INTERNATIONAL DESIGN CONFERENCE - DESIGN 2008
Dubrovnik - Croatia, May 19 - 22, 2008.

APPLYING THE MULTIPLE DOMAIN MAPPING APPROACH TO VARIANT MANAGEMENT

F. Deubzer, T. Braun, M. Maurer and U. Lindemann

Keywords: variant management, complexity management, multiple domain mapping, design structure matrix, graph visualization

1. Situation

Variant management as such means managing complexity caused by market and customers, which is why variant management is often seen as a subcategory of complexity management. As today's markets show an increasing individualization, dynamics and diversity concerning the customers, different authors point out the relevance and challenge for companies (e.g. [Anderson 2006, Maurer 2007, Wiendahl et al. 2007]), especially OEMs and suppliers in the automotive sector. While for a long time variant management meant focussing onto the most frequently ordered variants, niche markets and individualized products gain more importance and stand for profit for the companies nowadays and in the future. Nevertheless, activities need to be accompanied by new methods and tools. The described phenomenon, known as "the long tail" [Anderson 2006], has thus relevance and effects for the management of variants: the typical characteristics of the buyer's market with the resulting requests for individualized products will further increase and worldwide distribution will result in continuing demand for different country-specific variants. In brief, companies nowadays have to deal with niche segments on the market to be successful. These insights are not new, as for example the research field of mass customization (see e.g. [Pine 1993]) is dealing with those effects for several years now, nevertheless mostly from an economical or manufacturing point of view. Solutions for the development of technical products, dealing with variant management and the inherent complexity are not yet available, although promising methods were recently introduced [e.g. Baumberger 2007, Gahr 2006, Maurer 2007].

All the efforts to deal successfully with the emerging of niche markets cause a rise of complexity, making variant management more and more complex and difficult to handle. The complexity shows in different domains, all relevant for the successful management of variants. [Maurer 2007] mentions the technical domains in terms of components and manufacturing, as well as organizational means such as process steps, milestones, data exchange and the organization of personnel. Especially when speaking about variant management, the differentiation between departments is of additional relevance, as goals and the radius of influence and knowledge differ accordingly. The complexity to manage by an efficient variant management is thus not just the complexity of marketing and sales, which are directly connected to the described effects of increasing market complexity and dynamics. The thereby induced complexity in the domain technology and other domains needs to be handled as well. Thus, our research efforts concentrate on the combination and interdependency of different domains. Major goal thereby is the gain of transparency for decision making and planning in product development environments affected by the long tail phenomenon.

2. Existing Strategies and Methods in Variant Management

Accordingly to the different domains affected by the complexity of variant management [Maurer 2007], strategies to deal with this increasing complexity from different points of view exist within these domains, which are namely the following: the domain of engineering development, covering the technical aspects in terms of methods and tools, supplemented by the domain production, the organizational and the process domain [Braun & Deubzer 2007]. The following compilation of strategies and methods within these domains is not meant to give a complete overview, but to allow insight into the activities concerning variant management within these domains and to characterize current efforts in research and industry. As the presented results are mostly contributing to the engineering development methods and tools, these represent the focus of the state of the art.

2.1 Engineering Development Methods and Tools

The implementation of software tools for variant management is very common. Yet, the purpose and functionality of the tools differs. The configuration of products by the customer, e.g. on the websites of different car manufacturers, is in focus of configuration software inheriting the rules and boundaries of the variant configuration. These tools do not contribute to the management of variants or the methodical support thereof, but depict the possibilities, yet without giving additional insights or visualizing the context or the sum of all variants. The methodical tool support for the management of variants on the other hand is mostly based on the logic of variant trees, aiming at the efficient reduction of the number of variants and rating the variant variety. In combination with the number of orders for each variant, these methods enable the identification of the economically most relevant variants (see e.g. [Schuh & Schwenk 2001]). The effects of the long tail phenomenon are yet unconsidered by these methods, as are the thereby induced side-effects on design, service, marketing, etc.

Common, besides the mentioned methods from the economical perspective, are methods for the development of product platforms or modular product architectures, serving different purposes such as mass customization [Pine 1993], cost leadership [Meyer & Lehnerd 1997], or the definition of product families [Tichem et al. 1999], enabling the consideration of different aspects of the product lifecycle, but not providing the required transparency and different points of view for the departments and persons involved.

