

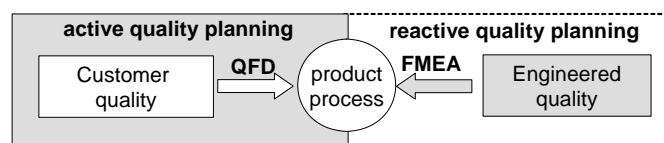
## MONITORING TOOL FOR A REACTIVE CUSTOMER ORIENTATED QUALITY MANAGEMENT

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### 1. Introduction

Nowadays, the rising market pressure in automotive industry, due to the world trade liberalisation and the increasing customer requirements, demands the design of innovative and high quality products. The high quality of products is an important condition for economic success of automotive industry. Quality costs like extraordinary expenses for late product modifications or warranty charges have an increasing influence on the financial statements of the car manufactures. Further more the sensation of customers regarding the quality of products have a big importance on the profitability and growth of companies [Buzzle 1989]. Taguchi [Taguchi 1999] relates the sensation of quality to two aspects: the customer quality and the engineered quality. Customer quality is addressed during the product planning and includes items as the function itself, features, colours and designs. Engineered quality is related to problems that customer don't want to face during the utilization of the products and addresses quality management methods and processes. Quality management consist generally of quality planning, quality assurance, quality control and quality improvement [Reinhardt 2006, Hering 2003]. Quality Function Deployment (QFD), being a major quality planning method, represents an interface between the customer and the engineered quality. Predefined customer requirements, benchmarks etc. are taken into account and projected onto technical parameters. The use QFD is regarded as an active quality planning approach. Considering that most design problems consist of the adaptation and enhancement of products [Kistner 1996], a holistic quality planning approach has to take systematically the engineered quality of preceding products into account. The observed car manufactures close the quality management loop by lessons learned measures. However this measures base upon operating experience, late product changes or customer claims aren't referred to their original cause and are not systematically considered in the design of succeeding products. The systematic evaluation of the engineered quality of preceding products and the consideration of this information are considered to be a reactive quality planning approach.



**Figure 1. Holistic quality management approach**

Further more the rising complexity of products has a big impact on the quality management and its elements. Rising customer requirements in terms of comfort and security demand the design of innovative products. Mechatronics, being the synergetic interaction of the disciplines mechanics, electronics and information technology, enable improved or new functionalities, the multidisciplinarity and the high degree of cross-linkings of mechatronic however lead to a high level

of complexity and actually evokes massive quality problems in automotive industry [Felgen 2005]. The results of a car manufacture quality management processes screening relates the quality problems among others to the handling of organisational and product-related interfaces.

Regarding this challenges a reactive, customer orientated quality planning method has been developed and implemented in the car company. The method supports the systematic evaluation of field data and the identification of critical properties by assigning field problems of actual onto succeeding car systems and its assemblies, components and interfaces. To support the implementation of this concept, a monitoring tool has been developed and will be presented in this paper. Section 2 gives a short description of the reactive customer orientated quality management concept and the deducted requirements for a monitoring. Section 3 describes in detail the structure and the features of the monitoring tool. The paper concludes with a summary and an outlook on further work.

## 2. Reactive customer orientated quality planning

Preceding the reactive customer orientated quality management method, a strategic evaluation of the future cars system leads to the decision what systems are going to be considered in the mentioned process. Further more a person in charge for a certain amount systems, the quality planner, is defined. The designed method for a reactive customer orientated quality planning can be divided in three major tasks:

- the identification of critical properties
- the projection of the critical properties on defined systems, assemblies, components and the definition of risk reducing measures
- the monitoring of the defined risk reducing measures and objective evidences

The designed method starts with the identification of critical properties. Properties are a combination of parameters (e.g. length) or functions (e.g. avoid noise) and values (e.g. 10mm) [Lindemann 2005].

A possibility to identify critical properties for an efficient and effective quality management is the systematic assessment of field data [Edler 2001]. Therefore the designed concept begins with an evaluation of customer orientated field data like warranty charges, customer satisfaction surveys (e.g. JD Power™). Further more in-house quality assessments like quality audits or lesson learned sessions help to identify major quality problems. A prioritization of the quality problems supports the selection of the most important problems, from which the critical properties are deducted. For example a preceding (resembling) system has been responsible for none acceptable noise problems in the passenger area. As a consequence a critical property would be to avoid bothering noises in the passenger area.

