Analyzing the Impact of Quality Tools and Techniques on Quality Related Costs: Comparing German Industries.

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Abstract

The proportions of quality costs in engineering budgets are higher than 30% on average and in manufacturing budgets higher than 20%. Measuring and analyzing quality related costs have proven to be beneficial. Although it is a well discussed topic in literature, the implementation rate in industry is still low. However, market leaders have significantly lower quality costs when compared to their competitors. This paper presents data regarding quality related costs and the effects after using quality tools and techniques. The study was carried out as an online survey of quality experts of German companies from three industries: Automotive, Mechanical Engineering and Electronics. Survey results are compared to literature, discussed and conclusions drawn. Findings indicate that the implementation rate of quality tools and techniques and the amount of total quality costs vary starkly among industries. Furthermore, evidence shows that there is untapped potential for increasing profits if quality related costs are reduced. The greatest barriers to attaining this potential are limited resources and access to data. There is a strong need for tools and techniques to facilitate the cost reduction exercise. Since existing models are theoretical in nature, the collaboration with real-world companies is required. Accompanying and coaching the client during the implementation phase is a key success factor to sustainably integrated solutions. Practical models can be derived from learnings of those projects as a guide to others.

1 Introduction

The past few decades have been characterized by a severe increase in competition on global markets for manufacturing companies. This has forced companies to shift their focus from the fulfillment of product requirements to the fulfillment of customer requirements. While in the early 20th century Henry Ford created an excess in demand with a mass produced standardized product, nowadays companies serve markets with the concept of mass customization. Additionally, due to globalization, customers are offered a greater range of products and services to choose from. These different conditions force companies to differentiate by offering superior quality. As a consequence, quality cost measurement and analysis, as well as the implementation of methods to reduce those costs, need to be an integral part of any day-to-day business operations [1]. A great benefit of reduced failure costs is an increase in perceived quality. This leads to a substantial growth in market share and the feasibility of charging higher prices, which subsequently increases profits [2].

An established and well known concept in the field of controlling and assuring quality is Total Quality Management (TQM). TQM aims to increase customer satisfaction and ensure continuous improvement. One suggested technique is quality costing with the purpose to identify need for action in order to decrease poor quality costs.

This paper contributes to the limited amount of reported data of quality costs of real-world companies. The data reported is the outcome of a survey carried out with quality experts from German companies of three examined industries: Automotive, Mechanical Engineering and Electronics. A return rate of 33.7% was generated by 94 out of 279 companies filling out the survey. The outcome of the survey is compared to findings relevant literature. The results are of interest to both academia and industry. The findings supplement literature with current quality related costs of real-world companies. Practitioners can use the findings to benchmark their own data. Results indicate that the implementation rate of quality tools and techniques varies strongly among industries. Also, the amount of Total Quality Costs (TQC) shows differences between the assessed industries. In addition to that, evidence shows that applying quality tools and techniques have an impact on quality cost reduction.

The paper starts by providing background on relevant topics and a general methodology. Secondly, the application case presents details regarding sample size and characteristics of the participating companies. Analyzed data from the survey is compared to relevant literature, discussed and conclusions are drawn.

2 Background on Quality Tools and Techniques

The following section provides the theoretical background of relevant topics. TQM and quality tools are reviewed and reported data of quality costs in different industries is presented.

2.1 TQM Accompanied with Quality Tools and Techniques

TQM is an extensive and diverse topic. Over time its development has been influenced by a subjective body of thought. There is no global definition of TQM and companies hold different interpretations and uses [3]. It is generally accepted to describe TQM as a philosophy that recommends a set of tools and techniques that aim towards an increase customer satisfaction and continuous improvement. Implementing mindsets to meet the internal customers' needs is achieved through tactics for changing a company's culture and structured technical techniques [4], [5]. TQM is also understood as a management system consisting of values, techniques and tools, as three interdependent components [6]. Common tools and techniques are summarized by Dale and McQuater [7] and presented in Table 1.

Table 1: Quality tools and techniques used in industry [7].

