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ECO-DESIGN IN PRACTICE - CASE STUDY WITH COMPUTER MOUSE

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1. Introduction

The impact of a product on the environment establishes a networked system of complex interdependencies and ramifications. A systematic and methodical course of action is vital for the implementation of effective improvements, so that environmentally-related product shortcomings can be accurately identified. It is equally important to recognize product expectations of various stakeholders including customers, legislators, entrepreneurs, etc. and integrate them in to the eco-design process. At the same time, this process must occur within an acceptable time frame and be quickly understood by product developers (many of whom do not possess a profound knowledge of environmental technology). The purpose of this paper is to introduce a simple and practical methodology to product developers. The advantage of this approach is its potential to implement a complex product analysis within a relatively short period of time and to subsequently facilitate effective product improvements.

2. Integrating environmental aspects into product development

Products and services always have certain impacts on the environment. These effects differ depending not only on the product but also on the respective phase of the life cycle of the product (Figure 1).

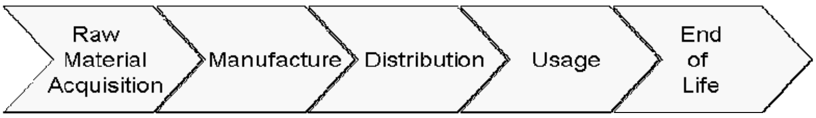

Figure 1. The Phases of Product Life Cycle [Wimmer 2001]

Integration of environmental considerations as early as possible into the product design is extremely beneficial, because all decisions at this phase will have a significant impact on the long-term product improvement and functionality. This stage is decisive in getting desirable results (such as: minimizing negative environmental effects at end of life). Considerations of environmental impacts concerns not only new products but also the improvement of existing products, and has a positive effect on branding and company image.

ISO-14062 systematizes the integration of environmental considerations into the design process. But only to a certain degree because, in practice, companies employ different approaches and tools to design and develop products, and different products also have their own specific characteristics. Therefore individual design decisions are left to the designer and the standard only stipulates implematation process (Fig. 2). Figure 2 shows that results of each stage of the planning process can be fed back into other stages and given to designers and constructors.

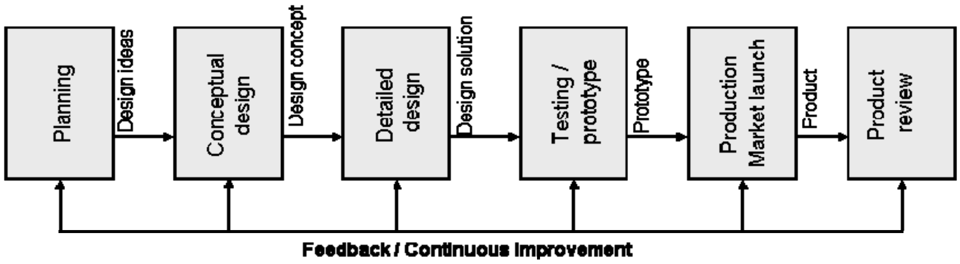

Figure 2. Generic model of a integrating environmental aspects into the product design process [ISO14062 2001]

The following will explain the several stages of Figure 2.

2.1 Planning

In the first design phase, the process starts with analyzing the external factors influencing the planned product, such as: market situation, environmental requirements, legal requirements, customer needs and expectation as well as competitors. These external factors should be considered in relation to the internal resources available to the organization when making decisions within the product's design and development process. The following should all be considered:

- financial resources
- production technologies
- availability of data
- suppliers' capabilities
- availability of sub assemblies, components and materials

2.2 Conceptual design

Conceptual design can be supported by:

- guidelines and checklists regarding environmental considerations, assembly/disassembly and recycling
- material databases
- analytical tools (e.g. LCA)
- manuals (books)
- the integration of environmental management and the product design and development process

The result of the conceptual design stage is a concept with best meets all requirements.

2.3 Detailed design

Various design approaches can be used in this stage:

- improvement of materials efficiency by minimal use of materials, use of low impact materials, and use of renewable materials
- improvement of energy efficiency by reduction of energy use, and use of energy from renewable sources
- design for cleaner production and use
- design for reuse, recovery and recycling
- design for optimizing functionality

2.4 Prototype

Prototype evaluation and testing is an opportunity to check the detailed design against environmental targets. Parallel to prototype evaluation, testing can occur, including material properties, wear resistance, functionality, quality and lifetime.

2.5 Production and market launch

Along with market launch the information about how to proceed with the product after end of life and how to minimize adverse environmental impacts during the usage phase should be prepared for the customer. The customer should be informed about how important environment aspects and requirements are.