In order to assign the critical properties onto the selected future systems and its assemblies or components a detailed systems analysis is necessary. The assessment of engineering drawings, requirement specifications and other system specific documents helps to identify assemblies or components, which are documented in an interface matrix. This matrix supports the systematic compilation of internal and external interfaces (interfaces to other systems). All detected interfaces are considered and treated as assemblies or components.

The last preparative step is the assignment of the critical properties onto the assemblies or components of the future system. To support this work step a dependency matrix has been adapted to project specific needs. The matrix consists of general information regarding the current project and the selected system. The first column comprises the critical properties (e.g. avoid bothering noises in passenger area); the first row lists all assemblies, components, interfaces of the analysed system. The question if there is a link between a critical property and an element of the analysed system, has to be asked for every cell. In case of the existence of a dependency, a specification can be written down.

By using a modified Failure Mode and Effect Analysis (FMEA) the critical properties can be systematically projected from a system-level view, to a design-level and finally to a process-level view. To do this, three different FMEAs are available: a system-level FMEA, a design-level FMEA and a process-level FMEA [Grant 1996]. A system-level FMEA aims to identify and prevent failures related to subsystem or assemblies during the early conceptual design. A design-level FMEA helps to identify and to stop failures on a component level. The process-level FMEA identifies and prevents failures related to manufacturing process for a certain item. In order to optimize the coherences and

traceability of the different FMEA, and to fulfil the customer orientated quality management specific needs, the contents (FMEA worksheets) had been restructured and endorsed.

Every FMEA refers to one system. The FMEA starts by the description of the critical properties (function, parameter and specifications). The second step includes the compilation of possible failure modes and impacts related to a critical property. The description of the failure cause has been particularised. The failure cause is characterized by an assembly or component and a critical property. As a consequence this description enables to change from an assembly-level to a component-level and delivers important for a design-level or process-level FMEA. Product- and properties-trees can be deducted. Further more risk reducing measures, person in charge and deadlines are defined. Risk reducing measures can be methods for failure detection or compensating provisions. All results are documented in the FMEA worksheets. Additionally the critical properties and the risk reducing measures are retained in relevant design documents (e.g. specifications sheet).

After completing the first definition of risk reducing measures and objective evidences, the quality control activities start. The defined methods for failure detection or compensating provisions are reviewed by the responsible quality planner. In case of non conformance, modifications are worked out in cooperation with the systems-engineering team. In addition the quality planner queries and evaluates the actual status related to the risk reducing measures and the objective evidences. Regarding this evaluation, the further proceeding can be modified. The quality control finishes when a defined objective evidence has been supplied.

Every system is characterized by a certain number of critical properties and the assigned assemblies, components and interfaces. For each assignment failure detection methods or compensating provisions have been defined and have to be monitored by the quality planner. In order to handle the high number of monitoring objects, a computer based monitoring tool has been developed. Regarding the described customer orientated quality planning concept, the following requirements for the monitoring tool have been deducted:

- Computer based tool to monitor defined risk reducing measures and objective evidence provisions
- User: quality planner
- Simple manageability
  - logic data input sequence
  - effortless data transfer from the dependency matrix and FMEA
- Integration in the in-house quality planning process
- Input data:
  - Prioritized systems
  - Identified critical properties
  - Sources for critical properties (warranty charges, JD Power, ...)
  - Additional critical properties occurring during the quality control
  - Risk reducing measures, responsibilities, deadlines
  - Objective evidences
  - Place of documentation of the critical properties
- Output data:
  - Reproducible description of a system regarding its assemblies, components, interfaces and critical properties.
  - Evaluated input data regarding different criteria (critical properties, assemblies, components, failure detection status, fulfilment status of objective evidences, ...)
  - Reports including different level of detailing

### 3. Monitoring tool

The monitoring tool for the customer orientated quality planning method consists of three major areas, which are (figure 2):

- the workspace area
- the reporting area

- the additional information area

The workspace provides the basis to enter the necessary input data and to monitor the risk reducing measures and the objective evidences. Further more the workspace allows the navigation between the different systems as well as the determination of the reporting and additional information area content. The reporting area consists of a management report, a quality route card report and a working report. These reports summarize the input data and the actual proceeding status at a different level of detailing. A graphic representation of the product- and properties structure are part for the additional information area. Further more selected information can be archived and displayed in history data sheet.

