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SYSTEMATIC SELECTION OF APPROPRIATE METHODS IN QUALITY MANAGEMENT

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ABSTRACT
The growing number and quality of new products on worldwide markets continuously challenge companies to maintain or expand their market shares. The acceptable time to market decreases and forces companies to reduce their development and production time. Quality of products and the efficiency and effectivity of quality processes therefore strongly influence the success of companies and become crucial competition factors.
A widespread repertory of quality management tools and methods promises to support design engineers in managing these often opposed but necessary requests to product development. This requires to select the most appropriate method and to successfully apply it in the development process.
This paper describes a systematic way based on the QFD method to overcome this dilemma. The stakeholders demands on products are describes and resulting requirements to product quality are derived. The systematic correlation of these requirements and the demands on process quality support the evaluation and the choice of adequate quality methods for the improvement of the development process. The paper concludes with a first evaluation of the proposed approach.

Keywords: Quality management, Quality methods, Development process

1 INTRODUCTION
Success in cut-throat competition of national and international markets increasingly depends on the quality of products as well as on the quality capability and efficiency of intra-corporate quality management. Quantity and quality of available new products are constantly increasing, while the amount of time for product planning and product development is reduced at the same time. Methods and tools of quality management support design engineers in accomplishing these important but sometimes opposed requirements. Most mistakes (75%) originate in the early phases of product design but become obvious in the later phases or even during the use of the product. Therefore 80% of the mistakes are primarily eliminated during control or use of the products. The later mistakes can be eliminated, the more expensive the cost of an improvement or repair and the damage to the image of product and company become, Figure 1.

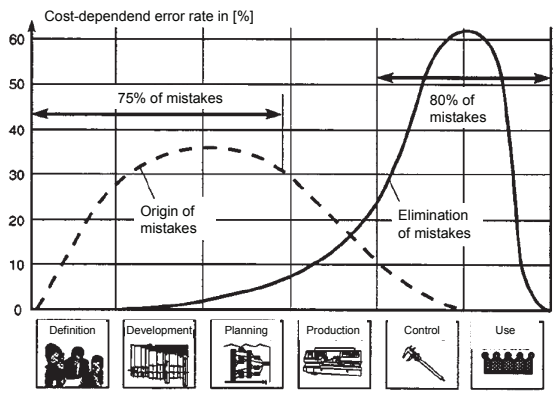


Figure 1. Mistakes during product development [1]

Therefore quality management has become more important recently to avoid mistakes in the early phases of product development to diminish their impact in later phases of the product lifecycle.
Product quality comprises not only functional compliance but also comprehensive demands concerning e. g. safety, ergonomics, recycling or disposal. The economic success of companies increasingly depends on delivery reliability and price as well as on the quality of the products. This results in a cause-and-effect-chain between time, cost and quality, Figure 2.

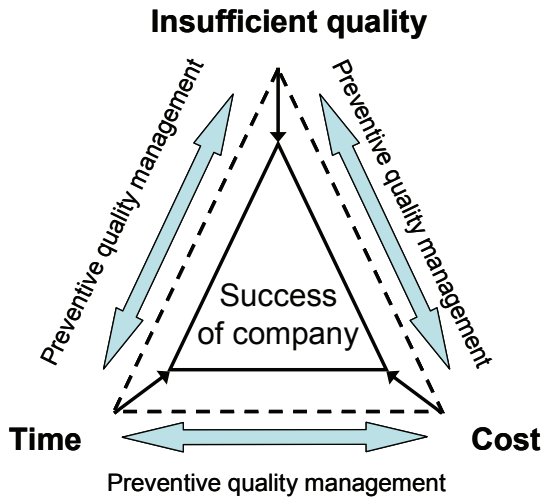


Figure 2. Factors of company performance [2]

An improved quality of products reduces the probability of rework and rejections, the cost of warranty and the number of displeased customers. Thus not only price and adherence to delivery dates but also quality become important factors for a long-time market success.
A preventive quality management ensures a systematic treatment of possible mistakes and therefore reduces the number of mistakes and their cost. Appropriate methods support this approach. Many methods in the area of quality assurance and quality management have accumulated in the past decades. In view of this diversity it appears necessary to systemize the selection of adequate methods and their application to achieve a high level of quality.

