UNIVERSITY OF ZIELONA GÓRA
Faculty of Management
and Faculty of Mechanical Engineering
In association with the Design Society

FOURTH INTERNATIONAL SEMINAR AND WORKSHOP
7th - 9th October 2004
Zielona Góra - Rydzyna
POLAND

Engineering Design in Integrated Product Development
Management of Design Complexity

ACTION ORIENTATION OF METHODS TO SUPPORT ENGINEERING DESIGN

U. LINDEMANN

Technische Universität München
Institute of Product Development

e-mail: lindemann@pe.mw.tum.de

Keywords: acceptance of methods, working methods, selection and adaptation of methods, procedural model, action and description in design

Abstract: *There is a lack of using even proved working methods in engineering design. Because of this circumstance we have to model the design and development process on a level describing actions. With help of formulating questions and looking for alternative possibilities to support the process of working on answers, methods will be an important part of these possibilities next to routine work or using just the experience. To be really successful working methods at least in the field of engineering design should support action and not only description.*

INTRODUCTION

There are different working methods available, which may be used in engineering design.

If one has finalized a functional description of a new product, the question of the variation and optimization of the functional structure or the search for available physical effects is arising. If the physical effects have been found and combined, the question of the optimal shape has to be answered.

Which are the working methods that fit best to the given problem? Is it possible to adapt the method to the actual situation? Do the methods support the required action or do they "just" help preparing the description?

1 THE PROBLEM

Since a number of years scientists claim that industry does not use their working methods in a comprehensive and adequate way. Within projects with industry we observed different situations of using or not using methods. Quite seldom methods are used in an excellent and efficient way. Quite often working methods were more or less unknown. Quite often they talked about brainstorming and it was just some kind of a discussion.

Case 1: A company in the automotive industry with some thousand employees tried to implement QFD. They asked consultants to train their staff by running a pilot project. After a few days in this project the QFD matrix grew up to more than 100 x 100. The project failed and there was no chance to start with QFD again – at least for a couple of years.

Case 2: About ten years ago a company (global subsupplier in the automotive industry) started to work with FMEA and they used this method continuously. Then the discussion came up about the way they did it. The key question was linked to the reason why they were doing specific steps. Some kind of frustration came up – "We have to do it, but why?".

Case 3: Within a successful company we observed that the FMEA-forms were filled out without understanding why they had to do this. They were asked to do FMEA by contract and tried to fulfil this condition with a minimum of effort.

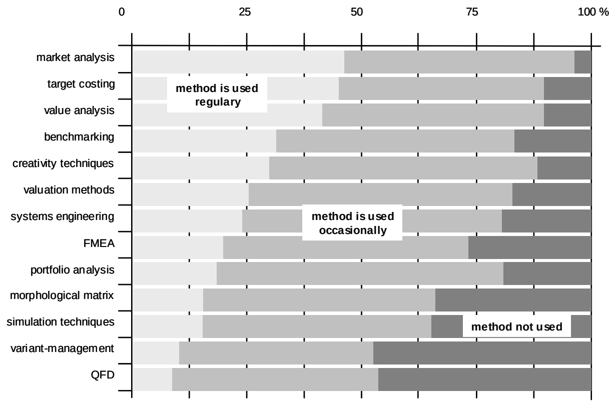

Figure 1: Use of methods in industry [11]

A questionnaire in 1995 [11] showed that industry does not use methods intensively, that they usually use methods just occasionally. If it is correct that the use of methods requires trainsing and competence, the use of methods just occasionally can not be efficient.

On top of these points of discussion Furnham [7] found out that brainstorming does not work at all. When we discussed his paper with some colleagues from psychology they agreed that Furnham's findings are correct, at least referring to the standard form of brainstorming.

1.1 Model of product development procedures

Product development processes as part of a development project have to be planned in advance to be able to control the project in total. Because of the creative nature of at least parts of the design processes it is quite difficult to create a plan which is sufficient for all details. Because of this difficulty and the aim of integration of different specialists within one design project, flexible "process building blocks" have been developed in a number of research projects [13]. In between these process building blocks have been transferred to practical use in industry successfully. These process building blocks may be "evaluate properties", "clarify the task", "compare alternatives" etc.