The seven basic quality control tools	The seven management tools	Other tools	Techniques
Cause and effect diagram	Affinity diagram	Brainstorming	Benchmarking
Check sheet	Arrow diagram	Control plan	Department purpose analysis
Control chart	Matrix diagram	Flow chart	Design of experiments
Graphs	Matrix data analysis method	Force field analysis	Failure mode and effects analysis
Histogram	Process decission program chart	Questionnaire	Fault tree analysis
Pareto diagram	Relations diagram	Sampling	Poka yoke
Scatter diagram	Systematic diagram		Problem solving methodology
			Quality costing
			Quality function deployment
			Quality improvement teams
			Statistical process control

Tools and techniques, as portrayed in Table 1, are described as practical methods, skills, means or mechanisms which are used for a specific circumstance [8]. Their purpose, when applied, is to achieve positive change and improvement [8].

One technique in Table 1 is quality costing, which is further explained in the next section.

2.2 The Idea of Quality Costing

The idea of quality costing emerged during the 1950s. Juran [9] identified the need to estimate the costs of quality and Feigenbaum [10] presented an approach to categorize those costs into the areas of Prevention, Appraisal and Failure (PAF). Relevant literature presents various terms for quality related costs, most of which are used interchangeably [11]. "Quality is free" according to Crosby [12] and costs only emerge when actions have to be taken if things are not done right the first time. Juran [9] interprets cost of poor quality as the sum of all costs that would disappear if there were no quality problems.

A generally accepted way for quality cost categories is defined by Crosby [12] and Feigenbaum [10]. While Crosby [12] defines quality costs as the price of conformance and non-conformance Feigenbaum [10] presents the PAF scheme: Prevention (P), Appraisal (A) and Failure (F). Conformance gathers any costs that accrue due to do things not being done right the first time, which correspond to appraisal and prevention costs in the PAF scheme. Nonconformance comprises work that does not match with customer requirements, which matches failure costs in the PAF scheme. Typical costs account for activities such as correcting, reworking or scrapping.

Schiffauerova and Thomson [13] summarize quality cost models. Those include the schemes according to PAF, Crosby, opportunity or intangible costs, process cost models and activity based cost models (ABC). Their findings indicate that all models applied in industry are rewarded with positive effects on cost savings. However, in relevant literature the classical PAF approach is predominantly represented [8], [14].

Feigenbaum [10] defines the cost categories as follows: *Prevention costs* comprise all efforts with the intent of preventing defects from occurring in the first place. Included are costs for quality control engineering, employee quality training, and the quality maintenance of patterns and tools. *Appraisal costs* include expenses for maintaining company quality levels by means of formal evaluations of product quality. The elements of appraisal costs include for example are inspection, test, quality audits, laboratory acceptance examinations, and outside endorsements. *Failure costs* are caused by defective materials and products that do not meet company quality specifications. They include loss elements such as scrap, spoilage, rework, field complaints, etc. They can be determined by the location of the detection. Internal failure costs comprise poor product quality detected prior to shipment to customers. External failure costs are poor product quality detected after the shipment to customers.

The basic assumption of quality costing is that investments in activities for prevention and appraisal will reduce failure costs. Furthermore, investments in prevention will decrease appraisal costs [14]. There are two views on how to consider the dependencies of quality related cost elements: the classical view and the modern view (please refer to Figure 1). The classical view presents a cost minimum prior to a perfect quality level. Further investments for better quality will lead to higher costs. The modern model believes that the cost minimum can only be achieved at a 100% conformance level. Costs of delivering products of imperfect quality are tremendously high.

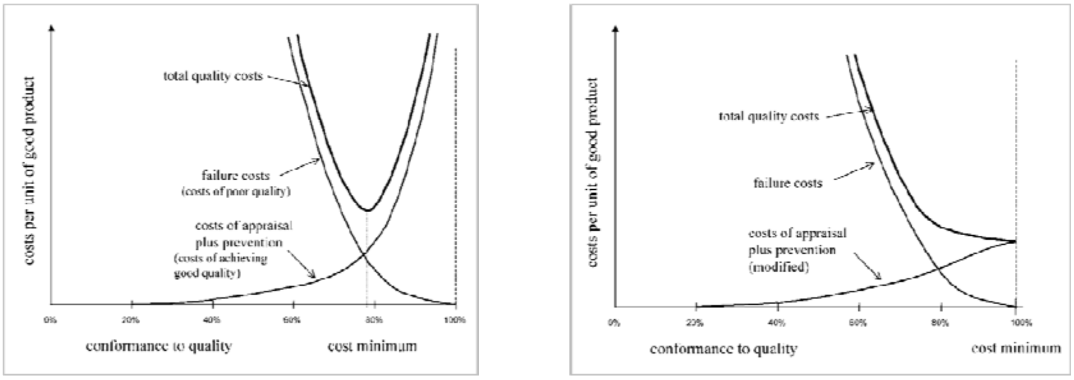

Figure 1: Classical view on the left and modern view on the right (depicted from [15]).