2 QUALITY MANAGEMENT IN THE PRODUCT DEVELOPMENT PROCESS

Quality is abstractly defined as the “degree to which a set of inherent characteristics fulfills requirements” [3]. A sufficient level of quality requires both quality of the product and of the product development and manufacturing process.
Product quality consists of technical, economical and subjective factors, Figure 3. From a technical point of view quality comprises mainly functional aspects. For example, the products must fulfill the intended purpose with a satisfying performance and achieve an adequate lifespan. Technical quality is mostly measurable and quite objective to judge. Economic quality of a product brings a reasonable input of factors of production and use into focus. Life cycle costs, market shares and value performance are examples for factors that account for economic quality. The purely economic view is expanded by a desired long term sustainability of the product and the interdependency with its environment. Subjective quality is the quality that is perceived e. g. by the user. It is rated based on his individual experiences and expectations, quality awareness, intended purpose, risk estimation and personal background.
These requirements to products are made by several parties that are influenced during the product lifecycle. Customers, companies and society have quite diverse demands to products that are difficult to fulfill simultaneously.
These requirements to product quality by the stakeholders can be summarized and allocated to the three categories of product quality based on their different motives, Figure 3.

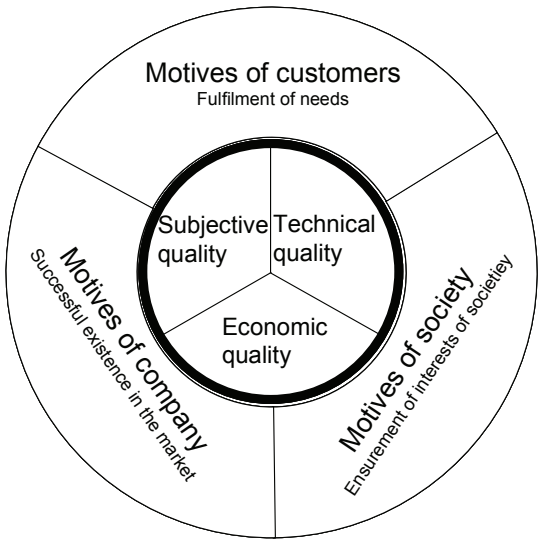


Figure 3. Views on product quality (based on [4])

The **customer** or user is obviously in the center of theses requirements. Maintaining a high level of customer satisfaction is a challenge for companies and requires first of all the prevention of complaints besides their internal handling and consideration in future product development. Customers' motives mainly demand

- fulfillment of functional characteristics that enable the customer to realize the estimated use of the product,
- functional expandability of the product,
- satisfaction of the customers preferences for the product e. g. concerning handling, comfort or optical appearance of the product,
- durability and reliability of the product,
- timely availability of the product,
- safety for the user and the environment before, during and after use,
- product and corporate image,
- easy maintenance and
- efficiency in purchase, use and maintenance.

Society is also affected by most products during their lifecycle. Their motives are focused on the avoidance of destructive impacts of products and therefore comprise

- safety of the product and its manufacturing process,
- consideration of moral, ethical and political aspects,
- economic use of resources and
- protection of the environment during the life cycle.

The producing **company** itself is mainly interested in sustaining business in the long term and claims

- enduring performance of a product and a product line in the market,
- a good image of the company,
- gaining satisfying shares in the market,
- keeping existing market shares and opening new markets by innovative solutions,
- safety of the product with regard to image and liability and
- economic success of the product and the company.

Furthermore product quality assumes process quality in product development and production. This "process quality" includes quality in the work flow of product development and in the use of adequate methods. The main task of the development department is to transform requirements to the product into possible adequate solutions and to judge their feasibility. Every step of the development process therefore requires a transformation that generates numerous alternative solutions.
The following evaluation identifies the best concept as input parameter for the next step of the development process. The optimal enforcement of all requirements and the choice of the best alternative solution predefine the result of the following development phase and at least of the overall outcome. Consequently the quality of the product depends not only on the fulfillment of the motives and needs of the stakeholders in Figure 3. It is fundamentally based on the quality of the development process and its sub-steps. The implementation of capable quality engineering that is based on scientific and technical knowledge as well as efficient quality management is strongly supported by quality methods.