Using these process building blocks typical patterns may be formed and standardised. The well known problem solving cycles known from systems engineering [5], ARIZ [1, 17] and even the TOTE-cycle may be explained by these process building blocks. Key elements are "analyse the target (the task)", "find solutions" and "select the (optimal) solution". This cycle was used for example by Ehrlenspiel [6] and other authors in a similar way.

In real processes there are a number of iterations within the cycle. To symbolise this, the elements of the cycle are overlapping.

If you go into a more detailed view of "analyse the target" and "select the solution" you may find it helpful to split these elements to detailed building blocks. The analysis of a large number of product development processes leads to a set of seven process building blocks, which may be used as some kind of a standard. As this pattern is some kind of a model of procedures we have standardised it as the "Munich Procedural Model" – MPM [15]. This model wants to explain the content of typical processes (sub-processes) within design and development and the flexible relation between the included process building blocks.

The base is the actual situation where one starts to act and the refection of the process before one switch to the next cycle. As content there are the elements "plan the target", "clarify the target", "structure the target", "find solutions", "analyse properties", "select the solution" and "ensure achieving the targets". Depending on the situation and the progress within the overall process it is possible to switch from one building block to another one, as long as the output-input parameters match.

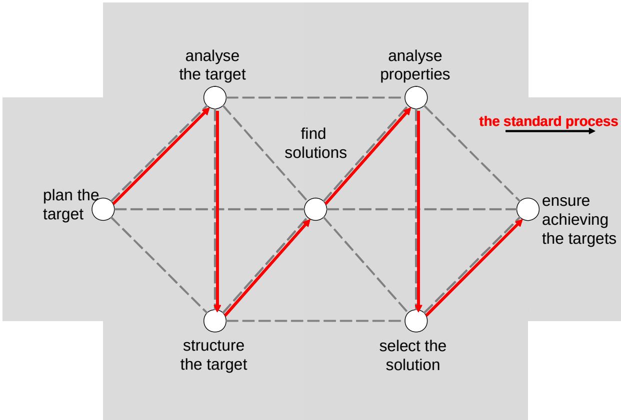

Figure 2: The Munich Procedural Model – MPM [15]

Within a "normal" development cycle the general way will be as described above. But if the target is quite new and the available information is scarce then it may be useful to switch from "plan the target" directly to "find a solution" and then to "analyse properties" in the sense of fast prototyping to learn more about the problem and then do the "normal" development. This pattern will be used with cycles within itself, in iterations and in a recursive manner. It may be used in small detail sub-processes as well as on the top level of a project.

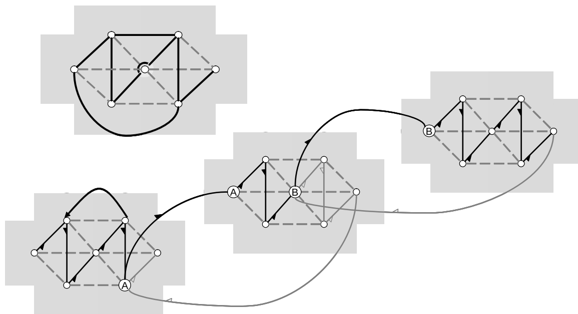

Figure 3: Using MPM in an iterative and in a recursive way [15]

This gives us in total a very complex process pattern, but the elements are of the same structure, which on the other hand supports the similarity.

1.2 Questions to answered using methods

Analyzing the practical use of methods in industry as well as with students we observed sometimes, that a method was used like a cooking recipe in a rather stupid manner. They know, what the next step in the procedure is, but they do not really know why this step is necessary. Because of these observations even when looking at experts we decided to split methods into a number of questions to be answered.

As there are usually several possibilities to give an answer to the question by using different methods there is an advantage to adapt the method to the given situation or develop a new method by just using different sub-methods. Doing QFD you may ask the question "How do we get information about the properties of the product X of our main competitor Y?". There is a number of possibilities to answer this question as for example "questionnaire with your sales and service staff", "analysis of literature, web-based information etc", "product benchmarking". If you decide to buy the product and analyse it, there may be the question "How do we find out the production cost?". Again there are different possibilities to give an answer – think in alternatives!

