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OPTIMISING CUSTOMER SATISFACTION BY INTEGRATING THE CUSTOMER'S VOICE INTO PRODUCT DEVELOPMENT

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ABSTRACT

A new solution approach for integrating customer feedback into product development was developed at the Department of IT in Mechanical Engineering (ITM), Ruhr-University Bochum. This approach aims at increasing product development effectiveness and optimising customer satisfaction. For this a methodology was developed, which enables acquiring prospective customer feedback for future (virtual) products and retrospective customer feedback on existing (market launched) products. A web-based feedback assistant was designed, which allows customers to evaluate product concepts based on customer oriented product test models for extracting feedback. The extracted feedback is mapped on technical product structures using an extended QFD approach and advanced methods for measuring customer satisfaction. The core of the integration concept is the extension of PDM functions, processes and metadata models, whereby technical product data, customer requirements and customer satisfaction indices can be linked context sensitively. The feedback integration approach enables an early product validation before the production/market launch and an analysis of dynamic customer requirements across several product generations. A feedback system was prototypically realised based on a PDM system. The research results are illustrated using the example of developing a mobile telephone.

Keywords: customer feedback integration, prospective and retrospective feedback, product development, product lifecycle management, marketing, House of Quality, digital product validation

1 INTRODUCTION

Increasingly shorter product lifecycles, cost pressures and the demands for customer oriented products require producing companies to react flexibly towards changed market conditions. Therefore the customer – as an company-external problem solution authority – moves into the centre of traditional value-added processes. Whilst marketing-oriented company divisions already pursue customer orientation to save business competition, in the product development a mostly technical product orientation dominates [1]. Strong adjustments of the product development for new technologies and technical features do not lead to a fulfilment of customer requirements. The results are product flops on the market, because products are either over-engineered or show fundamental deficits. Only one of seven product ideas is successful on the market [2]. This success ratio represents an existential risk for numerous companys considering the enormous innovation costs and the intensive resources in the product development.

The causes for the failure of innovations are various. On the one hand there are discrepancies between the customer requirements covered by marketing activities and the solutions actually demanded by customers. High market dynamics result from fast changing trends and fashions, so that product requirement specifications in product development frequently do not correspond to current customer requirements. On the other hand large communication and understanding deficits between product developers and customers exist, because they speak different languages. Customers require a total concept for an individual problem, whilst product developers measure the innovation success on the basis of reaching own, technical aims.

The customer demands a product, which solves a potential problem, fulfils the customer needs and provides a benefit for the customer [3]. Therefore customers make their buying decisions more and more on the basis of subjective impressions and pay attention to product comfort, reliability and secu-

rity. Innovation contents or technical finesse from a company's view are at best secondary parameters within the customers' buying decision.
The requirements for producing companies' pro-active creativity strongly increased in order to be able to offer competitive products with high customer value. Companies are required, no longer only to improve the efficiency ('doing the things right') but in particular the effectiveness ('doing the right things') of their product development processes. The early integration of customer feedback information ('customer's voice') into the product development process as well as permanently controlling customer satisfaction are therefore conditions for the successful development of products. From the described problem the following scientific questions are derived:

- Which are the crucial indicators for the organisation of customer feedback integration into the product development?
- Are methods for customer integration and customer satisfaction measurement already available and suitable?
- Which IT tools are suitable for extracting and analysing feedback information?
- How can the barriers between customers and product developers be overcome?
- How can customer feedback be translated into the product developer's language?
- How can customer feedback information be integrated into the product development processes and the IT environment?

2 OVERVIEW OF CLASSICAL CUSTOMER ORIENTED APPROACHES

Available approaches for integrating the customer's voice are strongly heterogeneous and result from very different points of view. The most important points of view are quality management, marketing oriented approaches and technically aligned methods for requirement analysis. Engineering approaches like product data management (PDM) or product lifecycle management (PLM) still do not include customers as a know-how capacity for product development [4]. The classical customer oriented approaches can be classified as follows:

1. identification and evaluation of customer requirements,
2. measurement of customer satisfaction,
3. customer integration approaches.

2.1 Identification and evaluation of customer requirements

The solutions for the identification of customer requirements are predominantly based on methods for customer observation and interviews. Customer observation represents an objective procedure. Product use, behaviour and customer reactions are analysed using video recording [5]. The customer observation method is used if information can not or only unsatisfactorily be determined by communication. This method detects not only difficulties during the product application, but also serves the the purpose of recognising misapplications. Customer observations can be conducted in the customer's natural environment (e.g. empathic design) [6] or in an artificial laboratory environment (e.g. product clinic) [7]. Customer interviews have the advantage, in relation to the customer observation, that the customer's opinion can already be considered in the product creation phase [8]. Generally only suggestions for product improvements result from customer interviews, only rarely further results for new product innovations.
To evaluate customer requirements conjoint measurement, quality function deployment (QFD) and the Kano method are applied. The core of QFD is the transformation of customer requirements into technical specifications. Therefore weighted customer requirements are transferred into solution-neutral design features and conflicts with the realisation are pointed out [9]. The Kano method is suitable for determining the coherences between customer requirements, product characteristics and customer satisfaction. By a special Kano interview, which is based on a combined functional and dysfunctional questionnaire, basic factors, satisfiers and exciters can be identified. These factors are used do determine the customer requirement's importance for the customer satisfaction [10].

