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THE K- & V-MATRIX METHOD - AN APPROACH IN ANALYSIS AND DESCRIPTION OF VARIANT PRODUCTS

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1 Introduction

Over the last few years diverse factors in the enterprise-environment have changed: more individual customer requirements, increasing market globalisation and competition and so on [3]. Enterprises react to the changing situation by offering an increasing number of variants of existing products in order to satisfy different customer requirements in different markets. Often the internal product complexity is augmented with specific modules without real advantages for the external variance (product variety). This usually causes high costs and generates only marginal gains. Moreover, the internal product complexity often causes an increasing number of dependencies and rules between single modules and makes the product-configuration process more complicated for vendors and customers.

A good approach to reach the objective of an extensive external product variance is to plan a modular product family with as few dependencies between modules as possible in order to permit the maximal number of combinations between different modules [2]. This way, it is possible to optimise the product variety in order to satisfy different customer requirements and to simplify the sales process. To achieve this objective, however, a methodology is needed to manage and analyse the internal and external product variances during the development process and, at the same time, to reflect the product-logic. This information has to be stored in a way that this data can be re-used later in a configurator during the sales process.

Although many companies already have well-structured products, these companies are typically large enterprises with products that are sold in large numbers. However, many small and medium sized companies still work on the basis of adaptive designs because the barrier to product-structuring is very high and methods and tools as well as support for these demand a lot of resources. Lack of resources is always a problem for these companies.

This paper discusses some of the results of the EUREKA-Project COMA and the experience with industry partners in the project. COMA's main goal is to develop a method for product structuring in the machine industry, which is easy-to-apply and supported by a software. The data created while using this method during the product realisation process is supposed to be used again in the sales process, as indicated in figure 1.

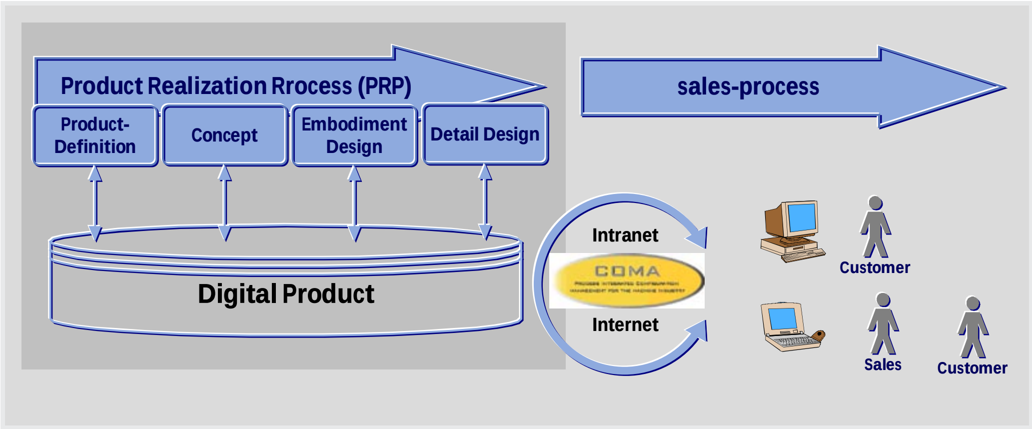

Figure 1: The design-process according to the idea of the "Digital Product" [1]

2 Existing Approaches

Many people have already dealt with product variance and the arising problems and also research has delivered many approaches in this area:

- First there have been various methods developed in order to support engineers during the challenges occurring in association with the product realisation process and variant products. A comprehensive listing of methods can be found in [3] and [9]. However, these methods often deal with only one aspect such as e.g. the reduction of variants, lack integration with other methods addressing related problems and focus on the activities within a single department (e.g. sales, production).

- Second there is also a large number of commercial software-packages to support the configuration of variant products. These software-packages usually allow the definition of complex rules, mappings etc. but are not integrated with existing design methods or description languages ([4], [6]).

- Third, desptite the availability of these methods and commercial software available, some companies have developed their own methods and IT-solutions to deal with their specific configuration process. The reason for this, is poor information about existing tools, limitation of the existing methods on specific aspects as well as poor adaptability and integration of software packages to specific configuration problems ([4], [5]).

The investigation of commercial configuration software has shown that the absence of a well-defined description language is a disadvantage. It makes it hard to begin structuring products and providing accurate product data for any configuration software.

Consequently, one of the crucial points is a description language for variant products that can be used on the one hand as a tool for managing and analysing variants in the product realisation process and on the other hand reflects the logic of the configuration during the sales process.

In this paper, a description language which might solve the mentioned problem is proposed.

3 Requirements for Use in Industry

In order to meet the requirements of the industry a description language has to support the aspects of variant generation, description and management during the product realisation process and later during the sales process.

The Must-Requirements of the description language can be summarised as follows and must:

- Allow the description of different product views because the language of the various departments of a company (such as design, sales, production) is different.
- Allow a consistent mapping between these different views.
- Allow the description of correlations between single parts or modules.
- Support the product realisation process and give an immediate overview of the product, its variants and the relations between them.
- Have a logic that is reflected in software to access, change and store this information. This knowledge can be accessed by different departments and represents the logical core of the configuration process.
- Be integrated into the enterprise-software environment in order to allow a consistent management of specific data (price, delivery-date and so on) in different systems (PDM, ERP).

