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The Eco-Value Analysis – An Approach to Assigning Environmental Impacts and Costs to Customers' Demands

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1. Introduction

Design for environment faces a conflict: On the one hand, products must be environmentally friendly; on the other, products must conform with the market [Dannheim 1999]. From the view of the customer, the value of a product is assessed by the supply of functions based on its grade of fulfilment [Birkhofer 2003]. The customer does not buy components; s/he buys functions. The existence of a products' function increases its market value, but every function leads to costs for the manufacturer and the customer and causes environmental impacts within the whole life cycle from materials' production to end-of-life.

Measures that improve the products' market value often lead to increased environmental impacts, since every product function causes some. Especially in the field of active products, environmental impacts resulting from use processes are very dominant: Life cycle assessments (LCA) of products, such as refrigerators, television sets, washing machines or vacuum cleaners, show that up to 90% of the total life cycle-related environmental impacts occur during the use phase [Dannheim 1997, Hauschild 1997]. Therefore, the realization of functions with environmentally relevant use processes must be weighed up carefully.

But creating the "ecological shelf-warmer" and bringing it to the market must also be discouraged, since such a product causes environmental impacts during production and at the end-of-life without ever being sold and used [Wiese 2000]. To ensure a product's conformity with the market, the customers' demands must be fulfilled in an optimal way. Therefore, the realization of successful products, which are environmentally friendly as well as conform with the market, requires a holistic view of technological, ecological and economical characteristics of products and their processes within the whole life cycle. It is important to identify the best compromise between the fulfilment of customers' demands, environmental impacts and costs. The questions to be answered are:

- "Which environmental impacts will be omitted if the regarded function were not realized?"
- "Which costs could be saved, if a certain function were left out?"

To answer these questions, the designer must be supported in analyzing the relationships between environmental impacts, costs and customers' demands. To achieve this, functions will be set against the environmental impacts and costs resulting from processes within the whole life cycle. In this approach technical, ecological and economical aspects are combined in the developed Eco-Value Analysis, which is an extension of the conventional value analysis.

2. Objectives of the Eco-Value Analysis

The conventional value analysis aims at the identification of starting points for the improvement of productivity, benefit and quality [Pahl 1996]. Its goal is the improvement of the value of the product [Ehrlenspiel 1998]. The Eco-Value Analysis extends this objective by environmental aspects. It aims at a holistic approach considering technical, environmental and economical aspects (Figure 1). This is achieved by analyzing the product's components according to environmental impacts, costs from different points of view and customers demands in the context of the product's functions. Based on the analysis, the importance of functions for the customer, environmental impacts and costs of functions face each other.

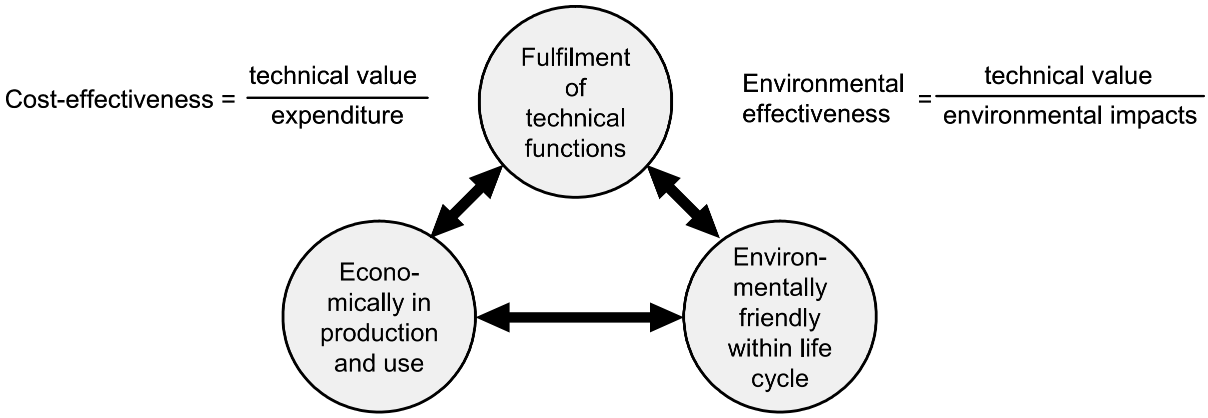


Figure 1. Cost effectiveness and environmental effectiveness

3. The Eco-Value Analysis

The Eco-Value Analysis is derived from the value analysis according to EN 12973 [EN 12973 2002] with the aim of considering environmental and economical aspects. Besides ensuring the products' function, the designer is confronted with a large amount of requirements, such as 'design for production' or 'design for ease of assembly', 'cost reduction' and 'quality improvement' in a field of decreasing periods of development. In this situation, there is not much time for considering requirements, resulting from design for environment. These days, the conventional value analysis is widespread in industry. In order to improve its acceptance and to spread the application of the Eco-Value Analysis, the well-known value analysis was selected as the basis. The subject of the Eco-Value analysis is an existing product or a new product. Within the product development process, the method can be applied in the early phases of clarifying the task and in conceptual design.

