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A Review on Cost of Quality Methodology and Hidden Costs in Manufacturing Industries

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Abstract
Identification and reduction of manufacturing cost is an important task for any manufacturing firm to maximize the profits. Based on budget allocation for all related processes and as improvement and quality costing aspects, Cost of Quality is a very effective methodology to be studied. This article presents a survey of published literature about various quality costing approaches and reports of the success of this IE technique in order to provide a better understanding of cost of quality (COQ) methods. Also this review study focuses on COQ models presented by researchers in addition to the traditional PAF approach. A mammoth task for most companies today is to tackle the inadequacy of most cost-accounting systems in addressing quality costs and in supplying appropriate data in a suitable format that considers total cost. The present study addresses these needs by first refining the traditional 'Prevention–Appraisal–Failure' (PAF) categories of quality costs and hidden costs through the definition and addition of two new categories: 'extra resultant cost' and 'estimated hidden cost'. This study aims at discussing COQ as a great IE technique in modern day industrial scenario to improve quality and reduce the cost of product simultaneously.
Keywords: Cost of Quality, Hidden Costs, COQ models

Introduction

The 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. Since then, many quality-control experts have written extensively about quality-cost systems 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 [1].Studies have shown that quality-related costs are too substantial for manufacturers to ignore, especially in today's competitive markets. In today's business environment of global competition, a firm's competitive position is enhanced by focusing on a customer orientation, rather than simply increasing the volume of sales turnover. This customer orientation requires a reduction in the cost of non-conformance and an enhancement of quality to meet the needs and expectations of customers [1].

Literature Review

Cost of Quality:

COQ was first introduced in 1951 as the 'cost of poor quality' by Juran, who defines it as 'the sum of all costs that would disappear if there were no quality problems' (Juran, 1951). Bohan and Horney (1991) define COQ as 'the total of all resources spent by any organization to assure that quality standards are met on a consistent basis'. In a bottom line view, the quality costs are the loss of profit and therefore called 'gold in the mine'. In the past, quality costs were assumed to be only rework, repair and warranty costs. However, the COQ perspective has developed over the years, and several models have been developed to classify and report COQ. Among other COQ models, Feigenbaum's (1956) PAF model is widely accepted in quality management. [5]

This study makes use of PAF, in which the quality costs are categorized as Prevention-Appraisal-Failure.

(a) Prevention cost: The cost of any action taken to investigate, prevent or reduce the risk of non-conformity or defect.

(b) Appraisal cost: The cost of evaluating the achievement of quality requirements including, e.g., the cost of verification and control performed at any stage of the quality loop.

(c) Internal failure cost: The costs arising within an organization owing to nonconformities or defects at any stage of the quality loop, such as costs of scrap, reworking, retesting, re inspection or redesign.

(d) External failure cost: The cost arising after delivery to a customer/user owing to non-conformities or defects, which may indicate the cost of claims against warranty, replacement and consequential losses, and evaluation of the penalties incurred.

Due to interrelations among COQ categories, it is assumed that investment in prevention and appraisal activities is more likely to decrease the cost of failure. In a similar manner, investments in prevention activities are also more likely to result in a reduction in the appraisal costs.

Cost of Poor Quality

The `cost of poor quality' (COPQ) of an organization is the difference between the actual operating cost and what the operating cost would be if there were no failures in its systems and no mistakes by its staff. According to the American Society for Quality Control (ASQC), quality costs are a measure of costs specifically associated with the achievement or non-achievement of product or service quality, as defined by all product or service requirements established by the company and its contracts with customers and society. The costs of quality are "those costs that are incurred to prevent a shortfall in quality and a failure to meet customer requirements, as well as costs incurred when quality does in fact fail to meet customer requirements".[4] Another important thing is that "whether it is called Quality Cost or Poor Quality Cost, it is designed to reduce the cost associated with poor quality". Fig.1 shows categorization of Quality Costs as per different established approaches or philosophies.

