# A Comprehensive Review of Cost of Quality

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**Abstract**

The paper gives insight into the published theories/models of the quality costing techniques and the case studies conducted in various organizations. It has been found that CoQ technique is not is not widely used by the industry. Each industry needs to modify the available models of CoQ as per purpose, need and environment. It has been found that in the various case studies that if prevention and appraisal cost is increased the failure cost decreases. The total cost of quality varies according to the type of industry. The support from the top management and interdepartmental coordination is vital for successful implementation of CoQ technique.

**Keywords** - Quality costing techniques, Cost of Quality (CoQ), Elements of quality costs

## Introduction

Quality of a product is an important and critical factor for remaining competitive. As every quality related activity comes with a cost so measuring and reporting Cost of Quality (CoQ) is important. The purpose of measuring CoQ is not only to reduce cost but also to ensure that cost incurred on the quality activities is of right kind (Omar, 2009).The general concept of the quality costs was given by Juran (1951) in "Quality control Handbook" as economics of quality. The concept of standardization of procedures in the industry was given in the form of ISO and QS standards. These standards define quality costs as measures of quality management and quality improvement tool. It is the balance sheet of TQM program. Quality costing is one of the tools and techniques which can be used by any organization for implementation of TQM (Laszlo, 1997). Quality costing is a management tool which is part TQM. It is a comprehensive system and should not be used as a piecemeal tool. It gives an overall indication of quality effectiveness (Hou, 2011).

The tool of cost of quality provides justification for any corrective action in the quality management program. The term "Cost of quality" does not mean that there is a cost in achieving quality as the saving made because of improvements will result in no actual cost (Juran, 1951, Deming, 1986)**.** CoQ helps to assess the potential for implementation of TQM in any organization (Campanella, 1999). Depending upon the type of industry quality related costs can vary 5 to 25 percent of annual sales turnover (Dale, 1999). High cost identified by the quality costing technique is an opportunity for profit improvement (Keogh, 2003).

Quality cost is the cost incurred by any organization to apply quality management system in the areas of design, implementation, operation and maintenance (Dale and Plunkett, 1999). The measurement of these costs helps in expressing the quality related activities in terms of money. Australian standard- 2561 provides methods to identify cost incurred for producing quality products (Oliver and Qu, 1999). It can help in tracing cause of poor quality, working out solutions and monitoring the process of improvement. Quality costing helps to fix the responsibility/ownership for the failure (Keogh, 1994).

Organizations feel that the increased investment for better quality must be justified by the increased profitability. It is normally difficult to foresee the economic viability of the capital investment for quality

improvement. Quality costing helps to make management believe that an investment to improve quality is not just a social responsibility but will also yield better returns and increased business. The management support will never fade if quality is perceived to be a valuable tool for increasing profits (Laszlo, 1997).There are four stages of Quality Management inspection, Quality control, Quality assurance and TQM. Inspection and quality control involve inspecting, checking and testing in order to ensure that only products confirming to quality are delivered to the customer. Quality assurance and TQM are based on prevention (Dale and Plunkett, 1999). The main objectives of quality management system are delivery of defect free product for customer satisfaction, reduction in defect rates and quality costs (Opperman *et al.*, 2001).

**Goal of Quality Costing**

The goal of Quality costing (QC) tool is to support and facilitate quality improvement process. The ultimate aim of QC is to identify failure costs and attempt it to reduce to zero, invest in the required prevention activities and reduce appraisal cost. Normally failures are revealed through appraisal activities or customer complaints. The defect correction becomes more expensive with its detection down the line i.e. near to customer. Quality costing technique helps to identify the roles of manufacturing, marketing, purchase & design function in quality management efforts. (Campanella,1999; Dale and Plunket, 1999).

The quality cost data defines the priorities for the needed corrective actions. The organization have experienced that communication with all the employees regarding the model to be used for improvement is very important (Keogh, *et al.*, 2003). A quality cost program should always move from top to bottom i.e. top management should make it a part of overall production process. Eldridge and Dale (1989) divided cost elements in BS6143: Part 2 into 3 groups (i)Costs which are possible to identify and quantify (ii) Activities whose frequency is too less to be accurately quantified. (iii) Activities which are not part of an organization's process.

Four major uses of Quality costing (Morse 1983, Dale and Plunket ,1999) are to promote quality as business parameter, to define performance measures, to provide ways to plan and control quality costs and to motivate employees at all levels by informing that they can improve profits without increasing sales. The base against which various quality costs are compared should be appropriately chosen. The common bases (Campanella,1999) are (i) Labour base – total labour, direct labour (ii) Cost base – shop cost, operating cost (iii)Sale base – Total sales or sale price of commodity or service (iv)Unit base – Number of units produced / services performed. Any base selected should take into consideration sensitivity to change in schedules of production/ services, level of automation, seasonality, etc.

