



A LITERATURE SURVEY OF COST OF QUALITY MODELS

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ABSTRACT:

To collect quality costs an organization needs to adopt a framework to classify costs. CoQ is usually understood as the sum of conformance plus non-conformance costs, where cost of conformance is the price paid for prevention of poor quality (for example, inspection and quality appraisal) and cost of non-conformance is the cost of poor quality caused by product and service failure. The scope of this paper is to present a survey on the topic of CoQ; it opens with a literature review focused on existing CoQ models; then it briefly presents the most common CoQ parameters and the metrics (indices) used for monitoring CoQ. In the third section, the use of CoQ models in practice, i.e., the implementation of quality costing systems in companies is discussed, with emphasis in cases concerning manufacturing firms.

Keywords: cost of quality (CoQ) models, P-A-F model, ABC model, CoQ indices, implementation

1. INTRODUCTION

In order to improve quality an organization must take into account the costs associated with achieving quality since the objective of continuous improvement programs is not only to meet customer requirements, but also to do it at the lowest cost. This can only happen by reducing the costs needed to achieve quality, and the reduction of these costs is only possible if they are identified and measured. Therefore, measuring and reporting the cost of quality (CoQ) should be considered an important issue for managers [1]. Moreover, such an objective even though not included in ISO 9001:2000 quality principles; it is suggested in the recently published ISO 10014:2006 [2].

To collect quality costs an organization needs to adopt a framework to classify costs; however, there is no general agreement on a single broad definition of quality costs. CoQ is usually understood as the sum of conformance plus non-conformance costs, where cost of conformance is the price paid for prevention of poor quality (for example, inspection and quality appraisal) and cost of non-conformance is the cost of poor quality caused by product and service failure (for example, rework and returns).

The broad concept of the "economics of quality" can be traced back to the early 1950s when the "cost of quality" (CoQ) was first propounded in Juran's Quality Control Handbook [3] and in Feigenbaum's Total Quality Control [4, 5]. Since then, many quality-control experts have written about quality-cost systems; see for example Refs [6-9], and the importance of quality-related costs has been increasingly recognized. Quality-related costs represent a considerable proportion of a company's total costs and sales; see for a brief account [10].

The scope of this paper is to present a survey on the topic of CoQ; it opens with a literature review focused on existing CoQ models; then, it briefly presents the most common

CoQ parameters and the metrics (indices) used for monitoring CoQ. Finally, the use of CoQ models in practice, i.e., the implementation of a quality costing system and cost of quality reporting in companies is discussed, with emphasis in cases concerning manufacturing firms.

2. REVIEW of COST OF QUALITY MODELS

Since Juran [3] discussed the cost of quality, many researchers have proposed various approaches to measuring CoQ. Reviews of CoQ literature can be found in [1, 6, 9]. In this section, we will briefly review the approaches to measuring CoQ. In agreement with the majority of previous researchers present work classifies CoQ models into five discrete generic groups which are: P-A-F or Crosby's model, opportunity cost models, process cost models and ABC models. These models are summarized in Table 1. Obviously, models within one group are not identical; see comments in [1].

Table 1: Generic CoQ models and cost categories

Generic model	Cost/activity categories
P-A-F models	Prevention + appraisal + failure
Crosby's model	Prevention + appraisal + failure + opportunity
Opportunity or intangible cost models	Conformance + non-conformance Conformance + non-conformance + opportunity Tangibles + intangibles P-A-F (failure cost includes opportunity cost)
Process cost models	Conformance + non-conformance
ABC models	Value-added + non-value-added

2.1 PAF approach

After Feigenbaum [4] categorized quality costs into prevention-appraisal-failure (PAF), the PAF scheme has been almost universally accepted for quality costing. The failure costs in this scheme can be further classified into two subcategories: internal failure and external failure costs. In general, these costs are described as follows:

- ✚ *Prevention costs:* These costs are associated with the design, implementation and maintenance of the total quality management system. Prevention costs are planned and are incurred before actual operation.
- ✚ *Appraisal costs:* These costs are associated with the supplier's and customer's evaluation of purchased materials, processes, intermediates, products and services to assure conformance with the specified requirements.
- ✚ *Internal failure costs:* These costs occur when the results of work fail to reach designed quality standards and are detected before transfer to customer takes place.
- ✚ *External failure costs:* These costs occur when products or services fail to reach design quality standards but are not detected until after transfer to the customer.

