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THE STRATEGIC PROCESS FOR DEVELOPING A BUILDING SET FOR COMPLEX PRODUCTS

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Abstract

Increasing market pressure, both in the meaning of higher customer demands and more competition, forces companies to develop more and more differentiated products with greater efficiency and fewer resources. One approach is the development of the product spectrum as a building set. Within this contribution, we would like to present an exemplary process for implementing a building set strategy mainly from the viewpoint of product development in early stages of the development process. That process contains the stages of planning and analysing the product architecture, the design of a building set, as well as further steps such as evaluation and implementation of the concept. Respective tools and methods will be introduced. The contribution is based upon practical experience in the automotive industry.

Keywords: Best practice, complexity management, integrated product development, variant management, modularity and standardization

1 Introduction

The set up of a building set strategy is an answer to the increasing demands on modern complex products, which have to be developed in many variants with high quality and low costs in an environment of reduced resources and development time. A building set strategy can also be found under the titles variant management, mass customisation, platform strategy, or the like in the broader sense [1], [2], [3]. Its main idea is to efficiently synchronise similar scopes and omit dispensable and unreasonable ones, especially concerning the product itself.

The development and implementation of such a building block strategy requires comprehensive efforts throughout the whole enterprise and during the product creation process. This strategic process begins with the planning, analysis, and definition of the product spectrum, which is supported by many methods referring to product analysis and architecture as well as estimations of economic efficiency. Still the focus of product development is the conception and design of the building set, where design guidelines and rules have to be regarded, e.g. design for variety, modularisation, and standardisation. Finally one has to regard the controlling and monitoring of the development process, e.g. referring to the variety in the long term product life cycle as well as the realisation and implementation of the building block strategy. All business units such as marketing, production, or logistics have to be integrated in this process.

In the following we would like to present and discuss the approaches and results of case studies on developing building sets within the automotive industry with the example of the car's cockpit. Nevertheless the tools and methods might be applicable for most industries as well. The case studies have been complemented by extensive analyses as well as adaptation, recombination and extension of existing methodologies [4]. Basic research on mass customization provided further insight in the theory of complexity, change, and variants [5]. The development of the building block strategy itself has been part of a bigger project on distributed product development processes, process representation and optimization, as well as controlling of the project status. This is a part of the long term relationship between the German automotive industry and the research institute.

2 Starting situation and objectives

Before starting with the actual development process and the respective methods, the actual and current situation influencing the design problem shall be introduced. As mentioned before the research took place in commercial enterprises; thus we were confronted with very special situations concerning corporate culture, decision making, political aspects, personal characteristics as well as design and development practice.

Within the analysis of the product and the organisational conditions within the regarded departments, it could be revealed that there was in general little knowledge and transparency about the structure of the product and its variants. In the same way costs, which have primary importance within the enterprises, are quite blurred, especially costs concerning variety and complexity as well as development. Though managers and designers have a general overview of the product structure, the variants, and the costs and fulfil their targets, a transparent and comprehensive representation is still missing. Furthermore development targets have not been detailed and communicated clearly and appropriately. Development activities are sparsely balanced, especially concerning different models. This included that the relevance of specific scopes for the customer have not been considered enough. These problems resulted mainly from the organisational structure, which emerged over time and became very personal and inflexible. The permanent efforts for daily business make long term efforts quite difficult. This results in a problem solving mentality rather than a strategic consideration of product development. Still there is great awareness that this kind of rigour and ignorance might be big problems. These statements shall not devaluate the design efforts of the regarded departments, they shall show always existing optimisation potentials. In the consideration of a degree of efficiency, those disadvantages are found almost everywhere.

The objectives of the project (i.e. implementing an interface management or a building set strategy) are the reduction of costs, both parts and development, and an increase in quality by increasing quantities, the more flexible and accelerated adaptation of designs, a faster and more lasting decision making, an enhancement of development performance, and a broader range of products. The respective action fields are economics (cost analysis, evaluation, and allocation, customer relevance, etc.), organisation (building block management, decisiveness, multi project development, integration of suppliers, etc.) and technical aspects (architectures, customisation, integration, interfaces, standardisation, etc.).