3 PROCESS QUALITY IN PRODUCT DEVELOPMENT

The view on quality in companies has significantly changed in the past decades from quality control (up to the 1970s) to quality management, Figure 4.

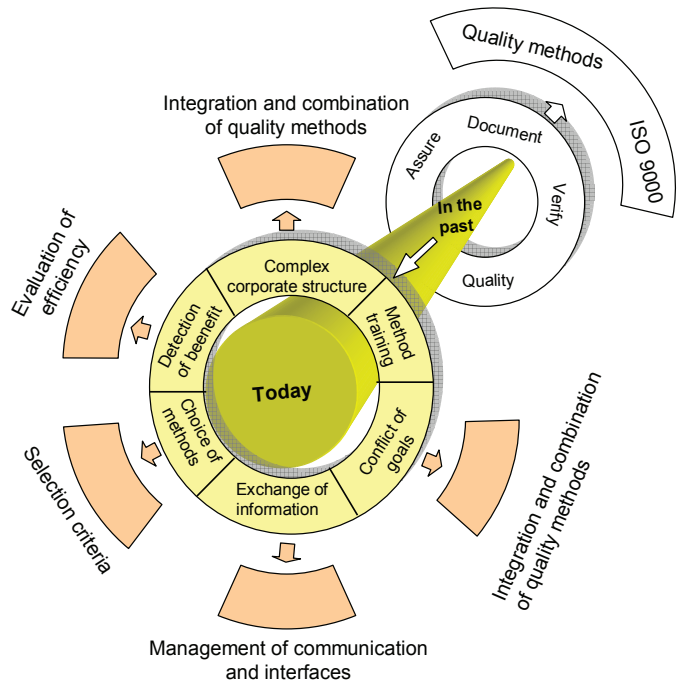


Figure 4. Changes in the quality perspective

Quality management in 1950s and 1960s mainly consisted of assuring product quality by use of adequate production technologies and a reasonable final checking accompanied by documentation. The quality department was mainly uncoupled and quality assurance more or less independent from the success factors time and money. A continued development included at first statistical control of manufacturing processes and in the 1980s increasingly quality management methods. Nowadays the focus of quality assurance is much more comprehensive. More complex structural organization in companies and conflicts between the goals of quality methods require the integration and connection of diverse methods and more intensive instruction for the user. Total quality management incorporates all departments and is targeted on satisfaction of the customer and long term success of business and society [5]. Structural organization, process organization and human factors are the main operators

influencing the product development process. Qualification, motivation, experience and soft skills influence the human performance of the staff whereas the internal information flow, the development process or responsibilities and hierarchical structure make an impact to organizational boundary conditions. Under these circumstances successful product development requires an effective use and control of quality management methods. Therefore it becomes essential to choose purposeful, more exactly most effective and efficient, quality methods during the development process.

4 SELECTION OF PURPOSEFUL QUALITY MANAGEMENT METHODS

One of the main reasons for lacking use of quality methods is unawareness of their precise effects and advantages. Significant selection criteria for the choice of the most purposeful method and the evaluation of the efficient and effective use of methods become important to achieve high quality at reasonable costs. Figure 5 shows the steps of a systematic selection process based on QFD for exemplary quality methods. They are implemented for mechanical engineering products in general in the following description.