2.2 Measurement of customer satisfaction

Customer-oriented methods for the customer's satisfaction measurement can be divided into objective and subjective procedures. Objective procedures evaluate the customer satisfaction using market-specific indicators, which are related to the customer satisfaction. Subjective procedures are based on the formation of individual customer satisfaction judgements. A differentiation between characteristic-oriented, incident-oriented and problem-oriented procedures is established [11]. Characteristic-oriented measuring procedures are based on the assumption that customer satisfaction is composed of several product characteristic evaluations. The customer-oriented evaluation is usually raised using customer surveys. The most important characteristic-oriented procedures are multi-attributive models, decompositional procedures, the vignette method, the willing-to-pay approach and the penalty-reward-factor approach. The disadvantage of these procedures is the limited number of characteristics, which can be considered within a customer survey. Incident-oriented procedures focus on positive and negative experiences within a product or service use. They are primarily aligned to services, but can also be applied for evaluating physical products. The most important incident-oriented procedures are the critical incident technique (CIT) and sequence oriented problem identification (SOPI). Problem-oriented procedures describe an improvement of the incident-oriented measuring procedure. They pursue the disclosure of satisfaction-relevant problem fields. Frequency relevance analysis (FRAP analysis), problem detecting method and complaint analysis are among these procedures [5].

2.3 Customer integration approaches

The existing solutions for the customer's voice integration into the value-added processes differ according to the addressed product lifecycle phase and thus to the point of customer interaction (table 1).

Table 1. customer integration approaches [12]

customer integration system	interaction point	degree of integration	integration approach
made-to-stock: manufacturing and sale of standardised products to anonymous customers	traditional mass production systems		
match-to-order / locate-to-order: selection of existing (standard) products according to customer requirements	sales, retail		customer relationship management (CRM), communities
bundle-to-order: bundling existing products to customer specific product (based on situation of use)	sales, retail		
assemble-to-order: assembling customised products from standardised, pre-fabricated parts	final assembling		mass customisation
made-to-order: manufacturing customised products including component manufacturing	manufacturing		
development-to-order: customer co-design of product construction, followed by customised made-to-order	design, development		lead user approach, co-designer

The lead user approach and the co-designer approach are relevant for the product development phase. The lead user approach was developed by Eric von Hippel and is based on extensive investigations, which showed that numerous innovations do not emanate from producing companies, but from customers. Partly the customers even develop innovative products (e.g. mountain bikes). The term of the lead users describes customers, whose momentary product requirements represent an anticipation of future market demands [13]. The term co-designer describes a customer, who is actively involved in product development processes and becomes a temporary co-worker of the company. The customer integration takes place on different integration levels. It can take place on a lower integration level in terms of focus groups or on a high integration level by directly being involved in the product design using specific design tools (tool kits).

3 RESEARCH APPROACH FOR INTEGRATING THE CUSTOMERS' VOICE

Isolated information technologies as well as heterogeneous marketing instruments are not sufficient for the claim of constant feedback integration. Therefore a concept was compiled, which is based on quality management methods, methods for the customer satisfaction measurement and product lifecycle management approaches. The assigned method components were specifically adapted and extended for the feedback integration [14].

In the capital goods industry customers are already intensively involved in the product development process due to customised products and contract manufacturing. Therefore the developed concept is limited to the range of the consumer goods as well as to market pull innovations and to incremental innovations. Customer integration for radical innovations does not appear beneficial, since the technical experience horizon and the imagination of customers are mostly not sufficient for these innovations. The objectives of the developed concept are:

- extracting customer needs as well as defining indicators, which have a direct impact on the customer satisfaction,
- systematically preparing and retrieving customer satisfaction indicators for product development,
- reducing product development periods and product failures through early product validation,
- developing high-quality products, which exactly fulfil the customer's requirements and promise maximum customer value.

3.1 Methodology for the integration of customer feedback into product development

The core of methodology is the extraction of prospective feedback information for future (virtual) and retrospective feedback information for real (market launched) products. The extracted feedback information is mapped onto technical product structures and made accessible for product development by integrating the technical information into a PDM system [15].

The information extracted by the retrospective feedback acquisition serves as an input for the development of new product generations. Therefore the concept is not limited to one product generation N (micro integration), but equally addresses the filtering and forwarding of feedback information into the development of the next product generation N+1 (macro integration). In the range of several product generations the developed concept facilitates the systematic accumulation of a knowledge base concerning dynamic customer requirements and the history of changed customer satisfaction with the products (figure 1).