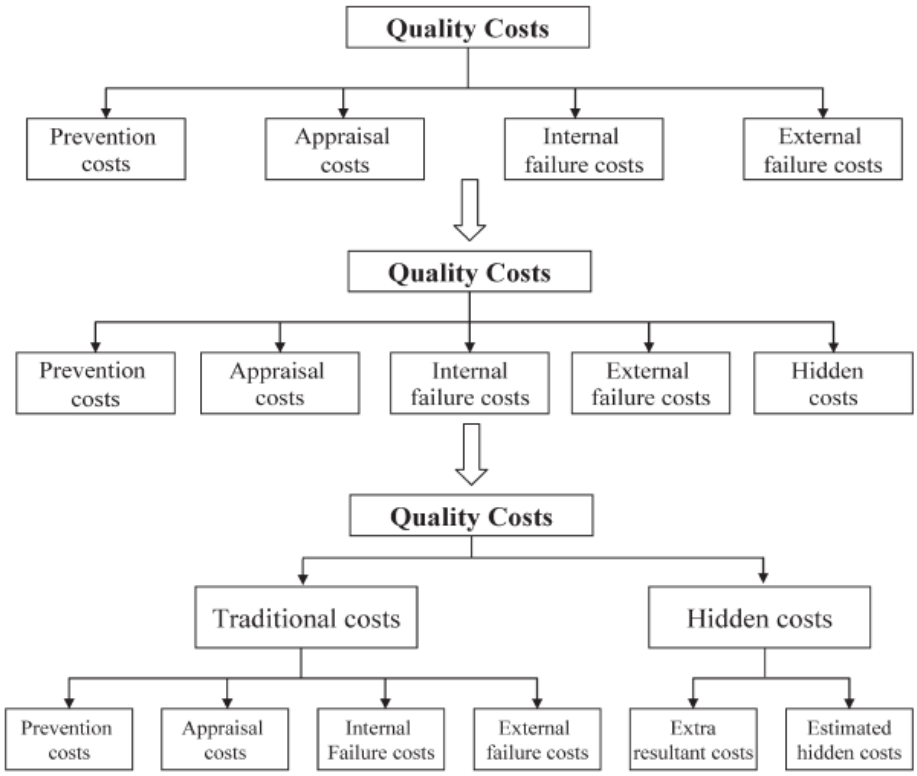

Figure 1. Definition of categories of quality costs [2]

Hidden Costs

The term 'hidden' cost (or 'invisible' cost) is used to indicate failure costs that are inadequately recorded in company accounts and/or failure costs that are never actually discovered. Such 'hidden' costs might be manifested as extra manufacturing costs as a result of defects or as additional costs for materials, machining time, and inventory space for scrapped and reworked parts Chen and Tang (1992) used the term 'indirect PQC' (Poor Quality Costs) and stated that these had three components:
(i) Customer-incurred costs (costs due to the failure of the product to meet customers' expectations);
(ii) Customer-dissatisfaction costs (which are difficult to quantify);
(iii) Loss of reputation costs (also difficult to quantify).
such hidden quality costs can be significant. Indeed have asserted that they might amount to 10–15% of turnover, and suggested that they could constitute up to 10% of actual production costs. Some researchers also estimated that the hidden quality costs are more than three times of the visible costs. Table 1 describes costs that are considered in hidden costs as defined by various researchers referred in this paper.

Table 1. Cost items involved in hidden costs as defined by various researchers. [2]

Researchers	Cost items involved in Hidden Costs
Chen and Tang (1992)	▪ loss of productivity ▪ overtime to make up production ▪ customer dissatisfaction costs ▪ loss-of-reputation costs
Juran and Gryna (1993)	▪ lost scales ▪ process downtime ▪ extra inventory ▪ lost discounts ▪ damaged goods ▪ premium freight costs

	▪ customer allowances ▪ overtime to correct errors ▪ loss of goodwill ▪ paperwork errors ▪ delays ▪ obsolete inventory ▪ incorrect orders shipped ▪ extra process capacity
Harry and Schroeder (2000)	▪ the cost of "handed back" ▪ the resultant costs of the defect bypass the quality-control system ▪ the extra costs in terms of additional labor hours and inventory ▪ the opportunity cost of lost customer loyalty ▪ the lost sales owing to poor quality in the past extra inventory due to longer cycle times
Giakatis et al. (2001)	▪ unsuccessful prevention activities plus the sequential losses ▪ unsuccessful appraisal activities plus the sequential losses ▪ the inefficiency of production equipment ▪ over quality
Han & Lee (2002)	▪ design change ▪ longer cycle time ▪ over quality ▪ production plan change ▪ operation cost increase ▪ market loss ▪ brand image damage ▪ delayed delivery ▪ inventory increase
Chen and Yang (2002)	▪ waste of human resources, equipment, and time ▪ the costs caused by inadequate quality, delivery, reliability ▪ increase engineering time ▪ increase management time ▪ shop and field downtime ▪ delivery problem ▪ lost orders ▪ lost market share ▪ decreased capacity
De Feo and Barnard (2004)	▪ incorrectly completed sales order ▪ pricing or billing errors ▪ excessive overtime ▪ lateness of paperwork ▪ premium freight costs ▪ excessive field service expenses ▪ lack of follow-up on current programs ▪ excessive employee turnover ▪ planning delays ▪ customer allowance ▪ excess inventory ▪ expediting cost ▪ development cost of failed product ▪ excessive system costs ▪ unused capacity ▪ complaint handling ▪ time with dissatisfied customer ▪ overdue receivables

Cost of Quality Models:

Since Juran [3] discussed the cost of quality, many researchers have proposed various 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 2.