According to relevant literature both views are valid but also strongly challenged. Both concepts are theoretical in nature, and therefore not strictly applicable to a given company in practice. A guide for practitioners is that the modern concept can be interpreted for the mindsets of people and the classic is for established institutions. Whilst targeting a zero defect policy should be aimed for, its implementation is often too demanding to achieve in practice. Therefore, it is mandatory to identify the balance of the right investments in prevention and appraisal activities and poor quality.

2.3 Reported Quality-Costs in Industries

Schiffauerova and Thomson [13], provide a comprehensive review on research on cost and quality models and best practices. They conclude that acquiring quality cost data is an important and beneficial exercise. Companies using quality cost based programs successfully reduced quality costs and improved quality for customers. However getting access to real-world data is a challenge. There is only a limited number of papers dealing with quantitative data regarding quality costs and much of this data appears to be fictitious [16]. Getting access to real-world data is a challenge because it provides transparency over companies cost structure. More importantly the delicate topic of poor quality impacts negatively the company's image when reported to the public. There is no unique method of performing the cost gathering exercise and each costing system must be tailored individually to the company [13]. It is not clear whether other cost categories such as opportunity costs and hidden costs are included or not. Additionally, differences in cost category distribution and their total amount depend on the size of the firm. Usually larger firms have implemented a more mature quality system and show lower Total Quality Costs (TQC) [17]. Therefore, if cost calculation and reporting structures are different, comparisons across companies and industries must be made with caution [16]. All these warnings led to the authors taking great care in choosing and evaluating sources containing real-world quality cost data.

Three types of graphs are shown below to present the reported quality costs in industry (Figure 2 - Figure 4). Firstly, the distribution of quality cost categories among TQC is shown. Secondly, typical Total Quality Costs for industries are depicted. Lastly, the effect after the introduction of quality improvement methods on quality costs for different industries is presented.

Williams et al [16] compiled in their review reported quality cost data that suggest a distribution of prevention, appraisal and failure cost as displayed in Figure 2. Failure costs are by far the largest category and amount to 75% of TQC. Costs for preventative and appraisal activities accounted for 5% and 20% respectively. Comparing this cost distribution to the classical or modern view presented in Figure 1 indicates a poor quality level of the reference group.

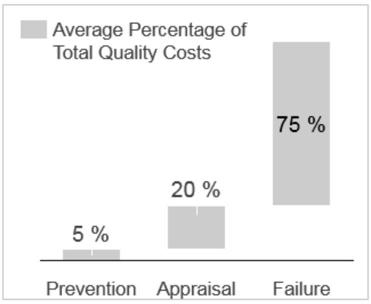

Figure 2: Suggested distribution of total quality costs.

After having presented the percentage of cost categories of the TQC elements the TQC in different industries are presented in Figure 3. Those reported TQC are usually expressed as a percentage of sales, turnover or manufacturing costs [1].

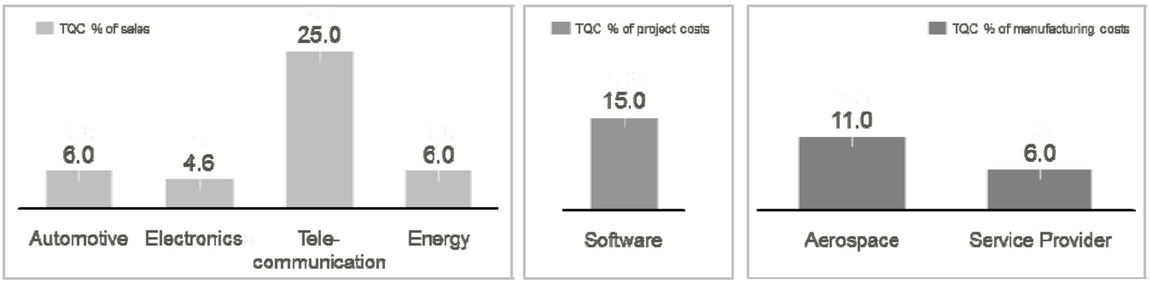

Figure 3: Overview of reported total quality costs in different industries [13], [18], [19], [20].