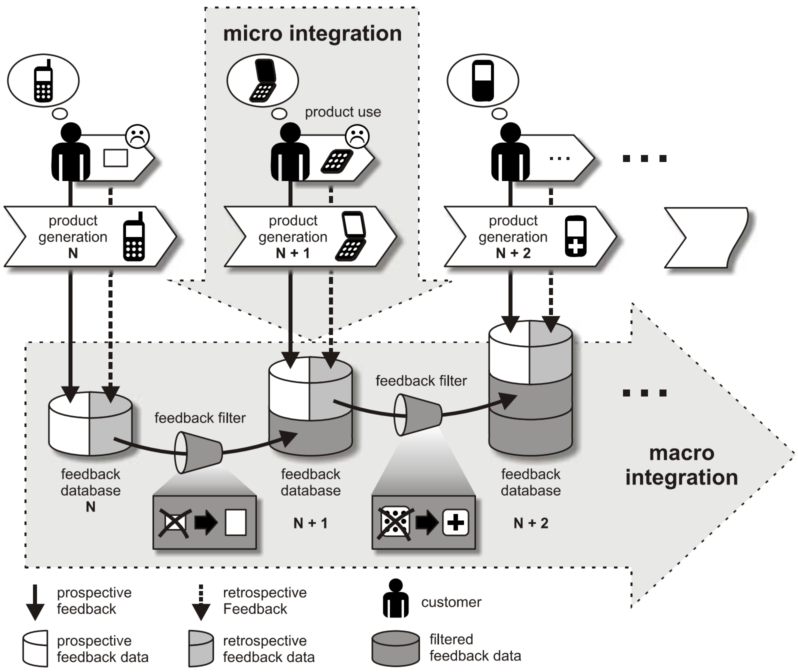

Figure 1. Micro and macro feedback integration in the range of several product generations

The methodology for the integration of customer feedback into the product development is divided into the following steps:

1. differentiation and selection of capable feedback customers,
2. prospective and retrospective acquisition of feedback information,
3. mapping customer feedback onto product structures,
4. extension of PDM meta data models, processes and functions for feedback integration into product development.

3.2 Differentiation and selection of capable feedback customers

The correct selection of feedback customers is essentially important for the success of the feedback integration methodology, since the quality of the feedback information is already specified in this phase. A method for selecting suitable customers was developed, which permits an integrated determination of the customer's market, innovation and pro-active capabilities.

The market capability describes the economical importance of customers for the company. It is determined by the cross-selling potential, the potential loyalty and the commercial stock generated by the customer. The innovation capability addresses the customer's innovation-relevant knowledge. The indicators for the innovation capability are the innovation content of the feedback, the information quality and the customer's willingness to supply feedback. The pro-active capability describes the customer's present relationship to the company and the resulting possibility of acquiring foresighted information for product improvements. For example current customers can only supply information for marginal product improvements, while the competition's customers are capable of supplying high potential information for fundamental product improvements. The determination of these three capabilities is carried out by an integrated scoring/portfolio model. Therefore scorecards are formed for the market capability, innovation capability and pro-active capability from the respective indicators described above. The resulting scores are the basis for the following creation of a three-dimensional customer portfolio. The number of necessary feedback customers depends on the innovation degree of the product. On the one hand a high number of feedback customers can guarantee a statistic informative value, if the new product represents only a marginal advancement of an existing product in the market. On the other hand the integration of a few trendsetters is supposed for products with a high innovation degree.

3.3 Prospective and retrospective acquisition of feedback information

The description of requirements by the customer can be substantially simplified through a customer's consciousness concerning possible problem solution alternatives. In many cases only the existence of solution alternatives leads to new or changed requirements. This conclusion led to the decision to offer digital product models from the product development to the customer in order to evaluate these product models.

T&E model for mapping product data on customer oriented product characteristics

A PDM system, which represents a consistent database within the product development, is required as source for offering product information. The digital product data is filtered and aggregated on the basis of their relevance for the feedback articulation. Since the customer's perspective on a product differs strongly from the product developer's technically oriented perspective, a characteristic-based, customer-oriented product model is generated from the aggregated product data. For this the product data managed in the PDM system is linked with customer-oriented product characteristics by using ontologies (figure 2).

The linked product data and characteristics constitute the digital test and evaluation model (T&E model) for the feedback acquisition. On the one hand the T&E model serves as a virtual prototype for the customer to articulate requirements and suggest improvement. On the other hand information from the product utilisation phase is deposited in the T&E model. Equivalent to the PDM system, meta data and physical product data are managed separately. The T&E model consists of three layers:

1. layer 1 (meta data): customer oriented product characteristics,
2. layer 2 (meta data): ontologies and correlation tables for mapping product data onto product characteristics,
3. layer 3 (physical data): relevant product data for the description and simulation of the T&E model.