3 The strategic process

The overall process of planning, analysis, solution finding, and implementation is represented in Figure 1. In reference to the problem solving cycle [6], covering the clarification of the task, the search for alternative solutions and the selection of one solution, this process differentiates between the preceding planning and the detailed analysis, and it integrates the selection within an extended process step of implementation.

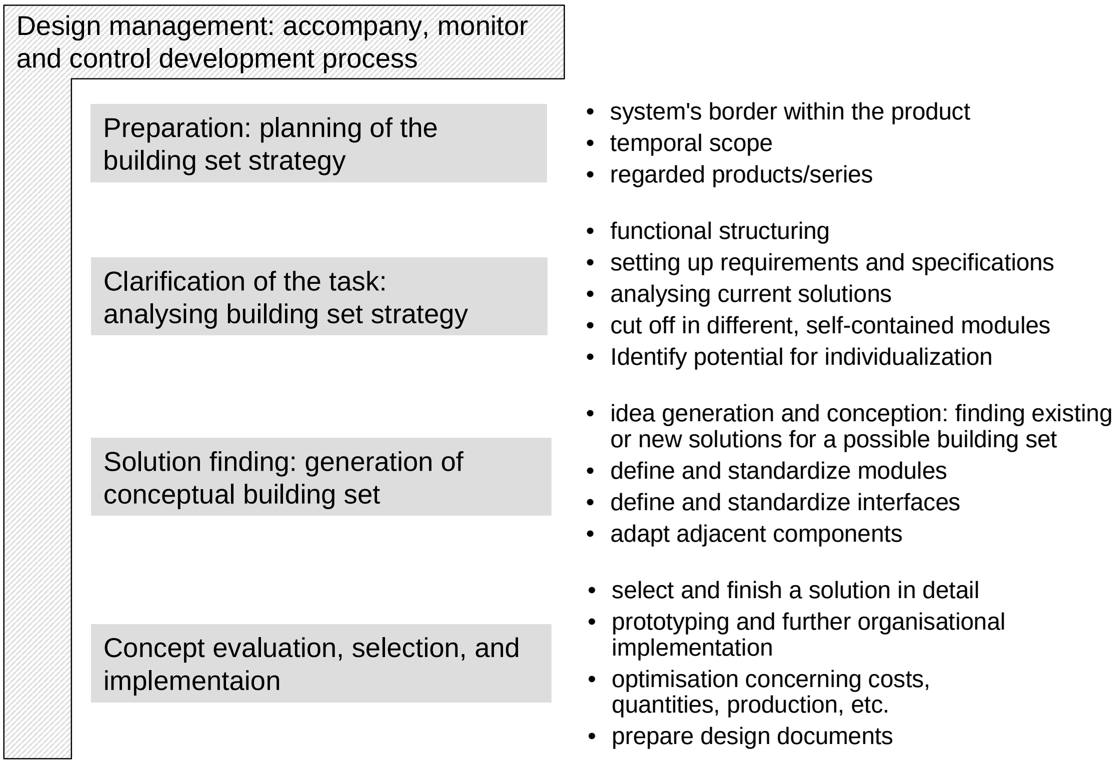

Figure 1. The overall process for the set up of a building block strategy

The steps of the process and the respective results must not be regarded in a strict sequence. There have to be iterations within the process. Analysis tools might also serve for the monitoring and controlling of the whole process. These points are described in detail in the following chapters.

