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SELECTING METHODS FOR LIFE CYCLE DESIGN BASED ON THE NEEDS OF A COMPANY

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1. Introduction

Since 1996, the Collaborative Research Center 392 (CRC 392), consisting of 19 researchers from different departments at the Darmstadt University of Technology, has been working in the field of Design for Environment (). The goal of the research center is to support the product designer during all phases of the product development process, according to VDI guideline 2221. Many companies ask the CRC 392 for support in designing sustainable and marketable products. The problem is that life cycle design becomes a very complex task since the whole product life-cycle has to be taken into account [Schott et al. 1996]. Most designers in the industry do not have the knowledge and/or time to integrate (good) life cycle design principles in their day-to-day work. Thus, a methodical support of the designer is indispensable. For successful use of methods in life cycle design, it is essential to select and customize the methods carefully according to the needs of the company [Ritzen et al. 2001].

2. Goal of the research

Within six years of research, many new methods for life cycle design were developed by the CRC 392. In addition to these, many methods were being developed by researchers in all parts of the world. Therefore, choosing the right methods from this mass of methods is very difficult, since all methods have different advantages and disadvantages. Which is the right method depends on many aspects, such as the design phase, the product, and the task on which the designer is working. Even if the designer knows which methods to choose, he or she would encounter the problem of compatibility of methods developed by different research groups. Therefore, they cannot simply be linked to a ‘consistent’ design methodology to support the designer throughout the whole design process, from defining the task to the documentation of the product. The approach described in this paper tackles these problems and is, therefore, a basis for successful method use.

3. Selecting methods for life cycle design

As mentioned before, a tremendous amount of methods for life cycle design have been developed by researchers all over the world. The problem nowadays is not the lack of methodical support in product design, rather that of choosing the most suitable method from the many methods now available to the designer. Method selection today is often based on the popularity of a method rather than a real analysis of companies’ needs [Ritzen et al. 2001]. To select the right methodical support for the designer based on the needs of the company, a three-step approach is suggested (Figure 1).