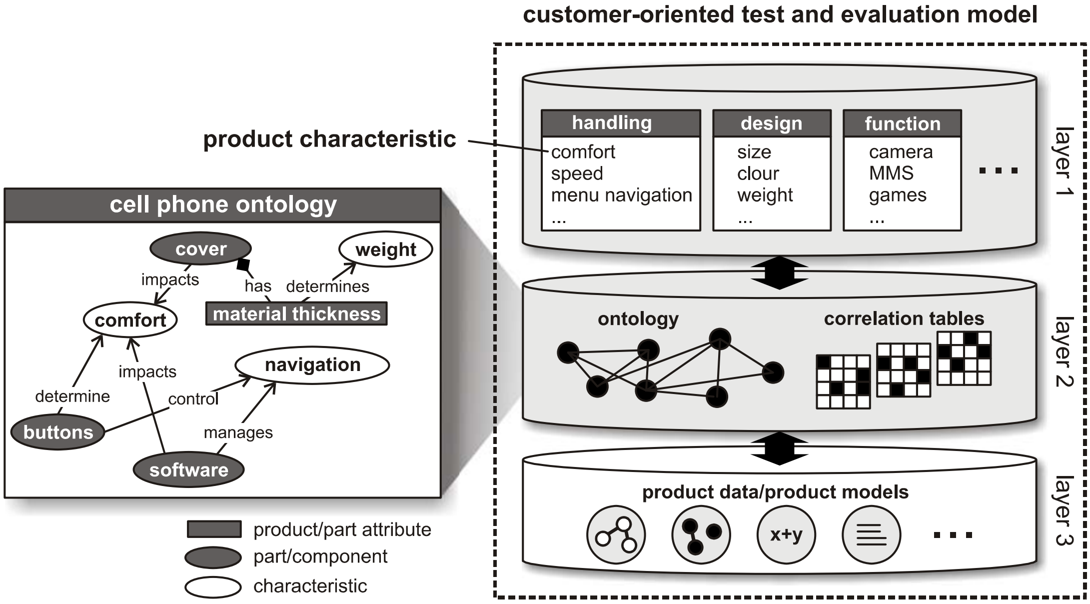

Figure 2. Customer oriented test and evaluation model (T&E model)

Prospective feedback acquisition

The prospective acquisition of customer feedback information takes place during the product development before the start of production (SOP) and thus before the use of the product by the customer. The acquisition of customer requirements and wishes in real time, parallel to product development processes ensures the topicality of customer needs. The aims of the prospective feedback acquisition are:

- extraction of customer requirements and customer satisfactions,
- extraction of the customer's preferred product characteristics (preference configuration),
- input for improvement and optimisation of product drafts,
- early validation of product drafts before the production release.

For this the selected customers are asked to deliver information concerning their buying decision parameters (e.g. product design), confidence parameters (e.g. security, reliability) and product use parameters (e.g. functions). The prospective feedback extraction is carried out in two fundamental steps. In the first step the T&E model is presented to the customer, which he can configure, test, and customise. In the second step the customer evaluates the flexible product characteristics, which result from the configuration and customisation of the T&E model.

Retrospective feedback acquisition

The retrospective acquisition of customer feedback focuses on the extraction of information from the product use under market conditions. On the one hand the customer directly formulates his experiences as well as product advantages and disadvantages during its use. On the other hand user information (e.g. complaints) is extracted indirectly from service and aftersales divisions of the company and led back into the product development. The aims of the retrospective feedback acquisition are:

- Verification of prospective feedback information, due to the market dynamics and changed customer requirements,
- identification of problems during the product use,
- analysis of characteristic customer behaviour during the product use.

The retrospectively extracted feedback information can be used to identify room for improvement within the development of the next product generation. In addition, predictions for the future trends of the customers' requests and satisfaction can be derived through the long-term feedback evaluation in context of the macro integration.

Web-based feedback assistant

A web-based feedback assistant was implemented for the collection of feedback information. This assistant is part of a client/server environment, which is based on a service oriented architecture (SOA). The IT architecture uses web services for the communication between the feedback assistant, the feedback data base application and the PDM system. The graphical user interface of the feedback assistant is arranged into three application areas (figure 3):

1. In application area 1 the customers can select preferred product characteristics and configure the digital product by using a configuration applet.
2. In application area 2 the T&E model is dynamically generated and visualised from the selected product characteristics and the preferred configuration. In addition, this area contains simplified CAD and simulation functions, in order to offer variation functions to the customer and to simulate product functionalities.
3. In the third range the customer has the possibility of evaluating the T&E model and its characteristics by selecting pre-defined evaluation scores, pull down lists and free text input. Additionally the importance of the selected product characteristics for the customer is questioned and evaluated by the Kano method.