**Literature Survey**

Juran (1951) said that quality costs are the costs of running quality department. Feigenbaum (1956), Masser (1957) gave the concept of Prevention, Appraisal, Internal failure and external failure. Measurement and use of cost of Quality was given by BS 6143 which gave PAF model. Crossby (1984) gave the concept of price of conformance and price of non-conformance and was based on IDEF.IDEF is structured flow diagram interrelating various functions of manufacturing process. Bostons (1988) suggested inclusion of complaints and managerial pressure in the flow diagram. Bajpai (1989) suggested simulation model relating to prevention costs and other elements of quality costs. Dahlgard (1994) gave the concept of strategic quality management and a new method for estimating total quality cost.

BS6143 Part 2 gives a macro level view which helps top management in decision making but does not give any direction for improvement of process at operational level. BS6143 can be used for the production processes only. Cost of quality is considered as a part of six sigma process for quality improvement (Magritzer *et al.*, 2002**).** Quality cost is used to measure and monitor the tangible aspects of quality. It helps to monetize and analyze key performance indicators of a business. It helps to identify improvement opportunities. It helps to give quality oriented focus in an organization (Laszlo, 1997,

Campanella, 1999**)**. Quality costing is a tool and technique which is used by an organization for implementing TQM. The organization which have already implemented TQM need to use quality costing to measure internal quality performance ( Laszlo, 1997and Dale & Plunkett 1999**).** The cost of quality (CoQ) system helps to justify the investment in prevention activities, which lowers the quality cost. CoQ system can help in development of performance measures for various areas of business. Crossby (1979) introduced the concept of zero defect as the quality performance standard. There exists a debate whether an organization should aim for zero defect or make their quality decisions on cost benefit model of quality cost. Kume (1985) said that it is not necessary that a decrease in quality cost will increase the profits. He argued that the constitutional quality cost model mainly deals with quality cost like (PAF) but overlooks hidden quality cost (e.g. quality of design and loss of sale). Schneiderman (1986) discussed that a sufficient investment in prevention activity will result into zero failure cost and no appraisal cost. Taguchi (1990) emphasized on robust design and insisted that the loss due to poor quality is always greater than that perceived by an organization. High cost identified by quality cost is an opportunity for profit improvement (Campanella, 1999). Gupta and Campbell (1995) share that prevention is most cost effective category for quality spending. Burgess (1996) suggests that the allocation of resources in P&A should continue till the cost of conformance is lower than cost of nonconformance. Studies undertaken in industry of various types have revealed that cost of the failures is usually between 20 to 40 percent of total cost. It has been found that average cost of poor quality amounts 15 to 20% of turnover for European manufacturing company and it is still higher for service industry (Dale & Plunkett, 1999). The determination, identification, qualification and analysis of various quality related costs helps on assessing the effectiveness of quality management and in determining problem areas, action required, projected savings (Krishanan, 2006). Visawan and Tannock (2004) and Burgess (1996) point out that the concept of economics of cost of quality overlooks impact of quality on market share. Implementation of cost of quality technique helps to focus upon the areas that need improvement, to gauge the progress of improvement activities and improves communication within the organization for better quality control (Prickett and Rapley, 2001**)**. The quality costs can help to pin point the defects and source of defects especially where the organization is large (Keogh, *et al.*, 2003**).**The application of CoQ technique helps in strong employee participation at strategic and operational level (Czuchry, *et al.*, 1999). Implementation of quality programs in companies like Xerox, General Electric and Motorola have reduced their quality cost from 30 percent to 2 percent of sales while improving their quality (Super Ville and Gupta 2001). CoQ technique helps to improve the quality culture of the organization Rapley, *et al.,* (2001). Quality costing can help companies to reduce manufacturing cost by identifying any excess cost and non-value added activities (Johnson and Kleiner, 1993).

Burgess (1994) discussed the two views on the cost of quality i.e. modern and classic. The classic view believes that there is optimum level of quality and any expenditure on prevention and appraisal beyond that point will not result into the increase in quality. The non-manufacturing departments want to limit cost of quality to manufacturing only. The focus should be more on utilizing the data for improvement than on categorization (Bain, 1989**).** It has been found that it may be easy to find a defect and rectify it but difficult to cut these out. The organization must evaluate their process and figure out what constitute the quality cost. There is not perfect model or prototype that can fit the industry. The model has to be designed by the industry. The CoQ is means of identifying problems and then finding a solution. CoQ should be designed by involving employees at all the levels and thus making them a part of system. The main purpose of implementing CoQ measurement system is to determine the level of quality that minimizes the total cost (Schiffauerova and Thomson, 2006 b).

