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# TREATMENT OF DECISION SITUATIONS IN THE DESIGN PROCESS

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## 1. Introduction

During the design process different decision situations arise at planning, managing and problem solving procedures. The designer has to master these situations in all phases of the design process, characterised by a certain level of uncertainty depending on applied design methods.
There are various approaches explaining and supporting decision-making procedures from different points of view. These are process view, organisation view, knowledge based view etc., presented by [Lonueville 2003, Zah 2003, Ben Haim 2001, Hansen &Andreasen 2000, Höhne 1997, Hwang & Yoon 1981]. All these descriptions and investigations are focused on selection of optimum variants in a field of solutions or on supporting compromises for improvement of alternatives through modification.
However, the designer is faced with other decision situations when he wants to optimise the design process with the objective to select adequate methods and find a proper sequence of operations.
The aim of this contribution is to characterise the content and the characteristic of the different decision situations as starting point for preparing and supporting decision making in product development process. A model of a generalised problem solving procedure shall help the designer to attain a survey of the situation and to choose adequate measures for his decisions. First the design process is analysed in order to find out and identify decision situations.

## 2. Decision-making in the design process

Decisions are constitutional steps in all loops and cycles of design operations in the product development process. Decisions have allways the objective to select the optimum variant from a number of alternatives. The content of these alternatives changes with the progress of the design process. Describing this context a basic model is the TOTE-scheme (Fig. 1). It should be used to explain the integration of decision-making in the sequence of developing operations during the design process (Fig. 2).
Any design phase starts at a certain state n as overall function, functional structure, solution principle or preliminary shape design. The result of the problem solving operations (synthesis, analysis, modification of intermediary results etc.) is the next concrete state n+1.
The model in Fig. 2 shows two types of decisions. At the beginning of a process phase the designer has to analyse the input information given as a description of the design object at a certain level of abstraction. Using the requirements from the specification of the task (requirements list) he has to select adequate methods for synthesis of solution variants. Simultaneously the sequence of necessary working steps has to be determined, generating a solution path.

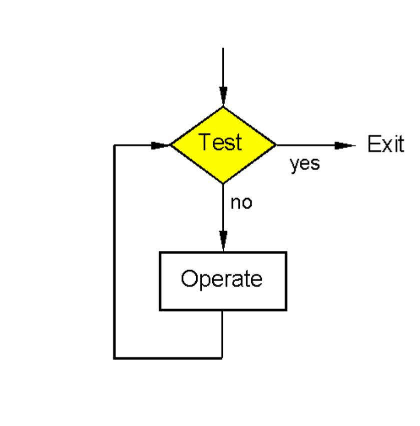


Figure 1. TOTE-scheme

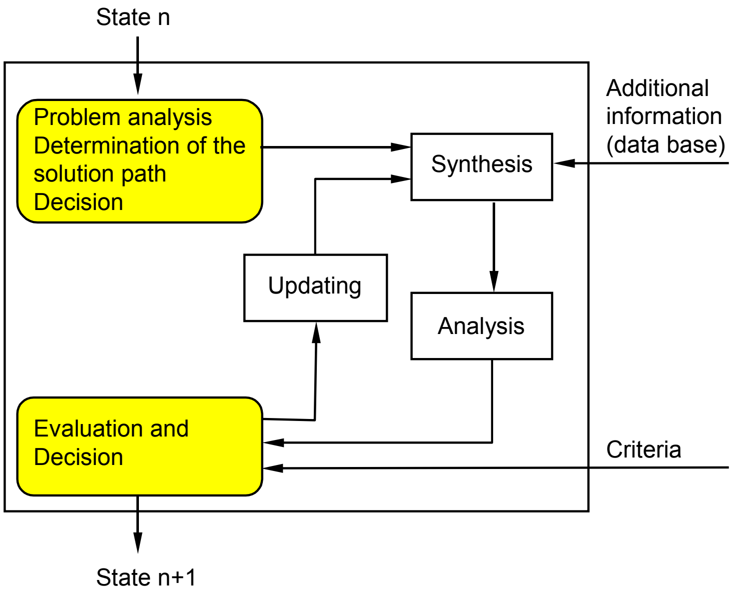


Figure 2. Operations of a design phase

Because there are available methods and tools (Fig. 3) als well as variouse possibilities of connecting them into a sequence of operations a decision is indicated to select the optimum solution path. This first “Test”-operation at the beginning refers to a decision to the design procedure.