Additionally, the description language and the related software should meet the following requirements:

- It should enable the extraction of information (e.g. reference numbers) about the structure of the variant product and eventually help restructuring or redesigning the product at a later stage.
- The description language should to be easy-to-understand and easy-to-use in order to increase the user's acceptance.
- An editing-tool also should loyally reflect the essence of the methodology in order to increase its acceptance by the user.
- A query-tool must be easy-to-use, in order to enable customers and/or vendors to directly configure the products based on the data defined in the description language.
- All the components of the software have to be product-independent and adaptable to the requirements of different companies.

4 The "K- & V-Matrix" as a Description Language for Variant Products

4.1 General Description of the "K- and V-Matrix"

The following methodology has been developed in the project COMA and presents a proposal for a description language, which is called the "K & V-Matrix" and is based on matrices. Matrices are useful in systems modelling because they can represent the presence or absence of a relationship between pairs of elements of a system. A major advantage of the matrix over the graphical representation is in its compactness and ability to provide a systematic mapping among system elements that is clear and easy to read regardless of size [7]. Other methodologies such as the QFD (Quality Function Deployment) or the DSM (Design Structure Method) have used this kind of representation. The similarities between these methods and the K-&V-Matrix are discussed later.

The "K-Matrix"

The K-Matrix represents the mapping between two correlated product views. In the matrix the elements of the first product view are placed down the side as row headings and the others of the second product view across the top as column headings. In the intersection fields of the matrix the relationships within the values of the properties of the product views are shown. If an intersection field is blacked out, it means that the value in the one view corresponds to the value in the other view. Thus, it is possible to perform a mapping between different product views.

A typical K-Matrix is the representation of customer relevant properties of the product and a technical (enterprise-internal) view. The simple example in Figure 2 shows how a inexpert customer of bikes can define the size of his frame (technical view) giving his height (customer view).

		Driver's gender	female	male	Driver's height	<170 cm	170-185 cm	> 185cm
Type of frame								
	women's		■					
	men's			■				
Size of frame								
	26"					■		
	28"						■	
	30"							■

Figure 2: Extract of the K-Matrix of a bicycle

The number of different views is unlimited and can include *customer*, *technical*, *production* and *CAD view* for example. Thus every enterprise can define its own product views following own internal requirements.

The K-Matrix focuses basically on the aspects of product variety, which can not be easily described with the QFD-method. The K-Matrix can be combined during the QFD process, complementaring the second house of quality, when the profile of the future product is mapped with single product elements.

The "V-Matrix"

Beside defining the customer view, technical view and the mapping between them in the K-Matrix, it is also necessary to describe the compatibilities of the individual properties within each view. Therefore the so-called "V-Matrix" (Compatibility-Matrix, *"**V**erträglichkeitsmatrix"* in German) defines the dependencies of the properties with each other.

The V-Matrix is a square matrix with an equal number of rows and columns. The matrix layout is as follows: the attributes and the respective values are placed down the side of the matrix as row headings and across the top as column headings in the same order. If pairs of properties (row i, column j) are compatible with each other, the intersection field (i,j) is blacked out. In the V-Matrix there are always two intersection fields (i,j or j,i) for the same two properties, so it makes sense to define only the fields above or below the diagonal elements of the matrix. If there are not any compatibilities between some elements, the corresponding intersection fields are left empty. With this matrix it is possible to compare every single variant of every module with each other in order to define all possible combinations within the product family. The example in Figure 3 shows that not every size of frame is compatible with the type of frames (black fields). The size of frame *woman* can not be combined with the size of frame *30"* (white field).

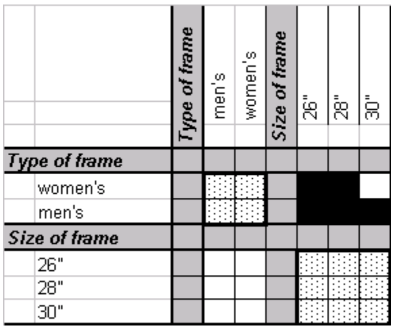

Figure 3: Extract of the V-Matrix of the technical view of a bycicle

Since there are two views in the K-Matrix (in this example *customer* and *technical view*), there must also be two V-Matrices: One for the technical view and one for the customer view. However, only the V-Matrix of the technical view must be defined, because the compatibilities between the customer properties can be derived from the technical compatibilities and the mapping between customer view and technical view. The V-Matrix for the customer view can be directly generated from the V-Matrix of the technical view and the K-Matrix. For example, the information that *women* taller than *185 cm* can't configure an appropriate bicycle in the V-Matrix of the customer view (figure 4) is derived from the information that there is no *women's frame* of *size 30''* (V-Matrix of the technical view, figure 3) and that cyclist's taller than *185 cm* need a frame of *size 30''* (K-Matrix, figure 2).

Thus, with the K- & V-Matrix the product views, the mapping between them as well as the compatibilities between product properties can be defined, visualized, stored and later - during the product configuration process - be queried.

