Ecodesign Strategies as a Basis for Green Development and Environmental Management in Organizations

Ostad-Ahmad-Ghorabi,H.

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1 Introduction

Ecodesign aims at minimizing the environmental impact of products throughout their entire life cycle. This is a new challenge for many organizations but at the same time a driver for stimulating innovative ideas in product development. An engineer in product development chooses and defines the materials needed for the product, affects the process technologies needed, influences the mode of transport and determines consumptions in the use stage as well as treatment possibilities in the end of life stage of the product. Experiences gained from industry projects show that accompanying companies during their product development process can effectively lead to the establishment of Life Cycle Thinking, green development, green product concepts and environmentally sound products [8]. Various tools, easy to apply approaches and methods are already available which can assist product development engineers in tracking the environmental contribution of their products throughout their life cycle [7, 4]. The earlier Ecodesign aspects are considered during product development processes, the larger is the potential for innovation throughout the life cycle stages.

However, to be able to obtain a detailed quantified environmental profile of a product as well as to gain ISO conformity of the assessment procedure, conducting a Life Cycle Assessment (LCA) based on ISO 14044 [2] series is essential. Based on the results of the environmental profile, environmental improvement strategies can be obtained.

Integrative approaches for implementing LCA and Ecodesign into decisive early design stages may be an additional burden to designers and engineers in product development. On the one hand designers and engineers are not necessarily environmental experts and on the other hand an environmental evaluation will confront them with a huge amount of additional data, numbers and facts. But at the same time they make many important decisions during the design stages which influence the resource consumption of the organization and the environment directly. This paper introduces a practicable approach for the implementation of Ecodesign into early design stages and discusses results of projects conducted with industry in this field. Further it will show how Ecodesign can help to establish a green development line and enhance the implementation of effective strategies in early design stages.

2 Methods

According to [1] the most common reasons for the application of LCA are for internal purposes, like product improvement, support for strategic choices and benchmarking. External communication is also mentioned as application, but often this communication is indirect. In many companies, the marketing department is the initiator of a LCA study, as it would like to show environmental benefits of products, but usually the marketing department finds out that LCA results are difficult to communicate. Often other departments, e.g. the R&D or the environmental department, take over the role of the initiator, which can create some confusion regarding the exact purpose of the LCA study.

Beneath, accomplishing a full LCA to gain quantified data for the resulting environmental impacts of a product is time and resource intensive. Meaningful results can only be obtained in case detailed product development parameters such as materials used, process technologies applied etc are known. Results obtained by a detailed LCA may remain specific to a certain product; concluding to other products is hardly possible.

The trend of conducting LCA is to avoid detailed and expensive studies and to tend towards screening and simplified studies [1]. On the other hand, aiming at shifting LCA from the marketing, R&D or environmental department into decisive early design stages, hence the design department, requires new approaches and methodologies.

The introduced methodology of 'parametric Ecodesign' in this paper incorporates proposing reference products, which correlate technical and environmental data, systematically. The methodology will help using LCA data to optimize product designs and to implement Ecodesign strategies already in the early stages of product development.

The idea is to focus primary on product families. A 'product family' is defined as a group of products which have common characteristics, either from a functional or from a technological point of view [3]. By applying parametric Ecodesign, an appropriate reference product can be modeled within the considered product family. By doing this, the environmental contribution of each extracted parameter (e.g. type and amount of materials used, process technologies, surface treatment, etc) can be tracked and influenced. At the same time a comparison of the resulting environmental impacts of a certain design with an appropriate reference of this product is facilitated. In a further step, this comparison could be visualized in existing CAD software, as first attempts to do so were conducted by the Vienna University of Technology. The visualization of the results helps designers and engineers in product development to understand the influences of the changes in design throughout the life cycle of the product, hence the environmental impacts of the product, see next section.

3 Results

The study conducted shows that it is possible to define an appropriate reference model. Further it was shown that such a reference model is able to represent the technical as well as environmental impacts of a product family [6].

To obtain a first reference product, product data from a multinational company producing office chairs were taken into account. Since this company is producing different office chairs with different designs the aim was to conclude from the life cycle assessment results of one office chair to the environmental profile of the other chairs. Based on this analysis, appropriate Ecodesign strategies should be extracted to improve the products. A common office chair consists of following components:

1. Base
2. Mechanism
3. Seat
4. Back
5. Arm rests

As discussed and summarized in [5] the office chair is a material intensive product. Its environmental profile is shown in Figure 1.