Table 2. 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 + opportunity Tangibles + intangibles P-A-F (failure cost includes opportunity cost)
Process cost models	Conformance + non-conformance
ABC models	Value-added + non-value-added

- ✓ *P-A-F models:* 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.
- ✓ *Crosby's model:* 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.
- ✓ *Opportunity or intangible cost models:* Intangible costs are costs that can be only estimated such as profits not earned because of lost customers and reduction in revenue owing to nonconformance. Here intangible or opportunity losses cost is incorporated into a typical P-A-F model.
- ✓ *Process cost models:* 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.
- ✓ *ABC models:* 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. While the PAF approach of COQ is activity-oriented, the process cost approach of COQ is process oriented, ABC is activity-oriented for the cost assignment view and process-oriented for the process view. The implementation of quality costing can produce significant benefits. The most important is that organizations are able to focus on areas that require improvement listed the following potential benefits of quality costing: (i) focusing upon areas of poor performance that need improvement; (ii) monitoring the progress of ongoing improvement activities; (iii) planning for quality improvement; and (iv) aiding communication within the organization to assist in the overall control of quality.

The critical issues for an effective quality-cost technique are as follows:

- To establish appropriate categorization of various quality costs, and ensure that every item of quality costs is captured;
- To collect and analyze the relevant data thoroughly, and thus to quantify all quality-cost items accurately;
- To identify areas of poor performance on the basis of the above data analysis; and
- To allocate responsibilities for the overall cost.

The elements of COQ implementation are described in Table 3:

Table3: Flow of cost of quality implementation. [7]

Step	Action	Details
1	To verify with factual costs that a cost of quality can be beneficial to the company	Review and analysis of financial data to determine the general levels of quality costs as they exist today
2	Obtain management commitment and Support	Developing an estimate of the cost of quality and gain management supports
3	Established an installation team	The quality cost team should include individuals from throughout the organization
4	Select an organizational segment as a Prototype	More detail example required. A specific area of operation must be exposed to management to show how actual quality costs can be calculated and be eliminated through analysis and corrective actions
5	The management presentation	Presentation must contain a clear description of the detailed intent of the programme and how it will be accomplished
6	Conduct the planned pilot programme	Prove the ability of the system to produce cost saving results. Resell management on the continued need for the programme. Allow system debugging prior to full implementation
7	Education of all functions/training	Key members should be educated in the concepts of a cost of quality and the detailed programme plan for implementation
8	Development of the internal quality cost accounting procedure	To describe each elements of quality cost to be used and to define how and when the actual cost are to be estimated or collected and assembled
9	Overall collection and analysis of quality cost data	Data are collected according to the quality cost elements. Analysed the data over a sufficient period of time
10	Quality cost reporting and use	Published the report to management and verified current opportunities for improvement

Research Methodology

The aim of the study is to develop a sense of understanding of Quality Costs and different accounting methods for the same in view of improving quality at reduced costs. By doing this the industry would not only improve the profits margin, but also build a strong relationship with their clients/customers based on the trust of quality they serve. The research strategy was made by identifying the relevant data source, keyword and selecting research papers in which detailed study of COQ and quality costing/quality cost accounting in industries has been done and the results and suggestions given by the respective researchers appear to be legit to the respective cases. The initial part shows an overview COQ and different approaches. In the other part, few case studies conducted for quality costing/quality cost accounting and COQ/COPQ by different researchers at different places is shown. The study of all the cases is then compared and is presented in the following sequence:

1) General overview of publications and the case industries.
2) Techniques and methods used by case industries and Results gained by the same.

Table 4 and Table 5 below gives the publication name (i.e. research paper title), the field area or product in which COQ study is carried out. The referred name on the left most column indicates the name by which the publication has been referred in the rest of the review paper. The table also gives information about the journal, authors‟ name and year of publication of the selected cases.

