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EFFECTIVE AND EFFICIENT APPLICATION OF ECO-QFD

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1. Introduction

The awareness of the importance of environmental impacts of products is steadily growing. In August 1996 the EN ISO 14001 "Environmental management systems - Specification with guidance for use" was passed. Parallel to this, a second "standard", the EU Eco-Management and Audit Scheme (EMAS), was developed. Since then many companies all around the world have become certified according to these standards, which formalize the process of integrating environmental issues within companies. The next step is to embed environmental issues next to those of quality and cost in the product development process.
To achieve this, steps like the ISO TR 14062, the Integrated Product Policy (IPP) and the directive on the environmental design of electrical and electronic equipment (EEE), as well as the forthcoming proposal for a directive establishing a framework for the setting of Eco-design requirements for Energy Using Products (EuP) have already been or will be taken.
Additionally, for some companies it is a problem that environmental soundness does not automatically imply market success and they often end up designing ecological shelf-warmers [Dannheim 1999]. If a product is successful on the market depends mainly on its added value [Stevels 2000], the additional costs for the customer (Figure 1) and the "instrument" used.

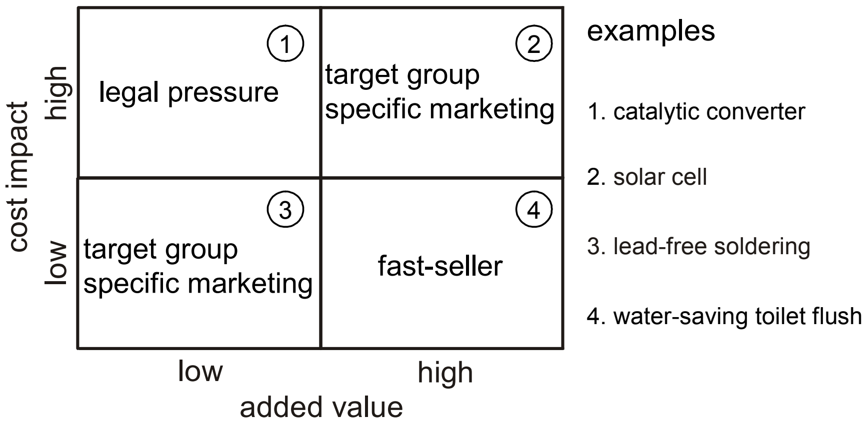

Figure 1. Different "instruments" for market success

To fulfill all directives and standards and ensure market success, methodical support is required which integrates environmental and market issues in a product. One method capable of this is the Eco Quality Function Deployment (Eco-QFD) [Masui et al. 2003, Ernzer et al. 2003, Zhang 1998], which is a modification and extension of QFD [Akao 1990]. Eco-QFD aims at products in categories 2 and 4 in Figure 1, since it helps balance and trade-off between environmental and market issues.

2. QFD and Eco-QFD

QFD is a method which orients the whole product development process towards the customer requirements with the goal of maximizing the quality. Quality, in this case, means fulfilling optimal customer requirements concerning function, reliability, delivery time, price, consultation, support, etc.
The core element of the QFD, the house of quality, has the structure shown in Figure 2 . On the left side, the customer correlation matrix is used to indicate how the customer requirements hinder or support each other. This part does not usually exist in the traditional QFD. The idea to integrate this “garage” was born by looking at environmental demands which often contradict each other. For instance, the aim is to reduce the amount of copper for environmental reasons (high impact), but copper is the best conducting material. Next to the left triangle, the ‘what’ elements (customer requirements) are collected and weighed by certain factors. In the upper part, the ‘how’ elements (product characteristics) derived from the ‘what’-elements are listed. In the roof of the house, the way in which the ‘how’-elements support or hinder each other when achieving the ‘what’-elements is assessed (technical correlation matrix). In the center of the house, the quality table is filled out using numbers indicating how strong the ‘how’-elements are related to the ‘what’-elements and can, therefore, contribute to their fulfillment. In the lower part of the house, the importance of all ‘how’-elements is calculated. This is done by multiplying the correlation value with each weighting factor (row) and adding up the whole column.