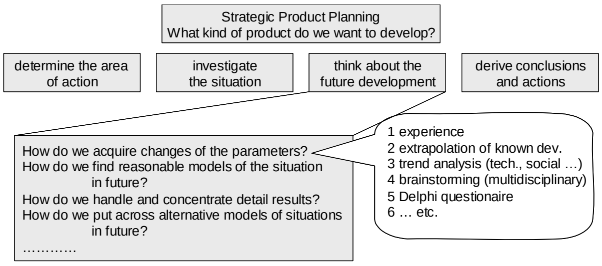

Figure 4: Product planning - four fields of action - questions and answers (fraction) [15]

An example may be the strategic product planning, which has to answer the question, which products should be developed for the future success of the company. This process has to be established and there are different possibilities to run this process depending on the requirements and the actual situation. One step within this process is the discussion and evaluation of what the future might be. Within this step a number of questions may arise as for example "How do we acquire changes of the parameters, which influence the positioning of our product in the market within the next 10 years?" or "How do we find reasonable models of the situation in 10 years from now?". These questions may be answered for example without using any method just depending on the sense of a manager or by analysing technical and social trends by a multidisciplinary team.

2 STEPS TO IMPROVE METHODS

2.1 Select the right method

Within product development projects there are a lot of processes, which may be split up to micro processes as clarify the task, clarify the situation, analyze, etc. Micro strategies will help to find out the right or at least a good sequence of these micro processes. Based on the given situation we may select the methods to be used within the processes.

Basic strategies as for example changing the view from top-down to bottom up help to keep processes run in the right direction. Some of these strategies can be summarized as switching between modalities (figure 5).

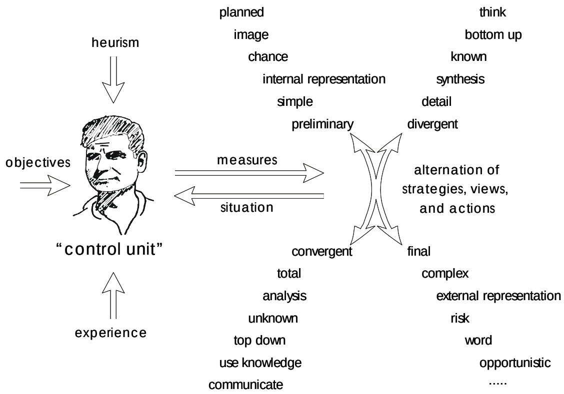

Figure 5: Switching between modalities [12]

In addition there are macro strategies as for example lean production, concurrent engineering etc. which are used on a more global level of management.

2.2 Levels of methods

The normal way to describe a method is a written document together with some successful examples. Today we also find a number of databases with information about methods; this information is usually structured in some specific way.

All these points do not answer the question about the content of the method, of what is 'behind' the method.

Several authors like Miller/Galanter/Pribram (TOTE - Test-Operate-Test-Exit Cycle) or Heckhausen/ Gollwitzer (Rubikon-model) [in 18] have described basic methods.

On this basis Wulf [18] developed his micro-methods of "discursive problem solving" (fig. 6) and the "political process of asserting solutions in a team". In the following we will call these kinds of methods basic methods.

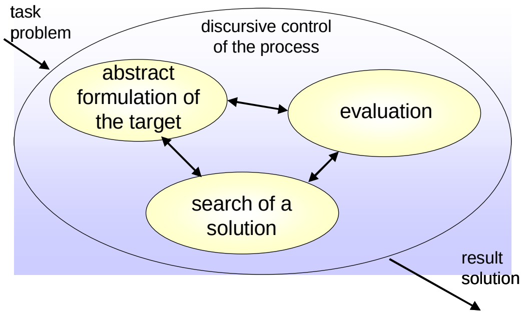

Figure 6: Discursive problem solving ([13, 18])

Another level of structuring complex methods was given by Zanker [19], Giapoulis [10] and Ambrosy [2]. They discussed elementary methods like 'analyze', 'compare', 'combine', etc. as key elements of the methods we use. Knowing about these elements, we have the possibility, to analyze, compare and restructure our methods.

The difficulty is that using elementary methods like "analyze" it may be necessary of do this with methods like DSM or methodologies like QFD on another layer.