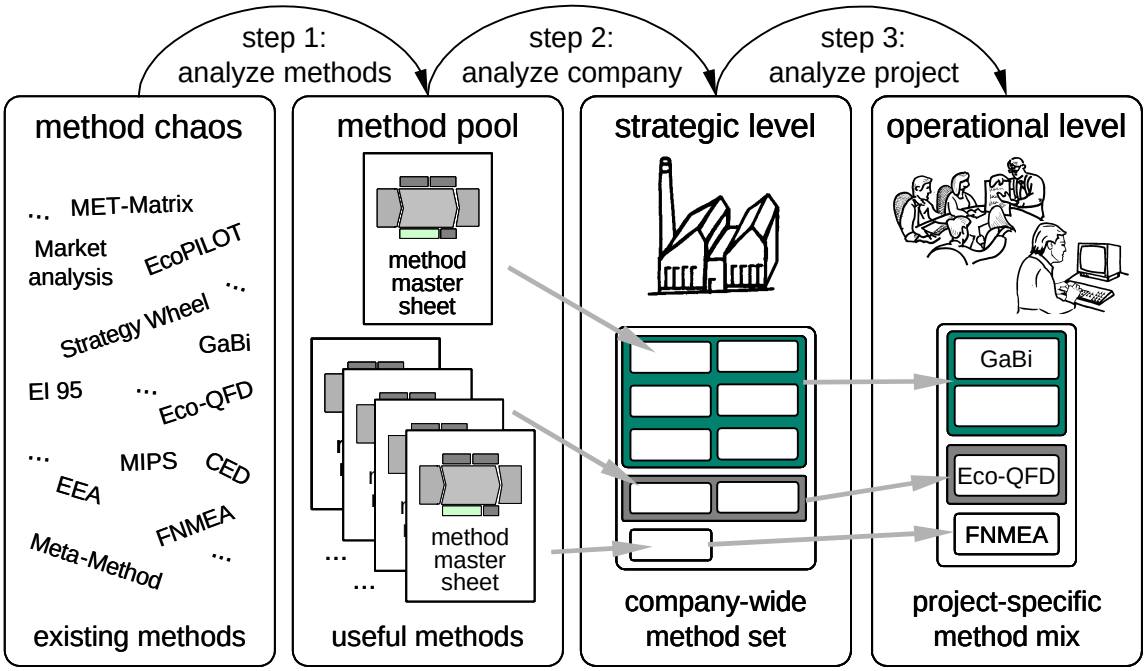

Figure 1. Three steps to select methods

3.1 Standardized method pool

In the first step most of the existing methods must be screened to determine whether they are suitable for the designer and mature enough to be applied in a product development process of companies. If the methods meet these two basic requirements, they must be reviewed in detailed. The methods must be evaluated and mapped onto a unified method-model. For analyzing the methods, a method assessment sheet is used. The most important facts of the method are summarized in a standardized master sheet of the methods. This master sheet also contains the method-model, which describes existing methods of different authors on the same level of detail in a standardized model. For this purpose a common method-model, the Process-oriented Method Model, from the project “thekey to innovation” [Birkhofer et al. 2001], was used (Figure 2).

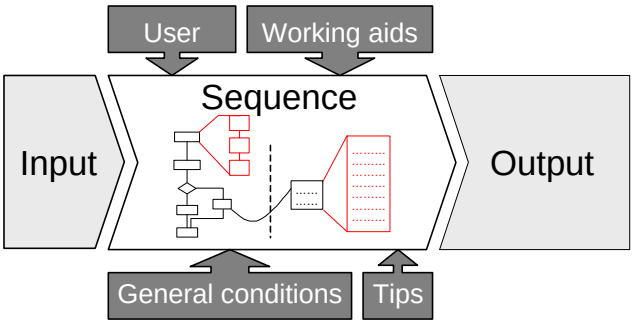

Figure 2. Modeling methods with the Process-oriented Method Model (PoMM) (simplified)

This method-model is based on a process-oriented model. The method has an input and an output of, e.g., information, documents, and knowledge. Between the input and the output, a sequence of steps (the method) are performed. The model also includes additional information about the requirement on the user of the methods, the working aids which could be used to support the method process, the general conditions for performing the method and some tips for method use. All methods useable in future method sets are mapped onto this model. The advantage of using this method-model is that all methods are described in the same way, and that the prerequisites and the output of the method are clearly defined.

3.2 Company-wide method set

After describing the methods consistently and summarizing them in the master sheet, one of the most important steps in selecting the right method is analyzing the company and deriving their requirements for methods. Carrying out a detailed analysis of the needs of a company is a complex and time-consuming task and is, therefore, often neglected. To tackle this problem, the process of analysis has been operationalized. Certain criteria important for the selection of methods have been identified in a literature study. The problem is that most of the requirements thus revealed are too general. Methods should be easy and fast to use, not too abstract, but understandable, and of course, they should lead to the right result. These overall requirements are independent of the company and its design process and are, therefore, not suitable criteria for selecting methods.

To identify useful criteria, three surveys have been carried out [Ernzer et al. 2001]. The first survey focused on the current practice of organizational implementation of life cycle design. The second survey was carried out together with the Institute for Product Development of the Technische Universität München, Germany. In this survey, consultants from industry and university, experienced in implementing new methods in engineering design, were asked about their positive and negative experiences with method implementation. The third survey was carried out to analyze life cycle design at 'environmental champions' in co-operation with the Department of Machine Design at the Royal Institute of Technology in Stockholm, Sweden. Environmental champions are companies that have already successfully implemented life cycle design in their design process.

Based on the experiences gained from reviewing literature, carrying out surveys, educating students [Ernzer et al. 2000], and designing products with industry partners, four groups of criteria influencing the requirements on methods were identified. Requirements arise from the product, the company and its surrounding environment, as well as individual designers. Since design methods are already adjusted to the general procedure of designing, the influences of individual designers are not considered in this phase. These influences are considered when designing the project-specific method mix.

The criteria influencing the requirements on methods can be seen in Figure 3. Using these criteria to analyze the company allows the derivation of requirements of methods, and thus, supports the method selection from the method pool.

