Quality Cost and Economic Analysis. A Synthesis in the Manufacturing Systems

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Abstract. The paper performs a literature review on existing models and methodologies to analyse and identify the cost of quality in manufacturing systems. The review shows that existing accounting models are insufficient to identify quality cost in detail in production processes. Existing models also do not cover the entire production activities and therefore need to be extended over the entire product life cycle. The authors therefore develop a new approach by refining and extending the method of activity-based costing to make it applicable for quality cost identification. The proposed methodology can serve as a building block for a later integration into superior supply chain management systems which allow to trigger continuous quality improvements of entire production networks.

1 Introduction

In recent years, companies have been forced to review and control tightly their costs. Quality has become a decisive criterion in the operation of manufacturing systems and for the selection, evaluation, and cooperation of suppliers, as it provides the opportunity to improve products and services. Eventually, that also affects the overall success of companies [1].

In the German automotive industry, quality standards are set by the German Association of the Automotive Industry (VDA) [2, 3, 4]. The VDA is the common representative of German automotive manufacturers and suppliers and supports their interests, exchanges opinions between members, recommends and develops methods and standards. The basic tasks of quality management in the automotive industry are very similar to those of other industrial sectors. For that reason, the VDA's quality standards are strongly oriented towards the DIN EN ISO 9000 standard. In the quality standard norm DIN EN ISO 9000 quality is defined as the fulfilment of all previously defined requirements. Accordingly, "the entirety of features of a unit under observation in regard to its suitability to fulfil

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defined and given requirements" [5] needs to be considered. Not fulfilling quality requirements ("non-conformance with a requirement") and ignoring error-prone processes simultaneously leads to errors and consequential costs, which reduce the profit of a company [6]. Transferred to the research and development and the operations level, this means that the previously defined target characteristics and features, which are decisive for the functional fulfilment of the product specifications, are not met. The specification is classified as a requirement or expectation that is specified and usually presupposed or mandatory.

Every error represents a deviation from the anticipated ideal state, which is outside of an imaginary corridor within which the customer requirements are located. The shop floor then describes the production facility in which a product is manufactured. Consequently, this means that shop floor management includes all management measures for product and process improvement at the direct point of value creation with the involvement of employees with the aim of fulfilling customer requirements [1-5]. Several studies have examined the measurement of quality costs and the quality level [6-12]. Such management and organizational deficiencies can have an impact of up to 20 % on the company's sales. Of these 20 %, only 5 to 8 % are easily identifiable in their cause of error [13]. As a result, it can sometimes be impossible to record more complex follow-up costs resulting from poor quality [14]. Therefore, such losses must be identified and repaired in a general and targeted recording system. The demands customers place on products nowadays require a high level of quality. Nonetheless, a 100 % quality level expected by customers will not be achieved, because it is simply not possible.

2 Impact of quality in production

However, striving for a high-quality level not only helps to reduce costs, it also minimizes waste of resources, deviations from targets and mistakes [7, 15]. Quality errors not only mean costs for rejecting a product, but also require the product to be manufactured again using the company's human, equipment and material resources. Cost of poor quality (COPQ) has an impact to various aspects of business operation, which (according to the description in Fig. 1), can be divided into the areas of internal and external failure cost as well as in cost for appraisal and prevention cost.

Furthermore, it can be stated that the amount of the costs also depends on the time of discovery within the production process. It becomes clear that the error costs turn out to be higher, the later an error is discovered. If an error is discovered during the early product concept phase, around 3% of follow-up costs for fixing can be expected. In the development phase the costs increase to approximate 12%. If the error is only discovered during the production phase, this results in an average of 35% follow-up costs. Errors that are finally discovered at the customer's site result in around 50% of extra follow-up costs. In this case, the additional costs due to the loss of reputation are not or only difficult to estimate. Especially in case that quality defects finally result in goodwill, warranty or recall and exchange campaigns. In this context, Deming particularly emphasizes the costs that can arise from product liability in the event of product recalls.