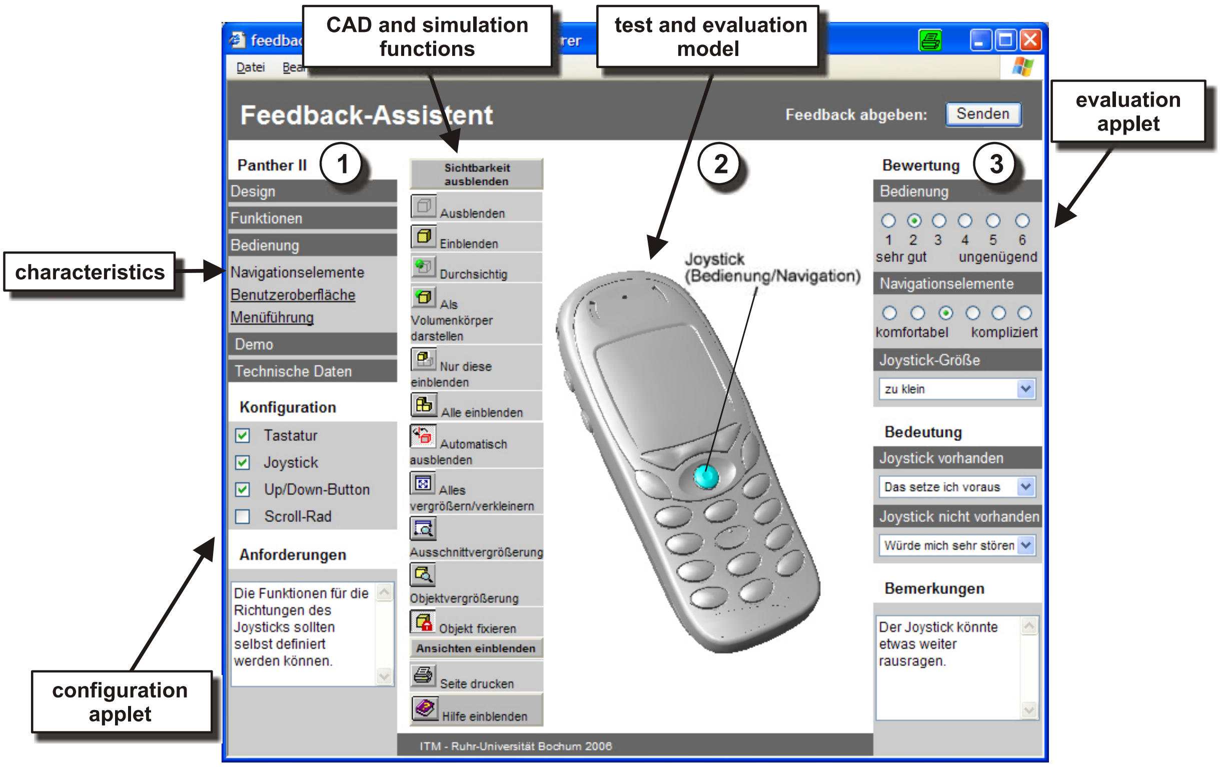

Figure 3. web-based feedback assistant for feedback collection [15]

The collected feedback information is stored, filtered and evaluated in a data warehouse (feedback repository). The result of the evaluation process is formalised feedback data, which is classified by customer requirements, customer satisfaction and product preference.

3.4 Mapping the customer feedback onto product structures

The customer-oriented product characteristics and the related feedback have a specific meaning for different product components. Therefore semantic mapping of the feedback on technical product structures is conducted using the house of quality (HoQ). The product structure represents the basis for product data management. Through the detailed feedback mapping onto product structures a context sensitive accesses to the feedback data within the product development can be reached. Since the comparison with competitors (used in the traditional HoQ) is not important for semantic feedback mapping, the appropriate tables were not used. Instead the HoQ was extended using tables for the formal feedback indicators, for the customer-oriented product characteristics and for the technical product structures (figure 4).