3.1 Planning of the building set

The planning of the building set in this context is mainly the definition of the regarded system's border. This definition has to consider different dimensions. Firstly, there is the question of the system border within the product, i.e. the parts and assemblies. This can become quite complicated, when different model ranges of the product or product families (e.g. B-, C-, and D-class cars) with different concepts are regarded. This is the second dimension that has to be defined. It is closely related to the temporal dimension that asks for the life time of the building set as well as for the future models of one class or several classes. The derivates of one model (limousine, wagon, convertible, etc.) and the configurable variability is normally covered by the building set in general, since here are the most similarities; theoretically this dimension has to be regarded too for specific components (e.g. a convertible top). These dimensions are intertwined and can only be defined in connection with the theoretically following analysis as well as early decisions about the package and concept of future products. It is also related to the implementation strategy (see below).

3.2 Analysis of the product spectrum

The next step after the broader scope is to analyse the existing product spectrum, since following generations are practically always based on their predecessors. From that the detailed specifications for the product to develop and the respective building set can be derived. The analysis comprises the package in the meaning of the geometrical structure, the respective parts and especially-and explicitly-the interfaces, functions, suppliers, costs, etc. Furthermore the variants of the parts (internal variants) and the variants for the customer (external variants, "degrees of freedom", i.e. the customers' possibilities of choice) have to be regarded, which finally shows the relevance for the customer. The results of the analysis are a modular grouping and classification of the parts as well as a specification of development needs concerning standardisation and individualisation as well as differentiation and integration.

Starting from a collection of the parts and the respective variants and suppliers of the existing product, a functional abstraction of the parts ("Which functions do the parts fulfil?") and of the overall system ("Which functions shall the system fulfil?") as well as an abstraction of the variants to degrees of freedom provide a more general regard of the product. The parts and degrees of freedom, as well as the functions and suppliers can be arranged in a matrix system (Figure 2).