Of note are the large differences, ranging from 4.6% of sales in electronics to 25% of sales in communications, as well as the various reference bases used. The differences concerning the total amount of quality costs have already been explained briefly. However, so far the change in TQC due to a maturing quality system has been left out. The term quality system refers to the use of tools and methods to improve quality. A low to medium maturity level is indicated by a rather unsystematic, corrective based approach and poor improvement results. If the improvement process is utilized and robust, the outcomes are satisfactory and continuously improving, it can be described as a mature quality system. Building on this theory, a company expanding its efforts regarding quality management will be able to reduce its quality costs in the long run [21].

This effect is in line with the left hand side of figure 4 below. It presents the change of TQC after the introduction of quality improvement methods for companies in three different industries. A reduction of TQC afterwards can be seen in all three cases.

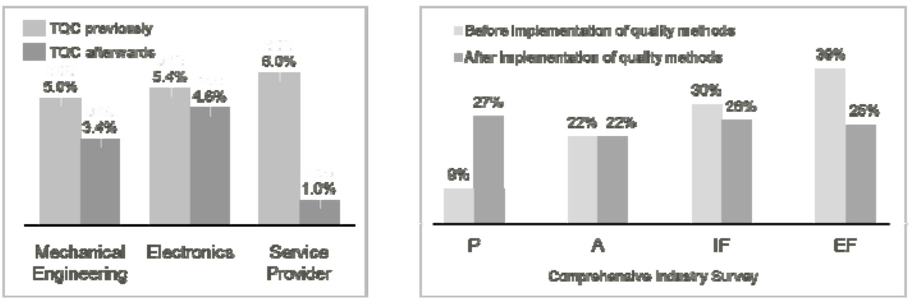

Figure 4: Impact of quality methods on the height (left side) [13] and on distribution (right side) [16] of TQC.

The right hand side of Figure 4 depicts the change of distribution of TQC categories before and after implementation of quality methods. To obtain the data, companies were asked to provide TQC distribution data for the year prior to implementation of a quality system and for the most recent two years. Sower et al. conclude that the distribution of quality costs changes as the quality system matures [16]. Their findings also support three effects as the quality system matures: (1) failure costs decrease, (2) external failure costs decrease with increased appraisal costs, and (3) both internal and external failure costs decrease with increased prevention costs.

3 A Case Study of Quality Costs in Selected Industries

This section presents the applied or real world case for selected industries. After the methodology is given the achieved results are presented and discussed.

3.1 Methodology and Sample Size of the Case Study

In order to retrieve relevant answers a logic tree was created. This logic tree served as a guide in forming a sound structure of questions for the online survey. Utilizing a decision tree, one can forecast results by simulating possible answers throughout the structure. In fact, the steps two, three and four were performed iteratively. After finalizing the online survey structure the link was sent out to companies.

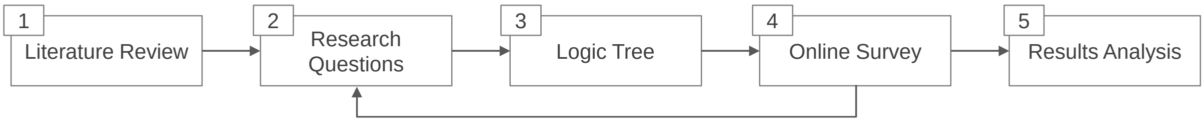

Figure 5: Case study methodology.

The survey was carried out with the online tool *unipark*. The main questions covered in the online survey were the total amount of quality costs and opportunity costs, the distribution of quality cost categories, and the influence of applying quality methods on quality-related costs. Further emphasize was put on the general organizational structure of quality management, the challenges regarding the implementation of quality tools and techniques, questions concerning the implementation and usefulness of different quality methods and particular measures of those quality methods.

The desired industries for conducting the study are Automotive, Mechanical Engineering and Electronics. In total 297 companies were contacted and 94 completed the online survey. This is a response rate of 33.69%, which can be considered as a high participation rate. 10 of the 94 participants took advantage of assistance and were guided through the survey by phone. This indicates a great deal of interest in the topic.

Table 2 provides further information about the participating companies regarding the three industries.

Table 2: Sample size of survey with corresponding sales and employee numbers.