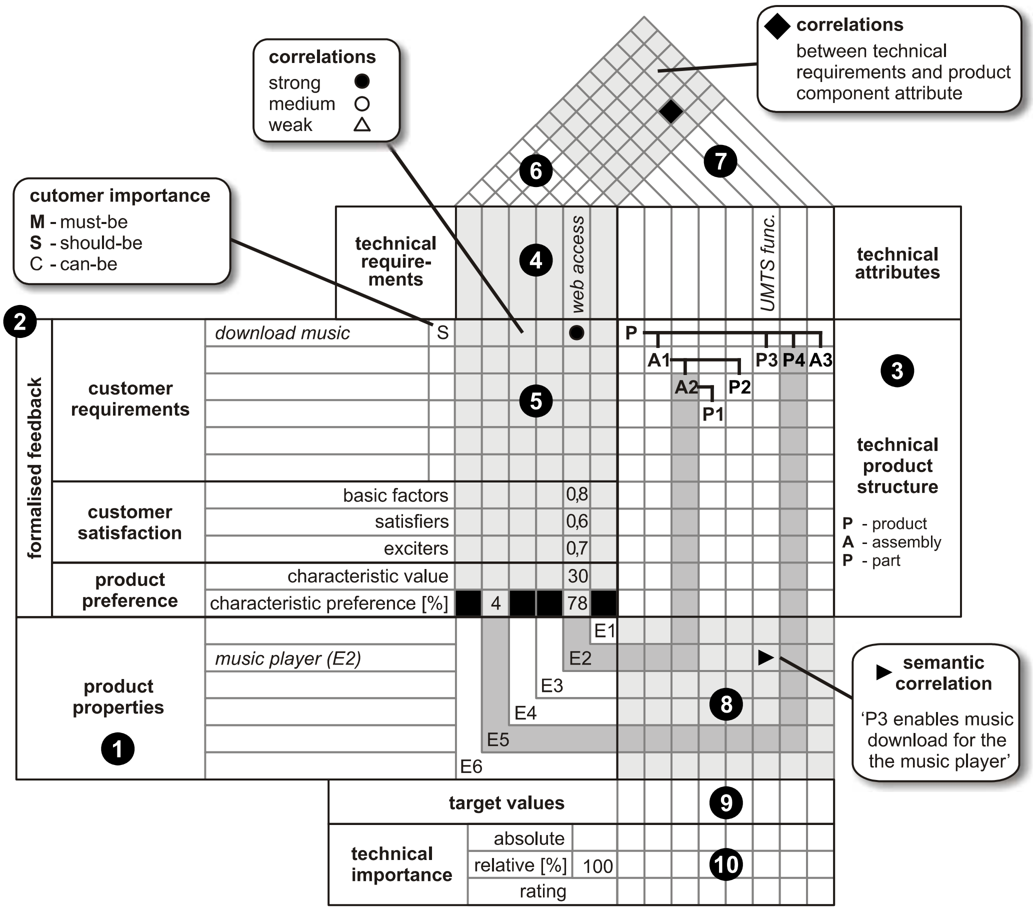

Figure 4. Extended house of quality for mapping the customer feedback onto technical product structures [15]

The following steps are necessary for mapping the feedback onto the product structure:

1. First of all the customer-oriented product characteristics of the T&E model are listed and labeled by an identification number (E1 to En).
2. In the second step the formal feedback is assigned. Therefore the weighted customer requirements, customer satisfaction values and product preferences related to the product characteristics are listed in the feedback table.
3. The third step contains the detailed representation of the technical product structure. In different hierarchy levels the several components of the structure (product, assemblies, parts) are registered.
4. Now the listed customer requirements are translated into significant, technical-oriented requirements.
5. The relations between the customer requirements and technical requirements are registered in the correlation matrix.
6. In the sixth step the mutual relations between the technical requirements are analysed in the conventional roof of the HoQ.
7. In the table above the product structure the concerned attributes of the respective product component are listed. Afterwards the attributes are set in relation with the appropriate technical requirement using an optional symbol in the correlation matrix.
8. In the next step the semantic linkage of the product structure with the feedback data and the product characteristics is set. By allocating the technical requirements to the product structure, the relationship between product components and product characteristics concerned becomes apparent.
9. On the basis of the characteristic values, the technical requirements and the assigned product attributes, an objective target value for each product component is calculated.
10. In order to prioritise improvement and optimisation measures in the product development all product components are weighted regarding their importance.

Multi-attributive model for the evaluation of customer satisfaction indices

The customer satisfaction, extracted by the feedback acquisition, cannot directly be mapped onto the product structure. The satisfaction related to a product assembly or part is composed by different satisfaction values of the respective product characteristics. In order to be able to calculate the satisfaction index for each component of the product structure, a three step multi-attributive model was developed, which is based on the characteristic-oriented procedures for the measurement of customer satisfaction. The computation of the satisfaction indices for several assemblies or parts takes place in the following three stages [15]:

- Weighting the satisfaction values (according to the Kano classification) and aggregating to a common characteristic-specific satisfaction value:

$$Z_e(E) = \frac{G_{Ba} * Z_{Ba}(E) + G_{Le} * Z_{Le}(E) + G_{Be} * Z_{Be}(E)}{G_{Ba} + G_{Le} + G_{Be}} \qquad \text{with: } G_{Ba} > G_{Le} > G_{Be} > 0$$

Z_e	=	*characteristic-specific satisfaction value*	G_{Le}	=	*weighting of satisfier factor*
E	=	*product characteristic*	Z_{Le}	=	*satisfier factor*
G_{Ba}	=	*weighting of basic factor*	G_{Be}	=	*weighting of exciter factor*
Z_{Ba}	=	*basic factor*	Z_{Be}	=	*exciter factor*

- Weighting characteristic-specific satisfaction values related to a product component and aggregation to a product-component-specific satisfaction value:

$$Z_k(K) = \frac{\sum (G_e * Z_e)}{\sum G_e} \qquad \text{with: } G_e = \sum_{i=1}^{m} (GA_{ei} * GB_{ei}) \quad \text{and} \quad e = 1 \text{ to } n$$

Z_k	=	*product component-specific satisfaction value*	GA	=	*weighting of customer requirement*
K	=	*product component*	GB	=	*weighting of correlation between customer and technical requirement*
e	=	*related product characteristic*	n	=	*number of related product characteristic*
G_e	=	*weighting of characteristic-specific satisfaction value*	m	=	*number of requirements/ correlations per product characteristic*
Z_e	=	*characteristic-specific satisfaction value*			

- Weighting and aggregating all component-specific satisfaction values, which are subordinated to the referring product component:

$$ZI_K = \frac{G_K * Z_K + \sum (G_k * Z_k)}{G_K + \sum G_k}$$

with: k = 1 to l

ZI_K	=	*satisfaction index for product component K*
G_K	=	*weighting of satisfaction value for product component K*
Z_K	=	*component-specific satisfaction value for product component K*
G_k	=	*weighting of satisfaction value for subordinated product component k*
Z_k	=	*satisfaction value for subordinated product component k*
k	=	*subordinated product component*
l	=	*number of subordinated product components*