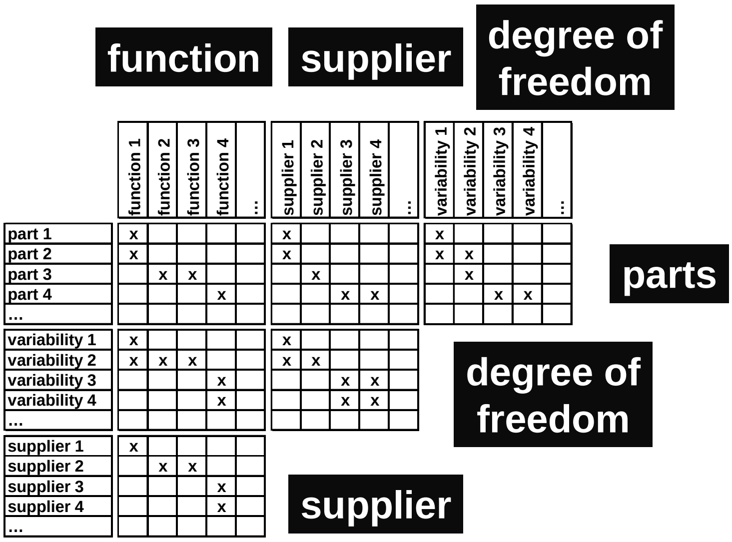

Figure 2. Matrices assigning parts, variants, degrees of freedom, and suppliers

With these matrices, by sorting the rows and columns, free scopes for development as well as integration and modularisation potential can be identified, e.g. parts that should be developed by one supplier because they serve the same function. Also a ranking can be conducted, e.g. in order to identify variability related complexity drivers, main suppliers, or central functions. The matrices are themselves not independent from each other, i.e. the contents of two matrices can determine a third one. These matrices can be extended by assigning identical elements, i.e. parts to parts in the meaning of an influence matrix or design structure matrix; central elements within one point of view can be identified, which has special importance for the technical interfaces. A rich picture of the geometrical structure helps identifying these interfaces (Figure 3). Here, core elements are in darker grey, interfaces out of the regarded scope are in light grey, and parts that do not have a customer relevant function and only serve as interfaces of core parts are white. As a first conclusion, central elements become big building blocks or building sets themselves; a functional regard helps modularising the system [7], [8]. Interfaces have to be standardized or easily adaptable in order to allow a flexible configuration of the relevant components. The latter addresses a crucial aspect of setting up a building set strategy: on one hand, the overall structure has to be defined, which incorporates the differently specified components and represents the whole product (building set in the narrow sense); on the other hand, the components have to fit into different product models (rather "carry over parts"). This meets the contradiction between the integration of components, due to high technical requirements and lacking space, and modularisation, as a major aspect of a building set. In this context, there is also the question of following a topdown or a bottom-up strategy regarding the market segment or quality rating of the product range. It could be recommended to implement a component first in a higher positioned product, so that it can become smaller and cheaper after some time for an implementation in lower products; it is also possible to develop the component for the lower variant firstly, so it will fit as well in the higher one. These aspects have to be encountered flexibly and the "artistry" is to implement both types within the strategy, namely on different levels of detail without unconsciously intermingling the approaches. This differentiation is both part of the planning and the actual development.

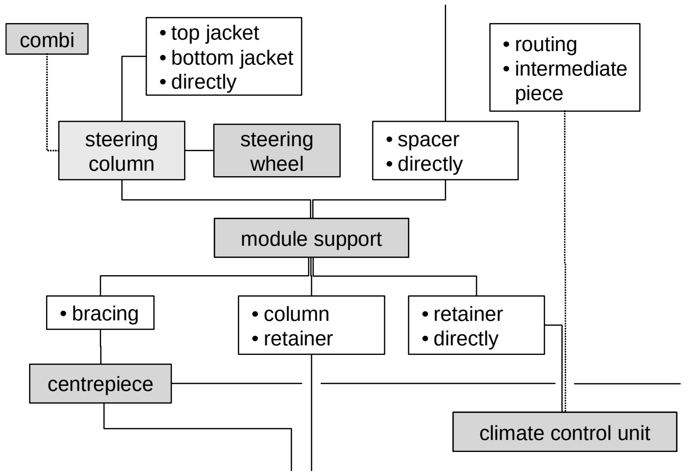

Figure 3. Geometrical structure of the product (extract)

The analysis finally leads to a regard of the component's relevance for the customer concerning its variability. In the automotive industry, which is very design oriented (in the meaning of appearance), a distinction between visible and technical variability is recommended (Figure 4). In this representation, costs are also regarded via the size of the points. For that and in general, an additional ABC analysis concerning the costs is fundamental. Other industries might use other differentiations.