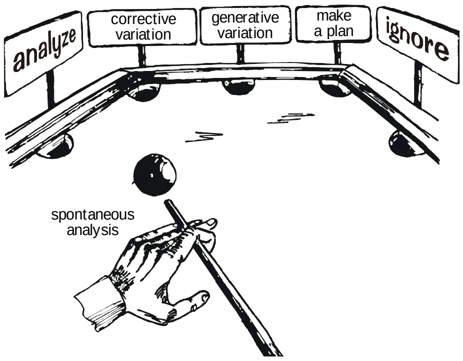

Figure 7: Elementary methods [10]

Methods like brainstorming, design structure matrix and methodologies like TRIZ (teorija resinija izobretatel´skich zadac) and QFD (Quality Function Deployment), which consist of several methods, are further levels, which will be used. The structure of these four levels has been proven by a number of research projects (fig. 8).

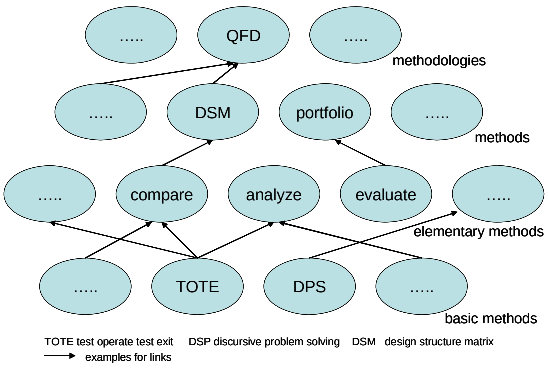

Figure 8: Levels of Methods [14]

In reality there seems to be a complex network of methods of all levels. Knowing about these levels helps to navigate in a conscious way of acting.

2.3 Design of methods

Some examples may give an idea of the adaptation of methods out of different reasons:

Brainstorming had been modified to brain writing, gallery method, and method 6-3-5 and other derivates. Within literature on QFD we find a number of different and specialized adaptations. Gaul [8] suggested using the House of Communication to analyze and plan communication processes in distributed product development processes.

These and other modifications came up by accident or on base of an isolated idea. It is our approach that methods may be developed like products in mechanical engineering. That means that we have to discuss the requirements for a method. Gerst [9] suggested working with functional structures of methods and elementary methods using their characteristics to form conceptual solutions for new methods.

The well known morphological method may help us to find the right combination of elementary methods as well as complete, well known methods, to form a new or a modified version of a known method or methodology (combination of methods) depending on the actual requirements (fig. 9). In addition a database of elementary methods, usual methods and methodologies may support this process. For experts also the basic methods may be of interest in this matter.

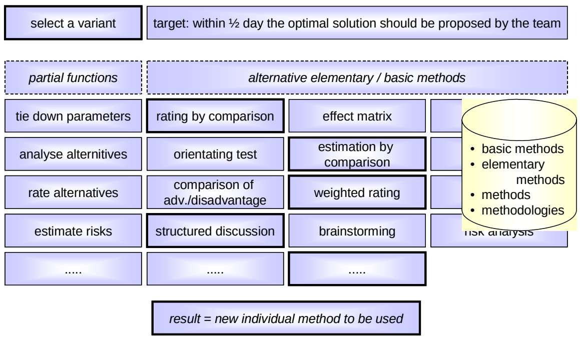

Figure 9: Morphological method for designing methods [9, 14]

A lot of research has been done in this topic, but there are still a number of questions concerning the situation and target driven adaptation.

2.4 Methods and processes

Required solutions and documents have to be produced by product development processes using methods, which help to fulfill the requirements of the task and fit to the given situation.

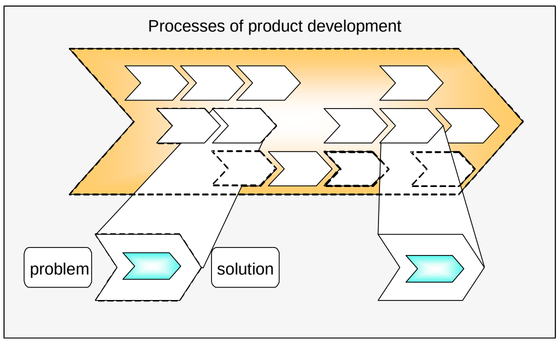

Figure 10: Sub-processes in product development

The process may be spitted into a number of sub-processes, which should be available as predefined standards. Within these sub-processes alternative methods may be used depending on the given situation. Using a method within a sub-process it may be necessary to act on different levels of abstraction and to switch between these levels.

