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# ECODESIGN IN TWELVE STEPS – PROVIDING SYSTEMATIC GUIDANCE FOR CONSIDERING ENVIRONMENTAL ASPECTS AND STAKEHOLDER REQUIREMENTS IN PRODUCT DESIGN AND DEVELOPMENT

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## 1 Introduction

The systematic improvement of the environmental performance of industrial products is a core element of good governance and good business. Improving the overall environmental performance of products is envisaged as one of the most important strategic goals and objectives in many company policies. Drivers for that can be found in an increasing number of environmentally aware consumers, asking critical questions about the life cycle of a product (e.g. "Do I buy an end-of-life problem if I choose your product?" – "What is the environmental performance of your product?"). Furthermore existing as well as upcoming European and international regulations e.g. the EU WEEE directive [1] and the End of Life Vehicle directive [2] among others are alerting companies not only to specifically consider the environmental stakeholder requirements but also significant environmental aspects of their products. As a consequence the product design and development processes within the companies including the technological innovation processes have to be adapted to the new requirements. This paper shows one way how to do that.

## 2 Objectives

Main questions in many product improvement situations are: How can we make sure to do the right thing when improving a product environmentally? How can we achieve the legal compliance and how can we meet the requirements from our customers? The objective of this paper is twofold - describing a systematic procedure of implementing ECODESIGN in a company and secondly giving a real case example to demonstrate the application of the systematic procedure.

The presented ECODESIGN procedure was developed by Wimmer et al [3] and consists of twelve steps for integrating significant environmental aspects of a product and environmental issues resulting from the stakeholder requirements into product design and development. To demonstrate the application of the twelve step approach an example of a redesign task in a Korean car manufacturer is given as the case study in the latter part of this paper.

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# 3 Methods

Implementing ECODESIGN always aims at improving overall performance, in particular environmental performance, of a product. A roadmap shown in Figure 1 is the basis for the twelve step approach. The roadmap indicates that possible areas for improvement are derived from the environmental stakeholder requirements as well as from significant environmental aspects of a product. ECODESIGN tasks or ideas are derived from the identified possible improvement areas. The ECODESIGN tasks are then fed into the product design and development process to improve a product. Lastly the environmental performance of the redesigned product, now “ecoproduct”, is communicated to the market.

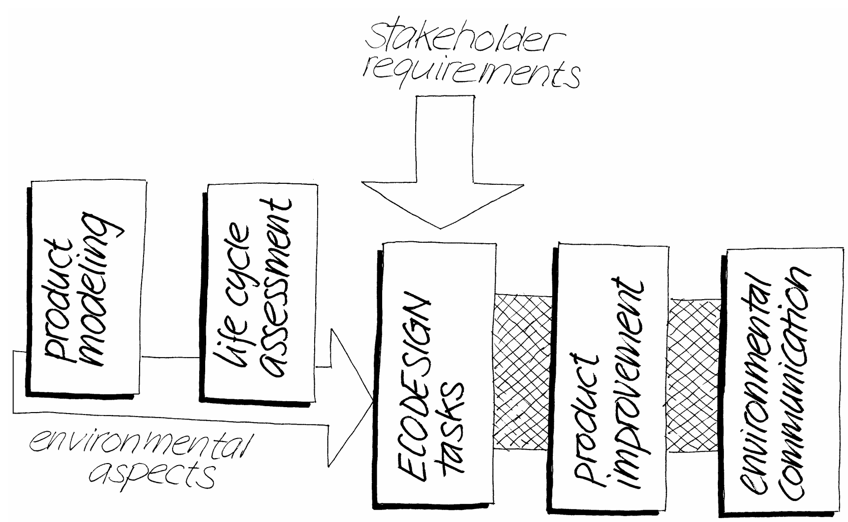


Figure 1. Roadmap for implementing ECODESIGN [3]