Table 4: General overview the case studies in industries:

Referred Name	Title	Journal/conference Year	Author /Authors	Field-area/product and/or Description
A	Towards managing quality cost: A case study	Total Quality Management & Business Excellence , 2009	S. B. Jaju , R. P. Mohanty& R. R. Lakhe	Foundry Industry
B	Improving the definition and quantification of quality costs	Total Quality Management & Business Excellence, 2008	Ching-Chow Yang	Literature studies and refinement of PAF categories of Quality costs and Hidden costs
C	Estimating quality costs in an automotive stamping plant through the use of simulation	International Journal of Production Research , 2010	A. S. De Ruyter, M. J. Cardew-Hall & P. D.Hodgson	Automotive Stamping Plant
D	Cost of quality: the hidden costs	Total Quality Management , 2010	Suresh Kumar Krishnan , ArawatiAgus & NoorehaHusain	Descriptive approach for Measuring the Cost of Poor Quality
E	Activity-based costing approach in the measurement of cost of quality in SMEs: a case study	Total Quality Management & Business Excellence , 2012	SerdarÖzkan & YaseminZenginKaraibrahimoğlu	Assembly oriented engineering company Products: High-pressure testing(HPT) &Hydraulic Power(HP) Units
F	Issues related to implementing quality cost programmes	Total Quality Management , 2010	Kamlesh Shah &PurnenduMandal	Harmes Electronics, USA
G	An exploratory study on cost of quality implementation in Malaysia: The case of Penang manufacturing firms	Total Quality Management & Business Excellence , 2011	Lee HoonTye , Hasliza Abdul Halim& T. Ramayah	Case of Penang (Malaysia) Manufacturing Firms
H	Hidden Cost of Quality: Measurement and Analysis	InternationalJournal of Managing Value and Supply Chains , 2015	Sailaja A, P C Basak and K G Viswanadhan	Electronic Industry
I	Managing Cost of Quality: Insight into Industry Practice	InternationalJournal of Managing Value and Supply Chains , 2015	Andrea Schiffauerova,Vince Thomson	i)Telecommunication ii)Micro-electronics iii)Aerospace Industry iv)Home products
J	Cost of quality management: An empirical study from Turkish marble industry	Scientific Research and Essay , 2009	OzgurAkkoyun and Huseyin Ankara	Marble industry

Table 5: Theory based papers

Referred Name	Title	Journal/conference Year	Author /Authors	Genre
K	Cost of quality usage and its relationship to quality system maturity	International Journal of Quality &Reliability Management, 2007	Victor E. Sower and Ross Quarles	Survey based paper
L	A Review of Research on Cost of Quality Models and Best Practices	International Journal of Quality and Reliability Management , 2006	Andrea Schiffauerova, Vince Thomson	Review paper on COQ models.
M	Cost Of Quality Models And Their Implementation In Manufacturing Firms	International Journal for Quality research , 2009	N.M. Vaxevanidi , G. Petropoulos , J. Avakumovic, A. Mourlas	Theory based paper

Study of Results:

The work done, methods adopted in formulating research and findings of various experts and researcher in their area of study, and the noteworthy points in their work have been summarized in table 6.

Table 6: Summary of papers referred

Referred Name	Methods/Techniques used	Study outcome
A	Single product selection. Data collection through cost quality check sheets. Trend analysis, regression analysis of industry records.	This paper helps to guide critical issues and offers some tools to help any company with this important area of activity.
B	i)Categorization of PAF ii)Cost items involved in Hidden costs iii) Cost of Quality account matrix	Research has developed a new conceptual system of quality costing, which involves the collection of quality-related financial information and the identification of appropriate classifications. Also, Analytical matrix and formulae developed to calculate quality costings.
C	Simulation modeling based on past records	The paper discusses simulation as great alternative to additional costing method. Simulation provides a flexible technique for understanding the economics of quality. The flexibility of simulation methods allow the generation of models with greater complexity than that allowed by the analytical techniques. The principle of the simulation involves the replication of the production environment and the allocation of costs into the PAF cost elements.
D	i)Interview ii)Flow chart iii)List of Activities iv) Tabulation v)Timesheets vi)Accumulation of Time spent vii) Translation into Money	-The data collection and Activity Documentation differentiating productive and unproductive work is the key factor of this research regarding quality costing estimation. Poor cost of Quality is quantified using mathematical formulation and activity conversion into money. The amount of money wasted by the University per year due to poor quality cost considering nine technician is concluded about RM 26330.40
E	Activity analysis from industry reports. Team selection for the activity	The use of ABC facilitates measuring and reporting COQ by detecting NVA quality-related costs. The COQ report under ABC provides organization with the opportunity for improving cost and quality control, and therefore competitiveness, and it has been shown that COQ measurement under ABC can be effectively used by small enterprises. This study also suggest that with the use of COQ/ABC, organizations may be able to detect and monitor the areas of poor performance that require improvement, control and manage quality-related costs and, consequently, gain competitive advantage by improving the quality and reduce costs.
F	Literature based research combining concepts of TQM and COQ	The authors here, have discussed COQ as a part of implementation of TQM philosophy. Tackling the issues such as the needs for quality cost programmes, ways to initiate a programme, steps in implementation, measurement bases for quality costs, relationships between quality cost components, role of accounting systems and professionals, etc. play a vital role in success of any industry trying to improve on quality.
G	-Data collection using questionnaire -Selection of key informants -convenience sampling	-After implementing the Cost of Quality, customer complaint, scrap & rework, failure costs were significantly reduced -Sales volume increased -Description of scale of COQ in Penang Manufacturing firms