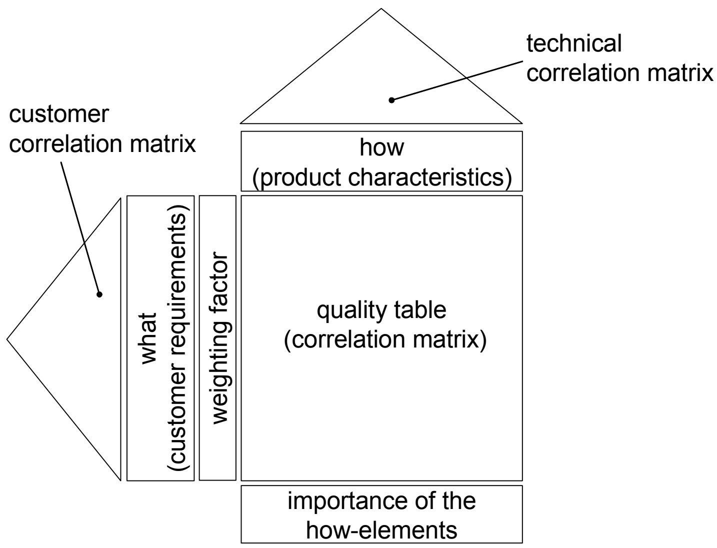

Figure 2. Structure of a HoQ (here the 1st HoQ)

Besides the classical QFD approaches, extended environmental approaches exist which combine environmental issues with customer requirements. The HoQ is extended by directly adding environmental to customer requirements within the quality table [Masui et al. 2003] or by adding an additional House of Environment (HoE) [Ernzer et al. 2003].
In general, a major drawback of QFD is its high effort for carrying out. In extending QFD to an Eco-QFD to increase the environmental quality of a product, this effort is increased even more. Therefore, it often exceeds the limited resources of product development projects. Very little attention has been paid to the question of how to carry out a QFD effectively and efficiently. This is also underlined by the Japanese Industrial Standard on QFD [JIS 2004], which describes very little how to effectively and efficiently carry out QFD. Thus, the goal of this paper is a first step to systematically analyze the QFD method and its process to identify optimization potential and to improve its efficiency and effectiveness.

3. Approach

In a first step the QFD process is analyzed using 9 elementary method activities. These elementary activities include activities like search, generate, evaluate, compare, combine, and divide. By doing so it is possible to systematically analyze the process and identify, e.g., superfluous, ineffective or mandatory activities. This analysis is visualized, similar to the functional structure of a product, in the *e*MAP (***e***lementary **m**ethod **a**ctivities for design **p**rocesses) where all activities, their arrangement, as well as their relationships can be seen [Ernzer et al. 2004]. In the *e*MAP (Figure 3), the beginning of the QFD process is shown: the search for product requirements (the selection of environmental requirements has been omitted due to its similarity).