2.2 Organization

Discussions with companies and related interviews show that the engineering development methods are accompanied by several organizational measures, such as the training and raising of awareness of the employees. Different projects show the importance of communication and coordination between employees and departments, especially their importance for variants, where the definition of interfaces of the product and departments possesses even more importance. Employees in the marketing, sales and development departments are usually instructed to avoid new variants in a desperate effort to keep the level of complexity low, not accounting for the effects of the long tail phenomenon [Braun & Deubzer 2007].

2.3 Processes

Recent developments have led to the modularization of processes to supplement the modularization of products and satisfaction of individual customer needs [Wunsch & Kimura 2005]. Crucial and necessary for the successful implementation of process modularization is the costing in accordance with the cause of cost, the so-called activity-based costing, which was actually developed to meet the needs of mass customization and individualized products [Gahr 2006].

2.4 Production

Finally, production has to meet the requirements caused by the development of different variants. Results of research activities are flexible production systems (e.g. to reduce set-up time) as a superordinate cluster of measures to meet different demands (such as those of mass customization) where flexibility in production is necessary. Subordinate and further measures are the segmentation of production, pre-assembly, purchased parts, and strategies to find the efficient degree of company-internal value creation (e.g. [Wiendahl et al. 2007]).

As the brief summarization of methods and strategies in the different domains which are affected by and necessary for variant management has shown, the existing activities and research are concentrating on either reducing complexity and/or cost, or to manufacture the existing number of variants and cope with their customer specified properties. A number of shortcomings is thus evident, as the approaches are addressing the problem of managing market induced complexity in variant management from the specific point of view of the respective domain. The transparency and effect of the different measures with regards to their effect in other domains are not yet clear, making their application and success in the context of a holistic variant management impossible, at least questionable. The following paragraph shall therefore make clear the motivation and requirements for a holistic variant management.

3. Motivation and Requirements for a New Approach

The existing methods allow for the variant management from a certain perspective, to optimize e.g. production cost, reduce development expenses, or to adapt flexible manufacturing. Projects with industry have shown that companies lack the ability to enable transparency for the involved persons and gain overview over the complex interdependencies between different aspects of variant management. The effects of measures to optimize one of the mentioned domains are not considered in many instances. Especially the cause-and-effect chains containing domain-spanning linkages are hard to grasp intuitively and knowledge about those linkages and related effects is hardly existent. The dynamic of the whole variant management system shows in the impact of activities within one domain onto other domains. For example, the management of the variants offered within the product portfolio from a sales perspective might allow for the satisfaction of the customers' needs and thus require no further optimization. The technical system in terms of carry-over parts, basic modules, interfaces of modules, manufacturing etc. might nevertheless require optimization to allow for the desired company profit.

The challenge companies are facing is hence the transparency to allow for a holistic view on variant management. The following multiple domain mapping approach was adapted to enable this holistic view on variant management. The approach will be shown by the example of the sales and the development perspective on a front seat of an automobile. The problems addressed are the following:

- what components and what functions offer potential for modularization within their domain
- how do sales perspective (offered functions and optional equipment) and development perspective (components) match or influence each other
- how do different existing product lines affect the modularization decision

4. Approach and Results

Basis for the approach is the Multiple Domain Matrix methodology developed by [Maurer 2007], using Design Structure Matrix (DSM) and Domain Mapping Matrix (DMM) methods and combining them to allow for a holistic view on systems and the management of complexity in product development. The DSM method allows for the abstract depicturing of a system by showing its elements and relations between elements in a square matrix (see Figure 1.). Different fields of application are known [Browning 2001] as well as are numerous algorithms to analyse the structure of the systems depictured in a DSM (for an overview see [Maurer 2007]). The visualization of the system analysis can be carried out as well in graph representation as in DSM-representation.

Results of the application of these algorithms allow e.g. for the definition of modules of products, identification of critical elements in structures or feedback loops in processes and many more. The DMM methods enable the combination of different domains by the use of non-square matrices, picturing the effect of domain-spanning linkages. The Multiple Domain Matrix (MDM), however, combines these two powerful techniques to a methodology to support complex product development.