It is also important that the largest portion of the future manufacturing costs of a product is being defined in the early product phase, i.e. in the conception and development. Thus, in these early phases, the cost drivers for errors occurring in the single production steps are also determined. Between 70-85% of the final product costs are already determined before the actual production of a product, while only around 5-7% of the total costs are incurred in these phases. In this way, high quality standards and quality processes established at an early stage also led to lower cost of poor quality. The so-called rule of ten serves as a rough guide for changing the level of potential costs. It shows that the costs increase by a factor of

10 over every stage of the internal production flow from conception to development, manufacture, final quality inspection and delivery to the customer if quality defects are discovered. The desired reduction in internal costs due to rework, rejects, and additional material use, etc., makes it clear that a cost reduction through quality assurance measures means an increase in productivity and economic key figures. Thus, the focus of quality management must be on the tasks described in Fig. 1 [5].
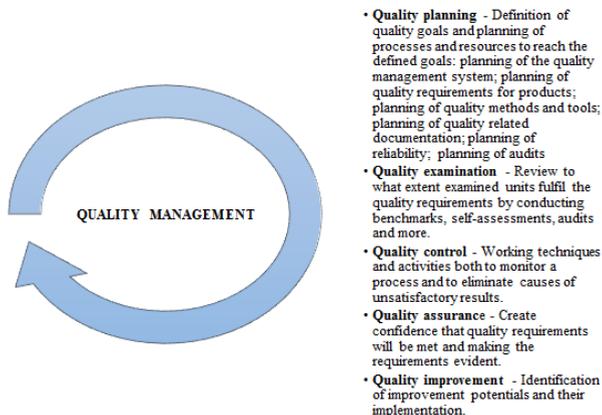
Fig. 1. The Quality management focus (a synthesis from [5]).

The aim for all process participants is to hand over the products for final acceptance, bearing in mind to achieve zero defects. In doing so, one of many factors is to motivate employees to eliminate all sources of error in their environment [14]. These improvement measures are supported by the implementation of several control loops, which significantly influence the initiation of optimizations [16]. The pooling of knowledge and authority to issue directives, makes it possible to change the error-prone processes [17, 18]. Accordingly, the profitability of a production company is increased, and competitiveness is ensured.

3 Quality cost models

In the existing literature several models concerning the classification and the handling of quality cost can be found. Fig. 2 shows an overview of several models.

Fig. 2. Quality cost models (enhanced according to [18, 19, 20]).

Feigenbaum's PAF Model classifies the cost of quality into three different categories: prevention cost, appraisal cost and failure cost [20]. According to Crosby, quality costs are, first a tool for focusing management attention on quality, and second a measure of the success of a quality improvement program [19]. Morse and Poston state that the objective of continuous improvement is to meet customer requirements at the lowest cost and that

this can only be achieved by eliminating the costs of rejects and rework [21]. Neglecting this means to lose business opportunities associated with according to costs. Cost models based on the method of surcharge calculation have the problem of the distribution of overhead costs to production processes. The entire production costs are reported in an aggregated form in the category of expenses by the nature of the calculation scheme.

This means that the quality costs are subsumed in e.g., overhead costs of labour or material costs as a total, not considering the criterion of separation of related costs. Therefore, the structure of expenditures should be presented as expenses by their nature or by the function [21, 22]. Therefore, this method is only partially suitable to clearly identify cost of quality (processes). Most authors propose to apply the activity-based cost model because it focuses on single processes [21-31]. This model can serve as a basis to identify processes. The methods need to be modified and adapted with a special focus on quality to calculate dedicated process cost for quality efforts in production.