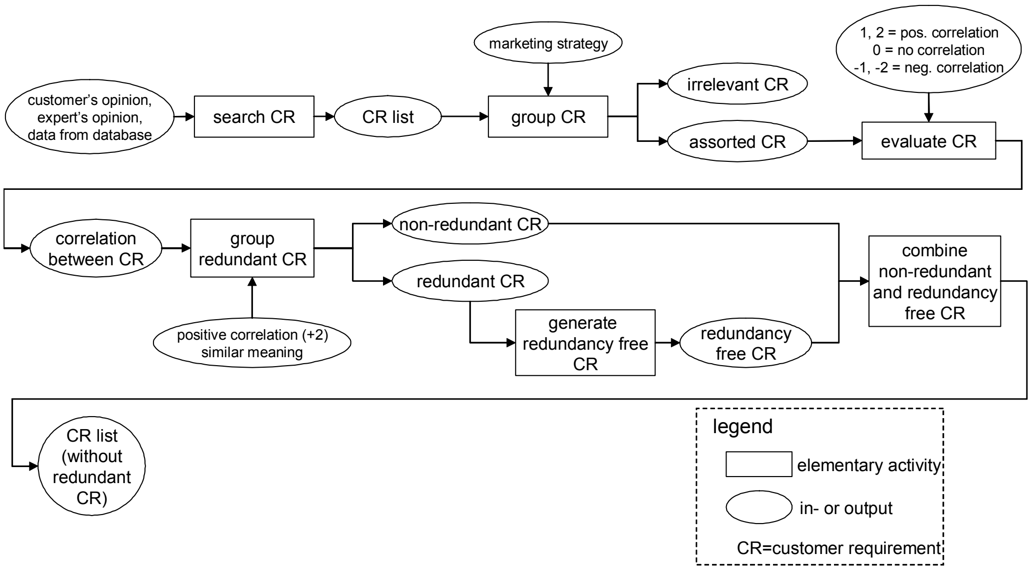

Figure 3. eMAP of the QFD process 'search product requirements'

Using *e*MAP it is possible to analyze a method, identify its core "function" and systematically improve the method, similar to a product using a functional structure. Furthermore, it is possible to add, omit or vary single activities. As in optimizing a functional structure, different variation strategies have been developed, e.g., changing the method (system) boundary, changing the order of activities, condensing or splitting activities, and harmonizing method fragments used for similar activities (for more details on *e*MAP see: Ernzer et al. 2004). The results of this analysis were used to optimize and modularize the Eco-QFD. One result was that only 6 out of 44 possible steps are mandatory to carry out a basic Eco-QFD. Therefore, the effort for carrying out a basic Eco-QFD can be tremendously reduced. This does not mean that the other steps are not practical, only that they are not essential.

Elementary activity	Potential problem mode	Potential problem effect	Potential problem cause	actual elementary activity					Recommended changes (action to be taken)
				Current controls/ tests	Occurrence	Severity	Detection	Risk priority number (RPN = O*S*D)	
Evaluate CR and PC	Too much argumentation about unimportant scores	Consumes time inefficient	No awareness of the particular score's impact	Time limit per score	3	1	3	6	Allow a min/max score
	Appropriateness of score	Wrong score is given	No common understanding of the score's meaning	Definition of scores	3	1	3	6	Diversified definitions for different correlation types
	Existing correlation is not seen	No score is given	CR and PC have too many cross-links or is to complex	Check technical and customer correlation and their impacts	2	3	1	6	Automatic correlation check
	…	…	…	…	…	…	…	…	…

Figure 4. Method Activity Problem Mode and Effect Analyze (MAPMEA) of an QFD

After an *e*MAP has been established, a **M**ethod **A**ctivity **P**roblem **M**ode and **E**ffect **A**nalysis (MAPMEA - a modified FMEA with scores from 1-3) is used to identify problems which might occur during method use and to assess their impact on the method's results. This analysis is carried out for each elementary activity (Figure 4). From this table, it is possible to derive tips and tricks for the moderator or user. One drawback of MAPMEA is that it is only useful if it is filled out by experts who are very familiar with the methods to be analyzed. One result showed the problem of customers sometimes stating components and parts instead of functions as requirements; another problem is the difficulty in finding matching and measurable product characteristics to the requirements. Therefore, hints on how to define functions and product characteristics should be developed.

Both methods were used to identify improvement options of QFD to increase the effectiveness and efficiency of the application. Two of the so-found improvement options will be described in the next section.

4. Improved QFD

The two examples of suggested improvement options discussed in this section are not necessarily limited to the environmental part of the QFD and are, therefore, also applicable in a conventional QFD.