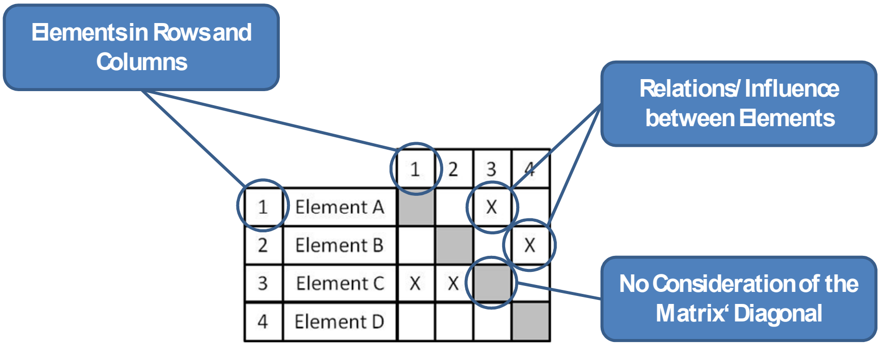

Figure 1. Composition of a Design Structure matrix (DSM)

4.1 Proceeding

The proceeding of the approach consists of five major steps (see Figure 2.), of which the "system definition", "modelling" and "structure analysis" will be discussed in detail in the following paragraphs. Minor adaptations to the original approach were necessary but are not relevant for the content presented in this paper.

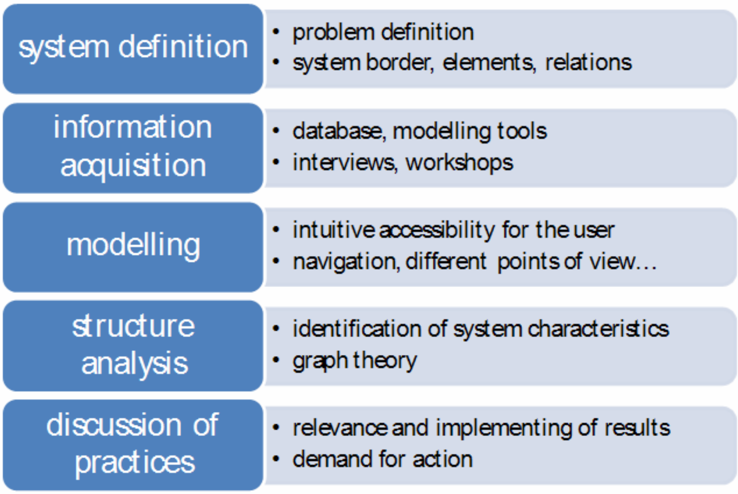

Figure 2. Proceeding according to the Structure Management Approach [Maurer 2007]

4.2 System Definition: Domains and Interdependencies

The problems addressed are mentioned in chapter 3, the system definition concentrates therefore onto the domains and interdependencies. An overview over the domains of the holistic system "variant management" is given in Figure 3 in MDM-notation [Maurer 2007], i.e. the domains are arranged in rows and columns of a square matrix. The DSM and DMM matrices between the domains contain the linkage type of the corresponding domains if there is any.

The considered matrices of the presented approach are encircled in Figure 3. The presented MDM is not claiming to be complete, in fact it was reduced to focus onto the domains relevant for the results presented in this paper, which are "functions", "components", "optional equipment" and "product lines". The following paragraph will show the results achieved by modelling and analysis of the intra- and inter-domain linkages.

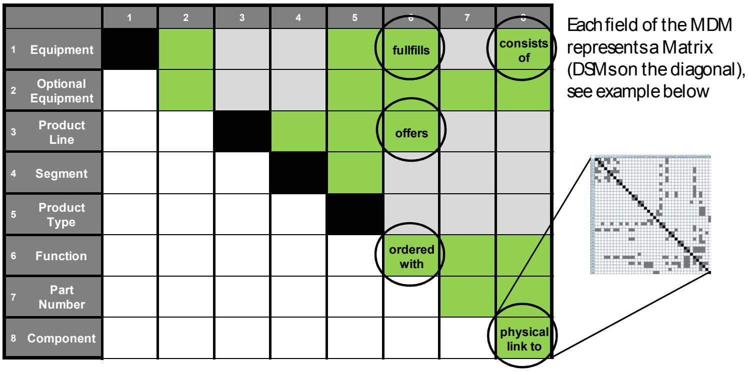

Figure 3. Variant Management MDM: Domains and linkage types

4.3 Modelling and Structural Analysis

To visualise and grasp the interrelations of complex systems intuitively, matrix- and graph-representation have proven to be very beneficial [see e.g. Browning 2001 or Maurer 2007]. The following paragraphs use one or both of the two representation forms to point out significant results of the application.

