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MANAGING COMPLEXITY IN AUTOMOTIVE SAFETY DEVELOPMENT

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1 TODAY'S CHALLENGE: MANAGEMENT OF INCREASING COMPLEXITY

The fragmentation of the automobile market continues unabated. Automobile manufacturers try to generate niches of demand between established automobile segments by designing ever new carriage concepts.

The challenge – and not just for Audi – consists of bringing ever more products in an ever higher quality to market within an ever shorter space of time, with rising customer demands and increasing pressure of costs. The consequences for the development process are that complexity will continue to increase in the future. A strategy is consequently to be able to control increasing complexity rather than having to avoid complexity relevant to competition. To this end new approaches and solutions are required, especially for the development process.

Complexity is also continuously rising in the field of vehicle safety, not only through fragmentation of vehicles and the associated necessity of adapting safety systems for numerous automobile variants. Most notably the increasing number of influencing variables – such as crash cases to be met and dummy-types to be considered – and their interconnection represent a significant part complexity. In addition influencing variables originate from different domains. Linkage between parameters from different domains – e.g. components and functions of a system and its subsystems – is (according to [1]) a further essential source of complexity.

The vehicle safety department of the Audi AG carried out a structural analysis of different sub-systems of frontal and lateral safety and acquired the basis for efficient management of complexity in cooperation with Teseon GmbH. Teseon provides consultancy for the application of methods and tool support for complexity management. A principal project goal thereby was to establish transparency and system understanding in a multi-domain complexity, which serves for reaching short response rates in tight development times.

2 STRUCTURE ANALYSIS USING MULTIPLE-DOMAIN MAPPING

The following multi-stage procedure (according to [2]) was carried out for the analysis of a frontal protective system with the perspective focused on OOP („out of position") as well as for the analysis of a lateral protective system with a focus on the understanding of the entire system.

1. System definition: domains involved, the elements of the domains and the types of dependencies between and within the domains were defined with the help of a Multiple-Domain Matrix (see [2]). Figure 1 shows the matrix for the case of the lateral protective system.
2. Information acquisition: the dependencies in various DSMs [3] and DMMs in the Multiple-Domain Matrix were collected in several workshops with the appropriate technical experts. Plausibility analyses were carried out after each workshop.
3. Modeling: the dependencies were represented using strength based graphs.
4. Structure analysis: various structure analyses were carried out on the basis of the data of the Multiple-Domain Matrix.
5. Discussion of practices and implementation: the relevant derivations for actions were decided on the basis of the results of the structure analyses.

The data collection and analysis processes were supervised by Teseon experts and carried out using the complexity management software Loomeo.

	Komponenten	Eigenschaften (statisch) der Komponenten	Eigenschaften (dynamisch) der Komponenten	Versuchs-parameter	Einsitzprozedur	Lastfall-Charakteristika	Dummy (-Eigenschaften)	Kriterien
Komponenten	K hat geometrische Abhängigkeit zu K	K-Änderung kann E-Änderung bewirken	K-Änderung kann E-Änderung bewirken	---	---	---	---	---
Eigenschaften (statisch) der Komponenten	E-Änderung kann K-Änderung bewirken	E-Änderung (stat.) kann E-Änderung (stat.) bewirken	E-Änderung (stat.) kann E-Änderung (dyn.) bewirken	---	E-Änderung (stat) kann ESP-Änderung bewirken	---	---	E-Änderung (stat.) kann Krit-Änderung bewirken
Eigenschaften (dynamisch) der Komponenten	E-Änderung (dyn.) kann K-Änderung bewirken	E-Änderung (dyn.) kann E-Änderung (stat.) bewirken	E-Änderung (dyn.) kann E-Änderung (dyn.) bewirken	---	---	---	---	E-Änderung (dyn.) kann Krit-Änderung bewirken
Versuchs-parameter	---	---	V-Änderung (dyn.) kann E-Änderung (dyn.) bewirken	V-Änderung kann V-Änderung bewirken	---	---	---	V-Änderung kann Krit-Änderung bewirken
Einsitzprozedur	---	---	ESP-Änderung (dyn.) kann E-Änderung (dyn.) bewirken	ESP-Änderung kann V-Änderung bewirken	ESP-Änderung kann ESP-Änderung bewirken	---	---	ESP-Änderung kann Krit-Änderung bewirken
Lastfall-Charakteristika	---	---	L-Änderung (dyn.) kann E-Änderung (dyn.) bewirken	---	...	---	---	Lastfall bestimmt Kriterien
Dummy (-Eigenschaften)	---	---	D-Änderung (dyn.) kann E-Änderung (dyn.) bewirken	D-Änderung kann V-Änderung bewirken	---	---	D-Änderung kann D-Änderung bewirken	D-Änderung kann Krit-Änderung bewirken
Kriterien	---	---	---	---	---	---	---	Krit.-Änderung kann Krit.-Änderung bewirken

Figure 1: Multiple-Domain Matrix for a lateral protective system

3 METHODS FOR STRUCTURAL COMPLEXITY MANAGEMENT

On the basis of the structure analyses carried out various methods for controlling the existing system complexity could be deployed and established.