3.1 Functions

Functions can be structured according to function type and class [Birkhofer 2003]. The function type consists of the practical function and added function, which can be further divided into prestige gains and individual edification [Oberender 2003]. The function class is made up of the main function, sub-function and undesirable function (Figure 2).

In the case of a coffee maker, the main practical function is 'brewing coffee'. Sub-functions are, e.g., 'storing water' and 'separating coffee from coffee grounds'. Examples of added functions are 'modern design' and 'bright surface'. The number of sub-functions and the effort of their realization to fulfil a certain main function is a measure for the simplicity of a product [Birkhofer 2003].

Functions are realized by components. Every component and its accompanying processes cause environmental impacts and costs in production, in use and in end-of-life. With the aim of developing products that are successful on the market, economical in production and use, and environmentally friendly within the whole life cycle, the realization of each function must be weighed up carefully.

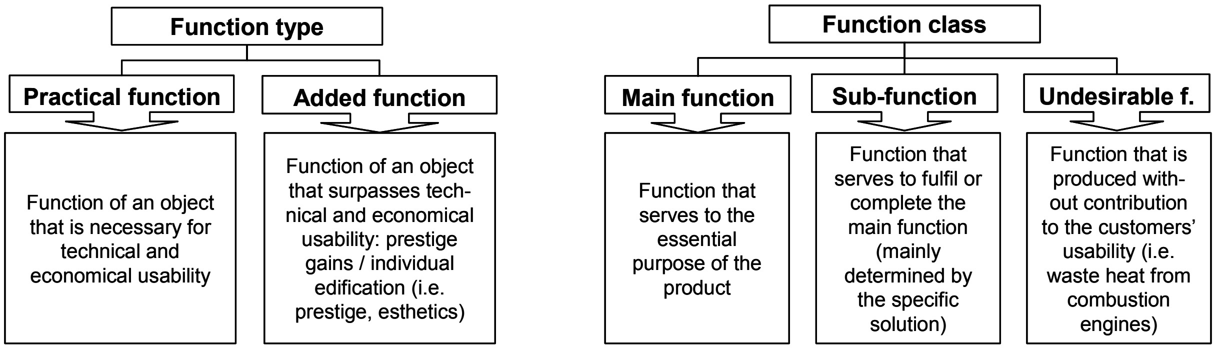


Figure 2. Function type (left) and function class (right)

3.2 The Matrix of Eco-Value Analysis

Figure 3 shows the matrix of the Eco-Value Analysis. The first column in the left section serves to list the functions of the product (4). In the second column, the function class is noted (5). Components and processes are written down in the middle section of the matrix (1). Three columns for each component serve to list the allocation of the component to functions (7), environmental impacts (2) and costs (3). Additionally, the calculated environmental impacts (8) and costs (9) related to the functions' allocations are written down in the cells of each column. In the right section, the assessment of the importance to the customer (6), the environmental impacts (10) and the costs (11) for each function is carried out. The last row serves to check the calculations (12). In the next section, the procedure for carrying out the Eco-Value Analysis is described according to the numbers in Figure 3. The numbers in Figure 3 correspond to the sequence of the process.

Function (4)	Class (5)	Component/process (1)												Assessment of function		
		Coffee pot			Time switch			Heating element			...					
		Alloca-tion [%] (7)	EI `99 [Pt] (8)	Costs* [€] (9)	Alloca-tion [%]	EI `99 [Pt]	Costs* [€]	Alloca-tion [%]	EI `99 [Pt]	Costs* [€]	...	...	...	Impor-tance for customer (6)	Sum of EI `99 [Pt] (10)	Sum of Costs* [€] (11)
			0,32 (2)	3,50 (3)		0,35	1,48		0,08	1,21						
Heating of water	MF							80 %	0,06	0,97	...	...	...	8,5	4,08	1,32
Storing of coffee	MF	50 %	0,16	1,75							...	...	...	6,5	0,37	1,63
Switching energy	NF				15 %	0,05	0,22				...	...	...	4,4	0,34	0,97
Timing of scald	NF				70 %	0,25	1,04				...	...	...	0,6	1,06	1,03
Keeping coffee warm	NF	15 %	0,05	0,53				20 %	0,02	0,24				3,4	1,17	0,81
Pleas. design (coffee pot)	NF	15 %	0,05	0,53										5,0	0,11	0,73
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sum: (12)		100 %	0,32	3,50	100 %	0,35	1,48	100 %	0,08	1,21	...	...	...	100 %	1,64	14,60