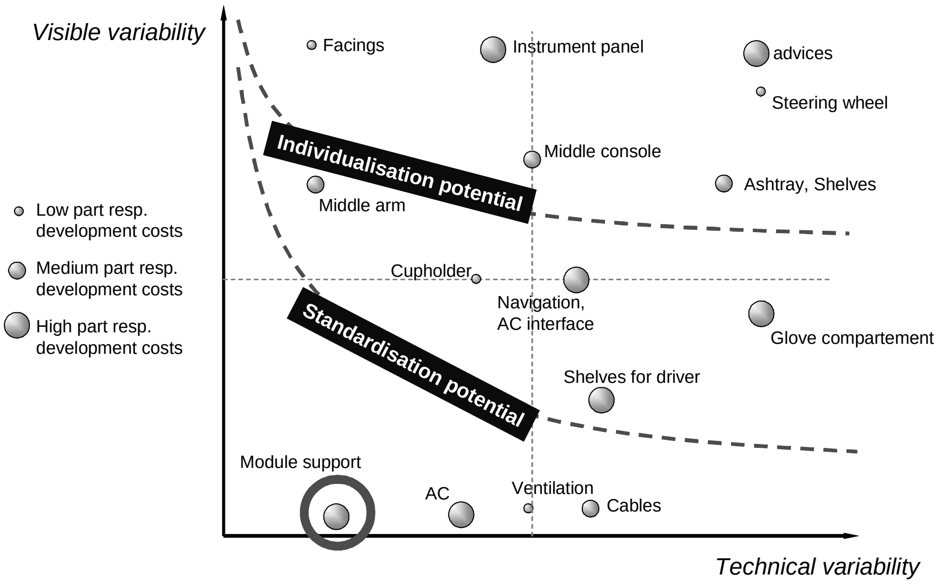

Figure 4. Visible and technical variability to reveal customer relevance

It has to be specified in such diagrams if the contents are actual or target values. In our case it is the target value, so that for each component the question can be posed if the component is already placed there; otherwise (actual value) the question would be if the component really should be placed there. This leads to individualisation or customisation potential in the top right corner, to integration potential in the lower left corner (especially if the costs are high, as they are for the module support, a metal support on which all the cockpit's components are mounted). In between the components might be differentiated in order to obtain an individualised and a standardised part.

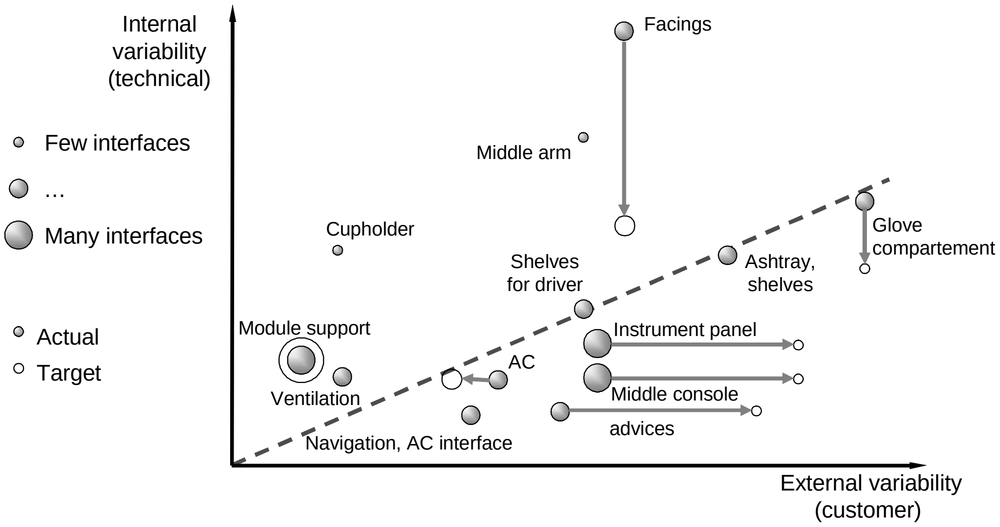

Figure 5. Internal and external variability as well as interfaces

Another representation compares the internal and external variability of the components (Figure 5). The general objective is to increase the external customer variability and to reduce the internal technical variability. Especially components with many interfaces shall be standardized, while components with high customer variability shall have only few interfaces. From these analyses, the specific development needs can be derived.

3.3 Development of a Building Set

The development of the building set in detail follows usual design processes, e.g. the general approach to design [9]. Some of the proposed steps are to be partly found in the here described process (e.g. the functional regard); other steps are to be extended due to the characteristics of the building set (e.g. varying specifications). Since this contribution focuses on the overall strategic process to implement a building set, a detailed description of the design process is not part of the regard. Only the development needs as well as some design approaches and principles shall be presented.

A demonstrative representation of the development needs is shown in Figure 6. Components with low customer relevance, high variability, and high cost shall be standardized, converted to a more detailed building set, or parametrically described. The latter possibility might lead to a concept building set on an abstract level, i.e. that sections of the design are standardised, so that at least these steps can be saved in future projects. Parts with high customer relevance and low variability should be individualised or customised to a greater extent; if it is possible, these parts should be separated into a standardised and an individualised segment ("optimise"). In each case, the interfaces have to be defined appropriately.