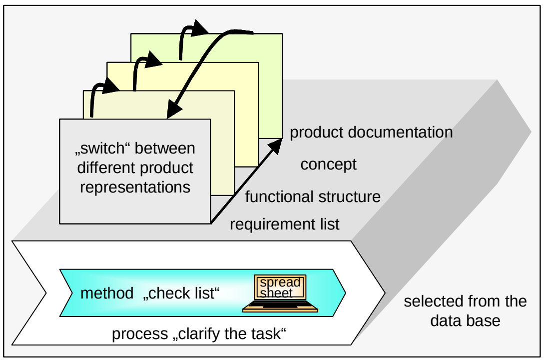

Figure 11: Product description resulting from processes

Processes are filled by a set of actions, which may be supported by methods and in addition by tools.

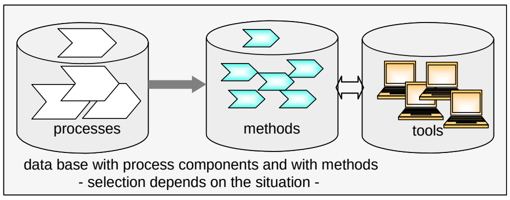

Figure 12: Process building blocks, methods and tools

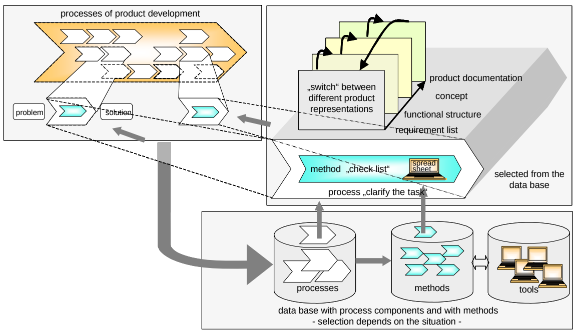

Figure 13: Processes to be supported by methods to be supported by tools

3 ACTION ORIENTED DESIGN METHODS

The two different levels (Fig. 14) of processes (actions) and the results (product representations) are necessary and important and we have to address both by the design methodology.

There is the fundamental level of action, where concrete design is elaborated upon. The level of action responds to its own rules – quick alternation between systematic and associative ways of proceeding, dialogue structure of the process of problem solving and the work within self-imposed temporary boundary conditions. All of this has to be taken into account when we are developing methodical support for this microscopic level of a development process.

The level of results should be structured by rules of design methodology. This level fulfils two different purposes. On the one hand, it establishes important landmarks (the different product representations) in complex development processes, which prevent the designer from getting lost on the level of action. On the other hand, the level of results allows management and other members of a design team to plan and control the development process. Of course, this more macroscopic level has to take into account the interim results from the level of action, in order to achieve an efficient process and appropriate results.

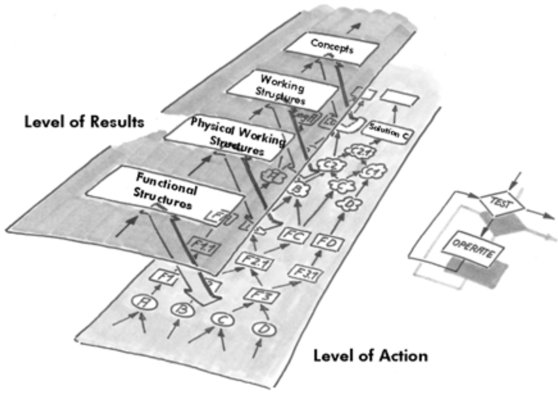

Figure 14: Two basic levels of the design process (results as product representations and actions within the processes) [14]

The distinction between a level of results and a level of action can also be applied to the huge amount of methods available in product development: There are action oriented design methods, which support the designer in elaborating upon intelligent, functional design. These methods are addressing teams (e.g. brainstorming, synectics, ...) as well as the individual designer (e.g. TRIZ, mind-mapping, ...). And there are description and documentation oriented design methods (e.g. requirement list, functional structure, morphological matrix, evaluation methods) which concentrate the results of the development process and allow them to be clearly presented. For the designer, these are milestones along his way to the demanded product. For the management, these allow the understanding, discussion and evaluation of crucial technical problems without being fully involved in the design work.