* data for manufacturing costs are estimated

Figure 3. The matrix of Eco-Value Analysis

3.3 Procedure

3.3.1 Product and process analysis

The procedure starts with a detailed analysis of the product and its processes with the aim of structuring the product into reasonable components (**step 1**). In the case of improving an existing product, this step is supported by analyzing parts lists, production structures and further product documentations. In case of analyzing a new product, the components can be deduced from function structures within conceptual design.

Step 2 serves to determine environmental impacts for each component and process. Eco-indicator '99 is suitable to estimate environmental impacts of components and processes within the design process. It is an easy-to-use method, which was developed for an appliance by designers within the design

process [PRé Consultants 2004]. Using enlarged databases, e.g. the database of SimaPro, about 1.600 materials and processes can be assessed using Eco-indicator ’99-values. But other methods are suitable for carrying out life cycle impact assessments (e.g. CML 2, EPS 2000 or full LCA). In the case of a developing a new product, estimations based on the data of forerunner products are suitable.
In **step 3,** the costs of components and processes are calculated. Dependent on the point of view, different cost types can be regarded. From the viewpoint of the manufacturer, the production costs of components or the achievable profit for each function can be considered. The latter is calculated by considering the turnover of functions related to the production costs. From the user’s point of view, costs for purchase of a function can be distinguished from costs that emerge within the whole life cycle from purchasing and using a function until its decommissioning. In the first case, only purchase costs, and in the second case, the total life cycle costs are regarded.

3.3.2 Identification and weighting of functions

Now the product’s functions have been identified (**step 4**) and allocated to function classes (**step 5**) (see section 3.1). Technical functions can be deduced from function structures [Birkhofer 2003, Pahl 1996]. It is reasonable to supplement the technical functions with functions from the viewpoint of the customer (e.g. added functions like ‘bright surface’). The determination of the importance of each function to the customer (**step 6**) is based on a market analysis or questionnaire. If no data are available, a pair-wise comparison [Birkhofer 2003] carried out with experts is suitable for weighting.

3.3.3 Allocation of components and processes to functions

The allocation of components to functions in **step 7** is the most important step in carrying out the method. The aim is to determine the share of the regarded component to realize the functions. The sum of each column is 100 %. The allocation of components to functions is estimated. Besides components, use processes and its environmental impacts (respectively costs) must be allocated to functions. If the use process corresponds directly with one component, it is reasonable to assign the impacts directly to the component. But there are use processes, which can not be assigned to components, e.g. cleaning or transportation processes. In this case, it is reasonable to handle these processes like components and to list the values in separate columns in step 1.

3.3.4 Calculation of environmental impacts and costs

In **steps 8** and **9** the environmental impacts and costs are calculated in respect to the allocations of the regarded component to the functions noted in column (8) and (9). **Steps 10** and **11** serve to sum up environmental impacts and costs for each function. Finally, in **step 12**, a check of the calculation is carried out by summing up environmental impacts and costs.

4. Representation and processing of the results

4.1 Portfolios to set the importance to the customer against environmental and economic values

Two portfolios serve to visualize the results of the Eco-Value Analysis (Figure 4). The portfolio on the left side of the figure compares the relative amount of the environmental value to the importance of each function to the customer. The relative environmental value is the reciprocal of the environmental impacts of the regarded function relative to the overall environmental impact. Similarly, the portfolio on the right side compares the economical value with the importance to the customer. In the case of economic value, different views on costs are possible (see section 3.3.1). The values for each function will be noted in these 2D-portfolios. This 2D-viewing is necessary because it is not sensible to note and read off values from a 3D-portfolio.