4.3.1 Component View

The matrix and graph depiction of the component structure stand for a classic DSM application and show clearly the potential for modularization and definition of interfaces. Figure 4 depicts two different component structures in graph representation, showing the difference of product lines.

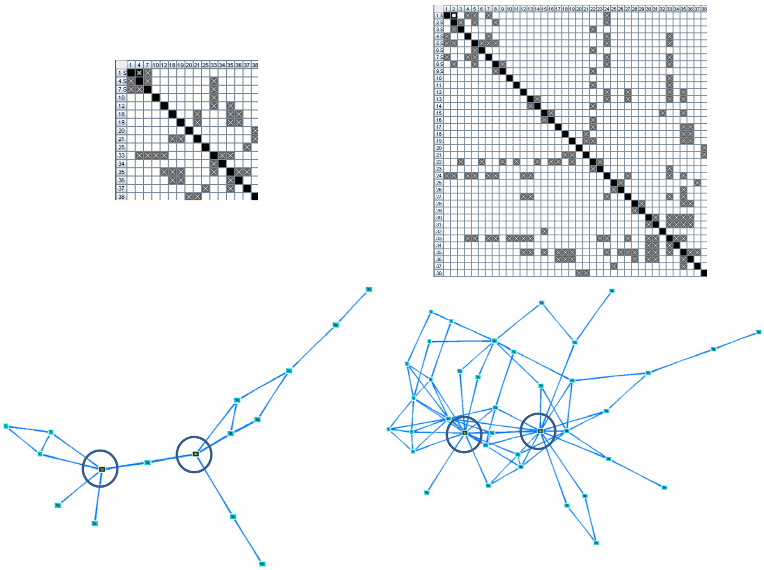

Figure 4. Component structures of different product lines

The connection between two elements in the left graph represents the fact that two components are ordered together often. The more frequent the order of a pairing is, the closer they appear to each other in the graph. Clearly recognisable are the significant elements of the structure, such as the highly interconnected ones in the middle and the lesser connected components on the outside. As a result, the highly interconnected elements in the middle are the possible basic modules, while those on the outside compose the optional equipment. This representation shows one specific variant only, i.e. the seat with manual adjustment options for a small product line, the results might have been achieved otherwise, too. The potential of the method is to bring different variants to overlap, as was done on the right side in Figure 4. This application of the method allows the identification of those parts being most important for the overall company, not just one single product line or department. It can be clearly seen, that the central elements encircled in the left graph are still central elements in the right graph, but a lot of interfaces and other components gain importance in this comprehensive view. Being the seat structure and the backrest, the central position of those two elements comes as no surprise, but the true position including the sum of interfaces and most relevant parts can only be seen in the comprehensive view. These results enable the analysis of modular product portfolios in a completely new way in opposite to the known variant trees and isolated views onto the problem [Schuh & Schwenk 2001]. Components can be identified, which represent the basic modules for all variants in all product lines.

4.3.2 Functional View

The functional view onto the product (Figure 5 shows the functions of one variant, similarly connected to each other as components in Figure 4) shows similar results as the component view, as few functions are ordered frequently (inner circle), less frequent, or hardly ever (between middle and outer circle).