The basic suppositions of the P-A-F model are that investment in prevention and appraisal activities will reduce failure costs, and that further investment in prevention activities will reduce appraisal costs [6, 8]. The objective of a CoQ system is to find the level of quality that minimizes total CoQ; see also section 2.5. Feigenbaum's and Juran's P-A-F scheme has been adopted by the American Society for Quality Control in 1970 [10] and the British Standard Institute (BS 6143 pt.2) [11], and it is employed by most of the companies which use quality costing [7].

2.2 Crosby's model

Crosby [12] sees quality as "conformance to requirements" and therefore, defines the CoQ as the sum of price of conformance (PoC) and price of non-conformance (PoNC). The price of conformance is the cost involved in making certain that things are done right the first time, which includes actual prevention and appraisal costs, and the price of non-conformance is the money wasted when work fails to conform to customer requirements, usually calculated by quantifying the cost of correcting, reworking or scrapping, which corresponds to actual failure costs.

2.3 Intangible costs' models

This group of models emphasizes the role of intangible cost within the overall quality cost scheme. In general, intangible costs are costs that can be only estimated such as profits not earned because of lost customers and reduction in revenue owing to non-conformance. Actually, in this group of models intangible or opportunity losses cost is incorporated into a typical P-A-F model.

2.4 Process cost model

In view of a number of drawbacks of the P-A-F model [12], the process cost approach, described in the revised BS 6143: Part 1 [13], can be used as an alternative. This approach recognizes the importance of process cost measurement and ownership. The process cost is the total of the cost of conformance (CoC) and the cost of nonconformance (CoNC) for a particular process. The CoC is the actual process cost of providing products or services to the required standards, first time and every time, by a given specified process. The CoNC is the failure cost associated with a process not being operated to the required standard [7]. According to this definition, we know that the content of this categorization (CoC and CoNC) is different from that of Crosby's (PoC and PoNC) mentioned previously.

The process cost model can be developed for any process within an organization. It will identify all the activities and parameters within the process to be monitored by flowcharting the process. Then, the flowcharted activities are allocated as CoC or CoNC, and the cost of quality at each stage (i.e. CoC +CoNC) are calculated or estimated. Finally, key areas for process improvement are identified and improved by investing in prevention activities and process redesign to reduce the CoNC and the excessive CoC respectively [7, 14]. It is believed that this will help to extend the concept of quality costing to all functions of an enterprise and to non-manufacturing organizations, and that it also gets people to consider in more detail the processes being carried out within the organization. The structure of the process cost model is schematically presented in Figure 1.

The use of a process cost model is suggested as a preferred method for quality costing within TQM as it recognizes the importance of process cost measurement and ownership, and presents a more integrated approach to quality than a P-A-F model.

The process cost model pursues a continuous improvement policy on key processes within the organization and innovates where appropriate, which in itself reflects both the kaizen approach and Deming's (1986) plan-do-check-act (PDCA) cycle [15]. It can be applied to both service and manufacturing industries, and can be used to improve a process stage with either a high non-conformance cost by increasing preventative costs or with excessive conformance costs. Quality problems and their causes can be determined more quickly than with the PAF model. However, a complete accurate analysis of a company's activities into interlinked processes without duplication may be more time consuming than with the PAF model [8].

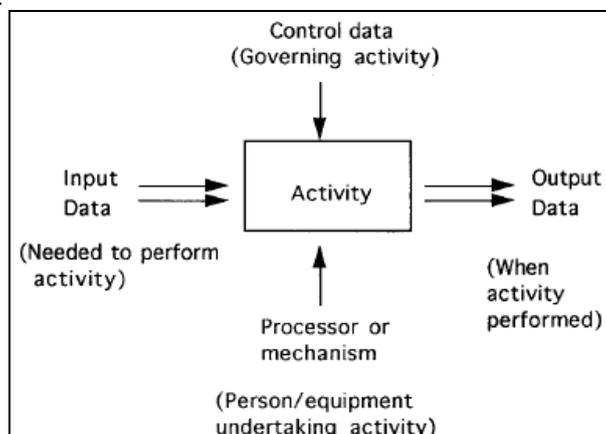


Figure 1: The structure of the process cost model

2.5 The old and the new CoQ models

Traditionally, aspects and opinions briefly presented above (section 2.1) are summarized in the so-called old CoQ model. This model was firstly proposed by Juran [3] and had been applied extensively till the 90's. This model which is presented in Figure 2 suggests that the costs of poor quality (internal and external failure costs) decrease with higher quality levels, while the costs of achieving good quality (appraisal and prevention costs) increase. The total cost function, representing the sum of both cost categories, has a parabolic shape. According to Juran's interpretation, the resulting cost minimum represents the economically optimal level of quality. The model's inherent quality-cost trade-off has widely shaped the perception that the optimal level of quality must be somewhere below perfection. Therefore the objective of any quality improvement program should be to find the level of quality (defect rate) that minimizes the total cost of quality.