The challenge in modeling a parametric reference product within a product family is to reduce the degree of detail of data in a way the results do not deviate too much from the detailed analysis. To model the different life cycle stages of the product all parameters and processes were tracked and evaluated. In a next step, these data were classified into classes using an environmental impact indicator, e.g. $CO_2 - equivalents$ emissions, as a parameter for environmental impact [6]. As an example, for the first life cycle stage of the considered office chair, all materials used in the product were classified into seven classes as shown in Table 1.

Table 1 shows that for a certain material the average value CA for its class is taken to represent the environmental impact of the material rather than the specific and detailed $CO_2 - eq$ value.

The average value for the class CA is calculated by:

$$C_A = \sqrt{(Min \times Max)} \tag{1}$$

For class M_I the averaged value CA is defined to be $700g\,CO_2 - eq/kg$, the one for class M_{VII} is defined to be $20000g\,CO_2 - eq/kg$.

The same approach as for the first life cycle stage can be applied for the other life cycle stages as well, i.e. for manufacturing processes, transport, use and end-of-life treatment. This approach results in a manageable amount of data packed into classes. As stated and discussed in [6] investigations show that using data classes and CA as the representative value for the class instead of detailed and specific environmental data for each unit process results in neglectable error deviations for the total environmental life cycle assessment result.

By now, the amount of data used for life cycle assessment was reduced by introducing the idea of the application of data classes. A first reference product can be obtained by tracking all materials, manufacturing processes, transport modes, use scenarios and end of life treatments and assigning them to data classes. By using the average value CA of the classes for evaluation, a quantified environmental profile for the product can be obtained. However, these data still form a high amount of data which have to be managed by the designer and the product developer. Experiences show that product developers tend to refuse to integrate life cycle assessment and further Ecodesign strategies into their work in case these approaches form an additional burden to their work.

To be able to face this problem and to integrate the methodology introduced above into early design stages effectively, first approaches were attempted to visualize life cycle data in CAD software.

Since the designer chooses the materials for the product and defines the shape, weight or volume (technical parameters) of the product as well as determines the manufacturing processes, surface treatment and transport modes to be used, defines a use scenario based on the functions supplied by the product and influences end of life treatment scenarios, the designer indirectly determines the environmental performance of the product too. Since the introduced reference product is able to link and correlate between technical parameters and environmental parameters, the required correlated data can be stored in databases in CAD software. The designer then is able to access life cycle assessment data by defining technical parameters, e.g. the amount of the materials used. All other associated life cycle data can be provided by the databases of the CAD software. For example if the designer chooses aluminum for a certain component of the office chair, the reference product will visualize the occurring environmental impacts of related manufacturing processes of aluminum or end-of-life treatment with the designer. Also environmental impacts occurring during transport or assumed impacts during use can then automatically be integrated into the designer's choice.

It is not necessarily the materials which have to be defined first, but any other technical parameter which is relevant for the design of a certain product can be chosen too, e.g. shape, volume, weight or else.

In case of the discussed office chair, the Back component contributes most to environmental impact. This is mostly caused by the materials used in this component (mainly PUR foam and Polyester). Visualization in CAD software would avoid the direct confrontation of the CAD user, hence designer and engineer in product development, with detailed LCA data. In fact, LCA results are presented to the product developer in a way that parts and components with the most environmental impact can be determined easily. Further, it can be tracked whether selected impacts, e.g. $gCO2-eq$, increase or decrease by changing the design of the considered parts and components. By being aware about the changes of the environmental impacts caused by changes in design, effective Ecodesign strategies can be applied to achieve product optimizations in those product development stages where minimum effort is needed and maximum benefit for all actors can be achieved.

Once most significant parts, components and processes have been determined, the Ecodesign PILOT [9] is able to propose appropriate Ecodesign strategies for product improvement. For the office chair shown in Figure 2, choosing materials with a good environmental performance is an effective strategy for reducing the environmental impact of the Back component. Figure 2 compares two different designs of the Back component. Since PUR foam has a high contribution to environmental impact, the new design of the Back was conceived in a way that no PUR foam was needed. The improved Back not only has an improved environmental performance but also an innovative design, which is appreciated by the market and the consumers respectively

