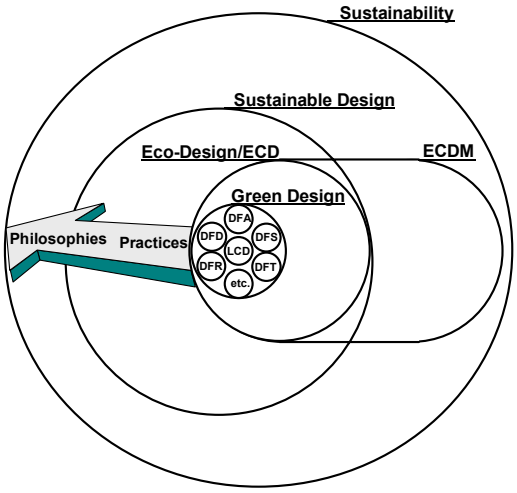

Figure 2 - Relationships between eco-design practices & philosophies [8]

To date there is much evidence that the activities at the kernel of Figure 2 are being carried out successfully (as reported by Cairncross [9] and Clegg and Williams [10]), and there are numerous sources of information describing the outer 'sustainability' edges of Figure 2. To bridge the gap companies need to formulate environmental design/manufacture strategies of their own, which are specific to their needs as manufacturers of unique products, as will be seen from the empirical results later in this paper.

REFLECTION

The product design process is often represented as a series of sequential stages, within which design decisions develop to produce a final product design. Upon this design process act various external product requirements, which the product designer must consider. A comfortable way for manufacturers to consider these external requirements has been to take a Design For X approach, where 'X' is the external requirement.

Although some environmental considerations can be treated in this manner it is evident from the literature that environmental issues are generally much more complex than other DFX considerations: they introduce morals and ethics; longer term considerations; and complicated goal setting. Environmental considerations also require a new set of decision-makers to be involved with design decisions.

[1] eco2-irn - ecologically & economically sound design & manufacture - interdisciplinary research network

Existing literature has shown that many single-issue 'green design' techniques have been adopted by academia and industry [11] and that academia is certainly working to develop theories for the more strategic of philosophical environmental issues, such as sustainability.

AN EMPIRICAL STUDY OF ECO-DESIGN PRACTICES

As part of a wider study, the author carried out an exploratory study of the environmental practices of manufacturers in the electrical and electronics industry sector [12]. The research method adopted for the research was an exploratory study consisting of one in-depth pilot study and twenty four interviews from practitioners from industry. The interviews were semi-structured around five main topics, two of which are relevant to this paper:

- design methods used in the company, and how these incorporated environmental criteria;
- eco-design tools and techniques used by the design teams.

The pilot study was used to form the hypotheses for the research and the data collected from the interviews were analysed using a qualitative data analysis technique.

The analysis of the data from this survey resulted in a model of eco-design integration being built, which is illustrated in Figure 3. The purpose of a model is to explain clearly a more complex reality. The model presented in Figure 3 represents the complex organisational transitions that companies were seen to go through when integrating environmental criteria into their designs, by describing a three stage process of change.

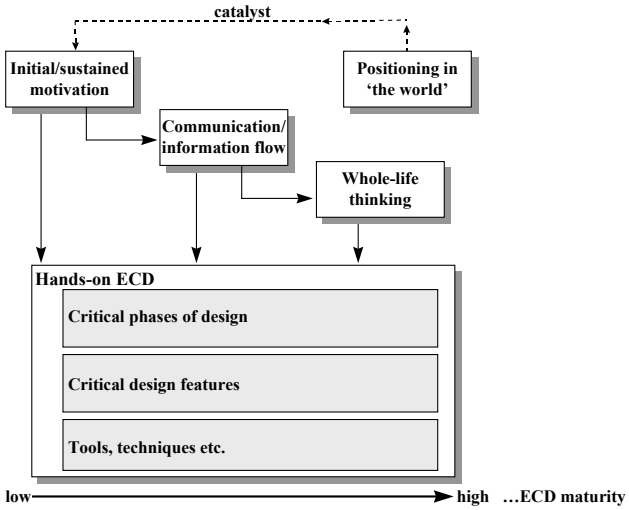

Figure 3 - Model of eco-design integration [12]