Analysis of impact:

The impact analysis serves to represent the impact of changes (and chains of impact) of intervention in the system. The starting point is the element which shall undergo a modification (for example when the thickness of the material of the gas generator housing is to be reduced for reasons of weight reduction). The structural environment is modeled using this element as a starting point (e.g. the mass flow curve progression of the gas generator). Integrated connections between modifications become clearly visible. The checklist-like character ensures processing is carried out at a high level of completeness. This supports change management in a very efficient way.

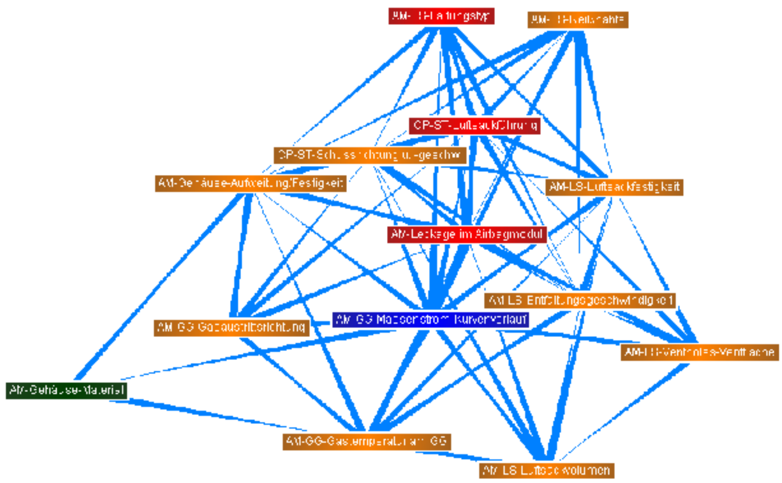

Figure 2: Impact of modifications exemplified by the mass flow curve progression

Trace-back analysis:

The aim of causal analysis is to determine the cause of an existing problem situation. Starting from the last element in the chain to be impacted a reverse analysis is carried out over the passive environments of the individual elements (going backwards step by step in the chain of impact). System elements that are positively constant or irrelevant for the case at hand can be hidden from view. Finally a structured summary of possible problem causes is obtained (see figure 2).

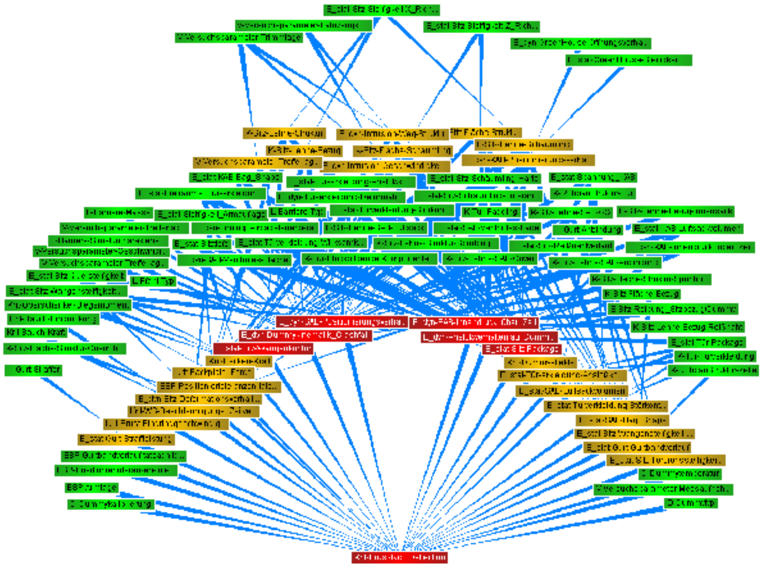

Figure 3: Analysis of the problem causes using the example of dummy criteria

"Set-screw" analysis:

In the development process various degrees of freedom relating to the degree to which the parameters can be influenced apply at different points in time, e.g. at a certain point in time before SOP certain parameters can no longer be adapted. The system behavior under certain boundary conditions can be represented with the help of the set-screw analysis. Again the local environment of the element under observation is investigated and the elements that can no longer be modified in this situation are hidden from view. It remains a view of the system that contains the still remaining possibilities of influencing variables in order to solve a problem.

Besides the methods of controlling complexity – here the main starting point is transparency – the next step consists of successively designing the product structures to be more robust in order to reduce the impact of modifications in general. Various structure attributes (clusters, circular paths, hierarchies, etc) can be considered to this end.

4 EXPERIENCES

The work carried out leads to a considerably sharpened understanding of the system. Previously apparently unknown connections become visible and therefore controllable and relations between elements of subsystems get transparent. Measures for adaptation become more efficiently manageable. This finally leads to increased reliability in the development processes while saving on resources.