Table 1 displays detailed explanations of the twelve step approach to implementing ECODESIGN outlined in the roadmap. Once a product for redesign has been chosen, environmental parameters are identified for the analysis of the stakeholder requirements using Environmental Benchmarking and Environmental Quality Function Deployment [4]. These environmental parameters are then matched to the corresponding environmental improvement strategies. The analysis of significant environmental aspects of a product using either Life Cycle Assessment (according to ISO 14040 or simplified version of full LCA) or the ECODESIGN PILOT’s Assistant [5], however, directly generates the environmental improvement strategies. For transforming the environmental improvement strategies into the ECODESIGN tasks or target oriented design changes the ECODESIGN PILOT [6] is used. The ECODESIGN tasks are then translated into the target product specifications.

Table 1. Twelve steps for implementing ECODESIGN in industry [3]

| Step | Leading questions | Tasks |
|---|---|---|
| **1** | What product is to be redesigned? | Describing the reference product with environmental parameters. |
| **2** | What are the stakeholder requirements? What is expected from the product? | Performing Environmental Quality Function Deployment. |
| **3** | What are the strengths and weaknesses compared with the competitors products? | Environmental Benchmarking with the competitor's products. |
| **4** | What are the significant environmental aspects of the reference product throughout its entire life cycle? | Applying the ECODESIGN PILOT's Assistant or performing Life Cycle Assessment and interpretation of results. |
| **5** | How to combine stakeholder requirements and significant environmental aspects into improvement strategies? | Deriving common ECODESIGN improvement strategies. |
| **6** | Which ECODESIGN guidelines should be implemented in the product? | Applying ECODESIGN PILOT's checklists to determine redesign tasks. |
| **7** | What are the environmental product specifications to start with? | Starting product improvement. |
| **8** | How to modify the functional structure of the product? | Adding new functions to and/or modifying functions of the reference product. |
| **9** | How to generate new ideas for the functions of the product? | Performing creativity session and/or searching for patents. |
| **10** | How to generate and select the best product concept variants? | Assembling ideas corresponding to each function of the redesigned product concepts and evaluate them against criteria. |
| **11** | How does the improved product look like? | Continuing embodiment design and layout, prototyping and testing. |
| **12** | How to communicate the environmental improvements of the product to the market? | Performing Environmental Product Declaration or self declared environmental claims. |

Even in large companies there are often uncertainties how to proceed when aiming at integrating the environmental requirements into product design and development. With the systematic approach outlined in steps 1 to 7 in Table 1 the often new topics of the environmental requirements in product development can be developed for the engineers and designers.

In the following section this approach will be followed up to the identification of the target specifications for the redesign process. It will be worked out how to systematically derive those specifications. Actually doing the redesign of a product or component can be seen as business as usual for product development. The key issue is to identify the "right things to do" – or the most important target specifications.

# 4 Implementing ECODESIGN – a case study

Together with the ECODESIGN team of a major Korean car manufacturer the ECODESIGN of a car component has been implemented. A fuel tank unit has been chosen for the case study. The fuel tank unit consists of the body shell, the heat protector and reinforce, the module fuel pump, the pad as well as other assembly components (see Figure 2). The twelve step approach up to step seven has been applied to the ECODESIGN of the fuel tank unit and details of each step are described in the following.

Figure 2. Fuel tank unit

## 4.1 Modelling with environmental parameters

As a first step environmental parameters have to be identified and the product (or component) chosen for redesign has to be modelled using these parameters. The rationale behind the product modelling with the environmental parameters is to select environmentally significant design parameters of the product. For this product modelling step the generic parameters given in Wimmer et al [3] can be used, and product or component specific parameters have to be added. The relevant environmental parameters for the fuel tank have been identified (see Table 2).