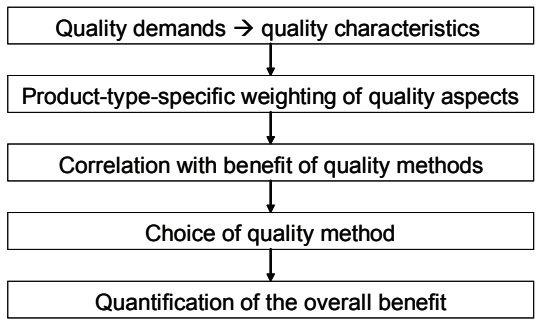


Figure 5. Systematic approach to the selection of adequate methods

Step 1: Quality characteristics are verbalized based on quality demands
Customers, company and society make demands on the quality of products in the three classes of quality requirements shown in Figure 3. The view of the stakeholders to an apparently similar demand, differs in their motives. Customers particularly want to get a safe product for themselves and their surrounding area. The company has to observe obligations and laws and to avoid liability assignments. Society is indirectly involved in the surrounding area of the user customer and claims a product without hazards for the public. Figure 6 assigns these requirements to the three factors of product quality described in Figure 3 and a set of common sub-factors. Requirements of customers and companies contribute to all factors whereas the demands of the society are not directly relevant for the economic view. A systematic arrangement of the quality demands in classes supports a better handling and the weighting of the requirements.

Step 2: Product-type-specific weighting of quality aspects
The weighting of the quality aspects on a scale from 1 (low) to five (high), Figure 6, supports the choice of adequate quality methods. The importance of a quality aspect in relation to quality methods depends on the product, e. g. the product type. Capital goods and consumer goods require different views on the quality of the product.

Step 3: Correlation with aspired benefit of quality methods
Quality methods are mainly used to achieve advantages for customers (external) or the producing company (internal). External effects are a larger flexibility on the market based on new demands of the customers, a comprehensive customer fulfillment and less customer complaints.
Primary, direct internal impacts besides fewer complaints are shorter time to market, less loops in the development process, less rejects or rework and a better documentation. Secondary, indirect internal advantages comprise increased motivation, a better interdisciplinary cooperation or a broader attention to quality aspects. The fulfillment of these effects obviously depends on and varies within the different

quality methods. On the other hand it correlates unequally with the demands of certain products. It is therefore useful to examine this correlation in a matrix like the house of quality in QFD, Figure 7. The illustrated example for mechanical engineering products in general benchmarks the strength of the correlation between the process view on quality management or quality methods and the product view on product quality with discrete values from 0 to 9. The correlation of the process related quality aspects is shown in the top part of the scheme. The values of the correlation in the columns are added in absolute and relative values at the bottom of the scheme. The importance of the process-related quality aspects are the fundament for the choice of an appropriate quality method.

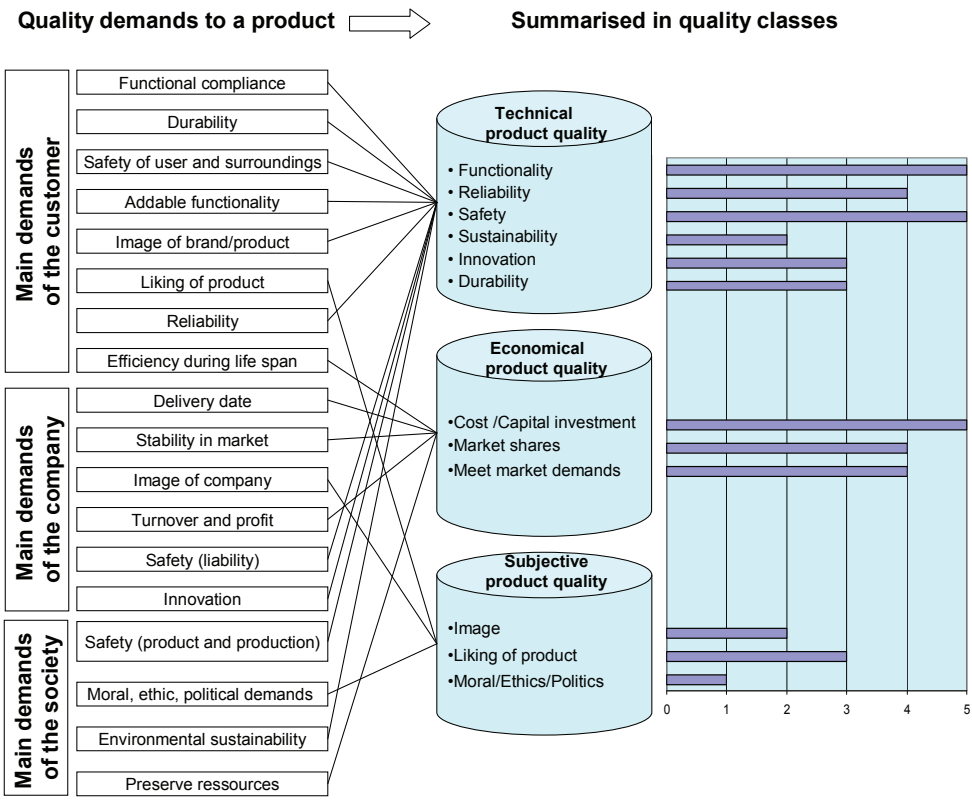
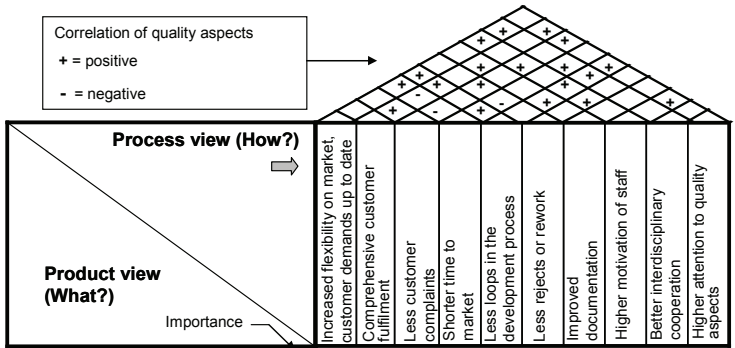


