POTENTIALS OF DSM, DMM AND MDM FOR REQUIREMENTS MODELING

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1   INTRODUCTION

More attention is dedicated to requirements management in industrial environments nowadays. Not only is it becoming established in software and electronic domains - especially the development of complex mechatronic products benefits by the methods of requirements management [1].

The term "integrated requirements management" is seen as an extension of the traditional fields of requirements management (i.e. the management of the requirements lifecycle and the interdependencies between requirements) to the extended strategic approach of Product Lifecycle Management (PLM). PLM is seen as the most promising approach (methodical as well as IT supported) to bring X-Engineering (Cross-Enterprise Engineering) [2] into reality. This does not only integrate all lifecycle phases of a product (from cradle to grave) but also pays special attention to the integration of multi domains, as well as locally distributed development teams. The focus of this research however is on early stages of the product development process including aspects of the approach of frontloading [3].

2   INDUSTRIAL CHALLANGES

Next to organizational challenges, as well as missing or insufficient reference processes for the collaboration of multi domains, the challenge most often stated is the handling of complexity. Especially within the automotive industry where interdependencies between complex systems and components form mechatronic products calls for methods and processes to offer support in early stages of product development.

This arises in early customer-supplier interactions, as well as in the following product planning and engineering phases. Where the focus at the beginning is to translate loose statements in technical requirements (Quality Function Deployment), the analysis and integration of requirements into the development process, as well as the reduction of product variants is in the centre of attention in the following phases. Additionally the development of ontology's includes relevant aspects as well.

3   SOLUTION APPROACHES

In order to reduce the mentioned complexity, the methodology of Design Structure Matrix (DSM), Domain Mapping Matrix (DMM), and Multi Domain Matrix (MDM) are seen as powerful approaches to either handle or reduce complexity.

3.1   Reduction of Variant Complexity

In general, products are structured according to specific characteristics represented in form of different Bill of Materials (BoM). Rule based variants BoM's are capable to represent individual configurable products with a high number of different variants [6]. However, to handle a high number of variants is a rather comprehensive task. To counteract to this challenge some additional factors need to be taken into consideration that focus on early stages of the development process. Most of these factors are out of scope of today's methods in product structuring. Zagel [6] defines interfaces within a product structure in his concept (including product families, components and structure elements, variants, as well as parts and assemblies) that use a combination of structure and specifications within a DSM.

The complexity of product variants may reach a high number by only specifying a few components options. In his example he describes the diversity of a car seat with 864 variants. By splitting up product structure elements and using DSM as a complexity reduction method that restricts "useless" variants, the number of variants has been reduced to 36 (by focusing on the variance of the seat

cushion). Through these feasibility rules the solution space could be reduced, however, specifications remained the same.

This example shows that variant complexity and configuration management is a challenge in detailing phase of product development. Since the number of variants is configured by requirements already in early phases, the goal must be to reduce the number of existing variants described by requirements. This ensures that certain complexity issues may not appear in later stages and therefore support engineers to focus on their expertise – product development – instead of dealing with unmanageable configuration item in e.g. PDM systems. Again, DSM is seen as a powerful methodology to perform requirements variant reduction by e.g. clustering and elimination of requirements of no meaning but the increasing of variants. This can be done, as proposed by Zagel, to manage product structures and requirements within a DSM to reduce the solution space. Here product structure elements, as well as requirements would be considered to form one domain that is the basis for analysis.

Another solution might be to look at requirements and product structure elements as two different domains to be analyzed with a DMM. The usage of constraints represented in ranking offers additional information to be used for analysis. Clustered requirements may also be investigated to group them and look at them as one configuration relevant requirement. This could be performed in DSM, as well as DMM.