When implementing a building set strategy, some design rules and principles can be used in order to facilitate the process. Some of these are to

- standardise interfaces and elementary parts,

- create variability via design of surfaces,
- hold out free spaces for development, and therefore
- use locally highly integrated components,
- avoid multi interfaces,
- structure the product hierarchically,
- place variability in software/electronics,
- group variability in components that are always different,
- separate design and operation from mere technical aggregates,
- try to use symmetrical components, etc.

In first instance, the interfaces shall generally be independent of degrees of freedom, the components dependent on as few as possible degrees of freedom, and the degrees of freedom among each other not interdependent. This would provide the highest possible variability for the customer; actually the independence of degrees of freedom is the only possibility how to achieve the extremely high amount of variants possible within one car model, which is in fact in the magnitude of several millions or even billions.

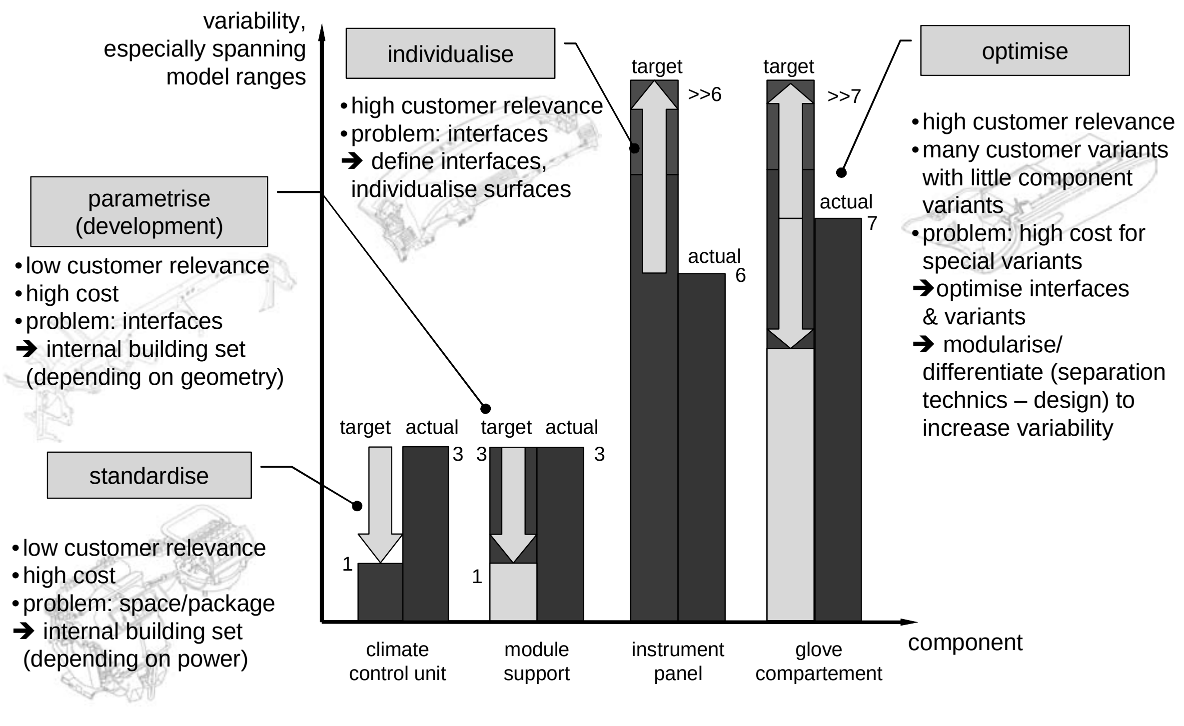

Figure 6. General approaches for building block design

This independence can be tracked best with the above mentioned matrix approach; it allows the designer to assign the variants clearly to the customer's possibilities of choice (degrees of freedom) and by that catch the interdependencies between the degrees of freedom themselves.