3.5 Extended PDM for the feedback integration

The information-technical integration of the feedback is carried out using extended meta data models in the PDM system. The meta data model represents the logic linkage of meta data and physical files and is extended by data objects for customer requirements/improvements and customer satisfaction indices. In addition to the customer satisfaction indices and technical requirements the customer feedback contains information about the product components preferred by the customer, which resulted from the variation and configuration of the T&E model (preference configuration). In order to assure access to the preference configuration for the product developer, the configuration management is extended by a prospective and retrospective preference configuration (figure 5). The prospective preference configuration describes the product configuration demanded by customers (‘as required’), which results from the configuration action of the feedback assistant. The retrospective preference configuration results from the customer’s evaluation of the used product and from the analysis of the product use information ("as used/favored").

The preference configurations are described by percentage rates for each product part or assembly. A low percentage rate leads to the exclusion from the preference configuration. The percentage rates are calculated based on the frequency of a product property selection by the customer (see feedback assistant) and the correlation between the product properties and the product parts or assemblies (see extended HoQ). The linkage of feedback and product data was prototypical realised using the PDM system Windchill. To link the feedback data to the product data in the PDM system, a XML file including the technical product structure is exported from the PDM system and stored in the feedback repository. This XML file is completed by a new product structure (generated by the percentage rates of the preference configuration), the satisfaction indices and by a link to the textual information about customer requirements stored in the feedback repository. By importing the completed XML file into the PDM system, the appropriate preference configuration is automatically generated by the PDM system.

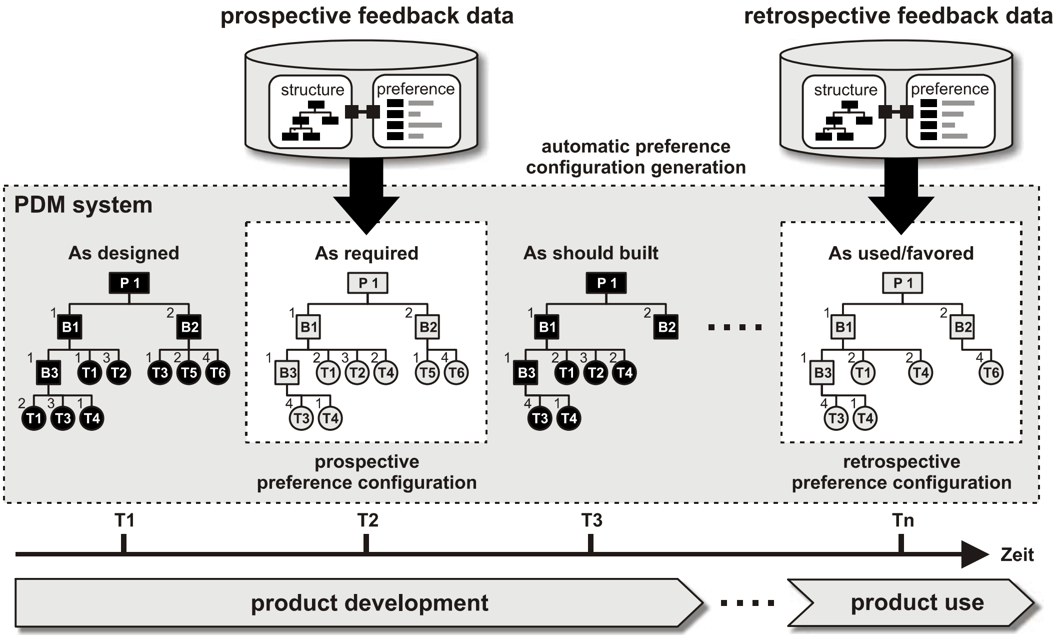

Figure 5. Extended configuration management with automatically generated preference configurations [15]

Using the structured XML file and the PDM system’s import function, every component of the generated product structure (preference configuration) is assigned to a specific customer satisfaction index and linked to the external feedback repository. The satisfaction indices of assemblies and parts in the product structure are consolidated and arranged in three signal classes, in order to offer to the product developer direct visualisation of the customer satisfaction status (figure 6):

- Signal green (optimal satisfaction range): The entire product or a product component corresponds as far as possible to the customer requirements and conception, so that further product optimisation is not necessary. The product may be released for production.
- Signal yellow (critical satisfaction range): possibilities for product improvements exist, which are capable of increasing customer satisfaction. A release for production is only conditionally possible.
- Signal red (discontent range): The entire product or a product component does not correspond to the customer requirements. There is compelling need for product improvement and optimisation. A release for production must not take place.

The described signals are linked to the feedback contents stored in the feedback repository. In this way the product developer can retrieve directly detailed feedback information for a specific product component using the PDM system (figure 6).