3.2   Quality Function Deployment (QFD)

Within the extended field of requirements management, several challenges arise during early phases of the product lifecycle. These are different for OEM's or suppliers. In the case of an OEM, usually marketing analyses are performed where basic "wants and needs (goals)" are elicitated. The result of these phases (often referred as requirements engineering) are statements describing the product. These need to be translated into more technical oriented requirements which are the further basis for the development of products. Quality Function Deployment (QFD) [4] is a method capable of that. Within the processes of QFD the House of Quality (HoQ) – a system of hierarchical lists, tables and matrices – is set up that contains among others the goals including their relations, as well as technical product requirements. Conflicts are outlined by a correlation matrix. DMM provides support in analyzing dependencies and/or group elements within the HoQ and the process of translating goals into technical requirements.

3.3   Requirements Analysis & Integration

Dependencies between e.g. requirements or functions reach a level of complexity rather fast. Not only that requirements change over time, they also have different priorities in certain phases of the development process. With the help of e.g. DSM such dependencies can be established. To outline priority, a numerical or relative ranking may be used. Since such matrices are usually static component based types, the analysis method of clustering may be applied to examine the structure of that system by grouping highly related nodes, called cluster [5]. That way engineers may identify and examine interfaces between the clusters, as well as areas of low relations.

The integration of requirements is among the most important aspects in the context of holistic PLM. Maletz [7] describes in his work how such integration may be performed by focusing on the functional approach. Several integration models are introduced (product, process and organizational). The product integration model emphasis on relating product requirements (dynamic behavior) to product functions (static behavior). Further on functions are related to position within the product structure (generic or conception structures) as well as processes (core development and support processes). These multi dimensional relations also need to be analyzed and optimized. Similar to the approach of Lindemann [8], this MDM is seen as the approach capable of handling these relations.

3.5   Ontology creation

Semantic Web and Ontology are terms becoming more and more important in today's industrial, as well as scientific environments. They are seen as methods to manage complexity, detect hidden interdependencies, as well as serve as a continuous knowledge layer to be constantly enriched with new information. However, ontology also has some disadvantages. One of the disadvantages is that the set-up and administration of ontology's is a rather complex task that requires a high level of experience (IT as well as methodical and engineering domain experts). Thus it makes it time consuming and dependent on domain experts that often "do not know what to do" with this new IT trend.

This is where DSM, DMM and MDM comes in handy. Ontology editors are in general confusing for engineers. They are used to work with domain specific tools or Excel. Thus the concept to work with matrices is well know and accepted for them. Ontology is, among other aspects, about the creation of dependencies to better understand the complex network of relations. So are matrices. By providing domain experts with e.g. hierarchical matrices to create dependencies with specific rankings, that information can be used for the creation of domain ontology's. The elements of the matrix hereby represent nodes, and the links represent weighted links (e.g. supports, is composed to etc.). This also represents a so called triple within RDF [9], as well as a semantic net to be integrated in PLM frameworks.

4   SUMMARY AND OUTLOOK

This paper outlines some potential that are beneficial within early phases of product development. The specific focus is on how DSM, DMM and MDM can be used with various aspects of requirements management. Several aspects of how to use such matrices have been discussed. It was shown that matrices are powerful methods to not only create and optimize dependencies, but also to reduce product configuration variety by eliminating variance of requirements.

Future work may include more detailed analysis of mentioned methodologies including prototypical realization and verification in industrial environments.

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10TH INTERNATIONAL DSM CONFERENCE

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Introduction

- More attention dedicated to requirements management & modeling

- From software & EE to "traditional" product development

- Integration aspects are essential
  → process & tool integration

- Embedded in PLM approach (strategic & platform oriented)

- Specific focus on early development phases

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Definitions

Requirements and the Requirements Modeling Process?