The old COQ model might have gained its wide acceptance because it coincides with an often observed "inspection mentality" of management. However, the view of old CoQ is in conflict with current trends in industry to strive for best possible quality, as the successful quality concept of six sigma demonstrates [16].

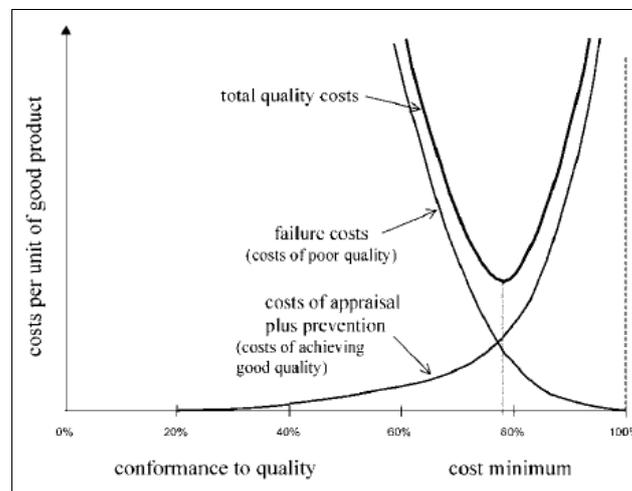


Figure 2: The old CoQ model

To explain the discrepancy between the old CoQ model and current findings in industry, four points must be considered. First, the model obviously presupposes a company with a poor quality level, and does not consider that companies might already have a considerable high quality level when they engage into quality improvement. Second, the model is a spotlight on the technological proficiency of the time it was constructed. The prevention of defects has since become more feasible due to technological advances, which benefits both the finding of feasible remedies and the methods of process monitoring. Third, the model makes no reference to the duration for which a company has been engaged in quality improvement. Fourth, the unit cost consideration makes a strong point that the exponential shape of the 'costs of achieving good quality' curve is unrealistic. At higher quality levels, more good products are available to bear the costs of both prevention and appraisal.

The so-called new CoQ model which is more in agreement with empirical findings from industry is presented in Figure 3. It exhibits a weaker increase in appraisal and prevention costs, accounting for a higher prioritization of prevention and new technological solutions that reduce the failure rate and make process monitoring feasible. The total cost curve is negatively sloped and the cost optimum shifts to the perfect quality level. In fact, the new COQ model reflects Deming's viewpoint that we do not need a CoQ model to determine an optimal level of quality. Deming [15] asserts that the costs of selling defective products is so high that quality costs will only be minimized when there is 100% conformance, or zero defects. Consequently, he thinks that there is no reason to measure quality costs since the only sensible strategy is to be sure that no defective products are produced at all.

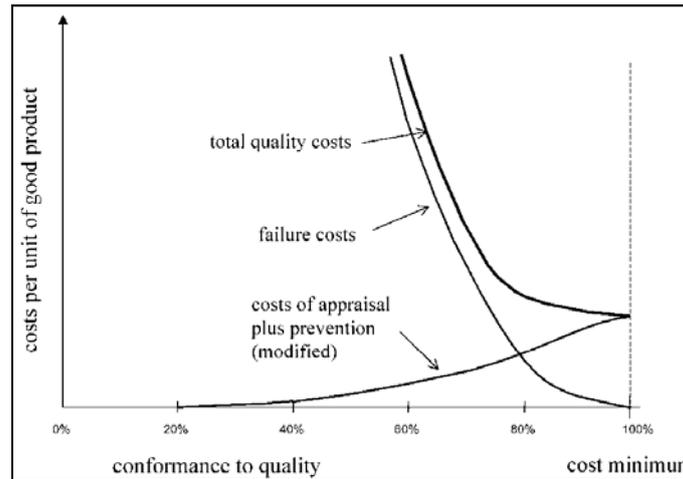


Figure 3: The new CoQ model

In general, it is accepted that the new COQ model presents a much more rounded perspective on quality costs and seems to reflect business reality much closer than the old model, at least for “world-class” organizations. However, there is also a criticism that both models are of a limited value; see the analyses presented in [16].