The monitoring tool has been realized in MS Excel™. An Excel datasheet has been supplemented by macros, which have been created in Visual Basic. The upgrading of application software for the support of FMEA, used by the car manufactures, has been set aside due the following reasons:

- too high investment to implement the necessary additional functionalities
- the monitoring tool has to cover different systems, the used FMEA tool is system specific

The three areas are going to be described in detail in the following chapters.

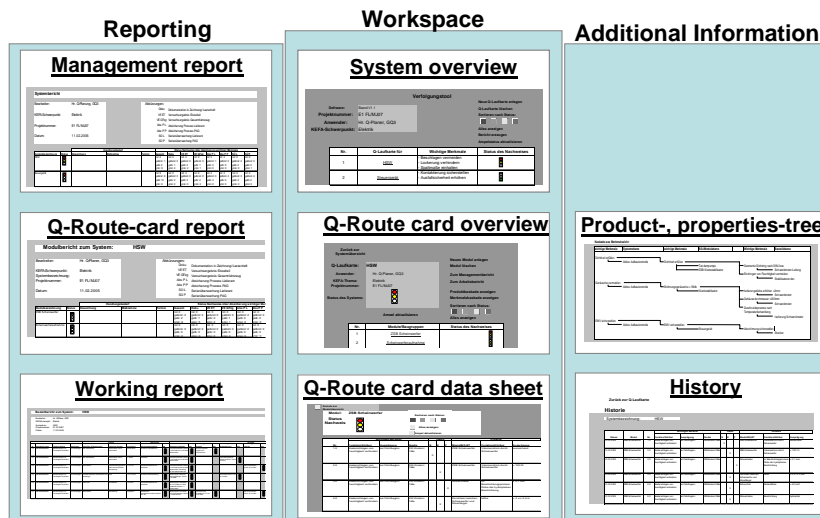


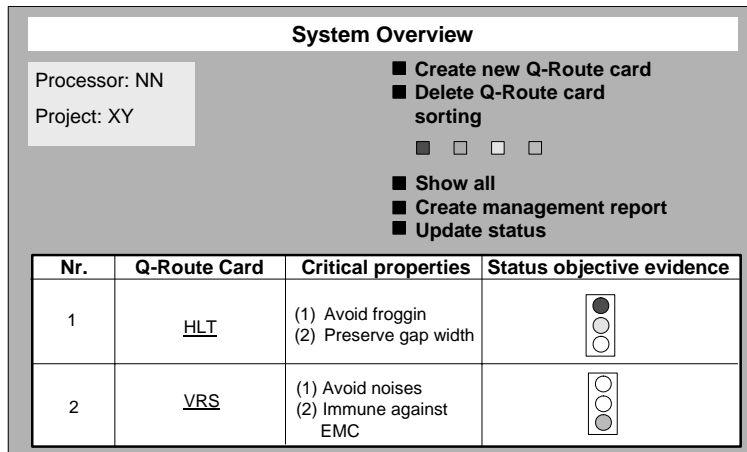
Figure 2. Monitoring tool: overview

### 3.1 Workspace

The workspace consists of three different graphical user interfaces, which are a system overview, a quality route card overview and a quality route card data sheet. The user interfaces are connected by hyperlinks and enable different input and output possibilities. The structure and functionalities of the different sheet are described in the following paragraphs.

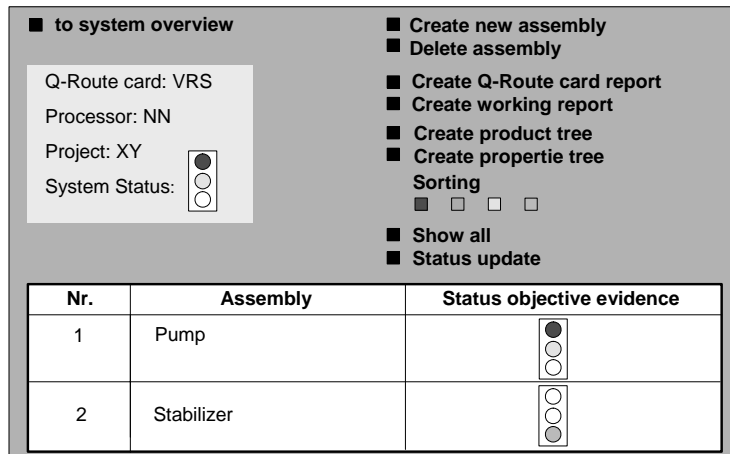
By activating the monitoring tool, the user attends the system overview sheet. This sheet contains an information centre with general information like the project number or the person in charge (processor). Additionally the information centre lists all systems in the field of responsibility of the person in charge. Every system is characterized by its critical properties as well as the status of the risk reducing measures and the objective evidences. The status is illustrated by traffic light symbols. The colours are changing according to the actual status. The task centre comprises different features. Creating new or deleting quality route cards can be realized by pushing the corresponding button. The application of the coloured buttons starts a sorting function depending on the system status evaluation. For example by pushing the red button, only systems with a red traffic light symbol are listed up. The complete list of systems reoccurs by using the button "Show all". In case of status changes during the quality control period the system status has to be updated. Last but not least a management report can