In the first stage of eco-design integration (**initial/sustained motivation**), the companies were observed to be reacting to a single external demand or force, such as CFC legislation or a competitor product. Progress to sustained motivation was said to require significant top management commitment, unlike the initial motivation which was a reactive posture. Initial motivation was sometimes observed to be entirely within the design process, with little management contact. However only after top management understanding and then commitment was gained could companies consider themselves to have achieved sustained motivation. It was in this phase of eco-design integration that companies were observed to be using DFX principles the most, due to the reaction to single issues, mainly from outside of the company (such as the need to recycle - due to European legislation).

The next stage of eco-design integration was observed to be **communication/information flow**. This stage was only achieved when more than one of the factors in the category of initial/sustained motivation were active within the company, and with the necessary ingredient of top management commitment. The companies which reached this stage of eco-design integration had begun to gain momentum towards the practice of eco-design (it was also observed that some had not yet managed to leave the reactive stage of initial/sustained motivation). This stage was characterised by increasingly wider involvement of departments into the eco-design process, and by an introduction of some organisational learning about eco-design principles (be it in the form of education of the workforce, membership of design reviews, environmental workshops and training sessions, or the provision of specific information on topics such as hazardous materials). This second stage of eco-design integration is where the majority of the companies interviewed were seen to lie. DFX tools were still used in this stage, specifically as teaching methods for designers, so they could learn how to solve their specific eco-design problems. However, the more advanced companies in this category had begun to recognise the life-cycle effects of their decisions, and that choosing environmentally superior 'material x' in the materials selection phase does not just stop there - it has knock-on effects throughout the rest of the product's life-cycle. Indeed, by choosing the 'best' material from an environmental perspective, the overall environmental affect of the product may have been worsened. At this stage, designers stated that they could no longer use simple tools and techniques, as they were suddenly having to consider many different life-cycle stages and many different stakeholders all at once.

The final stage of eco-design integration (**whole-life thinking**) describes the few companies who were seen to be ahead of the majority, and had developed a high understanding of the trade-offs available between different product life-cycle phases. An initial realisation in this category was that ecological improvements could also mean economical benefits for the company. This often led to an adjustment in the view of what constituted core-business for the company, from focusing on product development and manufacture to service provision. It is this change in philosophy that was said to enable the company to take the view that their products were assets which should be fostered even after they had been sold to the customer. Companies in this phase still used DFX techniques to constantly improve the environmental performance of their products (especially at the time when they began to view their products as *their* assets - and so needed to be able to easily refurbish and recycle the products themselves). However, much greater emphasis was placed on the fact that every new product should now fit into the company's strategic environmental business plan (often known as the asset management plan).

REFLECTION

The results from the above study show that DFX plays a part at every stage of companies' transition from eco-design novices to well-practised eco-designers, indeed, DFX was seen to be the way in which to start with eco-design and also to teach eco-design aspects to designers. However, DFX was seen to become more difficult to work with as the understanding of eco-design issues grew. This was particularly seen in the most highly populated stage of **communication/information flow**, where there appeared to be a lack of tools that aided designers to consider the wider life-cycle issues of eco-design.

CONCLUSIONS

Designers have experience in working constraints such as cost, time and quality. Having 'environmental protection' as a design goal introduces a whole new set of constraints and opportunities that cannot easily be handled in a DFX manner. The unique problem that *'environment'* has over *'manufacture'* or *'assembly'* is that it cannot be dealt with fully and

finally at one specific point in the design process as *'manufacture'* or *'assembly'* can. A whole-life approach is required to address the environmental performance of a product, which should question each stage of the design process and each interdisciplinary member of the organisation. However, there is still a place for DFX in eco-design, but as a supporting mechanism by which to consider some of the component issues of eco-design. 'Design For Environment' is not in itself a DFX, but another viewpoint on design, which contains certain DFX's within it.

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