2.6 ABC models

Prevention-appraisal-failure (PAF) approach (both old and new) and process cost approach are the two main approaches to measuring CoQ. However, these approaches still cannot provide appropriate methods to include overhead costs in CoQ systems [17].

These deficiencies could be overcome under activity-based costing (ABC) developed by Cooper and Kaplan of Harvard Business School [18, 19]. ABC uses the two-stage procedure to achieve the accurate costs of various cost objects (such as departments, products, customers, and channels), tracing resource costs (including overhead costs) to activities, and then tracing the costs of activities to cost objects. ABC uses the two-stage procedure to achieve the accurate costs of various cost objects (such as departments, products, customers, and channels), tracing resource costs (including overhead costs) to activities, and then tracing the costs of activities to cost objects.

The main shortcoming of traditional cost accounting is to distribute overhead costs over products by using volume-related allocation bases such as direct labor hours, direct labor costs, direct material costs, machine hours, etc. It will not seriously distort the product cost in the conventional manufacturing environment where overheads are just a small portion of product cost. In the modern manufacturing environment, however, the overheads will grow rapidly as manufacturers increasingly promote the level of automation and computerization, and the cost distortion of traditional cost accounting will be significant. In general, traditional cost accounting overcosts high volume products and undercosts low-volume products.

In view of this, the application of ABC methodology was proposed, in order to improve the accuracy of product costs [18, 19]. Early ABC systems focus on the accurate assignment of overhead costs to products. They do not provide direct information about activities and do not consider the costs outside the plant. Thus, a two-dimensional model of ABC was proposed in [17]. This ABC model was characterized by two dimensions: cost assignment view and process view. A detailed analysis of these two sub-systems is not presented due to space restrictions but a schematic overview is given in Figure 4, whilst in Table 2 a comparison between the main CoQ models and the ABC quality costing is presented; see also [17].

It can be easily concluded that the PAF approach of CoQ is activity-oriented, the process cost approach of CoQ is process-oriented, and ABC is activity-oriented for the cost assignment view and process-oriented for the process view.

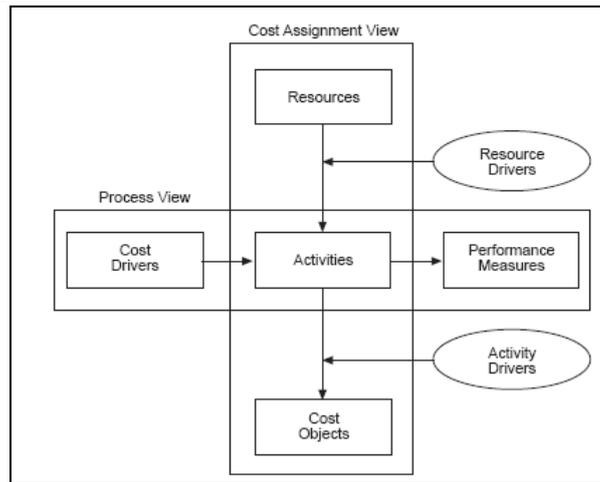


Figure 4: Two-dimensional model of ABC [17]

An integrated CoQ-ABC framework was proposed in 1998 and it was stated that “the cost and non-financial information achieved from the integrated CoQ-ABC system can be used to identify the magnitude of the quality improvement opportunities, to identify where the quality improvement opportunities exist, and to continuously plan the quality improvement programs and control quality costs” [17]. However, to the authors’ knowledge, very few implementations of this system in practice have been reported.

Table 2: Comparison between main COQ approaches and ABC (adapted from [17])

Aspect of comparison	CoQ		ABC
	PAF approach	Process cost model	
Orientation	Activity-oriented	Process-oriented	Activity-oriented (cost assignment view) Process-oriented (process view)
Activity/cost categories	Prevention Appraisal Internal failure External failure	Conformance Non-conformance	Value-added Non-value-added
Treatment of overhead	No consensus method to allocate overhead to CoQ elements under current CoQ measurement systems and traditional cost accounting		Assigning overhead to activities by using resource drivers in the first stage of ABC cost assignment view
Tracing costs to their sources?	No adequate method to trace quality costs to their sources		Tracing activity costs to cost objects by using activity drivers in the second stage of ABC cost assignment view
Improvement objects	CoQ-related activities	Processes activities	Processes/activities
Tools for improvement	Quality circle Brainstorming Nominal group technique Cause and effect analysis Force-field analysis		Process/activity value analysis Performance measurement Benchmarking Cost driver analysis

In general, one serious limitation of the ABC approach is the need to conduct a full-blown activity-based costing analysis to identify and rank each activity. However, a wide variety of service and manufacturing firms have found that simplified activity-based costing concepts can be used to identify non-value-added activities and quality improvement opportunities, without the time and expense required to implement a full ABC system [20].