Figure 6. Correlation between stakeholders and product quality

Step 4: Appraisement of the suitability of quality methods

The suitability of quality methods for the fulfillment of the aspired benefit is observed in the next step. The usefulness of quality methods like FMEA (Failure-Mode-and-Effects-Analysis), QFD (Quality Function Deployment), Value Analysis or FTA (Fault-Tree-Analysis) is rated on a scale from 0 (useless) to 7 (very high advantage) regarding the procedural quality aspects. An exemplary assessment of the QFD for products of mechanical engineering in general is shown in Figure 8. The diagram shows strengths and weaknesses of the methods related to the needs of a certain product type.
The appliance of QFD mainly helps to regard customer demands comprehensively. This results in a shorter time to market and less loops in the development process, because the development procedure is more focused. On the other hand QFD has a reduced impact on the documentation and reworks or rejects due to a lack of manufacturing quality.
Establishing the diagram in Figure 8 visualizes the strengths and weaknesses of methods and therefore supports the selection of adequate methods for the improvement of specific procedural aspects or problems.



		Importance	Increased flexibility on market, customer demands up to date	Comprehensive customer fulfilment	Less customer complaints	Shorter time to market	Less loops in the development process	Less rejects or rework	Improved documentation	Higher motivation of staff	Better interdisciplinary cooperation	Higher attention to quality aspects
	Process view (How?)											
	Product view (What?)											
Technical quality	Functionality	5	6	9	3	0	6	6	6	3	6	3
	Reliability	4	3	3	9	0	3	9	3	3	0	3
	Security	5	1	6	6	0	1	9	1	1	1	3
	Sustainability	2	6	3	1	0	3	3	0	0	3	1
	Innovation	3	9	6	0	6	3	3	3	3	3	3
	Durability	3	1	3	6	0	1	9	1	3	0	3
Econom. quality	Cost/Capital investment	5	0	1	6	9	9	9	3	3	3	1
	Market shares	4	6	6	6	6	6	3	3	1	3	1
	Meet capital demands	4	9	9	1	9	6	1	1	3	6	3
Subj. quality	Image	2	3	6	6	6	1	1	0	1	1	3
	Liking	3	9	9	1	1	3	0	0	1	1	1
	Moral, Ethics, Politics	1	1	3	0	0	0	0	0	0	3	0
Importance of values in column	absolute		183	227	174	150	169	216	90	86	109	92
	relative (0 to 10)		5,0	6,2	4,8	3,8	4,6	5,9	2,5	2,4	3,0	2,5

Correlation of product quality and effects of quality methods:
9 = high
6 = moderate
3 = low
1 = very low
0 = no