2.6 Product review

Feedback from customers is an important information source from which an organization can improve the design and development of future products.
In striving for product development and reduction of adverse environmental impacts of products other benefits, other than environmental protection, can also be experienced, such as:

- lower cost by optimizing the use of materials and energy
- stimulation of innovation and creativity
- meeting customer expectations
- enhancement of organization image or brand
- increased knowledge of the product
- reduction of risks
- improvement of internal and external communications

3. Eco-design implementation method

A starting point for the eco-design process can be an existing product, a prototype, a concept or an idea to meet a particular customer's requirement. Basically, the earlier the ecological improvements can be dealt within the product development process, the more effective the results and the lower the implementation costs will be. Therefore, environmental concerns should be systematically incorporated into the earlier phases of the product development process. The flow chart below illustrates a possible method of eco-design including ISO-14062 stipulations (Figure 3).

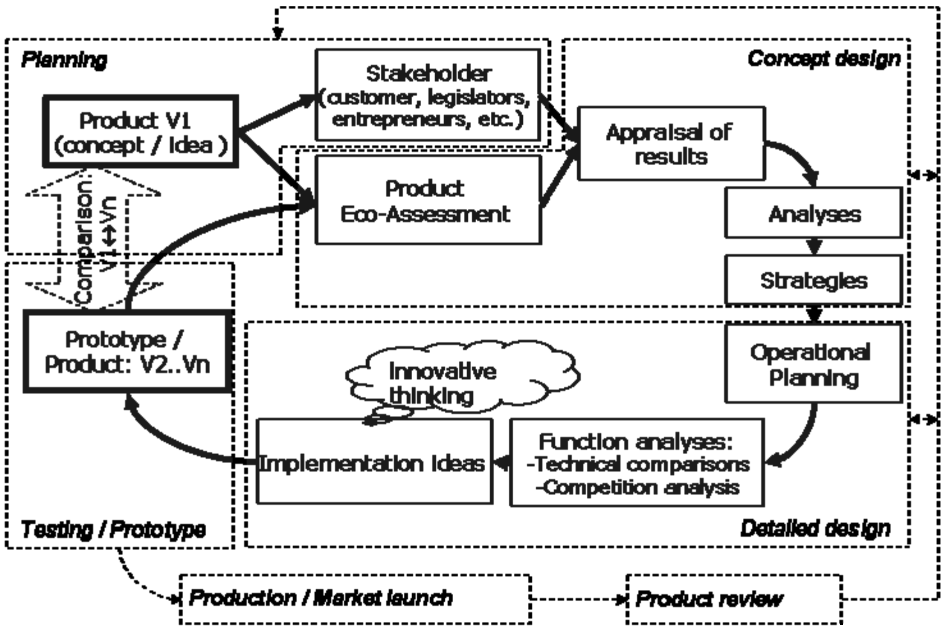

Figure 3. Systematic procedure for Eco-design (by KERP)

In order to offer a successful and environmentally sound product, the expectations of potential customers, the legal framework (both existing and projected) and internal corporate interests must first be acknowledged (illustrated under "planning" in Figure 3). At the conceptual design stage the complex and entire product life cycle and its environmental impact schould be considered. The analysis of all the factors from the planning and conceptual design stages forms a basis for realization of strategies (at the end of the "concept design" stage). Then concrete design measures (operational planning) and implementation ideas can be developed (e.g. a particular use of materials, specific construction of a component part, or development of an electronic circuit) (illustrated under "detailed design" in Figure 3). At the end of this process, a new and improved product proposal, prototype or a new idea will result, that should be compared with the original concept using the initial criteria (customer expectations, legislative, environmental impact, etc.) this happens at the "testing/prototype" stage. . Depending on the result of this comparison, the eco-design process cycle can be repeated from scratch and repeated as often as needed until a satisfactory result is achieved (called feedback/continuous improvement). The following will explain the individual stages of Figure 3 in more detail, using the example of a computer mouse.

3.1 Stakeholder

In this stage, the product-specific expectations of various interested parties (which are referred to as "stakeholders") are identified as completely as possible and also tabulated. Table 1 lists a few examples for our example computer mouse.

Table 1. Eco-mouse – Summary of Stakeholder Expectations

Description of expectations	Source
Restrictions on the usage of: Lead-, cadmium-, mercury-, chromium VI-, PBB- and PBDE	[RoHS-2003]
Disassembling - and recovery oriented product design	[WEEE-2003]
Rate of recovery: 75%, Rate of reuse and recycling: 65%	[WEEE-2003]
Information for recycling companies concerning: components and materials, the location of dangerous substances and preparations	[WEEE-2003]
Product protection for transport	Business partner
Minimisation of usage costs	Customer
...etc.	....etc.