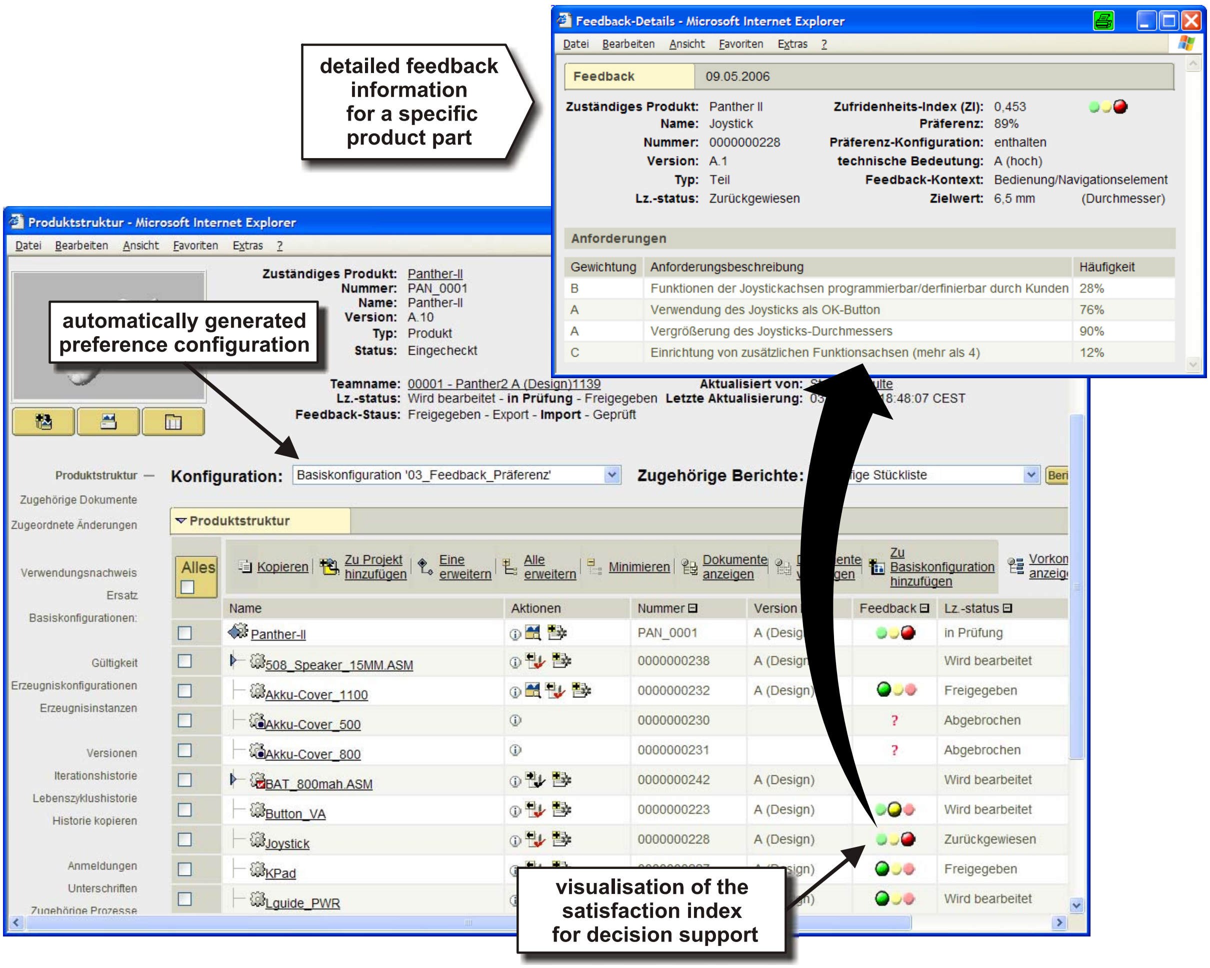

Figure 6. PDM-System with integrated feedback data [15]

4 CONCLUSIONS

The described approach for the integration of customer feedback into product development was prototypically realised and implemented. To evaluate the developed methodology and the IT prototype a product development scenario was used. This scenario contains the improvement and new design of mobile telephone navigation elements and was supported by Motorola, who provided development data of a mobile telephone. Since the approach's success depends on the acceptance of the web-based and IT supported tools by customers and product developers, need for an industrial testing and evaluation still exists. Additionally the appliance of the feedback integration approach must be attended by a motivation concept for the customers to participate in the product development.

The extraction of customer satisfaction and requirements only represents the first step of an extensive integration process. Without the purposeful forwarding and application oriented preparation the customer information for the enterprise is worthless. Effective use of customer information is only possible by its systematic, context-oriented integration into the working environment of the product developer. The integration of customers into product development must not be seen as a single project, but as long-term, continuous management task. Customer orientation as part of the enterprise strategy will, in the coming years lead to a transformation of the enterprise organisations from a traditional, monolithic organisation form to a customer-driven organisation form. This organisation form will be characterised on the one hand by an intensive cross-linking of the relevant knowledge carriers for the product development and by the integration of the customer knowledge into the product development processes. On the other hand products will evolve to integrated, customer-oriented total conceptions, which will contain flexible combinations of physical products and services. Regarding the integrated engineering of products and service a need for research still exists.

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