Table 2. Environmental parameters for a fuel tank unit

| | **Environmental parameters** |
|---|---|
| **General parameter** | Weight |
| | Volume |
| | Life time |
| | Functionality |
| | Number of parts |
| | Supply parts env. performance |
| **Use of raw materials** | Materials used |
| | Problematic materials |
| **Manufacture** | Production technology |
| | Production waste |
| | Air, Water, Soil emission |
| **Distribution** | Type and material of packaging |
| | Transportation |
| **Product use** | Usability |
| | Energy consumption |
| | Waste(in use) |
| | Air, Water, Soil emission (in use) |
| | Noise and vibrations |
| | Maintenance |
| | Reparability |
| **End of life** | Fasteners and joints |
| | Time for disassembly |
| | Rate of reusability |
| | Rate of recyclability |

## 4.2 Performing Environmental Quality Function Deployment (EQFD)

The second step consists of identifying the stakeholders' requirements (e.g. EU directives) and to translate these requirements into relevant environmental (design) parameters. For instance, if a stakeholder would require "easy to carry" for a certain product obviously "product weight", "product volume" and even "materials used" would probably be the relevant environmental parameters. To do this translation of the stakeholder requirements into the design parameters in a systematic way EQFD was used (see Figure 3).

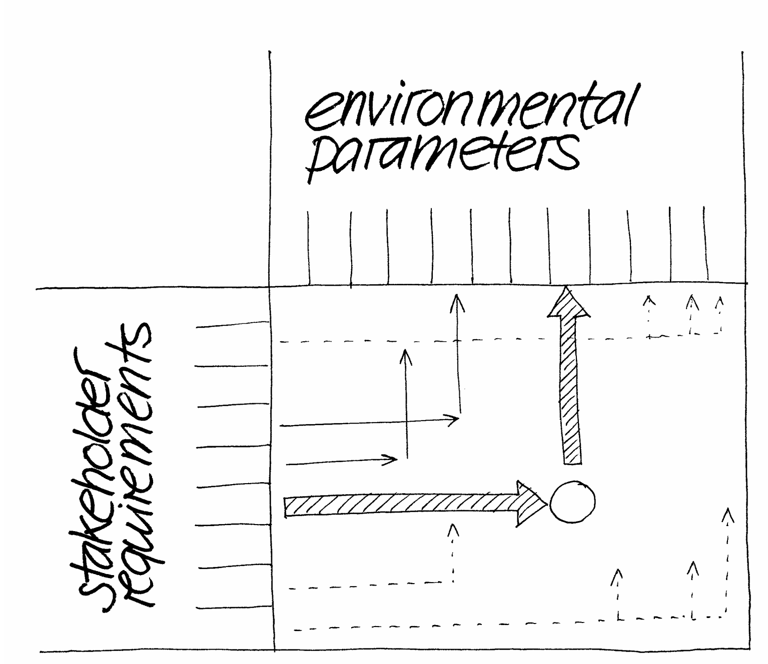


Figure 3. Translating stakeholder requirements into environmental parameter with EQFD [3]

Performing EQFD for the fuel tank unit resulted in the following three most relevant environmental parameters:

- Supply parts environmental performance
- Materials used
- Rate of recyclability

## 4.3 Environmental Benchmarking (EBM) with competitors' products

In order to evaluate own design solutions against other available designs the environmental (design) parameters are used once again. With EBM those parameters are highlighted in which the own product has weaknesses compared to the competitors solution. The numbers in Table 3 indicate the performance of the different products (5 indicates "very good", 1 stands for "very bad"). The most relevant environmental parameters are those with the biggest gap between own and the competitors' performance.