Industries	Total number of Companies	Segmentation by Sales (in Million Euro)					Segmentation by Number of Employees				
		< 5	10 - 40	41 - 100	101 - 1000	> 1000	< 50	50 - 250	251 - 1000	1001 - 5000	> 5000
Automobile	37	4	8	5	13	7	3	9	9	7	9
Mechanical Engineering	27	2	6	7	10	2	1	4	10	6	2
Electronics	30	19	5	2	1	3	19	8	3	1	3
Total	94	25	19	14	24	12	23	21	22	14	14

The majority of participating companies with 39% of participants stem from the Automotive Industry, followed by Electronics with 32% and Mechanical Engineering of 29%. More than half of the companies in the Automotive Industry are rather big companies with sales greater than 101 Million Euro. The distribution in terms of number of employees for those companies, besides the lowest segment, is fairly even. The majority of the Mechanical Engineering companies are midsized in terms of employees. In contrast with the two analyzed industries the companies from the electronics industry are rather small with less than 5 Mio Euro revenue and less than 50 employees. This very balanced spread through all segments of companies allows a representative overview for the selected industries.

3.2 Quality Costs in Selected Industries and the Impact of Using Quality Methods

Figure 6 presents general responses of the participants regarding the use of quality cost analysis, the reference value of quality costs and the type of quality cost model in use.

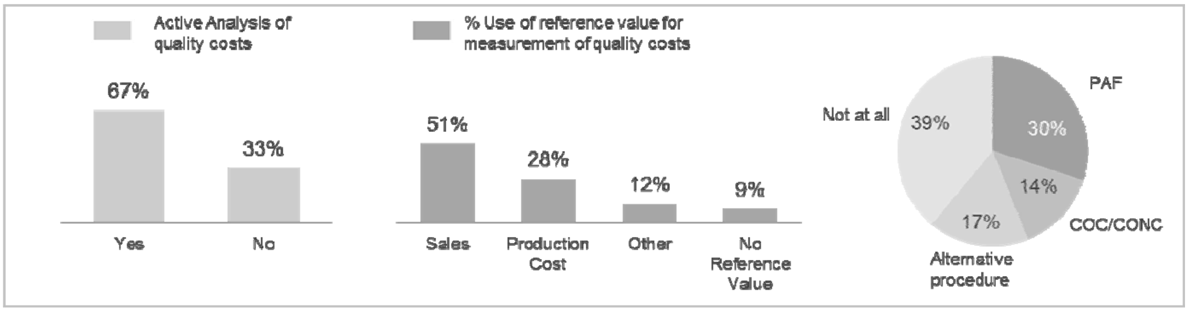

Figure 6: General responses regarding quality cost analysis.

The vast majority 67% stated that they, in general, collected and analyzed quality costs. The most common way to express those costs is a percentage of sales. This is used by 51% of the companies, followed by production costs 28% and other reference values 12%. These findings are in line with relevant literature [22]. PAF and the COC/CONC model are the most popular models used, which is also in line with findings in the relevant literature [13], [14]. However, 17% indicated using an alternative procedure and 39% do not use a quality cost model at all.

Figure 7 depicts the amount of the Total Quality Costs and the distribution of costs according to categories. The participants that indicated the use of a particular quality cost model were asked to provide costs according to the respective cost categories. Thus, those that indicated to use the PAF scheme (please refer to Figure 6) were asked about the distribution of costs according to its component parts of the PAF categories. The same accounts for the users of the COC/CONC model.

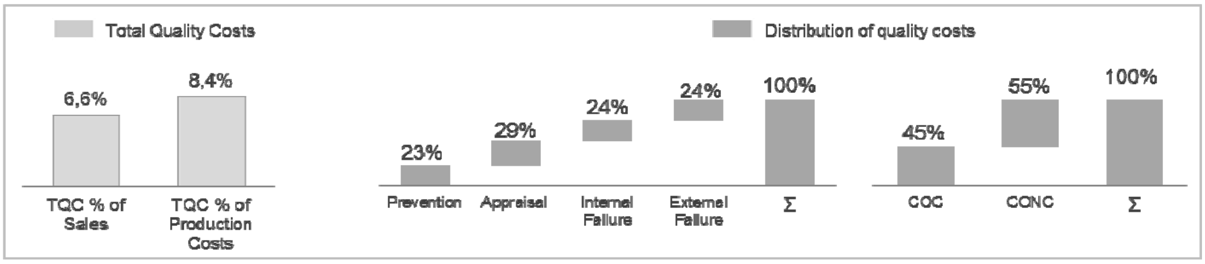

Figure 7: Total Quality Costs and the distribution of quality costs according to the PAF and COC/CONC scheme.