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Managing Complexity in Automotive Safety Development

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complexity under control

complexity under control

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  - Increasing set of safety requirements and functions
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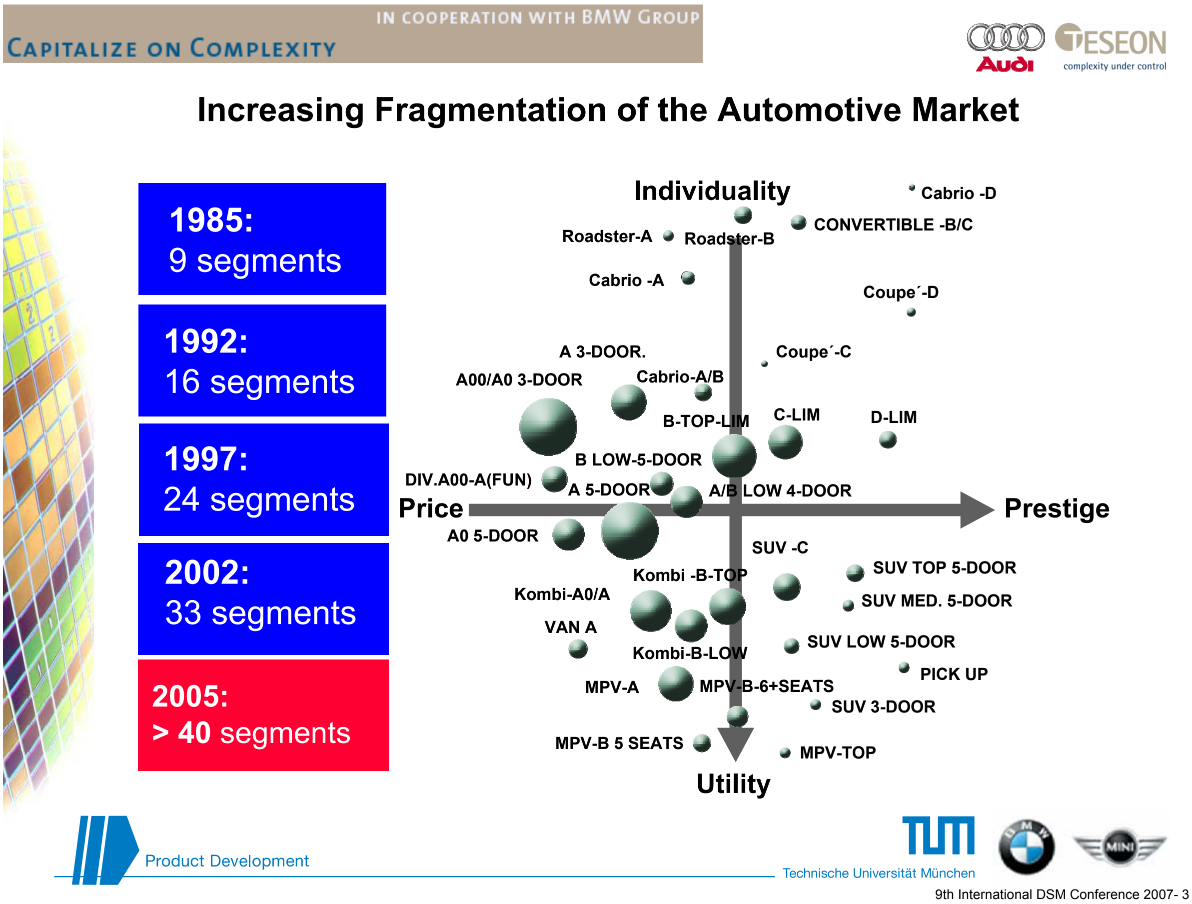
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CAPITALIZE ON COMPLEXITY
Increasing Fragmentation of the Automotive Market
1985:
9 segments
1992:
16 segments
1997:
24 segments
2002:
33 segments
2005:
> 40 segments
Individuality
Price
Prestige
Utility
Cabrio -D
CONVERTIBLE -B/C
Roadster-A
Roadster-B
Cabrio -A
Coupe´-D
A 3-DOOR.
Coupe´-C
A00/A0 3-DOOR
Cabrio-A/B
B-TOP-LIM
C-LIM
D-LIM
B LOW-5-DOOR
DIV.A00-A(FUN)
A 5-DOOR
A/B LOW 4-DOOR
A0 5-DOOR
SUV -C
Kombi -B-TOP