4.1 Minimal and Maximal Correlation

Through the MAPMEA it was found that, on the one hand, the weighting process of the demands in QFD often has a higher impact on the end results than the actual scoring in the quality chart. On the other hand, the discussions about the scoring in the quality table consume a considerable amount of time compared to the weighting. Therefore, the weighting should be carried out more thoroughly than the scoring. Furthermore, it was revealed that the QFD team often discusses whether a single score should be a 0 or 1 (1 or 3, and 3 or 9). Of course, these discussions often reveal interesting insights to the products, but after a certain point, these discussions are more about who is right than about the correlation itself. Such discussions seem never-ending and are not really goal-oriented. Therefore, it is suggested that it is possible to score minimum and maximum correlations within the quality table (Figure 5).

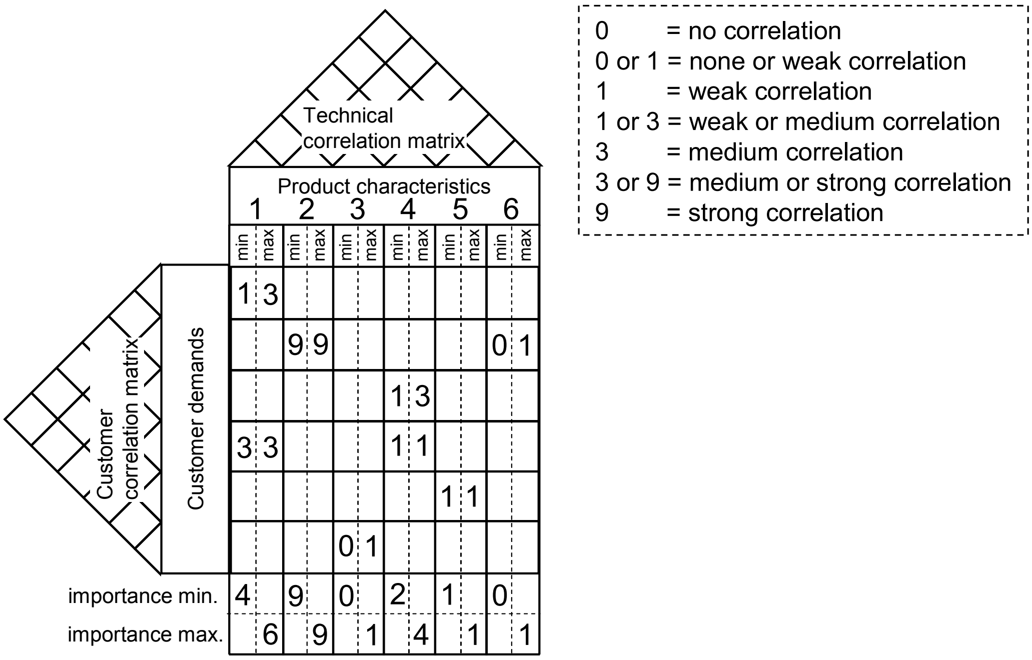

Figure 5. QFD with a Min and Max Correlation Score within the Quality Table (total importance is calculated without a weighting factor)

With this range of scores, a minimum and maximum total importance score is calculated for each product characteristic, so that the “never-ending” discussion is, if necessary, postponed until the final ranking. This has the advantage that the effect of the discussion on the final result can be directly seen and will only be carried out if necessary. As can be seen in Figure 5 only the rank of product characteristics #3 and #6 depend on whether the minimal or maximal score is chosen. However, since this decision is only about which of these characteristics should be ranked “least important”, it is nearly irrelevant and does not need to be discussed. Therefore, in this example none of the 4 min. or max. correlations need to be discussed until the final decision. Thus, less time is spent on useless discussions and can be invested on more important issues. Additionally, it is more likely that the decision for each score is based on a “real” group consensus, and therefore, no team member feels outvoted or ignored in the decision making process. This is especially important in carrying out Eco-QFD, since additional members, i.e. those from the environmental department, need to be integrated.