The participating companies stated having average total quality costs of 6.8% of sales, respectively, 8.4% of production costs. The range of those figures was from 1% to 15% of sales or production costs. Compared to relevant literature these figures are fairly low. Williams, A.R.T. et al. [16] published in their management review quality costs ranging between 5 to 25%. With the figured obtained in this study could lead to the assumption that in the meantime the quality awareness increased with positive impact on total quality costs.

Depending on the practice, the companies could choose in naming their cost categories according to the PAF or COC/CONC scheme. Since the PAF scheme can be translated into the Crosby model, the average can be calculated. Putting the numbers of the PAF and Crosby model of Figure 7 together results in an average cost of conformance of 49.8% and cost of nonconformance of 50.2%. Sower et al. [21] reported that after the implementation of quality methods, COC of 49.0% and CONC of 51%. This similarity can lead to the assumption that the companies of this study have already achieved a high quality level. Furthermore, it supports the assumption of an increasing awareness and importance of quality issues and costs.

Complementing the information regarding quality costs, Figure 8 presents the gathering rate of opportunity costs and their percentage of total sales.

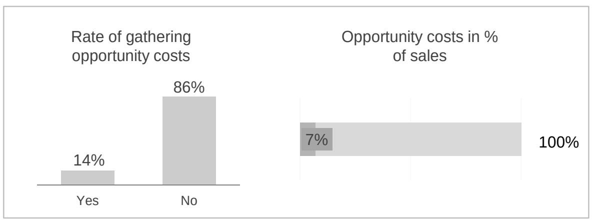

Figure 8: Opportunity costs gathering rate and its cost in % to sales.

The large majority of 86% do not collect data on opportunity costs. These comprise of costs regarding underutilization of installed capacity, inadequate material handling and poor delivery of service. These can be expressed as revenue lost and profit not earned. Companies in this study estimate opportunity costs to be 7% of total sales. When thinking of companies with sales of one billion Euro (please refer to Table 2), 7% is a huge untapped potential. Companies could take advantage of it when analyzing these lost opportunities and deriving proper measures.

In order to support this assumption with quantitative data, the survey gathered information about the implementation rate of quality methods. Participants were asked about six methods, an excerpt of the illustrated quality tools and techniques are shown in Table 1. Figure 9 however shows the average rates concerning implementation rates for all industries. Figure 10 illustrates the use of quality methods for the individual industries.

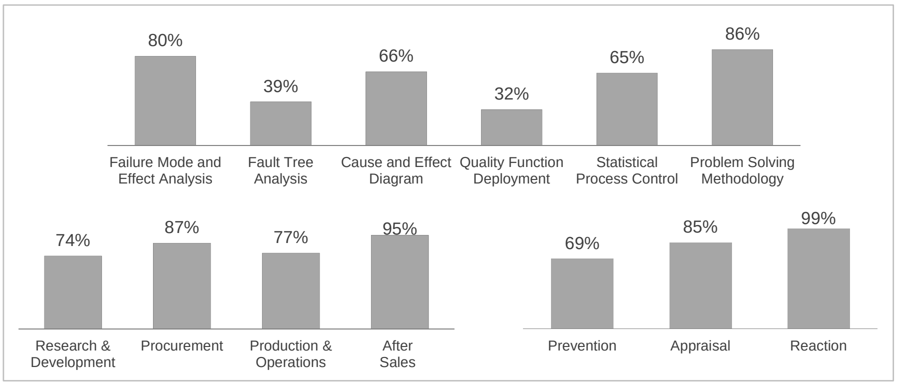

Figure 9: The implementation of quality methods – overview, place of action and purpose.

The problem solving methodology and failure mode and effect analysis (FMEA) seem to be widely used across all industries. On the other hand, tools to systematically display the causality between causes and effects and to control processes for better product quality are used by the majority of the companies. The cause and effect diagram and statistical process control (SPC) are used by two thirds of the sample group. Fault Tree Analysis (FTA) and Quality Function Deployment (QFD) seem to be poorly accepted. The reason for the poor implementation of QFD may be that it demands a lot of time and efforts to use. Also it requires the willingness to make compromises between stake holders of different departments.

The graphs on the bottom of Figure 9 show that most methods are applied reactively. This is in contrast to the common interpretation. Putting the focus of methods on preventive and appraisal activities should reduce failure costs [16]. Additionally, results indicate that methods applied in the area of Research & Development are least commonly applied. This is in contrast with the common understanding that defects at this step of the value chain are most expensive.