The goal of the simplified activity analysis is to identify the activities and costs associated with preventing, identifying, and correcting quality problems. To do so, each activity is broken out into four categories: (1) *essential work*, which encompasses value-added activities required to produce a product or service right the first time, (2) *prevention*

activities such as quality-related training and preventive maintenance that are carried out to avoid defects, rework, or delays, (3) *appraisal* activities such as inspections and data verification that are conducted to measure or test whether a product or service meets customer requirements, and (4) *rework and failure* activities such as problem resolution and defect correction that arise because products or services did not meet customer requirements.

The three activity analysis levels offer various degrees of detail and accuracy, allowing the firm to adapt the analysis to the quality improvement team's requirements and the available time frame and resources. Although the analysis levels vary in terms of data and time requirements, each follows a five step approach.

2.7 CoQ elements

In order to calculate total quality cost, the quality cost elements should be identified under the categories of prevention, appraisal, internal failure and external failure costs. BS 6143: pt.2 (1990); see [11], and ASQC [10] have identified a list of quality cost elements under this categorization. These lists just act as a guideline for quality costing. On the other hand, in order to identify CoQ elements, some organizations benchmark or borrow elements from other companies, which have established CoQ programs. Nevertheless, most quality experts suggest that CoQ programs should be tailor-made for each organization such that they are integrated into a company's organizational structure and accounting system rather than just being borrowed.

2.8 CoQ metrics

CoQ measurement systems should contain good feedback metrics (indices) as well as a mixture of global and detailed metrics. The latter actually represent the elements of CoQ and how the performance of these elements is measured. Some examples of detailed metrics are given in Table 3. Global quality metrics measure global performance; some examples are also given in Table 3. Return on quality (RoQ), defined as the increase in profit divided by the cost of the quality improvement program, is the most frequently mentioned global metric in the context of CoQ. Otherwise, very little has been published on metrics for CoQ.

Table 3: CoQ metric (indices)

Detailed metrics	Global metrics
Cost of assets and materials	RoQ= increase in profit/cost of quality improvement program Quality rate = $([\text{input} - (\text{quality defects} + \text{startup defects} + \text{rework})] / \text{input})$ Process quality = $(\text{available time} - \text{rework time}) / \text{available time}$ CoQ _r = external failure cost/total cost of quality
Cost of preventive labor	
Cost of appraisal labor	
Cost of defects per 100 pieces	
Cost of late deliveries	
Percent of repeat sales	
Time between service calls	
Number of non-conforming calls	
Number of complaints received	

3. IMPLEMENTATION OF CoQ MODELS

3.1 Usage of quality costing

Quality costing can be used as a lever to gain top management commitment to initiate an improvement project. Top managers tend to be influenced by data expressed in monetary terms rather than technical data such as defect rates. Their main area of interest can be reflected as a strategic business objective in a company. Their commitment is decisive for the success of a TQM initiative because many resources should be invested in quality improvement projects [8]. In addition to providing a communicating bridge between line and top management, quality costing can provide an overall index for managers to evaluate and monitor the economics, effectiveness and efficiency of quality activities in their organization. Quality costing integrates all the separate quality activities into a total quality

system. It forces the entire organization to examine the performance of each quality activity in terms of costs. Moreover, quality costing can be used as a starting point in setting up a quality system except where an organization already has one.

It should be also noted that the usefulness of CoQ reporting does not have consensus in the literature. Three noted authors on quality management (“gurus”), namely Deming, Crosby, and Juran, each have a different attitude to CoQ reporting (as outlined in [21]). Deming’s view is that cost analysis for quality is a misguided waste of time and measuring quality costs to seek optimum defect levels is evidence of failure to understand the problem. Crosby argues that quality costs need to be measured, not for management control, but for the development of “quality” thinking within the organization. The more popular approach is that of Juran who advocates the measurement of costs on a periodic basis as a management control tool.

3.2 Implementation in manufacturing firms

Despite the interest of the academic community and the quality consultants in CoQ models, the situation in the real world is different. The results of numerous industry surveys or research studies, as summarized in [1], confirm that CoQ is not a widely used concept. Quality cost calculations are not common even among the recipients of the Malcolm Baldrige National Quality Award [22]. On the other hand, most examples confirm that quality improvement and cost measurement processes bring about a huge reduction in a company’s CoQ.