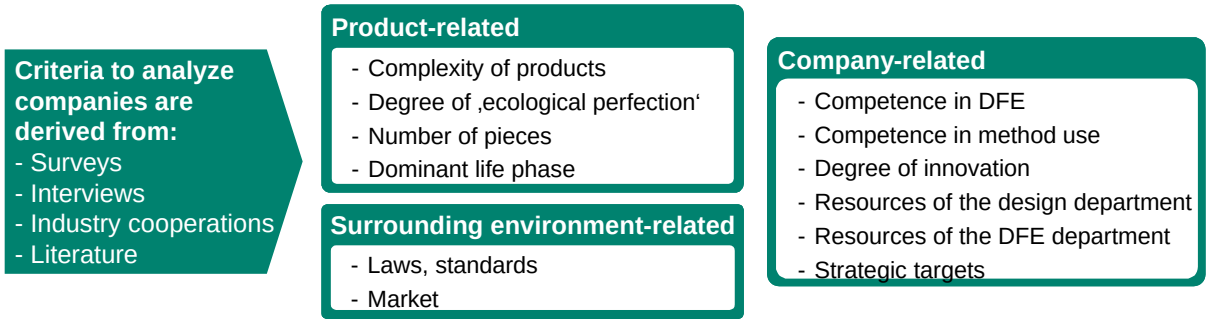

Figure 3. Standardized criteria for analyzing a company

The criteria are further divided in different quantitative and qualitative characteristics to distinguish between different companies with their corresponding needs. In general, quantitative are preferable to qualitative characteristics. One possibility of further dividing the criteria into different characteristics is shown in Figure 4.

With a standardized analyzing matrix it is easy to analyze the company and derive their needs. The discovered needs must be mapped to the requirements of the methods. A matrix showing the relation between the criteria and the requirements of the methods supports the mapping of the company's needs to the requirements (Figure 5). This mapping process is not as easy or 'mechanized' as it seems, since the criteria and their characteristics are highly interdependent and not equally important. The identified method properties are then used to select suitable methods from the method pool to form the company-wide method set. This step is still under development and will be evaluated in future projects.

Criteria		Characteristics		
Product-related	Complexity of products	≈ 10 000 parts Car, printing machine	≈ 1 000 parts Copy machine, turning machine	≈ 100 parts Hair dryer, gear
	Degree of ‚ecological perfection'	Holistic optimization throughout the whole life-cycle	Reduction of environmental impact in a single life phase	Company wants to comply with laws and regulations
	Number of pieces	Mass production	Small series and single products	
	Dominant life phase	Use	Recycling	No dominant phase / N.A.
Company-related	Competence in DFE[1)]	Ecological product and process knowledge available	Ecological product knowledge available	Little ecological knowledge available
	Competence in methods use	PD-Methods are used on a regular basis	PD-Methods are used	Little methodical support of the design process
	Degree of innovation	Every PD-team has DFE experts	Company has environmental expert team	Environmental health officer available
	Resources of the design department[2)]	More than 10 designers	Less than 10 designers	Less than 5 designers
	Resources of the DFE department	More than 10 environmental experts	Less than 5 environmental experts	Less than 5 environmental experts
	Strategic targets	Company defines and checks progress of product-related targets	Company defines and checks progress of plant-related targets	No environmental targets defined or progress is not checked
Surroun-ding env.-related	Laws, standards	Major restrictions on main product properties	Few restrictions on main product properties	
	Market	Environmentally sound products are demanded by the market	Unique selling proposition (USP) with environmentally sound products	No direct advantage from environmentally sound products

1) Assumption: The technical and economical competence available is sufficient
2) Assumption: The IT-Resources (Computer and Software) are proportional to the number of persons

Figure 4. Criteria for analyzing a company and their characteristics

These method sets must be made available to the whole company. That means that the prerequisites of the methods and the general set-up have to be arranged. Furthermore, lead-users (method experts) or help-desks for each method must be established. These institutions must be available to all designers of the company if a problem occurs during the method use or questions concerning the method must be answered. Last but not least, it is advisable that the results of the method be requested by the project leader to motivate the designer to use the method. Therefore, the methods must be formally determined by the managers.

		Product-related				Company-related						Surroun-ding env.-related	
		Complexity of products	Degree of ‚ecological perfection'	Number of pieces	Dominant life phase	Competence in DFE	Competence in methods use	Degree of innovation	Resources of the design department	Resources of the DFE department	Strategic targets	Laws, standards	Market
Properties of methods	Implementation effort	○	●	—	—	●	●	○	●	●	—	—	—
	Application effort	●	●	—	—	●	●	●	●	●	—	—	—
	Focus on design phases	—	—	●	—	○	○	○	●	—	●	—	○
	Focus on life phases	—	●	—	●	●	○	○	—	○	○	●	●