After having presented the general findings the next paragraphs show industry specific results of the survey.

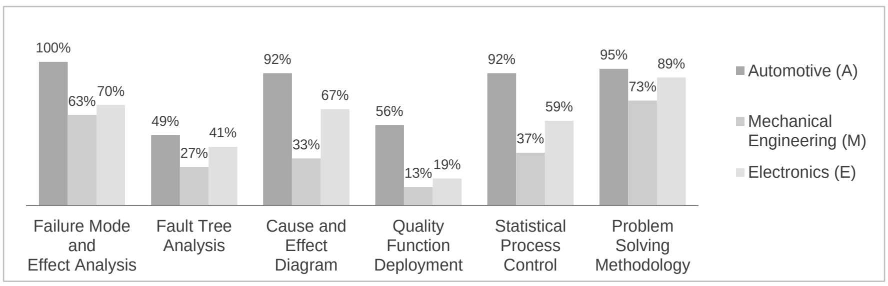

Figure 10: Utilization of quality methods by industries.

As one can see in Figure 10, the Automotive Industry presents by far the highest implementation rates regarding all stated quality method. The average implementation rate of quality methods is 81% in the Automotive Industry, 57% in the Mechanical Engineering and 41% in Electronics. Of particular note is that FMEA is in use in every single company of the Automotive Industry of those surveyed. On the one hand, this 100% rate can be explained by the effective and long term oriented measures included within the FMEA. On the other hand, in order to fulfill industry compliancy standards FMEA is mandatory especially for Automotive Suppliers. In addition to the aforementioned, the Mechanical Engineering Industry and the Electronics show strikingly low implementation rates regarding the methods Cause and Effect Diagram and Statistical Process Control (SPC). These are prominent and effective methods that could be implemented to achieve a higher quality level.

In order to complement the implementation rate of certain quality methods, the perceived effectiveness of applying those methods was evaluated by the participants. The companies evaluated the use of methods on a scale from 1, being the minimum, and 5, being the maximum in terms of usefulness, is displayed in Figure 11.

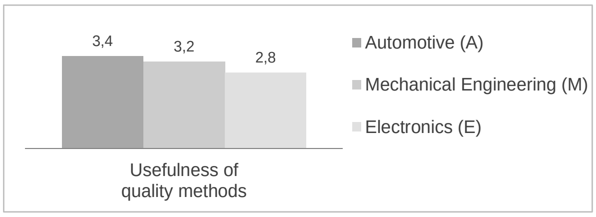

Figure 11: Perceived usefulness of quality methods.

In addition to the highest implementation rate of quality methods, companies of the Automotive Industry also perceive the usefulness the most when applying those methods. This may lead to the conclusion that the Non-Automotive companies in this survey are less prone seeing the benefit of introducing quality initiatives in order to improve their quality level. The authors assume that either quality methods are considered as unnecessary or that there is a lack of practical experience due to limited resource capacity for the implementation of methods. The latter may be the cause as the next section illustrates.

Figure 12 shows industry specific data regarding the practice of quality cost analysis and categorization per industry.

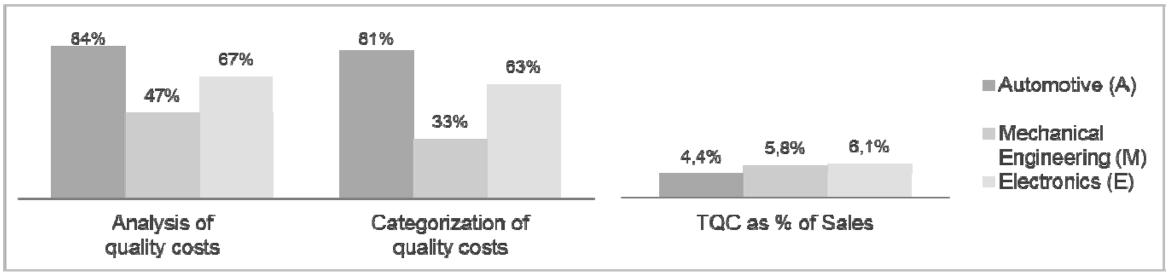

Figure 12: Industry specific general responses of quality cost analysis.

Based on the responses, 84% of companies in the Automotive Industry actively analyze quality costs. Beyond the analysis they also categorize those costs into their component parts. This can be considered as common practice in comparison to the other industries. In the Mechanical Engineering Industry roughly every second company analyzes quality costs and only one third splits them into sub-categories. Two thirds of the companies in the Electronics sector analyze quality costs and 63% categorizes them. The Automotive Industry is by far the industry most concerned about keeping transparency regarding quality costs.