SUV TOP 5-DOOR
Kombi-A0/A
SUV MED. 5-DOOR
VAN A
SUV LOW 5-DOOR
Kombi-B-LOW
PICK UP
MPV-A
MPV-B-6+SEATS
SUV 3-DOOR
MPV-B 5 SEATS
MPV-TOP
Product Development
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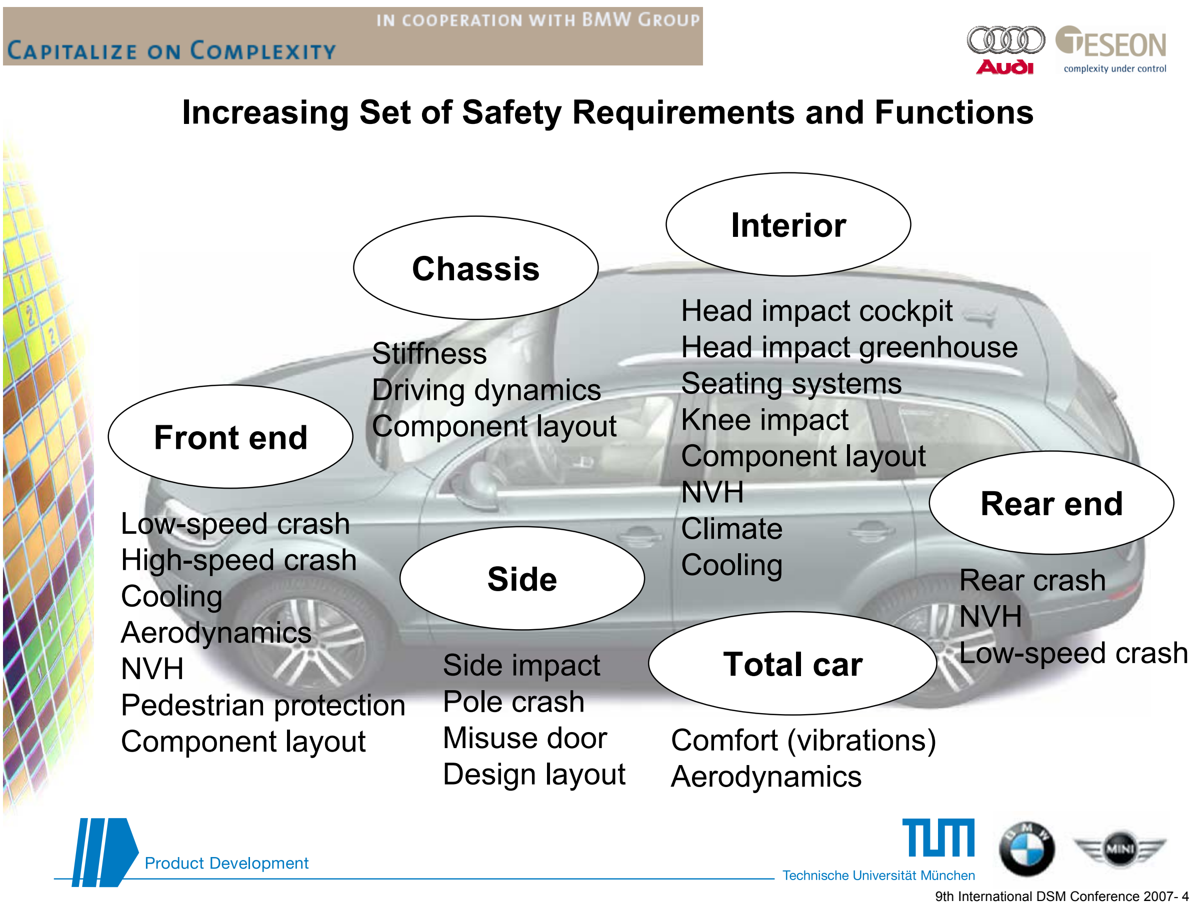
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Increasing Set of Safety Requirements and Functions
Chassis
Stiffness
Driving dynamics
Component layout
Interior
Head impact cockpit
Head impact greenhouse
Seating systems
Knee impact
Component layout
NVH
Climate
Cooling
Front end
Low-speed crash
High-speed crash
Cooling
Aerodynamics
NVH
Pedestrian protection
Component layout
Side
Side impact
Pole crash
Misuse door
Design layout
Rear end
Rear crash
NVH
Low-speed crash
Total car
Comfort (vibrations)
Aerodynamics
Product Development
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Today's challenge: Management of increasing complexity