be created by using the corresponding control button. Every listed system possesses a hyperlink to navigate to the corresponding quality route card overview. It is important to notice, that every system is characterized by one quality route card.



**Figure 3. System overview sheet**

The constitution of the quality route card overview is comparable to the system overview. The information centre itemises additionally the system the route card is related to as well as the system status. Further more the relevant assemblies and their status are listed up. Beside creating and deleting assemblies, the task centre allows generating the quality route card report and the working report, which are described in chapter 3.2. In addition a product tree and a properties tree as well as a history (chapter 3.3) can be created by pushing the corresponding button. A sorting function related to the assembly status is included too. By activating the assembly hyperlinks, the user attends the data sheet level.



**Figure 4. Quality route card overview sheet**

The contents of the data sheet provide the basis for the described features (reports, product trees, etc). The structure of the data sheet corresponds to the FMEA worksheet. The critical properties, the failure cause (chapter 2), and the risk reducing measures have to be inscribed. The information can be easily transferred from the FMEA due the analogue structure of both working sheets. Additionally the source of critical property has to be entered. The further area of the data sheet serves for the quality control. All risk reducing measures, documentations of the critical properties and the defined measures as well

as the relevant objective evidences are characterized by a status, which is evaluated by the quality planner. The evaluation is performed by in-house criteria's. The status has to be settled in the quality route card data sheet. The status of components, assemblies or systems is deducted by the worst-case principle; this means that the worst evaluation determines the overall status.

### 3.2 Reporting area

The reporting area provides the basis for a documentation of the actual status of work. There exits three reports with different levels of detailing. The management report gives an overview of the work progress. Beside general information (processor, project, and date of actualisation) the management report (figure 5) list up all systems accounted by one quality planner and the according system statuses by the means of traffic light symbol. Further more an overview of all assembly statuses related to the listed systems and a statistic evaluation of these statuses per type of objective evidences are provided. In case of critical problems (red light evaluation), reasons for the occurrence and possible measures, including deadlines, can be documented in this report. The management report is suitable to discuss the results with the executives.

Management report											
Processor: NN			Abbreviations:								
Project: XY			OV: Overall								
Date: . . . . . 20..			Do: Documentation								
			Ts: Test single component								
			Tt: Test total car								
			Sp: Supplier process coverage								
			Sr: Supplier production run monitoring								
		Call for action			Status objective evidences						
System	Status	discrepancy	measure	deadline	Ov	Do	Ts	Tt	Sc	...	Sr
HLT					R: 0 R/Y: 1 Y: 2 G: 8	R: 0 R/Y: 0 Y: 1 G: 4	R: 0 R/Y: 0 Y: 0 G: 2	R: 0 R/Y: 0 Y: 1 G: 1	R: 0 R/Y: 0 Y: 0 G: 0		R: 0 R/Y: 0 Y: 0 G: 1
VRS					R: 6 R/Y: 8 Y: 12 G: 6	R: 0 R/Y: 0 Y: 2 G: 2	R: 2 R/Y: 0 Y: 2 G: 0	R: 0 R/Y: 0 Y: 2 G: 2	R: 0 R/Y: 0 Y: 2 G: 2		R: 2 R/Y: 4 Y: 2 G: 0
...					R: R/Y: Y: G:	R: R/Y: Y: G:	R: R/Y: Y: G:	R: R/Y: Y: G:	R: R/Y: Y: G:		R: R/Y: Y: G:

Figure 5. Management report

The quality route card report has an equivalent structure to the management report. The only difference pertain the level of detailing. This report list up all assemblies of one system as well as the according statuses. Last but not least the working report corresponds to the working data sheet and is suitable for discussion with the person in charge of the defined risk reducing measures and the objective evidences. The selection of the reports can be realized in the workspace (chapter 3.1)

### 3.3 Additional Information

The product tree is a hierarchical representation of the assemblies, components and interfaces of one system. Further more every element of the product tree is related to the corresponding critical properties. The product tree is automatically generated form the data in the workspace and helps to optimize the patency and the traceability during the quality management process.