The graph on the right side of Figure 12 illustrates the Total Quality Costs of the surveyed industries. Companies of the Automotive Industry have by far the lowest Total Quality Costs. Those costs account for 4.4% of sales, which is 27% lower when compared to companies in the Mechanical Engineering Industry and 39% lower when compared to Electronics. These are significant differences when considering that the total sales of some companies is greater than 1 billion Euro (please refer to Table 2). Comparing Total Quality Costs to the perceived usefulness of implemented quality methods leads to an interesting conclusion (please refer to Figure 11 and Figure 12): Companies with a high implementation rate of quality methods that do perceive their usefulness, show evidence of lower Total Quality Costs.

Having explained the Total Quality Costs and methods used in the analyzed industries the next paragraph focuses on whether using quality tools have an impact on quality costs. Figure 13 shows how quality managers of different companies and industries rate possible cost changes triggered by the implementation of quality methods.

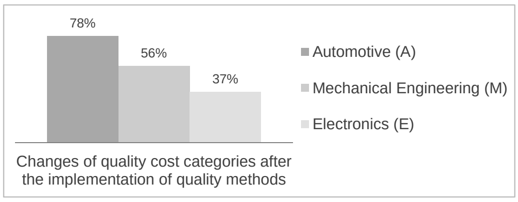

Figure 13: Rating the impact of using quality methods.

While only 37% of the Electronics Industry observed any changes, 78% of the Automotive Industry did. This great disparity can be explained by a similar disparity concerning the implementation of quality methods. If methods are implemented effectively, integrated in a QM system and fully understood, a change in quality cost categories is much more likely. Therefore, the high rate of change in quality cost categories within the Automotive Industry and the low rate of change within the Electronics Industry seem to be a logical consequence of their individual implementation strategies.

Although analysis of quality costs and deriving measures to improve costs is beneficial, it is not globally in use by the participating companies of this survey. Figure 14 displays the main obstacles for gathering and analyzing quality costs.

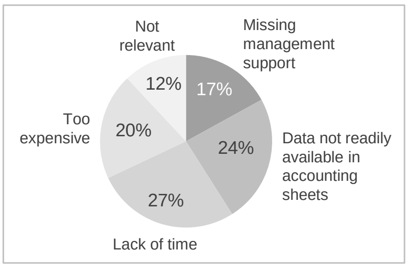

Figure 14: Obstacles for gathering quality costs.

The main reasons companies do not collect quality data are a lack of time and that the data is not readily available in the accounting sheets. Hence, additional efforts are required to retrieve costs from accounting sheets and translate them into the cost categories. This may also be considered too expensive, as 20% have stated. 17% indicate missing management support and 12% consider quality costs as not relevant. These mentioned reasons suggest the need of tools and techniques to facilitate the collection of cost data exercise. If this service can be provided with reasonable efforts companies could be more likely to analyze quality costs.

4 Conclusion

This paper supplements the limited data in data in literature of quality costs of real-world companies. The data obtained is retrieved from quality experts from German companies. The study was carried out as an online survey with examined companies of the Automotive, Mechanical Engineering and Electronics Industry.

Findings indicate that the use of quality tools and methods do have an impact on quality costs. However, there are differences between practicing quality costs analysis procedures as well as between the different industries. Although analyzing quality costs has proven to be beneficial, it has not been widely implemented. Time constraints and difficulties in retrieving quality costs from the accounting sheets are the main obstacles. Results show as well that the minority of companies gather opportunity cost data although they present a significant percentage of sales. Reducing the cost data collection for both opportunity and quality costs should be a target. As such, there is a real and current need for providing suitable tools, techniques and methods to industry.

Evidence shows that companies with a high implementation rate of quality methods have significant lower quality costs. This should motivate other companies to introduce methods for quality improvement. However, the implementation task is not always straightforward. Methods need to be tailored to the individual companies to be integrated into their quality management system. This requires specific knowledge and expertise. This is in line with the authors' experiences with clients. Lately, the need for globally prefabricated solutions has strongly declined. Instead it is important to tailor customized solutions with regard to quality costs. Accompanying and coaching the client during the implementation phase is a key success factor to sustainably established solutions. Any activity which gains a sustainable competitive advantage should include quality cost reduction procedures.

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