4.2 Quality Table Check

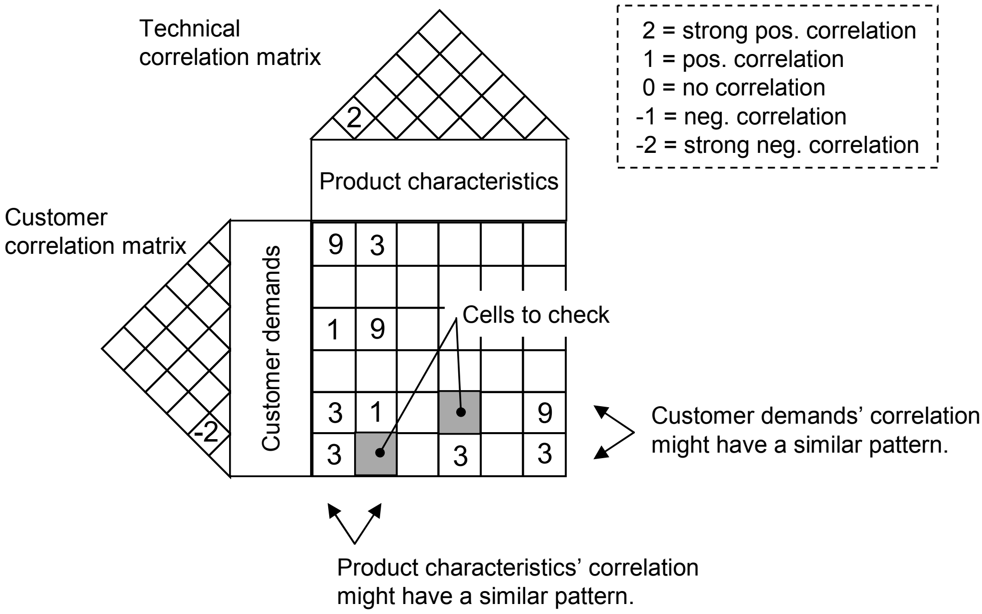

Figure 6. Verification of relative strengths using correlation matrices

The MAPMEA further revealed that, due to the high number of correlations within the quality table and the complexity of the product, existing correlations are sometimes overlooked. Thus, it would be helpful if a check could be carried out. By analyzing existing quality tables it was found that the technical and customer correlation matrix can be used by the team to verify the scoring within the quality table. A strong correlation between two customer requirements (or two technical characteristics) often results in the similar correlation pattern of the two requirements (or characteristics) within the quality table. This check is shown in Figure 6, where the grey shaded cells should be checked. This is a quick and easy way to crosscheck the completeness of the quality table, since this can easily be automated in a computer program, e.g. in excel using macros.

5. Conclusions

From the results above, it can be seen that even for a fully established and commonplace (in terms of research) method, it is still possible to identify improvement options by systematically analyzing the method. Using *e*MAP and MAPMEA the method developer is systematically guided by analyzing the method, understanding each activity within the method, and identifying possible improvement options. Two improvement examples found using these methods are explained in detail. These two improvements help to increase the efficiency and effectiveness of QFD, and therefore, the practicability within industrial design projects.

6. Outlook

To evaluate how effective and efficient the two suggested improvement options are, an empirical study is currently being carried out in the Laboratory for Design for Environment of Darmstadt University of Technology. In this study student teams apply the conventional and the improved QFD to two different products. To eliminate the influence of the products and the order in which the QFD are carried out, these two influencing factors are systematically altered throughout the study. For evaluating the overall effectiveness and efficiency of both QFD, a combination of subjective and objective measuring criteria are used. The students are interviewed by a standardized questionnaire, the requirements lists are rated and the duration for completing the QFD (improved or conventional) is timed. These results are analyzed and compared to evaluate the effect of the improvements.

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