Figure 7. Correlation between product quality and process quality

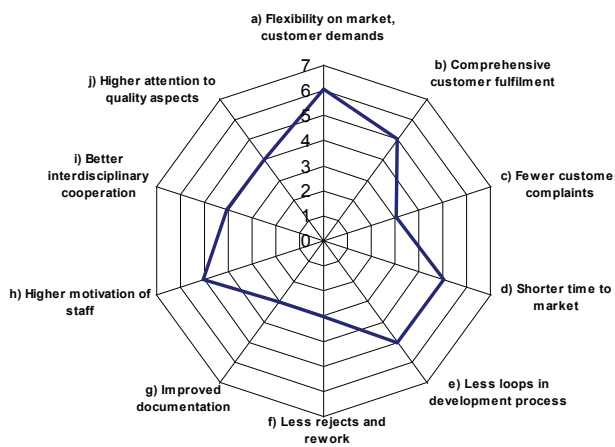


Figure 8: Impact of QFD on procedural quality aspects

Step 5: Quantification of the overall benefit
The overall benefit of quality methods mainly depends on their effect on weak parts of the development process. Quality methods should improve the weaknesses of a development process.
The benefit of the use of quality methods depends on the rating of their impact on procedural aspects in Figure 8 and on their relative importance (Figure 7). The product of these two factors specifies a weighted impact on specific procedural aspects for certain products or groups of products. The summation of these products indicates the overall benefit of a method for the application in the development process.
This overall benefit helps to generally evaluate and select effective methods and complements one another with the results of step 4. Both aspect imply that the selection of beneficial methods may depend on the weaknesses of the development process and on the type of product or industrial sector.

5 EVALUATION

A significant evaluation of the effectiveness and efficiency of quality methods depending on constraints like product type or industrial sectors is difficult to realize and missing up to now. A first evaluation of the approach described in this paper was therefore undertaken by comparing the results to those of a survey by Theden [6]. Theden analyzed the rentability of quality management and quality methods based on the presumption that quality expenses are mainly influenced by insufficient processes and activities in a company. This thesis is underlined by Linss [2]. He assumes that the main proportion of quality expenses consists of hidden costs resulting from e. g. demotivated staff or lost customers.
Theden examined the efficiency of a selection of the most used quality methods in his survey: QFD, FMEA DoE (Design of Experiments), SPC (Statistical Process Control). He choosed the automotive industrie, the electrical industry, machine- and plant-engineering and chemical industry as examples for his survey of the efficiency of quality methods.
Result was an estimation of strengths and weaknesses of the methods. For example, the method of QFD was applicated by an average of 35 % of the companies according to Theden. QFD was regarded weak in the improvement of rejects and rework. Strengths were described for the reduction of loops in the development process. This corresponds with the results of the approach described in this paper.

6 SUMMARY AND CONCLUSION

A broad variety of methods and tools nowadays supports engineering designers in their everyday work. Quality methods improve both weak parts of products and all stages of their development processes to achieve technically and economically optimized products. Actual research mainly concentrates on the development of new methods, specific problems during the application of quality methods and the increasing extension of quality management processes towards comprehensive steering approaches.
Successful product development requires an effective use and control of quality management methods. Therefore it becomes essential to purposefully choose the most effective and efficient quality methods during the development process. Adequate quality methods must regard the demands of customers, companies and society as stakeholders of all kinds of products in order to improve not only the technical, but also economical and subjective factors of product quality.
The house of quality used in QFD provides a helpful basis for a purposeful selection of appropriate quality methods. The correlation of required quality characteristics of a product and the procedural quality aspects of quality methods enables both a general and a specific evaluation of quality methods.
A first evaluation of the approach was carried out by comparing it to surveys about the estimation of efficiency of quality methods in literature. The results show a consensus of the assets and drawbacks of selective quality management methods and their efficiency for the improvement of products of mechanical engineering. An interesting issue could be to combine of certain methods, e. g. QFD and FMEA. This may strongly support their widespread use and improve their effectiveness and efficiency. A continued research about the efficiency and effectiveness of quality methods and their selection for specific fields of application is necessary.

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