3.2 Product eco-assessment

The negative effects of the product on the environment usually vary with the stages of its life cycle (Raw material, acquisition, Manufacturing, Distribution, Usage and End of Life). Therefore, it is imperative to conduct separate analyses of these stages. The purpose is to pinpoint the stage in which the most environmental impact occurs in order to flesh out the specific countermeasures, without generating a problem in another stage of the product's life cycle. In this manner, environmental damage can be minimized in the most efficient way. In order to gain an overview of the environmental impact, a tabulated form is used which represents a quantified model of the product's life cycle stages. The quantitative environmental analysis utilizes a host of environmental factors and indicators to display various environmental effects and influences in measurable quantities. In our case study, energy consumption ratios are used and illustrated in the life cycle-oriented product model. The computer mouse with all its component parts, including the battery charging station, is the object of analysis. A usage life of 6 years is assumed. Of course, restricting this "eco-balancing" to energy

values involves a great amount of simplification, which means that many environmental issues are discounted. Nevertheless, in this manner sufficient information can be retrieved in order to identify the *critical* stages of the product's life cycle, at a reasonable cost.
In simplified form, Figure 2 summarizes the life cycle stages model of our reference mouse.

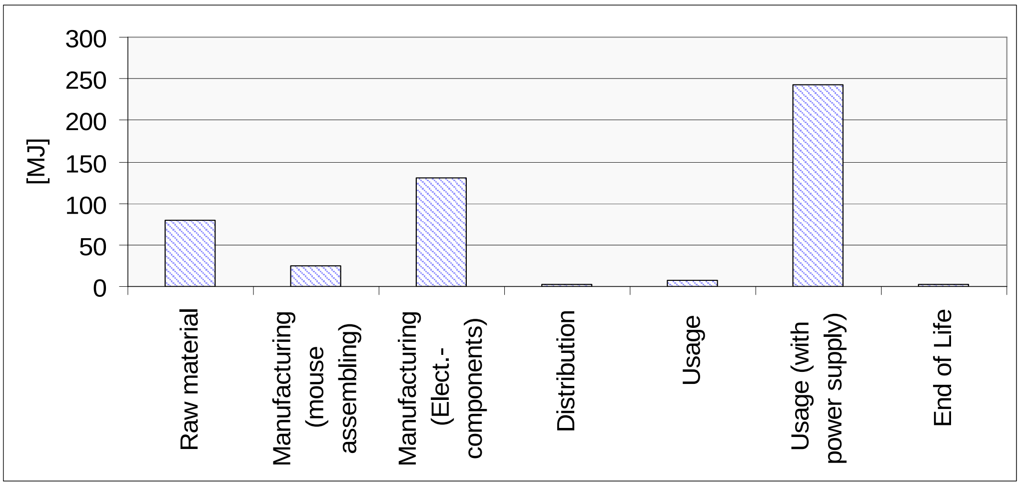

Figure 4. Example: a graphic summary of a life cycle stages model

The above evaluation clearly indicates that the greatest amount of energy consumption occurs during the manufacturing stage. This is primarily caused by the high energy consumption incurred during production of electronic components (mainly semiconductors). Significantly high energy expenditures are also observed in the raw material preparation phase. The use of a power supply unit must also be considered (to power the charging station) and the assumption made that this unit will be permanently connected to the power supply, which entails extreme energy drains throughout the usage phase.

3.3 Product-specific improvement strategies

Based on our environmental assessment and the identified expectations of the stakeholders, improvement strategies can be defined as "signposts" for further steps towards an optimization of environmentally-specific product properties. For example:

- Optimization of energy efficiency (during usage)
- Minimization of material usage
- Environmentally sound procurement of third-party components
- Improvement of recyclability
- Service and maintenance optimization

3.4 Operational Planning

In order to realize the established strategies, the next phase focuses on a host of practical implementation measures that will allow for the ultimate realization of the product through the use of concrete design ideas. An essential element is the ranking of measures in order of priority. Several proposals which apply to a wireless computer mouse are listed below:

- Reducing/optimizing the use of electronic parts
- Implementing lead-free soldering technology and components
- Refraining from the use of materials composed of outlawed substances (RoHS Directive)
- Avoiding/reducing materials that are generally considered to be environmentally undesirable
- Allowing for easy identification of environmentally problematic components
- Minimizing total energy requirements through selection of an appropriate functional principle
- Preferably using recyclable raw materials

- Reducing the variety of diverse fastening techniques
- Producing bonds and joints which are easy to dismantle

3.5 Idea Brainstorming

The acquired strategies and measures pave the way for the product ecologization which should be effectuated through concrete, product-specific implementation ideas.
Idea brainstorming can be supported by the following interim steps:

- Analysis of production functions and function carriers
- Competitor analysis
- Brainstorming solutions by means of comparing various versions
- Defining ideas

Brainstorming ideas requires a great amount of innovative thinking, spontaneity and creativity. Although it is very difficult to place these qualities into plans and frameworks, the systematic method, described in the above mentioned points, proves very helpful. Exemplary ideas generated by means of this technique are listed below:

- In order to prevent environmental damage through faulty usage (in this case, battery charging), instead of using batteries, double layer capacitors (DLC) are utilized (which becomes possible after optimization and re-design of the circuit). The DLCs have a robust charging quality and a very long lifespan (approx. 100,000 charging cycles). Therefore, they need not be replaced throughout the entire product lifespan (no maintenance expense).
- For the version of the charging station with power pack/supply, the power supply is integrated directly into the casing of the charging station and furnished with power-down functionality in order to reduce the high amount of idling power drain (over the entire lifespan)
- The electrical circuit needs to be examined, and simplification potential, component reduction and functionality integration potential needs to be identified (e.g. through the usage of alternative miniature components and integrated circuits)
- Through the analysis of data sheets and manufacturer information, the components are evaluated (for composition, toxicity, conformity with RoHS Directive), and inputted into the our component ordering system.
- Regarding hazardous substances and recyclable materials, the product documentation is prepared in accordance with WEEE specification. This is done via an Internet declaration RECYCLINGPASS (www.recyclingpass.net). This alternative is considered to be cost-effective, easily accessible and ecological – since no paper or electronic data carriers are required.
- The casing is made from renewable materials (“liquid wood”).

3.6 Comparison of reference product against eco-design product and results assessment

Of course, the implementation of ideas generated in such a manner is followed by expectations with regard to an improvement of ecological product characteristics. The degree of this improvement, however, should be scrutinized and compared with the original version. To be able to make a quantitative comparison between the reference product and the eco-optimized product, a new life cycle stages model for the optimized design (eco-mouse) needs to be devised (similar to point 3.2). Instead of the product model table, the summary of results is illustrated by a chart, which is shown in Figure 5.
As this chart depicts, it is possible to achieve substantial reduction of energy consumption (for the scenario with a power pack supply) through the use of power-down functionality (for periods when no charging occurs) of the power supply. Remarkable reductions can also be achieved in the raw materials preparation stage and the manufacturing phase.

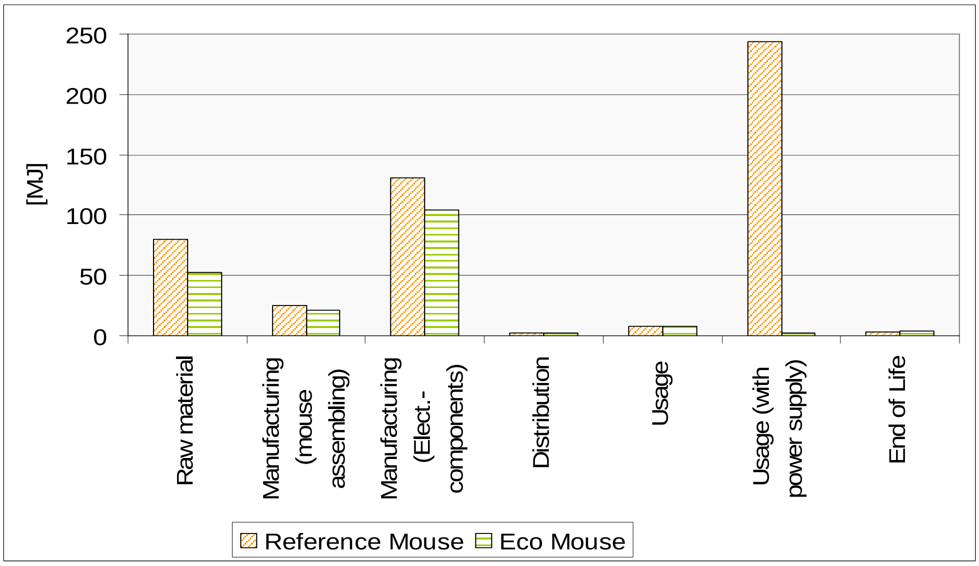

Figure 5. Comparison of life cycle models reference and eco-mouse

4. Results Summary

In conclusion, the proposed eco-design activities have resulted in a complex, ecologically-optimized product. Following the methodical identification of product shortcomings through the determination of stakeholder expectations, analysis of recyclability and the compilation of a quantified lifecycle model for the reference product, effective improvement strategies, as well as measures and implementation ideas were developed. Above all, the main points of focus with regard to eco-design of the case study portrayed were: compliance with new legal requirements (WEEE and RoHS), the fleshing out of an innovative energy conservation system, the usage of recyclable materials for the casing, and the optimization of circuits and component parts. However, eco-design is not a goal to be accomplished in a single action. Rather than that, it is an ongoing process in which the findings generated in the course of one design stage will have and impact on subsequent stages. With this in mind, an "Eco-mouse 2" project is a logical and necessary follow-up!

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