"A requirement is a statement identifying a capability, physical characteristic, or quality factor that bounds a product or process need for which a solution will be pursued*."
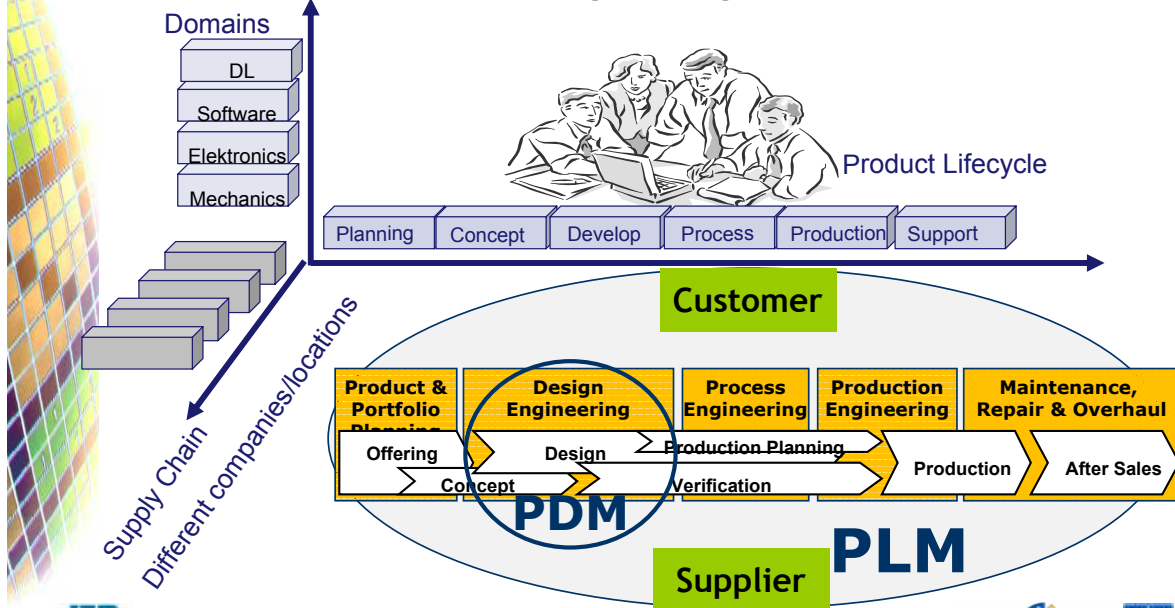

*IEEE Std 1220-1994

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FOLLOW THE FLOW OF INFORMATION!

Virtual Vehicle VPE
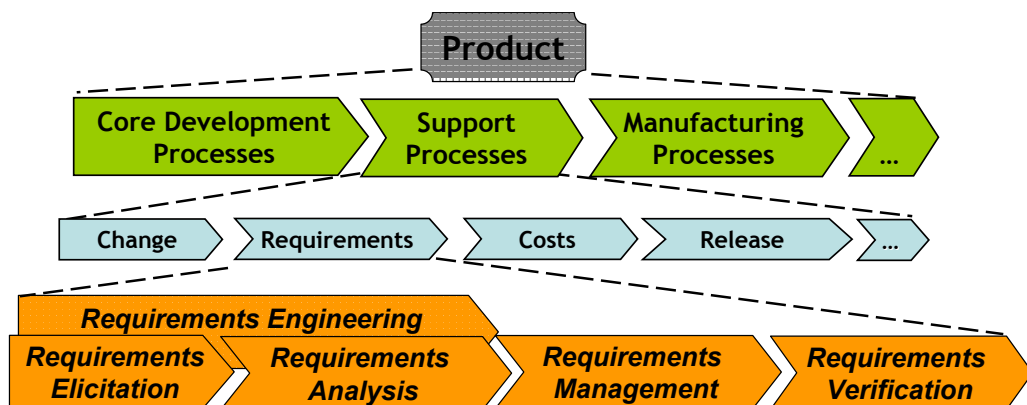
Definitions II

PLM and Cross-Enterprise Engineering?

Source: VPE

10th International DSM Conference 2008- 5

FOLLOW THE FLOW OF INFORMATION!