	-Measurement instrumentation using five point Likert scale	
H	Data collection and Categorization: i) Direct quality cost elements ii) Hidden quality cost elements iii) Opportunity cost elements	Following outcomes we got studying this paper: i)Identification of all processes and quality cost elements in all corresponding activities, Comprehensive data collection and quantification, Grouping in to direct and hidden Cost of Quality. ii) Analysis of impact of hidden COQ on total quality cost and also on organizational bottom line. iii) Comparison of traditional COQ system with enhanced COQ with hidden costs included. iv) Hidden cost of quality is more than 3 times higher than the direct quality cost elements
I	Participative approach of different companies for comparison purpose	The companies under assessment were compared on the basis of their strategy regarding quality of their product. Results show that company that adopts formal COQ approach or quality cost accounting approach performs better than those that don't. COQ programs should be part of any quality management program.it is emphasized here that education on the practical level is needed for managers to understand better the COQ concept in order to appreciate fully the benefits of the approach, to increase their ability to implement a COQ measurement system and to save money.
J	-Statistical quality control tools -PAF costs for three different type of marbles were distributed	Here, It was found that quality costs vary depending on product types in range from 9 to 34% of total production costs for three different stone types. Development and application of computer program and statistical quality control tools introduced. All costs occurring in marble processing systems were examined, identified, classified and calculated. Several cost formulas were generated to define and control the system with models. A new computer program incorporating these models and other algorithms was developed to control total and quality costs in marble plants.
K	Comparison of quality programs of four multinational companies and benefits of adoption of a COQ approach in each case	Only company A measures cost of quality and uses a formalized COQ model. Company D is at the point of starting to use this quality measurement tool. Company B and Company C focus their quality efforts solely on continuous quality improvement. They measure, monitor and work mostly with the cost of non-conformance, and do not formally include cost of conformance in their analysis.
L	Study involves following COQ models through various published literatures: i) PAF model ii)Crosby's model iii) Opportunity or Intangible cost models iv) Process cost models v) ABC models	Every model should be adjusted according to the company's needs; different subcategories and groupings used and element definition is different accordingly. Research indicate that companies that use COQ programs have been quite successful in reducing COQ and in improving quality for the customer. The model most commonly implemented in practice is the classical P-A-F approach.
M	-Literature survey of Quality Costing and methodologies -Relation development among COQ models	PAF approach 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. Study shows this can be overcome by ABC approach. This study shows the evolution of COQ approaches in business. 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 rather limited.

Conclusion

Many research papers on COQ propose quality cost models, methods and techniques, and provide abundant information on the topic. The literature review of the practical use of COQ suggests that companies that use COQ programs have been quite successful in reducing COQ and in improving quality for the customer. The model most commonly implemented in practice is the classical P-A-F approach; however, other quality cost categorizations are documented as being used with success. Even though the P-A-F categorization serves as a basic concept, the individual costing systems still differ considerably from company to company. Every model is usually adjusted according to the company's needs, which results in the various COQ structures. Also, a variety of elements is included or deemed unimportant and left out of the calculations. Moreover, the selected bases for COQ calculation vary as well, which causes an inconsistency in quality cost figures and makes it even more difficult to compare the results of the COQ programs among companies. The underlying principles of the P-A-F

approach however remain generally unchanged throughout the researched companies. Here hidden cost play a major role in cost increasing element, it can be identified and quantified in COQ model focusing as to eliminate task. COQ measurement should be part of any quality management program. The methodology is not complex and is well documented. COQ programs provide a good method for identification and measurement of quality costs, and thus allow targeted action for reducing COQ. Further education on the practical level is needed for managers to understand better the COQ concept in order to appreciate fully the benefits of the approach, to increase their ability to implement a COQ measurement system and to save money.

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