Bringing ever more products
... in an ever higher quality
... within an ever shorter space of time
... with rising customer demands
… and increasing pressure of costs
... to the market

... demands for new approaches and innovative solutions in product planning and development

Fact:	**Increasing complexity**
Strategy:	**Managing complexity**

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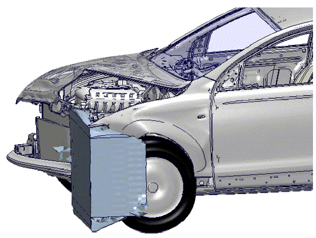
Structure Analysis Using Multiple-Domain Mapping

Initial situation in automotive safety development:

- Increasing quantity and linkage of influencing parameters
- Changes to influencing parameters often cause far-reaching effects
- Increasing costs because of increasing number of car crashes

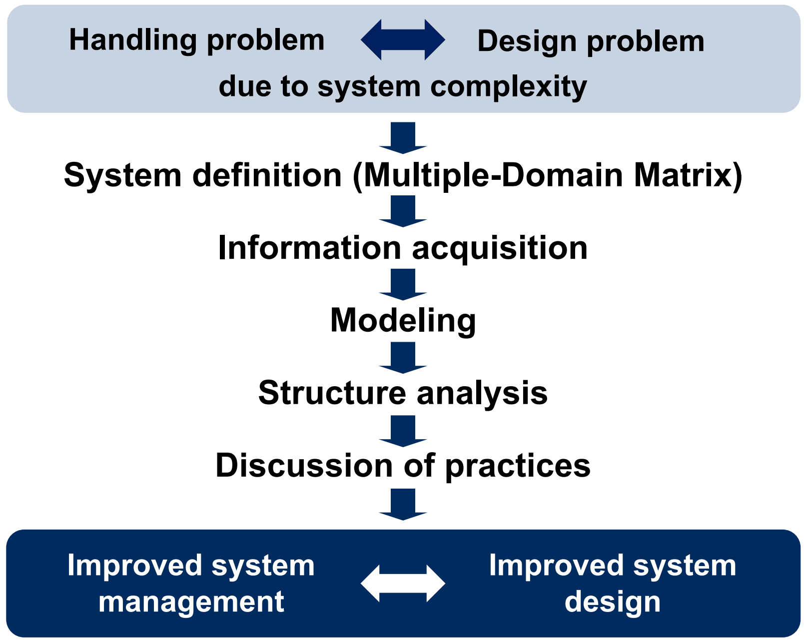
Objectives for optimization:



- Creation of system comprehension
- Awareness of change impacts
- Comprehension of domain-spanning interrelations (components, functions, characteristics, ….)
- Robust product structures concerning product adaptations
- Identification of opportunities and restrictions for product adaptation

→ Structure analysis of front and lateral protection systems using the Multiple-Domain Mapping approach

Procedure



Multiple-Domain Matrix

	Komponenten	Eigenschaften (statisch) der Komponenten	Eigenschaften (dynamisch) der Komponenten	Versuchs-parameter	Einsitzprozedur	Lastfall-Charakteristika	Dummy (-Eigenschaften)	Kriterien
Komponenten	K hat geometrische Abhängigkeit zu K	K-Änderung kann E-Änderung bewirken	K-Änderung kann E-Änderung bewirken	---	---	---	---	---
Eigenschaften (statisch) der Komponenten	E-Änderung kann K-Änderung bewirken	E-Änderung (stat.) kann E-Änderung (stat.) bewirken	E-Änderung (stat.) kann E-Änderung (dyn.) bewirken	---	E-Änderung (stat) kann ESP-Änderung bewirken	---	---	E-Änderung (stat.) kann Krit-Änderung bewirken
Eigenschaften (dynamisch) der Komponenten	E-Änderung (dyn.) kann K-Änderung bewirken	E-Änderung (dyn.) kann E-Änderung (stat.) bewirken	E-Änderung (dyn.) kann E-Änderung (dyn.) bewirken	---	---	---	---	E-Änderung (dyn.) kann Krit-Änderung bewirken
Versuchs-parameter	---	---	V-Änderung (dyn.) kann E-Änderung (dyn.) bewirken	V-Änderung kann V-Änderung bewirken	---	---	---	V-Änderung kann Krit-Änderung bewirken
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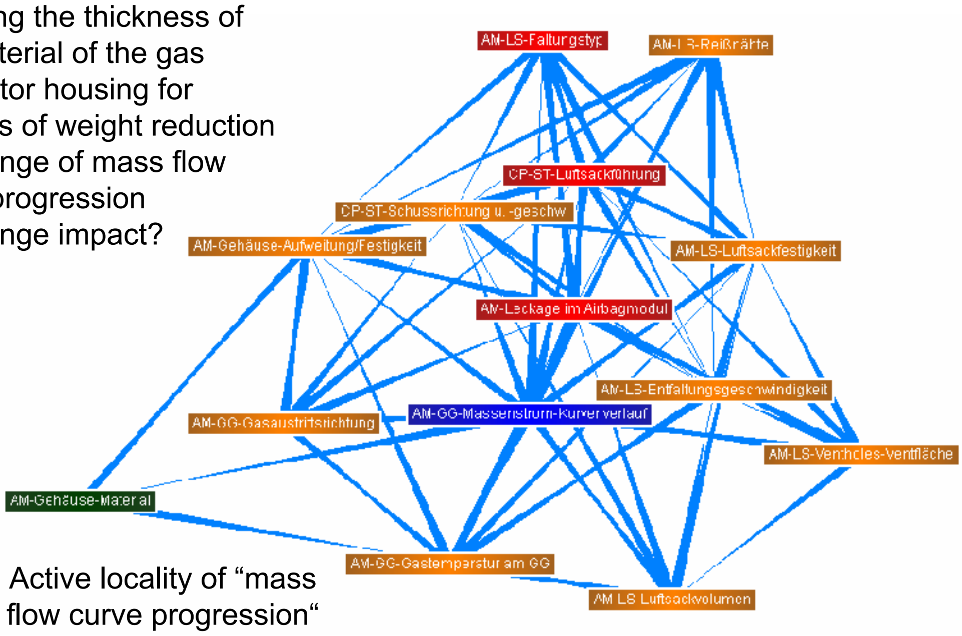
Kriterien	---	---	---	---	---	---	---	Krit.-Änderung kann Krit.-Änderung bewirken

Analysis of Impacts

Adapting the thickness of the material of the gas generator housing for reasons of weight reduction
→ Change of mass flow curve progression
→ Change impact?