Table 3. Environmental Benchmarking of the fuel tank against the competitor's products

| **Environmental benchmarking** | **Environmental parameters** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | general | | | | | | material | | manufacture | | | .. |
| | weight | volume | life time | functionality | number of parts | supply parts env.performance | materials used | problematic materials | production technology | production waste | air, Water, soil emission | .... |
| **fuel tank A (plastic) (own product)** | 4 | - | - | 3 | **1** | - | 5 | 3 | 5 | 3 | 3 | .. |
| **fuel tank B (steel)** | 3 | - | - | 3 | **1** | - | 4 | 1 | 3 | 1 | 1 | .. |
| **fuel tank C (plastic)** | 5 | - | - | 3 | **5** | - | - | - | - | - | - | .. |

Final environmental parameters generated from EBM are the following:

- Number of parts
- Fasteners and joints
- Rate of recyclability

Step three completes the evaluation of the stakeholder requirements. Customers, laws, voluntary agreements (such as eco labelling schemes) are covered and even competitors performance is included. The relevant design parameters are identified and redesign activity could start. Still missing, however, are the significant environmental aspects – those are discussed below.

## 4.4 Screening Life Cycle Assessment (S-LCA)

To develop a good understanding about the significant environmental aspects of the fuel tank unit an S-LCA has been carried out (see Figure 4). The system boundary therefore includes the use stage with the fuel consumption relating to the weight of the fuel tank. The total driving distance of a car was assumed with 140,000 km.

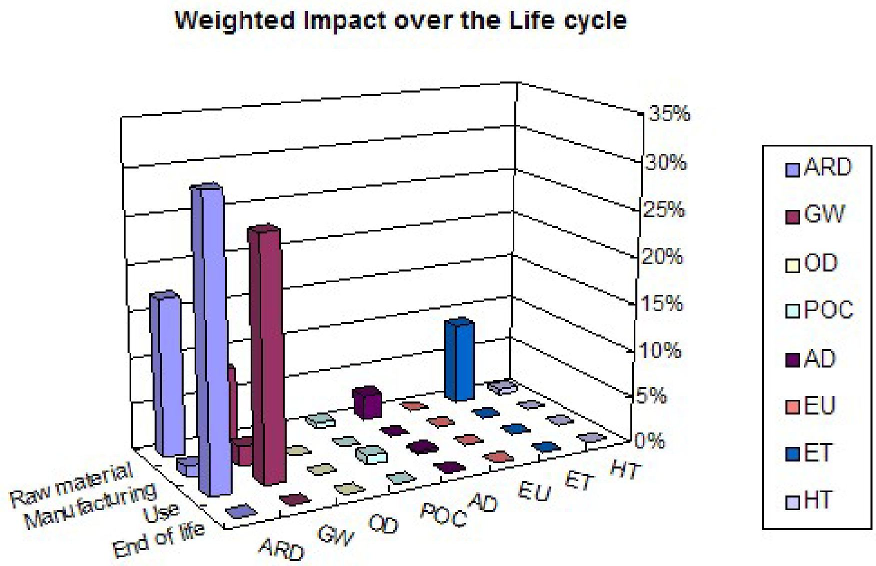


Figure 4. Weighted environmental impact for the fuel tank unit

The results from the S-LCA show that the use stage is the most dominant life cycle stage causing 58% of the weighted environmental impact of the fuel tank unit. Second important is the use stage of raw materials with 39%. The first impact is only caused by the weight related fuel consumption occurring during the total driving distance and therefore linked exclusively to the weight of the fuel tank unit. The second impact is caused from the materials used in the unit and was further investigated. The contribution of the weighted environmental impacts over the different parts is given in Table 4.

Table 4. Weighted environmental impact of materials used in the fuel tank unit

| Parts | Material | Contribution(%) |
|---|---|---|
| Body shell | HDPE | 45.12% |
| | Nitrogen | 17.92% |
| Heat protector and reinforce | cold rolled steel | 12.18% |
| Module fuel pump | Pump | 11.51% |
| Pad | Rubber | 7.64% |
| Other assembly components | POM | 2.17% |

The body shell (including its coating) and the heat protector and reinforce are the most significant parts of the fuel tank unit contributing most to the environmental impacts during the first stage in product life cycle (use of raw materials).

The environmental impacts caused during the use stage and caused during the use of raw materials require ECODESIGN strategies for improvement such as “Reducing material inputs” and “Selecting the right material” following the logic of the ECODESIGN PILOT [6].