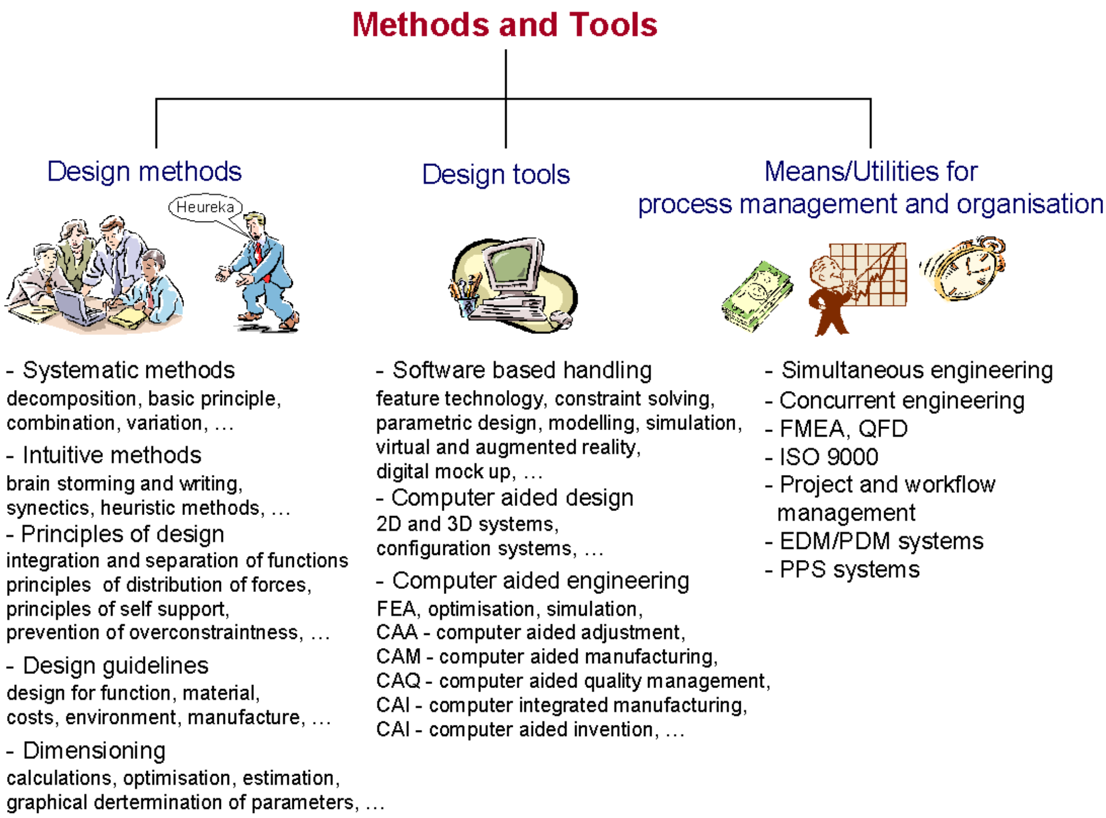


Figure 3. Design methods, tools and utilities

The second type at the end of the developing phase is a decision on the generated solution variants. Selecting variants for updating and optimisation and finally selecting the optimum variant for the further development has to be achieved. For this decision operation one can find a significant number of supporting methods, models and tools in the literature as: multicriteria utility, fuzz set and probability analysis, design analytic methods as well as information content approach [Zah 2003], using well known matrices, diagrams, evaluation scales etc. However, the first type of decision is reflected and investigated rarely. It shall be discussed below more closely.

## 3. Decision situations in the design process

Based on the given interpretation the overall design process also contains both types of decisions. A procedural model of problem solving operations in the design process is shown in Fig. 4. This model is appropriate for the complete design process as well as for it's steps and phases.