Virtual Vehicle VPE

Industrial Challenges (Extract)

- Insufficient support for early development phases
- Increasing complexity & different understanding of requirements
- Interdependencies between domains - mechatronic

10th International DSM Conference 2008- 6
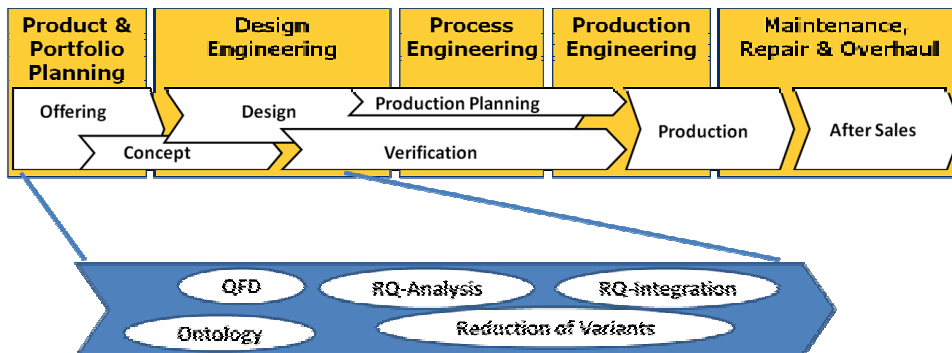
Solution Approaches

Apply methods of Design Structure Matrix (DSM),
Domain Mapping Matrix (DMM) and Multi Domain Matrix (MDM) to:

- Reduce complexity – especially variant complexity in early phases of requirements definition

- Translate customer wishes into technical requirements with the help of Quality Function Deployment (QFD)

- Support requirements analysis and integration aspects of requirements

- Provide a framework for the creation of ontologies

Reduction of Variant Complexity

- Reduce variant and configuration complexity analytically

- Prevent complexity where it is created – not where it shows its effects – requirements

- Bring requirements and solution space into close relation – conceptional & functional product structure

- Apply DSM to group/sequence individual requirements and extended for requirements & product structure analysis