## 4.5 Deriving common ECODESIGN improvement strategies

Finding the ECODESIGN improvement strategies means first combining the stakeholder requirements with the environmental aspects and then linking the identified environmental parameters with the ECODESIGN strategies (see Table 5). For each environmental parameter there is a corresponding ECODESIGN improvement strategy in the ECODESIGN PILOT. How the environmental parameters match with the improvement strategies is described in Wimmer et al [3].

Table 5. Deriving ECODESIGN improvement strategies from stakeholder requirements and environmental aspects

| | **Environmental parameters** | **ECODESIGN improvement strategies from the ECODESIGN PILOT [6]** |
|---|---|---|
| **EQFD** | Supply parts environmental performance | Selecting the right materials |
| | Materials used | Selecting the right materials |
| | Rate of recyclability | Recycling of materials |
| **EBM** | Number of parts | Reducing material inputs |
| | Fasteners and joints | Improving disassembly |
| | Rate of recyclability | Recycling of materials |
| **S-LCA** | -- | Reducing material inputs<br>Selecting the right materials |

## 4.6 Applying the ECODESIGN PILOT's checklists

Since every ECODESIGN improvement strategy in the ECODESIGN PILOT comes with a checklist, according to Table 5, four different checklists had to be worked out. With each checklist a design assessment is performed and those ECODESIGN measures most relevant and not fulfilled yet for the product are identified. The way to perform this design assessment is described in [7]. The resulting ECODESIGN measures from that design assessment of the fuel tank unit are listed in Table 6.

Table 6. ECODESIGN measures to implement for the fuel tank unit

| | **ECODESIGN measures from the ECODESIGN PILOT [6]** |
|---|---|
| 1 | Use of materials with a view to their environmental performance |
| 2 | Avoid or reduce the use of toxic materials and components |
| 3 | Reduce material input by integration of functions |
| 4 | Use easily detachable connections |
| 5 | Ensure labelling of materials conforming to standards |
| 6 | Ensure simple extraction of harmful and valuable substances |
| 7 | Make possible extraction of process materials and unavoidable harmful substances |

## 4.7 Identifying target specifications for product improvement

A workshop with the design team and working through the ECODESIGN measures in Table 6, brought up the following target specifications for improving the product (see Table 7).

Table 7. Target specifications for the fuel tank unit

| | **Target specifications for product improvement** |
|---|---|
| 1 | Reduce the total weight of the fuel tank unit by optimizing body shell thickness |
| 2 | Reduce the number of parts |
| 3 | Reduce the number of different materials |
| 4 | Use recycled HDPE for the body shell |
| 5 | Avoid the hazardous materials as required from ELV (Hg, Cd, Pb, $Cr^{6+}$) |
| 6 | Change fasteners and joints to snap-fit |
| 7 | Integrating the suction pipe functions into the fuel pump |
| 8 | Label parts and materials exceeding 50 g weight |
| 9 | Change the design for easy fuel extraction at the end of vehicles life |

The target specifications are currently under review by the car manufacturer for possible application to the design in the next generation of fuel tank units.

# 5 Conclusion

A systematic procedure of implementing ECODESIGN in a company for product design and development and its application to a car component, fuel tank unit, has been presented here. The twelve step approach is a detailed step by step approach for implementing ECODESIGN. It is based on integrating the environmental improvement strategies stemming from the stakeholder requirements as well as significant environmental aspects of a product into product design and development. Checklists belonging to improvement strategies were used to identify ECODESIGN measures. The measures are in turn translated into ECODESIGN tasks and then target specifications.

The application of the proposed approach to the fuel tank unit of a car indicates that practical target specifications of the fuel tank unit were derived systematically. This indicates that the twelve step approach can be a viable ECODESIGN method for manufacturers to integrate the environmental aspects of their products into their product design and development processes.

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