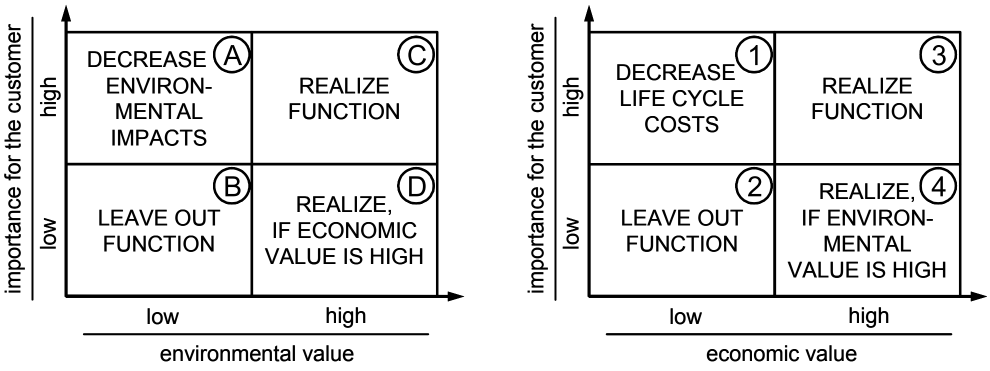
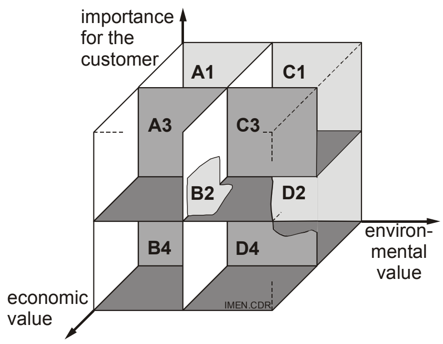


Figure 4. Representation of results and recommendations (isolated view)

Main functions which serve the original purpose of the product, e.g. heating of water in a coffee-maker, can not be left out. The environmental impacts and costs of these functions should be decreased by selecting more efficient physical effects or working principles and more suitable operation procedures. In the case of a coffee-maker an immersion heater could be used instead of a flow-type heater, or the insulation of the heater could be improved.

4.2 Strategies for designing environmentally and market friendly products

A holistic view is needed in order to develop products which are environmentally friendly as well as conform with the market. To achieve this, combinations of the results of the two portfolios shown in Figure 4 must be regarded. Dependent on different combinations, strategies for designers can be deduced (Figure 5).



Field	Cust. imp.	Env. value	Econ. value	Strategy
C3	high	high	high	realize function
C1	high	high	low	reduce costs and realize function
A3	high	low	high	reduce env. impacts and realize function
A1	high	low	low	no recommendation [1]
D4	low	high	high	realize function if customer will pay for it [2]
D2	low	high	low	leave out function
B4	low	low	high	leave out function
B2	low	low	low	leave out function

[1] depends on the amount of importance for the customer and the effort to decrease env. impacts and costs
[2] depends on the customers' willingness to pay (more detailed information is needed)

Figure 5. Strategies for designers (holistic view)

4.3 Example of use: Coffee maker

A coffee maker for household use was analyzed. In this case study, the analysis was carried out from the view point of the manufacturer. Only some results are presented here. As one result, the functions 'switching energy, 'easy use', 'anti drip', 'easy cleaning' and 'protection against burning' are located in field C3 and should be realized. Due to the high environmental and economic value of the components which serve to realize these functions, no design improvements are necessary.

Design improvements exist in leaving out the functions 'timing of scald' (B2), 'flavour-function (D2) and 'decalcify-function' (D2), since the customers' importance and the environmental or economic value are low. The coffee pot is allocated to C1. Accordingly, it should be realized after reducing manufacturing costs. Here, this could be achieved by making the lid just one part instead of two.

There is no recommendation given for the function 'aesthetic design' of the coffee maker' (A1). Despite this, a pleasant design for the coffee maker should be realized, due to the high importance of design characteristics in the real buying decision. But the environmental impacts and manufacturing costs concerning the design of the coffee maker must be reduced. The water level display is located in

D4, so this recommendation for realization is limited. However, its environmental and economical values are very high, and nearly all the coffee makers of the competitors have a water level display. Thus, the best compromise would be to include this function in order to improve the marketability of the coffee maker.

5. Conclusions and outlook

The eco-value analysis supports the designer in analyzing the relationships between customers' demands and the resulting environmental impacts and costs from different points of view. The method results in the environmental and economical relevance of the customers' demands with the aim of identifying environmentally critical customer demands. Concerning cost aspects, different points of view for the manufacturer and for the customer can be regarded and analyzed. Based on this, different strategic objectives can be pursued. Against this, environmental impacts are independent of different viewpoints.

Conflicts are pointed out. Based on the accompanying portfolios, recommendations to support decisions are given. From a holistic point of view, strategies for designing products, which are environmentally friendly, cost efficient and conform with the market can be given. The method supports the strategic decision of the company and its marketing in the field of developing environmentally friendly products in conformity with the market.

In further steps, additional possibilities for processing and representing the results will be analyzed. Besides this, the implementation of the method into a software tool is planned, in order to minimize the effort in estimating environmental impacts of components and calculating environmental impacts and costs allocated to functions.

Acknowledgement

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