A survey on available development methods, makes it clear that many description and documentation oriented methods have been developed by the academic community. They were usually poorly accepted in industrial practice. On the other hand, a number of well established methods also exist, such as TRIZ, FMEA or QFD, which seem to have had hardly any problems to be accepted in the professional surrounding. Of course, these methods are professionally promoted by management consultants, but it would be an over-simplification to put their success down to this fact alone. Their success primarily results from their sense of supporting concrete action in the development process.

For example, most of the elements of the TRIZ-methodology directly address the level of action and try to set in motion the dialogue of problem solving. The purpose of the functional analysis within TRIZ [17] is to derive "problem formulations" which 'push' the process of solution finding. The "Laws of technical evolution", as well as the "Principles for solving technical contradictions" from Altschuller [1], establish a formal way of proceeding which leads to abstractly formulated design aims.

The functional structure following for example Ehrlenspiel [6] or Pahl&Beitz [16] is an important part of the whole product representation as an intermediate result of the processes. Its main focus is description and not action.

4 CONCLUSION

Action and description are two key elements of design methodology. The integration of action oriented methods within the set of design and problem solving oriented methods is necessary. Because of the complexity of real design processes there is an attempt called CiDaD [4], to use the software possibilities of dynamically linking information and knowledge about working methods in design to support designers during their work.

References

[1] Altschuller, G., "ERFINDEN – Wege zur Lösung technischer Probleme", VEB Technik, Berlin, 1984.

[2] Ambrosy, St., "Methoden und Werkzeuge für die integrierte Produktentwicklung", Shaker, Aachen, 1997.

[3] Bichlmaier, C., Grunwald, S., "PMM – Process Module Methodology for Integrated Design and Assembly planning" In: Proc. of the 1999 ASME DET Conferences, Las Vegas (USA), New York, ASME 1999. (CD-ROM)

[4] CiDaD, registered trademark no. 302 04 507.4 / 41 in Germany (Competence in Design and Development).

[5] Daenzer, W., F.; Huber, F., "Systems Engineering" Industrielle Organisation, Zürich, 1997.

[6] Ehrlenspiel, K., "Integrierte Produktentwicklung", Hanser, München, 2002.

[7] Furnham, A., „The Brainstorming Myth", Business Strategy Review, 2000, Vol. 11, No. 4, 21-28.

[8] Gaul, H.-D., "Verteilte Produktentwicklung - Perspektiven und Modell zur Optimierung", Dr.Hut, München, 2001.

[9] Gerst, M., "Strategische Produktentscheidungen in der integrierten Produktentwicklung", Dr.Hut, München, 2002.

[10] Giapoulis, A., "Modelle für effektive Konstruktionsprozesse", Shaker, Aachen, 1998.

[11] Grabowski, H.; Geiger, K., „Neue Wege zur Produktentwicklung", Raabe, Stuttgart, 1997.

[12] Lindemann, U., "A Model of Design Processes of Individual Designers." Proceedings ICED 1999, Munich, 1999 pp 757-762.

[13] Lindemann, U., Wulf, J., "Action Orientation in Design Methodology", Proceedings ICED 2001, Glasgow, 2001 pp 131-138.

[14] Lindemann, U., "Efficiency and Effectiveness of Working Methods" In: Internationale QFD-Tagung, München, 2002.

[15] Lindemann, U., „Methodische Entwicklung technischer Produkte", Springer, Heidelberg, 2004.

[16] Pahl, G., Beitz, W., "Engineering Design: A Systematic Approach", Springer, London, 1996.

[17] Terninko, J., Zusman, A., Zlotin, B., "STEP-by-STEP TRIZ: Creating Innovative Solution Concepts", Ideation Int., Nottingham (New Hampshire), 1996.

[18] Wulf, J., "Elementarmethoden zur Lösungssuche", Dr.Hut, München, 2002.

[19] Zanker, W., "Situative Anpassung und Neukombination von Entwicklungsmethoden", Shaker, Aachen, 1999.