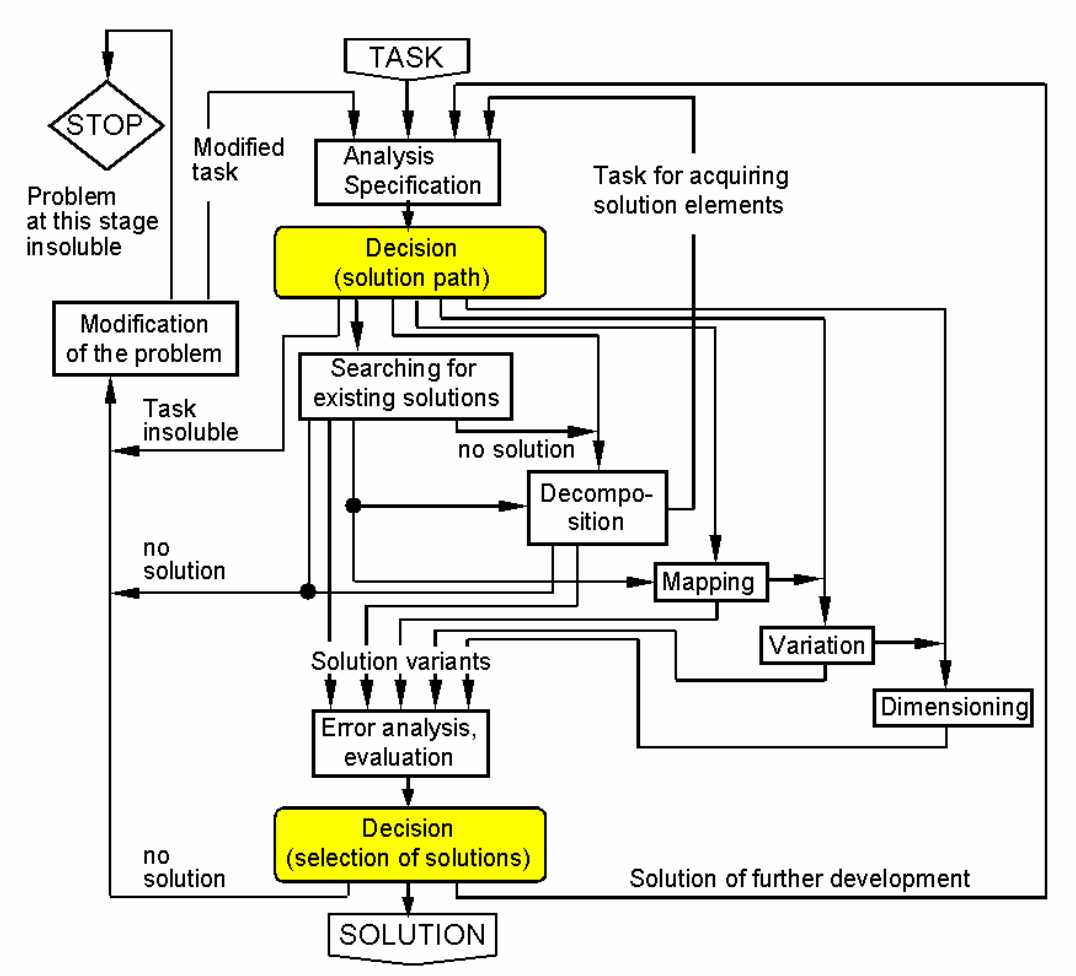


**Figure 4. Problem solving procedure**

As mentioned at the beginning the designer has to decide the solution path, the models and tools to be used for solving tasks and problems and compile a sequence of the problem solving operations.
With this decision the designer determines the efficiency of the design process. For this reason the task analysis must also include aspects being relevant to the determination of the solution path. One approach is to characterise the knowledge gap of the task, which can be classified as follows [Hari 2003]:
Level:

1 - Revision or Variant Design

2 - Adaptive Design
3 - Original Design
4 - Research

These types of knowledge gaps require different development cycles and efforts, which gives a raw orientation for selecting methods and operating concepts as “Top-Down” or “Bottom-Up” procedures. Figure 4 shows a logic sequence for checking and selecting adequate problem solving operations supporting a substantiated decision on the solution path. Following problem solving operations have been generalised:

- Search for existing solutions
  Each process starts with a retrieval of existing solutions, the state of the art etc. establishing the fundamentals for the other operations.
- Decomposition
  In cases of complex products, problems or negative results of the search the next possibility is to decompose the object resp. the problem. This result contains the essential components of the problem and opens activities to acquire solution elements.
- Mapping
  Assuming that the result of decomposition is not only a list of components but also a structured description (e.g. a function structure as decomposition of an overall product function) the solution elements can be mapped onto the abstract structure, generating solution variants.
- Variation
  Given or developed solutions at any level of abstraction can be modified to generate new and optimised variants.
- Dimensioning
  This operation is indicated for the quantitative determination or variation of the solution variants parameters
- Error analysis, evaluation
  This operation checks the properties of the generated solution variants, compares them with the requirements and prepares information for the following decision. This decision determines the efficiency of the product, its fabrication, application and all phases of it’s life cycle.

## 4. Decision-making on the solution path

In relation to the complexity of the problem or the design object and the level of the knowledge gap the solution path optains juctions and loops. The model in Fig. 4 outlines this situation and may support the designer in decision-making, preparation of the process schedule and establishing a project plan.

For this reason we have to consider the characteristic of the situation. At the beginning of the design process it is not possible to determine all design operations and the sequence of them. This is caused by the insertainty of heuristic problem solving operations and by the dependency of the application of methods on the progress of problem solving and the developed product structure.

From this point of view the model in Fig. 4 offers three appraaches to support then decision and the determination of an effective task or problem solving schedule:

1. The planning of design operations including the means, the capacity and the man power should be flexible, starting with a raw schedule of the overall process. The best solution path can be find gradually by adaptive plannig at the beginning of every main design phase.
2. The selection of adequate methods and tools can be supported by a structured problem oriented preparation of them. A proposal gives Table 1.