Active locality of “mass flow curve progression“

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Analysis of Impact

Which impacts result from system interaction/change?

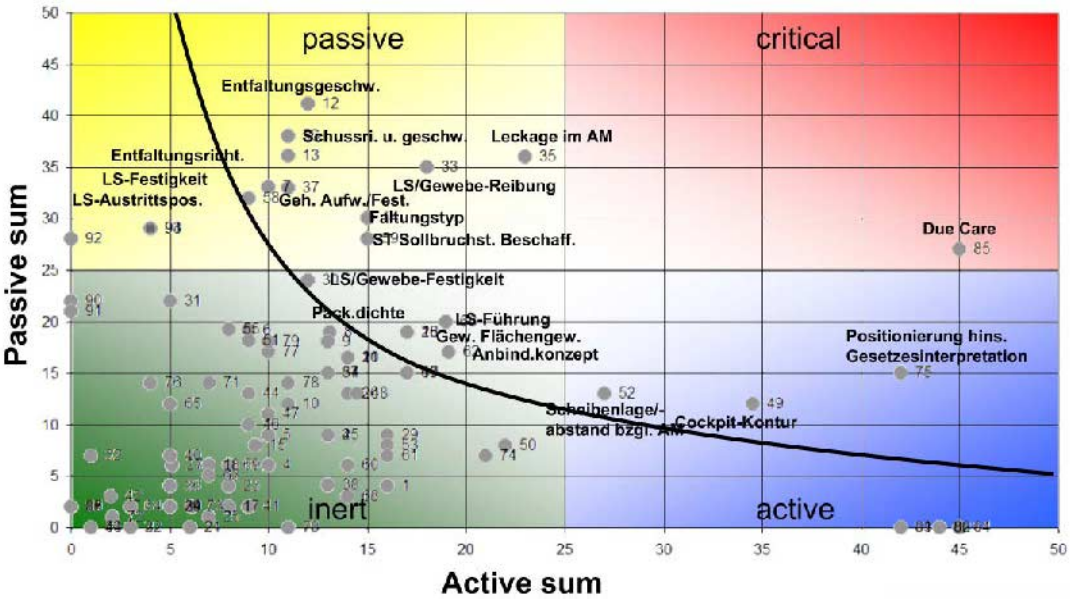
Objectives:

- Representing the change impact (and impact chains)
- System comprehension: improved awareness of consequences resulting form interacting in complex systems
- Impact on critical elements
- Impact scenarios for specifically selected system elements

Procedure:

- Starting point: identification of considered element in the network
- Identification of the active locality (outgoing dependencies)
- Consideration of criticality of adjacent elements (coloring)
- Investigation of affected dependencies and going forward in the network

Analysis of Impact – Parameter Influence Portfolio



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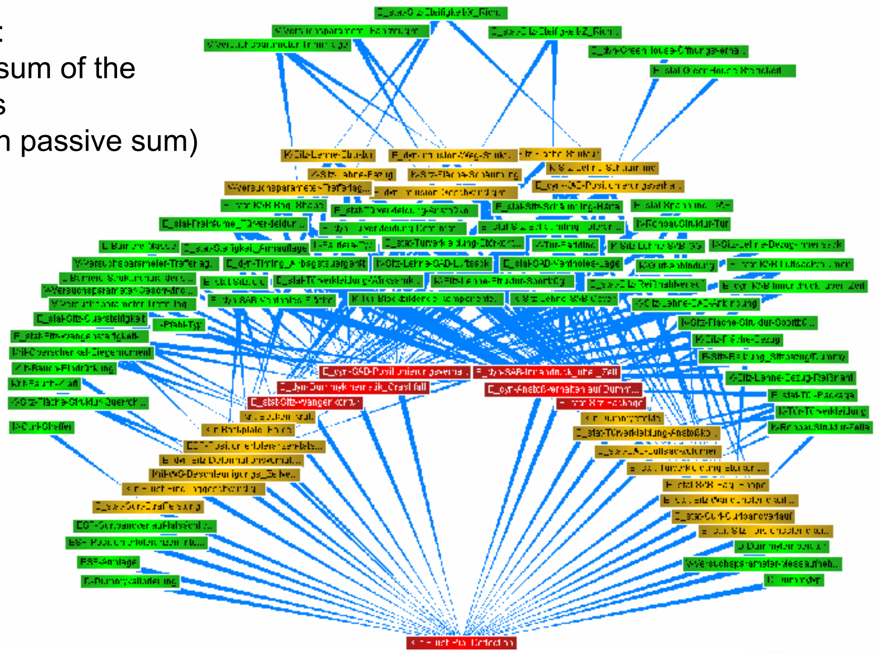
Trace-Back Analysis

Coloring:
passive sum of the elements
(red: high passive sum)



Trace-Back Analysis

Which causes may have led to an existing problem situation?