3.4 Evaluation

The evaluation of the building set strategy concerns different aspects, which can be reduced to cost mainly. A more differentiated evaluation is implemented within a computer based project monitoring tool for controlling [10]. This approach covers the aspects of cost, weight, dates and milestones, functions, tests, prototypes and tools, etc. It is mainly based on the same structure as represented in Figure 7 in a simplified way.

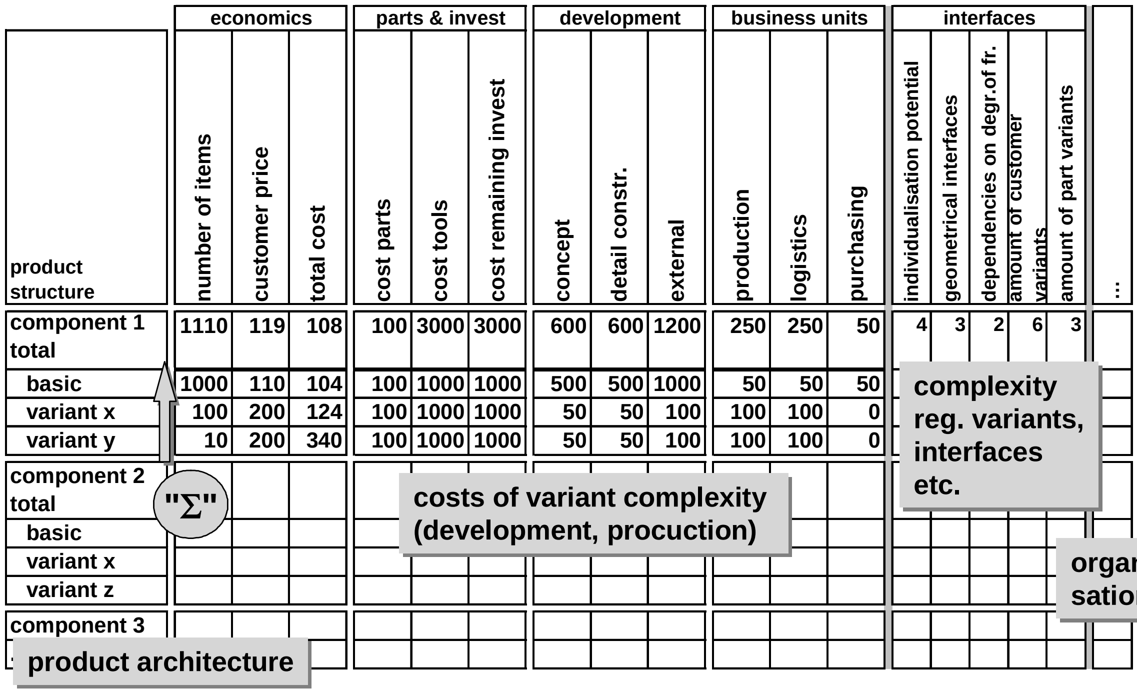

Figure 7. Tool for analysis, development and controlling of variants (costs and complexity)

This matrix comprises the product structure with a distinction of general components and the respective variants (in relation to the degrees of freedom) in the left column. Within the rows, the quantities and the detailed costs regarding parts, tools, development, and other business units are listed. From this, the total cost for a single variant and the total cost for the varying component can be summarized (e.g. cost for tools), eventually in relation to the quantities, i.e. some kind of average (e.g. cost for parts). In a database approach, which has been implemented as a prototype, the cost for a degree of freedom ("variant") can be calculated component spanning, e.g. the distinction of having the steering wheel on the left or the right side might concern ten components and by that might cost an exact amount of money. In the right side of the matrix, the above described representations and the analysis matrices are integrated in order to have a comprehensive overview and to relate the addressed criteria to the actual cost. For precise conclusions, the detailed and exact costs within the whole enterprise have to be seizable, which is actually not completely found in any company. Nevertheless, this tool serves for analysis as well as the development, and the final controlling and evaluation of the cost concerning variants and complexity, and can be used in defined areas. The building set strategy might be evaluated by other key figures such as e.g. the platform efficiency (derivative product engineering costs / platform engineering costs) [3]. These key figures have importance first for accounting and a final evaluation of the whole building set strategy, they are less beneficial for practical product development. Here, the benefits in number of parts, interfaces, and variants, development capacities, production resources, and the like are to evaluate directly.