There are some similarities between the Component-Based DSM (Design Structure Method) and the V-Matrix. Both matrixes consider the interactions between product elements in order to reduce design complexity. However the V-Matrix describes the interactions in form of compatibilities and focuses on the aspects of the configuration of variant products. In contrast, the objective of the DSM is to reduce the complexity of the product development process by reducing the need for difficult coordination across large development teams [8].

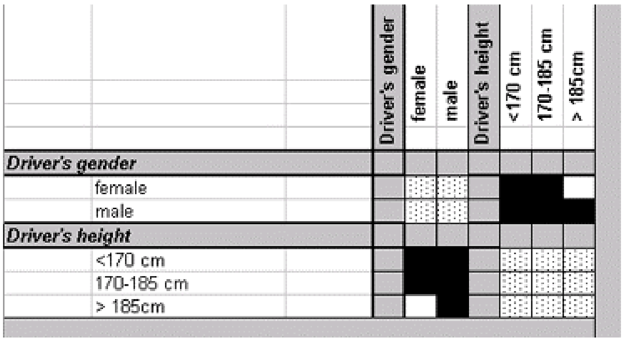

Figure 4: Extract of the V-Matrix of the customer's view of a bycicle

4.2 The software to support the K-&V-Matrix

In order to provide software to support this methodology, a data model was designed to store all the information contained in the K- & V-Matrix. In order to prepare for good integrability and performance this data model has been implemented in a relational database. As suggested by the concept of the “Digital Product” [1], it is very important to avoid the generation of redundant data and thus it is necessary to integrate such a software in the IT-environment of a company.

An editing tool provides the possibility to define and maintain the data very easily without having to interact directly with the tables in the database. The complex content of the database is visualised in a graphical user interface using a similar representation as the K- & V-Matrix.

A query tool lets the customer and/or the vendor configure a product and thus interact with the data in the database without having to care about the data structure. The query tool checks the information in the compatibility-matrix and thus makes the selection of unfeasible combinations of product-properties impossible. Besides this configuration-process, the tool provides ways to integrate additional product-specific information (like CAD-drawings, further product-specifications, 3D-Visualizations and so on), so that it finally becomes a information-platform of the products for employees and customers.

4.3 Examples for the Use in Industry

One example of a successful application of the K- & V-Matrix and the related software is industrial computer housings. This product is modular and consists of five pre-designed and pre-manufactured components (housing, backplane, device holder, power supply, filler panel) which are assembled according to the customer requirements. However, some restrictions prohibit all components from being combined in all possible way.

The information concerning the components and their compatibility as well as the customer requirements satisfied by a certain combination has to be obtained from the ELMA catalogue. This was not satisfactory, because

- there was no comprehensive overview of the components and the customer requirements

- although the product structure was defined, there was no explicitly defined set of customer requirements

- the catalogue was structured according to the housings, so this was the first element to be defined during the configuration process

- there was no clear path from customer requirements to the required components, so adequate solutions had to be found by trial and error or with the help of an expert

In order to come up with a better solution, the K- & V-Matrix method was applied in the following steps:

- The technical view was established: the type of component (housing, device holder etc.) became attributes and the components itself (housing A, housing B etc.) associated values.

- The compatibilities of the components were defined in the V-Matrix of the technical view.

- The customer requirements had to be defined in collaboration with company‘s vendors. Just as for the technical view, the customer view was established using attributes (e.g. *number of slots* for PC-Cards) and associated values (*1, 2* etc.).

- The K-Matrix, as the mapping between customer view and technical view was defined.

The benefits of the application of the K- & V-Matrix method to this product can be summarised as follows:

- An accessible and understandable knowledge-base for the product was established

- Since the developed software was used, the V-Matrix of the customer view was generated automatically from the V-Matrix of the technical view and the K-Matrix. This is useful for later analysis of the customer requirements that can be satisfied with the technical properties of the product.

- With the software, the data created while defining the matrices could be used for a web-based configuration tool for internal use and online-sale. As a replacement for the print catalogue, it enables the customer to configure the product himself without the help of a vendor.

- Good visualisation of the relations between customer and technical view and the compatibility of the modules.

- The proceeding of the configuration process is now completely free and doesn't depend on the organisation of a catalogue.

5 Conclusion

The methodology and the related IT-tool presented in this paper provide a useful tool for analysing and structuring product variety. The K-&V-Matrix represents two main aspects of variant structuring, which build the logical product description for the configuration process.

On the one side the mapping between different product views enables the representation of various product views. On the other side the representation of the compatibility permits to describe which modules of the product can be combined. A major advantage of the matrices over the graphical representation is in its compactness and ability to provide a systematic mapping among system elements that is clear and easy to read. This enhances the users' acceptance independently of their background.

This methodology is especially suited to highly modularised products where the complexity of the relationships between single elements is relatively low. Studies have started to investigate the possibility of supporting complex relationships in product structuring.

The method and the tool presented here don't claim to replace configuration software but they lower the barrier for product-structuring and provide some basic functionality of a configurator. In case product structuring leads to a point where additional functionality is needed, the bridge to configuration software can be made.

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