**Table 1. Prepared methods for process planning**

Problem → Solution

| Task specification | Problem solving / Synthesis | | Decision |
|---|---|---|---|
| | a) qualitative | | |
| | descriptive | intuitive | |
| • Problem analysis<br>• Evaluation<br>State of the art<br>Patents<br>• Trend analysis<br>• Application analysis<br>• Scheduling<br>• Requirements list<br>• Process planning | • Basic principle<br>• Decomposition<br>• System analysis<br>• Combination<br>• Variation<br>• Configuration<br>• Design guidelines<br>• Prinipiles of design | • Brain storming<br>• Method 635<br>• Delphi method<br>• Synectics<br>• Analogy methods<br>• Gallery method<br>• TRIZ<br>• Heuristic principles | • Error analysis<br>• Risk analysis<br>• Value analysis<br>• Cost estimation<br>• Evaluation methods<br>• Decision rules |
| | b) quantitative | | |
| | • Numerical calculation, optimization graphical methods, estimation<br>• Modelling, simulation | | |

The model in Figure 4 supports the elaboration of a work plan (Fig. 5) in different variants considering multi-criteria evaluation and decision as duration of the process, experience and capacity of the team, available tools etc.

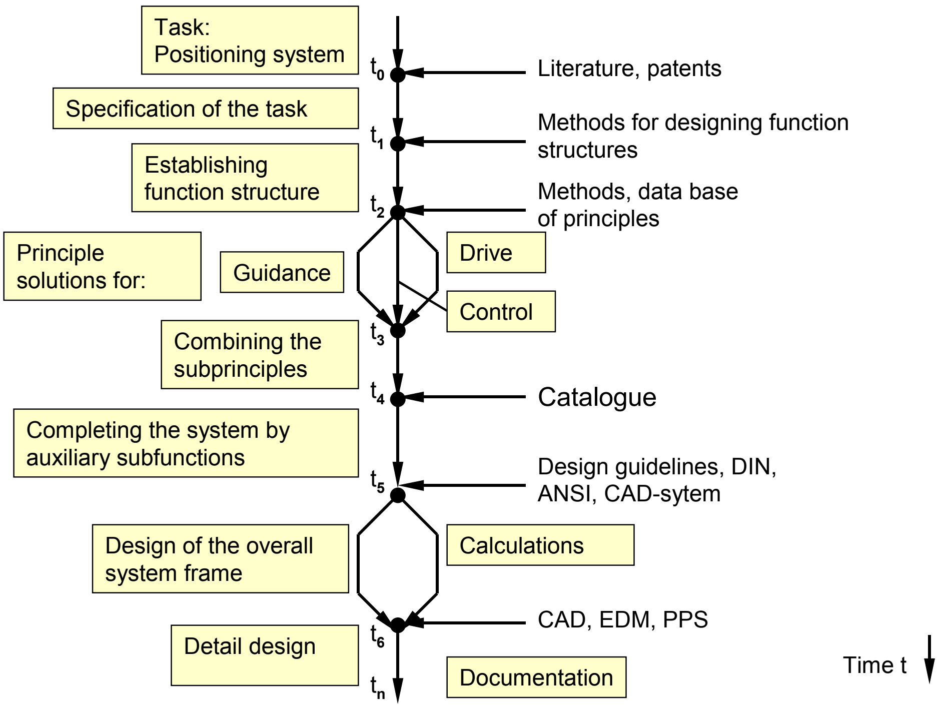


**Figure 5. Example of a working plan for developing a positoning system consisting of drive, guiding and control units**

## 5. Conclusions and Future Work

This contribution is a position paper to the Workshop "Decision Making" dealing with decision situations arising during the design process. Analysing the problem solving procedures in the product development process two main types of decision situations can be distinguished.

At the beginning of the design process as well as each process phase the designer has to decide on the design procedure based on the content of the design taks. This is a decision on the efficiency of the design process.

The second type is a decision on the design results selecting the optimum solution variant. This is a decision on the efficiency of the developed product and its life cycle costs.

For understanding and supporting the first type of decision a model is presented, which describes the problem solving procedure, in particular the relationship between problem solving operations and both types of decision-making. It supports the designer to come to a flexible design procedure.

Future investigations are focused on following topics:

- Application of the proven evaluation and decision methods for determination and selection of optimum design procedures.
- Determination of significant decision points during the problem solving procedures.
- How can adaptive planning resp. forward scheduling be realised?
- Which are the criteria of effective design procedures?
- Which kind of information is necessary to support decision-making on the design procedure at the beginning of the process?

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