Objectives:

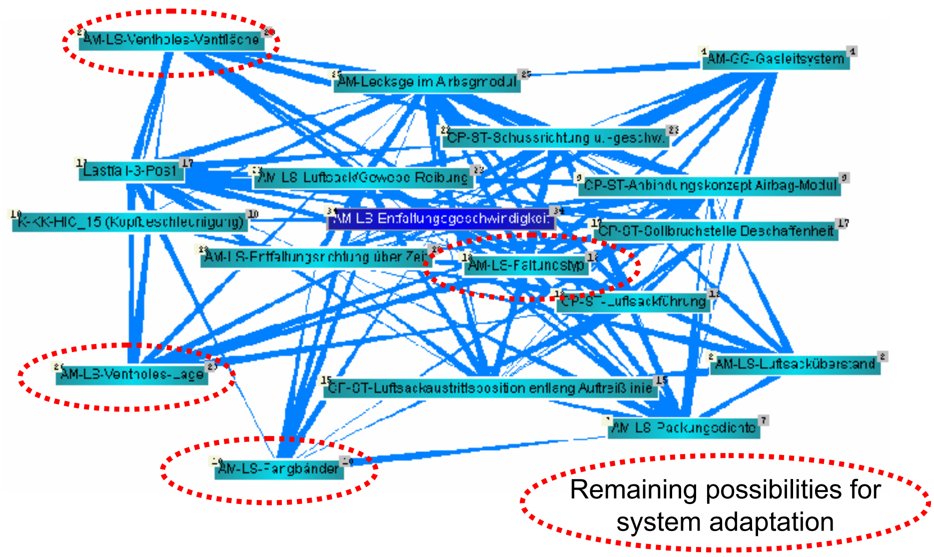
- Determination of the originating causes of an existing problem situation
- Detection of dependency paths that initiate an undesired effect

Procedure:

- Starting point: identification of the impacted element in the network
- Identification of the passive locality (incoming dependencies)
- Hiding constant and irrelevant elements from view
- Detection of possible problem causes by going backwards in the impact chain

"Set-screw" analysis

Locality of "Airbag expansion speed" after hiding all elements that can not be modified in the actual situation



"Set-screw" analysis

Which set-screws for influencing the system are remaining?

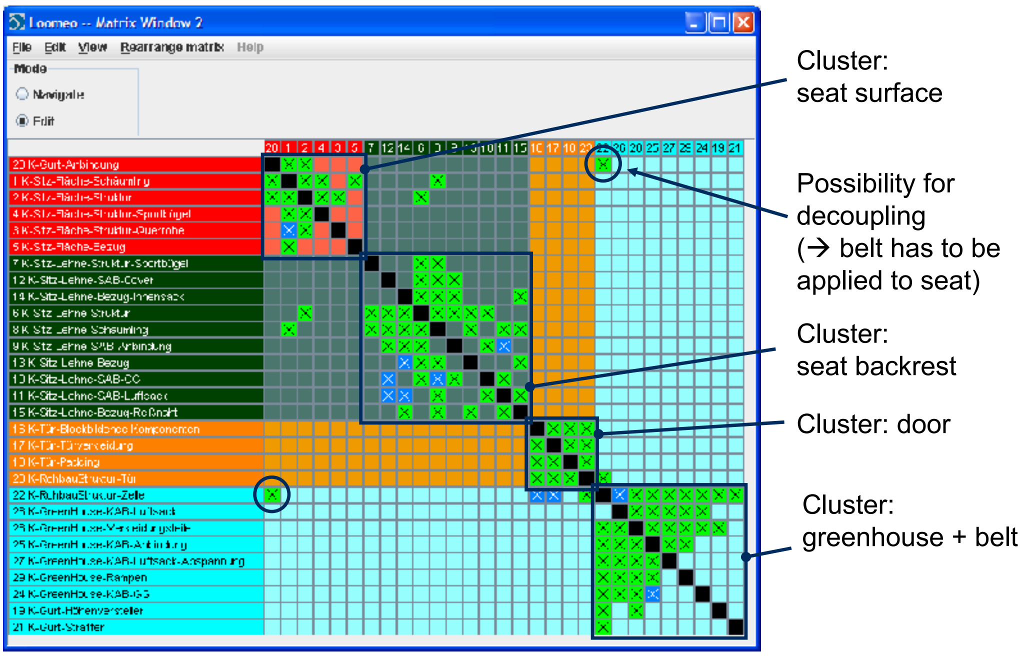
Objectives:

- Representation of system behavior under selected boundary conditions
- Identification of possibilities for systematically influencing system variables considering an existing degree of freedom at a certain time