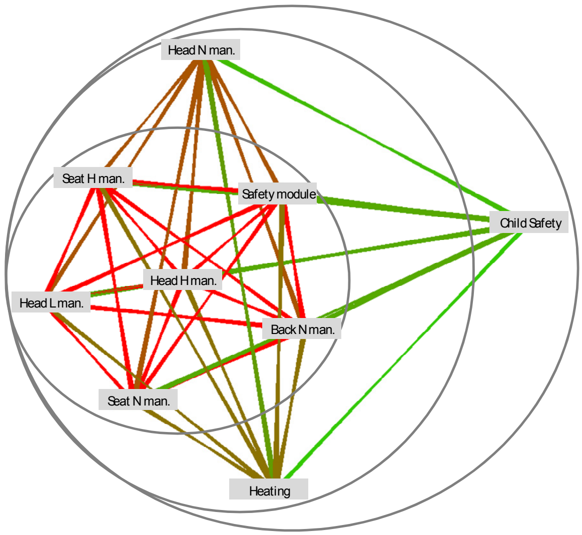

Figure 5. Functional structure of one variant

4.3.3 Communality in System Design

Interesting insights are shown by the integration of different variants from a functional perspective, as shown in Figure 6 (similar to Figure 4 on the right). In this case, only two variants were combined, showing clearly the shift in the core of the variants, as some functions are pushed out from the inner core, representing the basic modules for one variant but not the combination of variants, while others do not significantly change their position. This proceeding shows, that the presented approach makes insights into existing coherences available which cannot be achieved by other approaches. Remarkable are the differences between the isolated and the combined view, giving a hint about how mistaken isolated decisions might be.

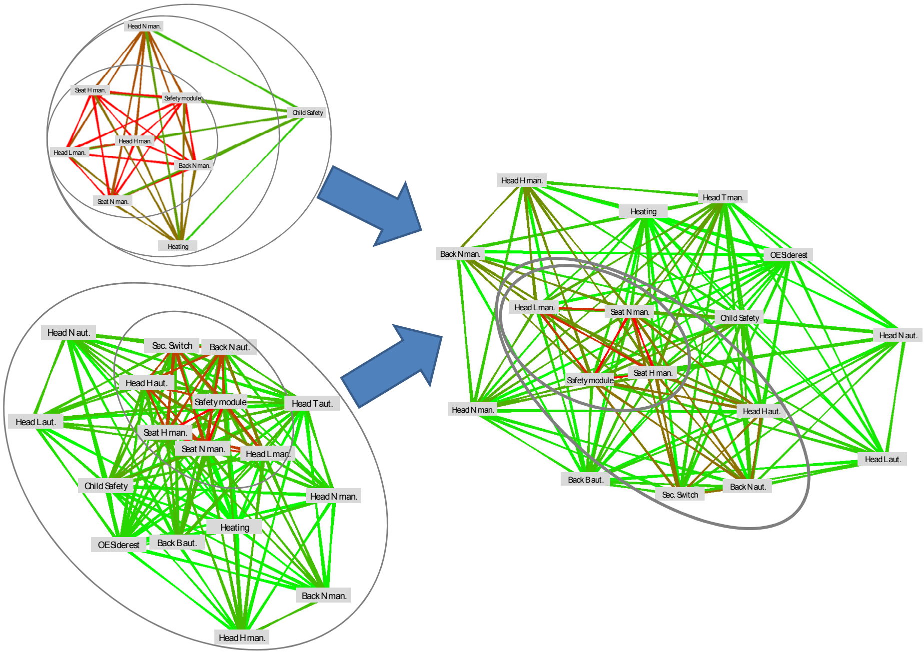

Figure 6. Communality in system design from a functional perspective (segment)

4.3.4 Integral View of Components and Functions

A likewise remarkable result is shown by the integral view of components and functions, presented in Figure 7. The presented matrix is a DMM of components (rows) and the packages of optional equipment (columns). Major difference between a DMM and a DSM is the square character of a DSM in opposite to the non-square DMM. Due to that matter, different algorithms for structure optimization apply. The relations stand for "component is part of package", groups of similar packages are marked in the graph and matrix by dotted lines, significant groups of components are encircled by full lines.