4 Strategy implementation and boundary conditions

For the research project two possible objects could be regarded: either a recently finished product development, or a new, upcoming one. The first kind of project has the advantages that, for research purposes, all data and information about the product and its development process are or should be available; practically, even here information is missing due to changed employees, completed files, etc. The latter approach has the advantages of timeliness and pressure due to practical importance, i.e. these topics have to be processed anyway; in contrast, these processes last quite long and a lot of information is missing in the early phases. Finally, our approach has been to examine a building set for models that were already finished, shortly before the start of production, as well as in a very early phase of development. By that we could comprise all advantages as well as the different above mentioned dimensions. In the same way, two practical approaches have been possible to implement the building set strategy. On one hand, it is possible to directly implement the building set strategy; on the other hand, a theoretical building set can be developed, which serves as an argument to convince other divisions of its significant advantages and the general possibilities and feasibility of such a strategy. In each case, it is crucial to integrate all other divisions and suppliers involved, either from the beginning or after an initial conviction. On one hand, "other" divisions are a major obstacle in designing a building set since it always means compromises (and there are always reasons against any strategy), on the other hand system suppliers can support such a process when forced to be able to implement different (also standard) components and concepts of other suppliers, which are possibly involved.

In order to integrate all concerned parties and finally implement the building set effectively, some boundary conditions have to be fulfilled, mainly in relation to the organisation. The integration of the divisions is best realised by a team precisely installed for that purpose; such a team shall cover the different development divisions according to the scope of components, according to the whole product creation process (i.e. pre-development, development, production, sales and marketing, etc.), according to different functional aspects and disciplines (i.e. mechanics, electrics, design, safety, quality, etc.), and of course the suppliers. This team has to obtain the responsibility for the building set; a progress from rather hierarchical organisations towards more emphasis on teams can be observed generally and seems to be recommended. Next to this positive collaboration of the divisions, there has to be transparency in the cost and product structure, a dividing of the development efforts between all models involved-not only the first one-, a very early decision of concepts for future projects, and the support by the management with one person responsible and pushing that strategy. Additional requirements are that there is competition between suppliers that might have to be established, a clear allocation of responsibilities, a division of advance development concerning concepts for upcoming projects and general technologies, an optimized documentation of solutions, as well as a mapping of the technical structure with its interfaces to the organisational structure with its interfaces. By that, such a methodology for developing variant rich mass products cannot replace a long and complex development process nor the designers involved in it. It is just a support and rough description of a possible proceeding. Actually it seems to be most important to have a person responsible for such a development, to have the will to build up a building set strategy, and to have definite decisions on which a development can base on.

5 Summary and critical considerations

Building set strategies are an answer to increasing demands concerning quality, cost, and variety, with at the same time constant or even decreasing resources for product development. We have presented a strategic process to implement such a strategy within the automotive industry, together with methods, representations, tools, principles, and boundary conditions. The process mainly comprises the planning and analysis, the development, as well as the evaluation and actual implementation of the strategy. A main result is that implementing the building set strategy is rather an organisational than a technical problem. More speculatively, it might not be important if it is a *building block* strategy that makes sense, but that it is one *strategy* and direction on which the company can build its progression and concentrate its forces. A critical aspect is that there is a motivation and a pushing stakeholder for the strategy. And it has to be mentioned that a building set strategy is not per se advantageous and beneficial; it does not seem to be meaningful or have much potential if the regarded scope is, under certain circumstances, very design oriented with few merely technical parts, quite reactive in the development process, and not able to make strict specifications for other divisions.

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