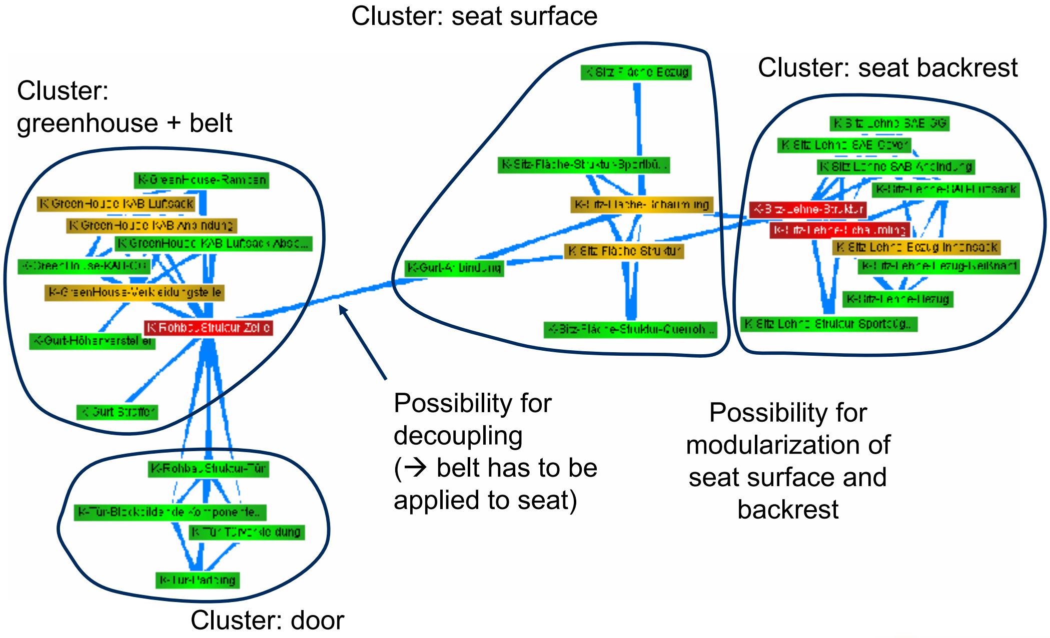
Procedure:

- Starting point: identification of the relevant element in the network
- Identification of the local environment (outgoing and incoming dependencies)
- Hiding elements from view, which can no longer be modified
- Detection of set-screws: remaining possibilities for influencing variables

Obtaining robust product structures

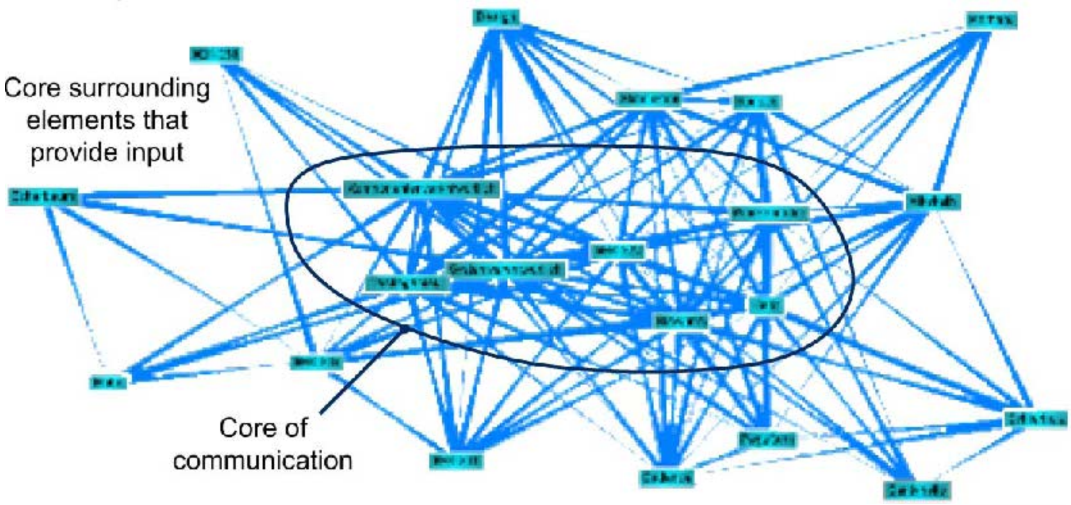


Obtaining robust product structures



Impact on Organizational Structure

Derivation of an organizational structure from product dependencies: person/responsibility A should communicate with person/responsibility B because component 1 (in the responsibility of A) is linked to component 2 (in the responsibility of B)



Experiences – Improvements

- Awareness of parameters that influence the system
- Awareness of the types of influence on the system
- Comprehension of cause-effect chains of system parameters
- Identification of adaptation needs in case of change
- Awareness of consequences in case of system interaction
- Awareness of system interaction that should be avoided (constraints)
- Determination of causes of an existing problem situation
- Identification of system optimization and development potentials

✓ Improved reliability of development processes

✓ Efficient management of adaptation measures

✓ Saving resources