● strong relation ○ weak relation — no relation

Figure 5. Relation between criteria of a company and their requirements to methods (excerpt)

3.3 Project-specific method mix

After the company-wide method set has been found, it is necessary to form a project-specific method mix, since not all methods within the method set are used in all projects within the company. The selection of the methods depends on the nature of the project, whether it is an original, adaptive, or variant design project. For each of these design types, different characteristics and focuses of the design project can be defined [Pahl et al. 1996]. Furthermore, the tasks to be carried out or problems to be solved are important for singling out methods for the method mix.
In a next step, the methods must be adapted to, e.g., the project duration, the designer using the method, and the aim of the project to increase the efficiency of the method use. The adaptation of the method to the constrains of the project is supported by the lead-user (method expert) or help-desk.

4. Modular method set

According to the guideline VDI 2221, the design process is divided into different stages. For each stage, different methods exist for similar tasks. Therefore, to simplify the project-specific method selection process, the company-specific method set consists of different modules for different tasks within the design process. Some of these tasks must be performed in order to develop a product. Thus, for these tasks a so-called basic module has been developed. One example of a basic module is the extended requirements list. Possible methods for this would be a life-phase-oriented checklist for finding requirements, or an environmental assessment using life cycle assessment (LCA) to derive ecological requirements of a product by analyzing previous products. Besides the basic modules, the use of which is recommended, supplement modules exist. Supplement modules are not strongly recommended, but in ‘special’ design projects they provide the designer with additional information and support. One such method would be the development of future trends using scenario techniques. The last type of modules are sub-modules, which consist of single methods and can support basic and supplement modules. Examples of these methods are the Eco-QFD or the Eco-FMEA.
For each of these modules, different methods exist which are interchangeable. Which ones are used depends on the requirements of the company. For example, a company decides whether to use the cumulative energy demand (CED) or the material input per service unit (MIPS) for assessing the environmental impact depending on the type of product (material or energy intensive products). From the similar inputs and outputs of the process model, it can be seen that these methods are alike. The method-model within the method set supports the company with this information, so that the company is not left by itself to choose the right method.

5. Conclusions

For the successful use of methods in life-cycle design, it is essential to select and customize the methods carefully according to the needs of the company. In this paper, an approach to the systematical analysis of the company and the selection of the methods has been proposed. This theoretical approach will be improved, detailed and verified in further research by applying it in education and industry cooperations. First experiences and results are summarized in the next sections.

5.1 Validation in the project seminar

A prototype of one method mix was successfully used in the project seminar on life cycle design at the Darmstadt University of Technology [Ernzer et al. 2000].
One major difference between the method mix used in the seminar and the one used in industry is the stronger focus on a clearly defined requirements list . The students have nearly no background of the product. The students benchmark the product with competitors, carry out market analyses to evaluate the customers’ needs, environmentally assess the product using an LCA, and use scenario techniques to predict the product’s future. These methods give the students a broad overview of the product. In companies, most of these methods are not carried out with each product development, since the company knows or should know their competitors’ products, the future trends and the market. These methods are basic modules for the seminar, but supplement modules in the industry.

5.2 General experience gained from carrying out life cycle design project

To assess the environmental impact of a product for life cycle design, it is not always necessary to carry out a full LCA; rather, it suffices to use rough ecological estimation methods instead. Most of the main environmental impacts of the product can still be identified and successfully reduced. It is only useful to carry out a whole LCA if the ecological improvements of a completely new product concept must be verified or if hazardous materials with unknown environmental effects are used.
Furthermore, it is advisable to review a design project, collect all the experience and develop a product-specific checklist to shorten the design process in the future. As our experience from the project showed, it is not unlikely that general checklists found in literature lead to counterproductive results if they are used by environmental non-experts. This is due to the lack of knowledge of environmental impacts of materials and processes, as well as the complexity of their interrelations.

6. Outlook

The research approach presented in this paper is intended to initiate discussions on the topic of method selection for life cycle design.
The criteria and their characteristics, as well as the relationship between the requirements must be validated through a survey and through application in industry. According to these new findings, the approach will be adjusted and restructured. If the number of survey participants is large enough, it might furthermore be possible to prioritize the criteria.
Although a large number of methods for DfE are available, there are still some 'blank areas' in the method pool which must be filled by analyzing more methods.
Nevertheless, the above described approach simplifies and operationalizes the method selection for life cycle design.

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