The second element of the additional information area is the properties tree (figure 6). According to the product tree, the properties tree is a hierarchical representation of systems; the focus however lies on the critical properties. Every of these properties are represented regarding their system-level, assembly-level or component-level classification.

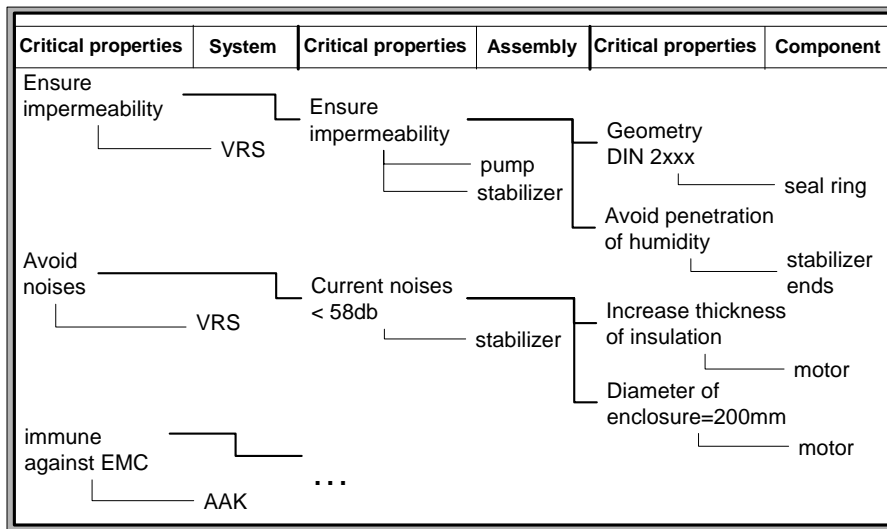


Figure 6. Properties tree

The history area allows the archiving of selected data from the workspace work sheet. Additionally a column including the date of the archiving is created. The archiving is carried out automatically by the monitoring tool after a specified period. It is only carried out, if any changes have been undertaken in the work space during the defined period. This period can be adjusted by the user. By using the auto filter features of Excel different analysis can be conducted. For example the progress regarding the provision of objective evidences can be exposed.

#### 4. Summary and conclusion

The high quality of products is an important condition for economic success of automotive industry. Rising customer requirements and the growing complexity of car systems pose new challenges for quality management processes and methods. Regarding this challenges a reactive, customer orientated quality planning method has been developed. The method supports the systematic evaluation of field data and the identification of critical properties by assigning field problems of actual onto succeeding car systems and its assemblies, components and interfaces. By using a modified Failure Mode and Effect Analysis (FMEA) the critical properties can be systematically projected from a system-level view, to a design-level and finally to a process-level view. Risk reducing measures can be defined on every of these levels. In order to facilitate the quality control, which includes the monitoring of the defined risk reducing measures and of the objective evidences, a computer based tool has been designed. Beside the easy transfer of the FMEA results, the tool provides different output forms as reports with different levels of detailing, graphic displays of product and property tree. Every report allows observing the general state of the defined quality management measures. Recapitulating the reactive quality management method in combination with the designed monitoring supports the patency and traceability of quality management processes. Currently the described method and the monitoring tool are applied in everyday life. To implement the customer orientated quality management method and the monitoring tool in the company, a course of instruction has been conducted. Further more all features have been documented in a user manual. However first optimization suggestions have been formulated by the users. The optimization of the transferability of the FMEA results, the assurance of the data security and the improvement of the graphical user interface summarize the major requirements verbalized by the users. As a consequence the design of an interface to FMEA-tools seems to be one requirement for further work. Additionally a computer based tool to evaluate the customer orientated field data as well the system analysis including the interfaces is part of future work.

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