4 Quality related activities in the production process

According to a literature review (synthesis presented in Fig. 3) cost of quality can be basically distinguished into "cost of good quality" and "cost of poor quality".
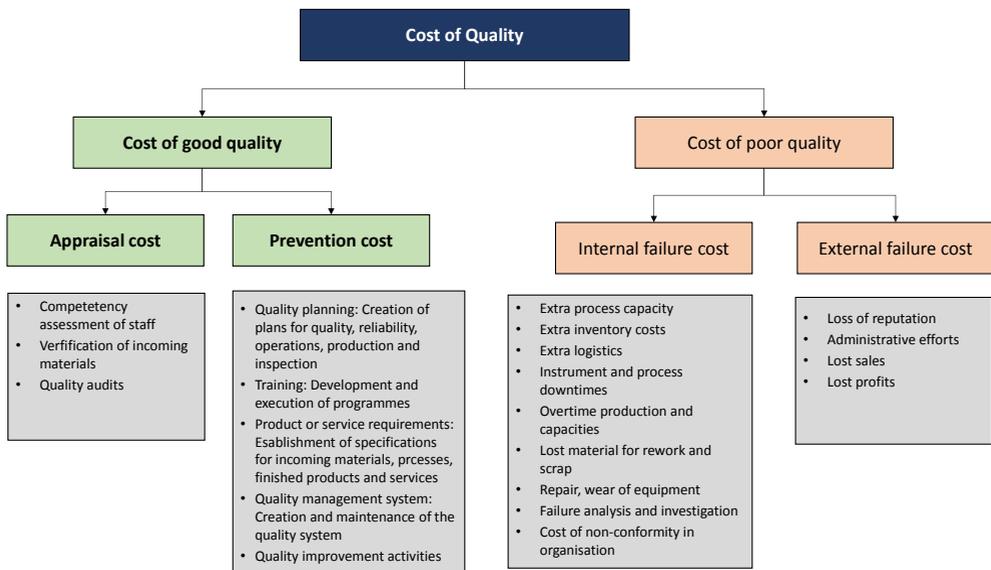

Fig. 3. Classification of cost of quality (authors own development).

Cost of good quality comprise all costs which are associated with achieving, maintaining, and improving the quality of products. Such cost can be sub-divided into prevention and appraisal cost. Appraisal costs comprise the expenses of testing (including related cost for inspection and test equipment and operators), measuring and analysing materials, products, and parts to make sure that product quality and specifications are being met. Examples are the cost for prevention include all cost related to the prevention of a poor-quality outbreak in any process or products. Activities of prevention refer to the quality philosophy of "do it right the first time" as the ultimate objective of every quality management program. Items in this category include cost for quality planning, cost of product design, training and information retrieval and handling.

On the other hand, cost of quality is driven by cost of poor quality. Such cost is not different to other costs do that they can be measured, analysed, and budgeted. The costs

need to analyse to reach a higher customer satisfaction on a lower level of associated costs. A reduction in these cost positions lead to increased profits. According to [17-19, 36-38] cost of poor quality can be separated into internal and external failure costs. Internal failure cost occurs prior to delivery or shipment of the product. Such cost includes e.g., cost of scrap, rework, failure analysis, reinspection, testing and avoidable production losses. The category of external failures describes the cost for failure fixing after the delivery or shipment of the product and during or after furnishing of service to the customer. Such costs are e.g., warranty, customer complaint handling, return of products or allowances.

5 Activity-based quality cost model

As a synopsis of the literature research of many authors there is currently no methodology available that offers an integration and single analysis of all cost activities relevant quality in production.