In a research concerning Australian manufacturing firms [21], it is indicated that of the 136 respondents, 35 firms (25.7%) currently measure the cost of quality in some form. Among the remaining 101 firms which did not measure cost of quality, 37 firms (27.2%) indicated that they plan to implement a CoQ reporting system in the future, and a further 64 firms (47.1%) had no plans to implement CoQ reporting in the future.

In an earlier empirical research, Porter & Rayner [7] studied twenty quality-oriented manufacturing firms in the North of England. The survey revealed that only seven (35%) of the sample made any attempt to monitor quality costs. Only “failure” or “tangible factory” costs were recorded and all figures given appeared to involve an element of estimation. Estimates ranged from 0.8% to 3% of turnover with a mean of 1.9 % of turnover. Six companies estimated that such costs had fallen, in one case from 6.5 % to 1.75 % of turnover. One firm claimed that failure costs had increased from 0.5% to 0.8% of turnover since gaining certification. This had been caused by the adoption of tighter specifications, resulting in more internal rejections.

In 1995 a similar research was performed in 250 companies, in the manufacturing sector, having a minimum of 50 employees [23]. The situation concerning CoQ was improved: 86 % of the companies responded, noted that they did not use BS 6143 standard, however, 78 % provided information about the perceived total cost of quality within their company. It is also interesting to note that only 59 % of the companies stated that they presented quality cost information at management review meetings.

In general, very few studies establish an effective empirical relationship among quality cost components and quality. This is because it is very difficult to observe the quality data for a particular industrial segment unless firms agree to provide the required data.

In 1994, Carr & Ponoemon [24] study the relationships among quality cost components by using 46 paper and pulp manufacturing mills in USA for a period of 48 months. They observe the following relationships: internal failure is the most expensive and prevention is the least expensive quality cost component, the combination of internal and external failure costs is always higher than prevention and appraisal costs, and the quality reject rate decreases with increased volume output. Moreover, this study suggests that only internal failure and external failure costs have a statistically significant correlation with the level of quality. At the same time, Bell et al. [25] estimate that quality cost in the manufacturing industry is between 5 % and 25 % of sales.

In a recent report concerning a leading wire and cable company [26] results, partially in agreement with [24] were obtained: The research, initially, indicated the statistically significant relationship between quality and the combination of appraisal and prevention

costs. The final results significantly indicated the following: (i) There is an inverse relationship between appraisal cost plus prevention cost and failure cost; (ii) there is a direct relationship between appraisal cost plus prevention cost and quality and (iii) there is an inverse relationship between failure cost and quality.

4. CONCLUDING REMARKS

1. In order to improve quality an organization must take into account the costs associated with achieving quality since the objective of continuous improvement programs is not only to meet customer requirements, but also to do it at the lowest cost.
2. Total Quality Management (TQM) focuses on process improvement and the elimination of all forms of waste. A realistic estimation of quality costs is an essential element of any TQM initiative. However, in spite of the extensive literature on the importance and principles of quality costing, only a minority of organizations implements CoQ models and uses formal quality costing methods.
3. CoQ reporting is beneficial at both the corporate and operational level. At the corporate level it gets management's attention and provides a benchmark against which financial improvement can be measured over time. At the operational level it helps to identify, prioritize, and select projects; provide financial benefits of process improvement and monitor project improvements.
4. The P-A-F model is the most recognized internationally approach for quality costing. However, the P-A-F model is mainly a cost categorization scheme and it has serious limitations. A TQM system requires a process approach and the P-A-F model generally fails in this area. A promising alternative for quality costing is the family of process cost models. These models focus on key processes within the organization and attempt to quantify the cost of conformance and the cost of non-conformance. This approach can be a driving force to process improvement in itself and is totally compatible with a TQM holistic model. All CoQ systems should contain good feedback metrics (indices) as well as a mixture of global and detailed metrics.
5. Models based on the activity based costing (ABC) methodology, which are activity-oriented for the cost assignment view and process-oriented for the process view could be also applied for quality costing; however, their implementation is not widespread
6. A number of researches concerning the implementation of CoQ models in the manufacturing sector have been already reported. In the majority of them the P-A-F model is applied. In spite of the fact that most examples confirm that quality improvement and cost measurement processes bring about a significant reduction in a company's costs of quality towards quality excellence, research studies, reviewed reveal that CoQ is not a widely used concept.

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