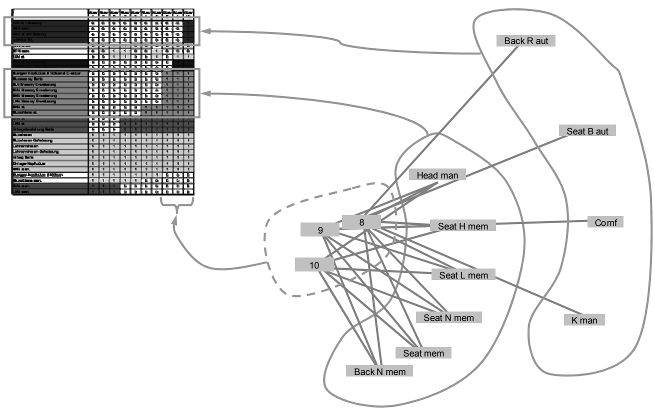

Figure 7. Integral view of components and functions (segment)

The connectivity of the graph allows for different interpretations: e.g. which diversification can be reached amongst the packages and by which components; or how can component modules be established from the perspective of optional equipment packages. The unusual depiction of two domains in one graph provides answers for these questions by arranging the components and packages amongst each other. The closeness of packages suggests the merging of basic modules for example, as on the other hand the closeness of components suggests the grouping into technical subsystems.

5. Conclusion

The presented approach enhances existing strategies in variant management and shows new directions on how to improve different aspects thereof. To give an example, the definition of basic and optional modules under consideration of sales and marketing perspectives not only of one product line but numerous variants allows for an overall benefit for the whole company. Communication between different departments is thus enhanced, change impact across boundaries of departments becomes transparent. Future research will incorporate numerous different domains to expand and solidify the results of this paper. The holistic view of the method and the systematic building of packages and modules across different product lines are both not provided by other methods currently available, making the up to now intuitive decisions explicit.

Ongoing research is investigating solutions on how to visualize and analyze variant spectra from the perspective of product properties [Braun & Deubzer 2007], which is adding a whole new dimension on the possibilities in variant management.

References

Anderson, C., "The Long Tail: How Endless Choice is Creating Unlimited Demand", Random House Books London 2006.

Baumberger, C., "Methoden zur kundenspezifischen Produktdefinition bei individualisierten Produkten", Dr. Hut Munich, 2007.

Braun, T., Deubzer, F., "New Variant Management Using Multiple-Domain Mapping", Proceedings of the 9th International DSM Conference, U. Lindemann, M. Danilovic, F. Deubzer, M. Maurer, M. Kreimeyer (Eds.), Shaker Aachen, 2007.

Browning, T. R., "Applying the Design Structure Matrix to System Decomposition and Integration Problems: A Review and New Directions", IEEE Transactions on Engineering Management, Vol.48 No.3., 2001, pp292-306.

Gahr, A., „Pfadkostenrechnung individualisierter Produkte – eine flexible entwicklungsbegleitende Kalkulation", Dr. Hut Munich, 2007.

Maurer, M., "Structural Awareness in Complex Product Design", Dr. Hut Munich, 2007.

Meyer, M., Lehnerd, A. P., „The power of product platforms. Building values and cost leadership", The Free Press New York, 1997.

Pine, J. B. II, "Mass Customization: The New Frontier in Business Competition", Harvard Business School Press Boston, 1993.

Schuh, G., Schwenk, U., „Produktkomplexität managen",Hanser Munich, 2001.

Tichem, M., Aandreasen, M. M., Riitahuta, A., "Design of product families", Proceedings of the 12th International Conference on Engineering Design ICED 1999, Lindemann, U., Birkhofer, H., Meerkamm, H., Vajna, S. (Eds.), München, 1999, pp 24.-26.

Wiendahl, H.-P., ElMaraghy, H. A., Nyhuis, P., Zäh M. F., Wiendahl, H.-H., Duffie, N., Kolakowski, M., "Changeable Manufacturing - Classification, Design and Operation", Annals of the CIRP, Vol. 56, No.2, 2007.

Wunsch, M., Kimura, F., "Towards Mass Customization Design based on Patterns", 3rd Interdisciplinary World Congress on Mass Customization and Personalization 2005, HKUST (Eds.), Hong Kong, 2005.

Frank Deubzer (Research Assistant)
Technische Universitaet Muenchen, Product Development
Boltzmannstr. 15, Garching, Germany
Tel.: +49 (0) 89 289 15137
Fax.: +49 (0) 89 289 15144
Email: frank.deubzer@pe.mw.tum.de
URL: http://www.pe.mw.tum.de