4 Discussion

Effective Ecodesign strategies for optimizing the environmental performance of a product can only be implemented when a meaningful environmental evaluation and life cycle assessment has been accomplished before. Often, this evaluation takes place at the end of the product development process, when a product has already been produced. The initiators and actors involved in the evaluation of the product at the end of the development process do not necessarily have a technical background; they might be from the marketing department or the R&D department as mentioned in this paper. The results of the environmental evaluation are either used for external communication of the benefits of the product or for internal communication to gain product improvements. In the latter case, the results have to enter and be included into the product development process again; and exactly at this point the dilemma starts: the results are often communicated to the design department, to designers and engineers involved in product development who do not necessarily have an environmental background and who see themselves restricted in their work and confronted with a huge amount of data, numbers and facts which are difficult to interpret and to understand. Additionally, most available tools, methodologies and approaches developed for easing the environmental evaluation are conceived for the end of the product development process. Seemingly, an environmental optimization of the product becomes then an iterative, time- and resource consuming venture. On the other hand, accomplishing a life cycle assessment at the beginning of the product development process is a time and resource intensive process too, since often data is unknown or unavailable and has to be obtained troublesome. Beneath, the actors involved at the beginning of the development process have a technical background rather than an environmental. Often, appropriate life cycle thinking amongst engineers in product development is missing. The approach discussed in this paper helps to overcome the described dilemma by introducing a methodology which can be integrated in the decisive early design stages. This integration is mainly achieved by:

- Tending from detailed LCA to screening LCA
- Reducing the amount of data to be handled by defining data classes
- Proposing a reference product which on the one hand correlates available technical and environmental data and on the other hand is able to represent a whole product family and not just a single product
- Evaluating life cycle data of a new product to be designed based on the evaluation of the reference product
- Aiming at visualizing the evaluation results directly in CAD software
- Obtaining Ecodesign strategies for environmental improvement of the design

The described approach avoids a direct confrontation of the designer with detailed life cycle data but rather integrates LCA data effectively into the design process. Based on the proposed and foreseen environmental performance of the product appropriate strategies for reducing the occurring environ-mental impacts over the product's life cycle can be applied.

Organizations can benefit by implementing Ecodesign strategies in early product development stages and by establishing a green development not only because of reducing environmental impacts and achieving compliance with environmental legislations, but closely related to that by reducing their internal resource consumptions and costs respectively. Innovative ideas for new product concepts and the fulfillment of stakeholder and customer requirements are some more benefits worth to be mentioned here amongst others.

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Class	**Range** $[gCO_2-eq/kg]$	C_A $[gCO_2-eq/kg]$	**Example**
M_I	0-1000	700	Unalloyed steel
M_{II}	1000-1500	1225	Low alloyed steel
M_{III}	1500-2500	1936	ABS with 30% glass fibre
M_{VI}	2500-5000	3536	PUR, PS, LDPE
M_V	5000-10000	7071	PC, PA, Nylon
M_{VI}	10000-15000	12247	Aluminum 15% recycled
M_{VII}	15000-max	20000	Polyester

Table 1: Material classes [6]

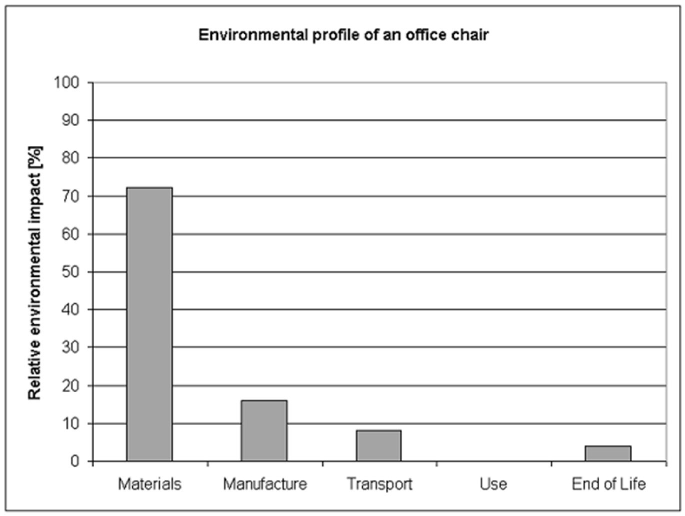

Figure 1: Environmental profile of a typical office chair

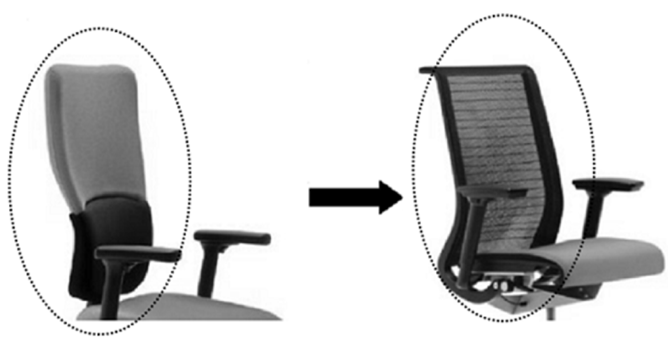

Figure 2: Left: Design of Back using PUR foam, Right: Improved design avoiding the use of PUR foam