- Expand methodology to DMM – requirements, product structure

- Analytical enrichment of dependencies analysis to restrict configuration expansion
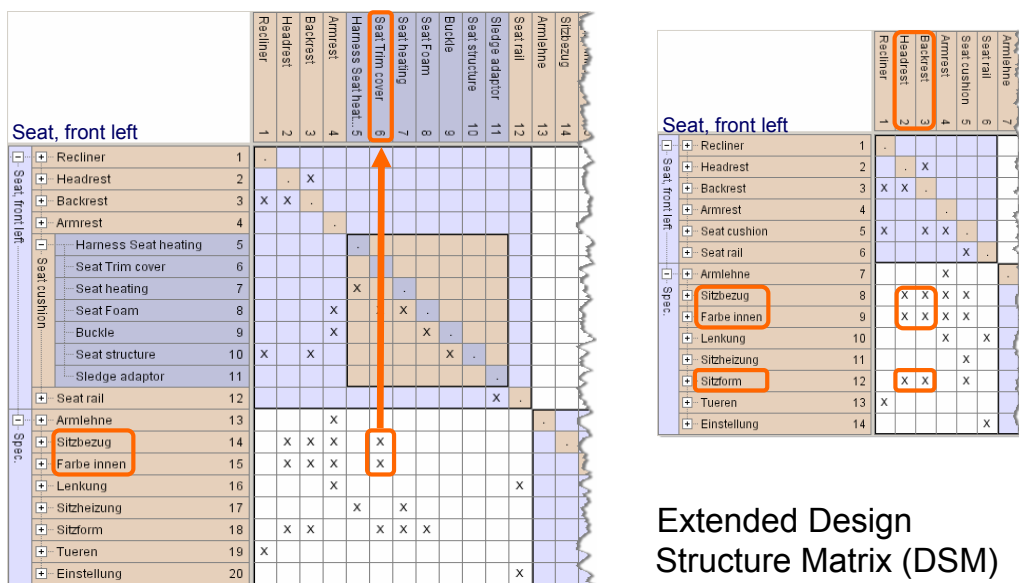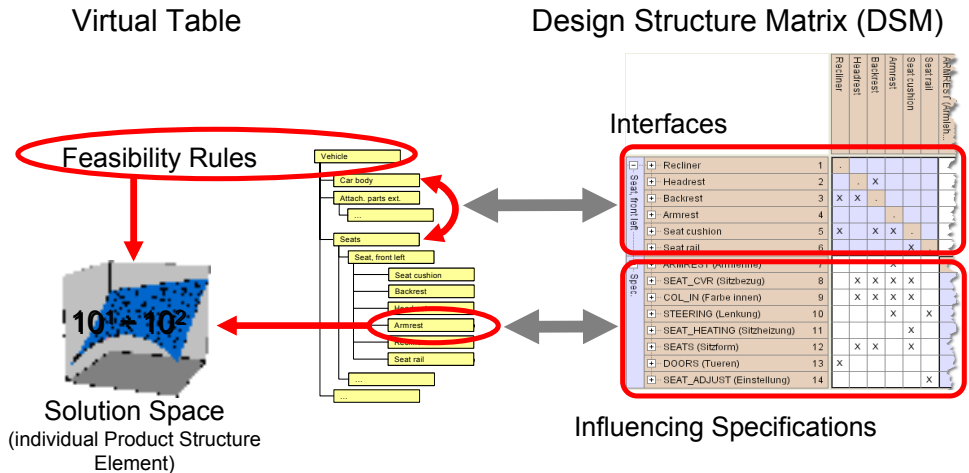
Interfaces of DSM to Product Structuring
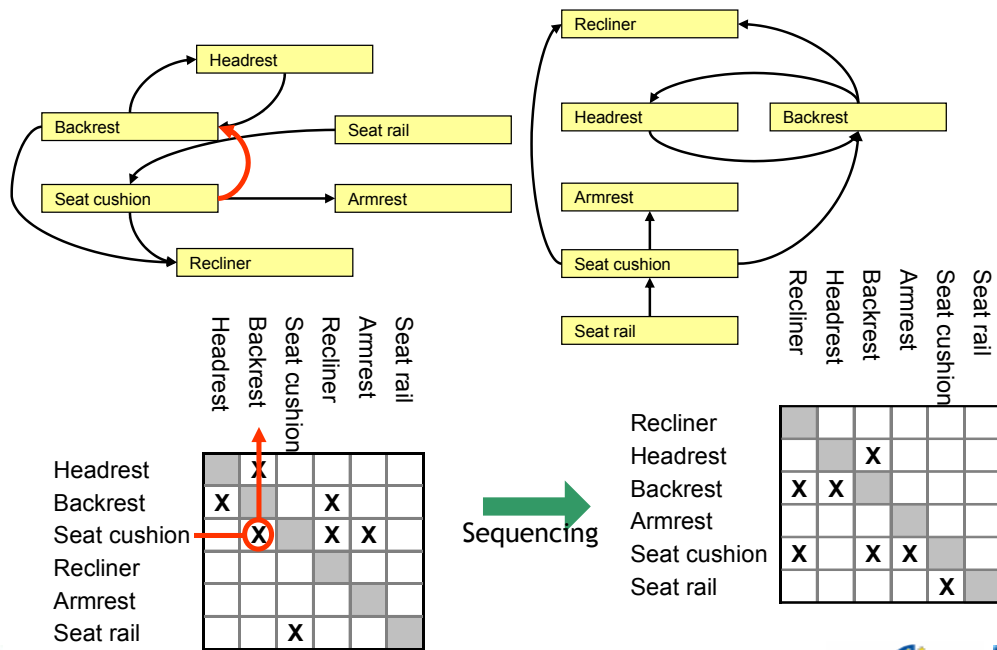
Source: M. Zagel ,VPE