According to [35, 39-41] a holistic approach needs to cover not only the internal manufacturing but also the entire supply chain from procurement of materials up to the fulfilment of all contractual obligations ending with the delivery of final products to the customer (including warranty and possible replacement in case of non-conformity). By this understanding, a quality-oriented supplier management includes not only the price negotiation, but it also covers the following quality related aspects of supplier selection, reduction of material and process cost, maintenance and improvement of material and process quality, supplier performance assessment and the supplier development over the time [42-46]. Fig. 4 shows the entire supply chain over the activities in a production process starting from procurement up to the delivery of final products to the customer.
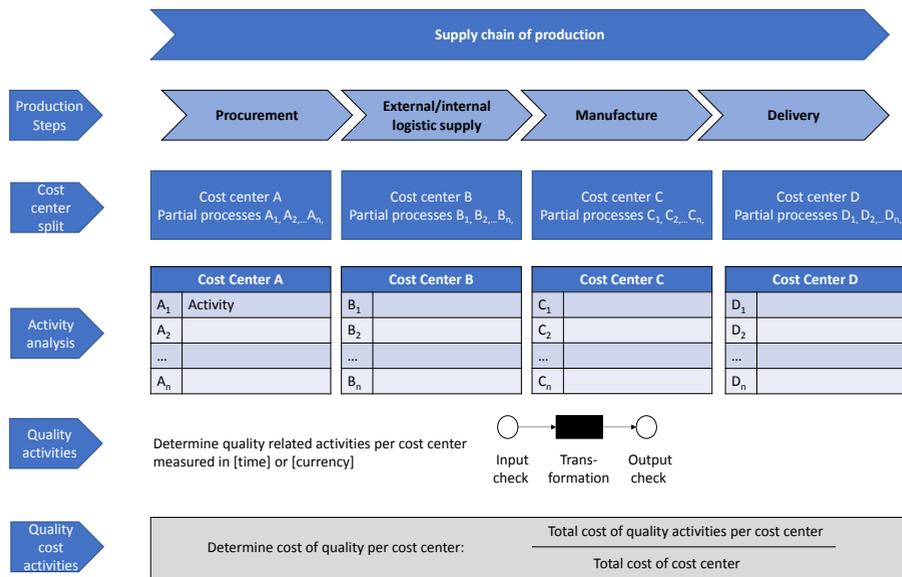

Fig. 4. Method to analyse and evaluate the cost of quality in production (authors own development)

The single production steps represent the process of product creation. The process starts with the early phase of material procurement and ends with the product delivery to the customer including the fulfilment of all contractual obligations concerning product quality and e.g. replacements or warranty obligations). Each of the single production steps can be broken down and split into according cost centers. According to the previous literature

research (as presented in Chapter 3) a quality cost model must then be able to identify single quality related processes. This step will be executed in the analysis of single activities in the cost centers. A list of all relevant activities must be established for each cost center to identify quality relevant activities. In the next step -in deviation to the classical activity-based costing method it is proposed to not aggregate the single activities to so call "core processes/main activities" because this would imply to again subsume e.g., short quality related activities into larger "blocks" of activities. The proposed method especially aims to identify exactly these (maybe even small/short) quality related processes and its aggregation for visualization and further processing and optimisation.

The single quality related activities need to be summed up by their time consumption or cost and need to accordingly relate to the total time or cost volume of the cost center. By this the methodical approach allows to extract and visualize the cost of good/bad quality for a production or even broken down to a single product (if divided by the number of products produced).

6 Outlook and further research needs

According to [34, 47-50] the knowledge of quality costs alone does not improve quality. The implementation of quality costs provides just the input for a closed loop quality feedback system which triggers continuous quality improvements.

The proposed method to identify quality cost can therefore just serve as the basis for such an integrated quality system that focuses on a continuous quality improvement. In further research steps the methodology must be extended over the entire product life cycle [22, 32, 33, 51] to also allow the steps of cost analysis and the implementation and tracking of quality improvements. To do so the method needs to be integrated in superior Enterprise Resource Planning (ERP) or even supply chain management systems.

7 Research summary

The research paper describes -based on a literature review- the cost of quality and their economic impact to manufacturing systems. The problem of quality cost is largely discussed in literature since many years.

The literature has shown that the identification of single positions of quality cost seems to be problematic due to the nature of existing cost accounting rules and models. Therefore, the accounting model of activity-based costing has been adapted, detailed, and modified to get a "deeper" insight to the single processes and allows by this to identify single quality cost related activities. The identifies activities must be transformed into cost and can then serve as a basis for further examination and improvement. By this the newly developed method serves as a basis for future integration into holistic ERP or supply chain management systems to enable entire production networks to put focus on quality management and continuous improvement along the entire production chain and over the product life cycle (as suggested also by the studies presented in [51-54]).

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