Reduction of Variant Complexity II

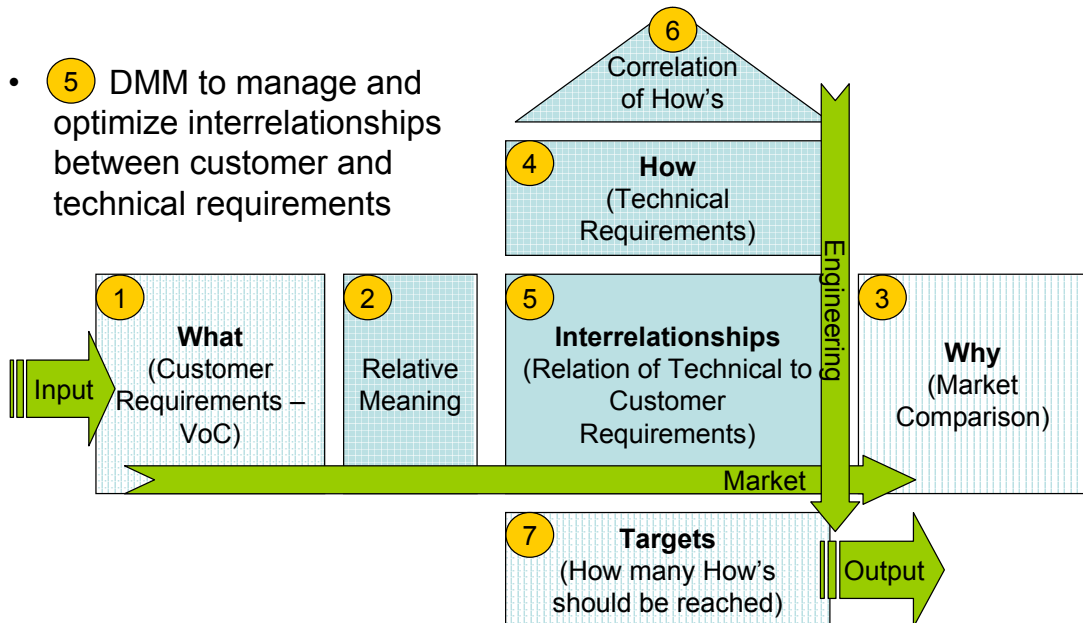Extended Design
Structure Matrix (DSM)

Reduction of Variant Complexity III

Virtual Table

Design Structure Matrix (DSM)

Feasibility Rules

Interfaces

$10^1 - 10^2$

Solution Space
(individual Product Structure Element)

Influencing Specifications

Quality Function Deployment

- (5) DMM to manage and optimize interrelationships between customer and technical requirements

(6) Correlation of How's

(4) **How** (Technical Requirements)

(1) **What** (Customer Requirements – VoC)

Input

(2) Relative Meaning

(5) **Interrelationships** (Relation of Technical to Customer Requirements)

(3) **Why** (Market Comparison)

Engineering

Market

(7) **Targets** (How many How's should be reached)

Output

335

Requirements Analysis & Integration

DSM to:

- Establish and analyze dependencies between requirements – analytical representation
- Numerical or relative ranking for requirements priorization
- Clustering for requirements structure examination

DMM to:

- Relate requirements with:
  - functions, product structure and processes

MDM to:

- Multi dimensional integration aspects:
  - requirements (R), functions (F), product structures (PS) and processes (Proc.)

	RQ	F	PS	Proc.
RQ	DSM			
F	DMM			
PS			MDM	
Proc.				

Ontology Creation

Basics:

- Semantic web & ontologies as method for complexity handling
- Continuous and growing knowledge layer

Challenge:

- Time consuming set-up through IT specialist
- support through domain experts – communication barriers
- How to make it user friendly?

Approach:

- Allow domain experts "hidden" ontology creation though matrices

Ontology Creation II

Lines and rows define ontology classes

Summary

- Increasing complexity is becoming an issue – matrices as approach to reduce requirements variants in early development phases

- Matrices as optimization methodology of translation of customer and technical requirements - QFD

- Requirements dependency analysis including priorization and analytical optimization through matrices

- Supporting of product and process integration aspects through more dimensional matrices

- Matrices as "user friendly" front ends for ontology creation