Quality costing may help in (Porter and Rayner 1992) (i) Getting proper support from senior Management (ii) Highlight the areas where improvement is needed (iii) Estimating the potential benefits by improving quality.Dale and Plunkett (1999) discussed that the major use of quality costing includes promoting quality as a performance measure, identifying improvement areas, helps in planning the quality costs to be incurred in future. It has been found that organizations do not fully appreciate the cost

of quality approach (Schiffauerova and Thompson, 2006). The major quality cost elements are indirect & normally fall out of boundary of single department and co-operation among various departments is required to identify these cost elements (Robert and Sartawi, 2011). Cost of doing business consists of hidden failure cost and visible failure costs. Since the hidden failure costs are not traceable they are taken as part of operational cost (Krishnan, 2006).

The objectives of having CoQ system in Industry are (Ali Uyar, 2008) (i) Overall quality improvement (ii)To set cost reduction targets and measure progress (iii)To have better control of quality activities (iv) To have better strategic planning (v)To evaluate the effectiveness of quality system (vi) To motivate employers.The main objective of measuring and reporting CoQ are (Oliver, 1999) (i)To identify high cost problem areas (ii)To measure effectiveness of Quality system (iii) To indicate cost reduction and monitor (iv) For strategic quality planning (v)Provide improvement (vi)Supplier's performance. The limitations of COQ reporting system includes non-inclusion of important costs, difficulty in assigning overhead costs, variation in activity etc. (Morse 1983). Lack of management support is one of the reasons for non-reporting of COQ (Gupta and Campbell, 1995). The quality efforts by most of the organization are not systematic and tend to identify problems than preventing (Corradi, 1990). There is a need for industry specific quality cost classification system (Gibson *et al.*, 1991; Sitkine *et al.*, (1994)). Accounts personal should be involved for preparing CoQ reports for consistency and accuracy (Roth and Morse (1983) & Keogh (1994))**.**

The reasons for not measuring COQ have been given as (1) Lack of Management support (2) Manufacturing process complexity (3) Cannot be used for operational strategy (4) Quality is part of Organization's Culture so measurement not needed.

The aim of collecting quality costs should be to improve the quality of product, to measure performance and planning for quality costs in future. It helps to educate employees regarding benefits of TQM for competitiveness. It helps to monetize the inbuilt inefficiencies of the process (De, 2009**).**

**Models and Approaches for Cost of Quality**

Plunket and Dale (1988) compares the various models proposed between 1971 and 1986. The models have been divided into five groups mainly based on their approach in explaining the relationship between various costs of quality. Robertson (1971), Besterfield (1979) etc. suggested the models which indicate the reduction in failure and appraisal costs by increasing prevention costs. Some models combined prevention and appraisal costs. Burgess (1996) further reduces the categories of models to three.

Huckett (1985) based on actual data and literature from various companies show prevention, appraisal and failure cost separately. These models show that increase in the expenditure on appraisal & prevention generally reduce failure cost resulting in the decrease in the total cost of quality. This contradicts some notional model which say that the total cost of quality will start increasing even if cost of prevention and appraisal increase beyond a certain level (optima).

Modaress and Ansari (1987) introduced two more dimensions of quality cost model: (i)Cost of quality design (ii) Cost of inefficient utilization of resources, although they did not made any empirical study to support the above two dimensions.

Dale and Plunkett (1988) studied the industry data and found that the data did not fit into the optimal quality model and par value model (where optimal quality is 100 percent). It has been found that the models have assumed perfect design quality. Cooper and Kaplan (1988) developed ABC model. Tsai (1988) proposed an integrated model where both ABC and CoQ approaches have been integrated.

Crossfield and Dale (1990) developed Quality activity management planning (Q-MAP) model. Chen and tang (1992) proposed pictorial approach to poor quality cost management by using the influence diagram and entity relationship diagram.

Porter & Rayner (1992) discussed the cost-benefit model which means that any expenditure on

improvement and prevention activities is an investment and it will give returns in the form of reduced failure cost, increased customer satisfaction resulting in increased market share. Grove and Fox (1990) gave the concept of CoQ as "Cost of Quality" and "cost of un-quality".

A process model was developed Ross (1977) and was used for quality costing by Marsh (1989). Using this model the cost of conformance (CoC) and cost of non-conformance (CoNC) are identified.

In 1992 "process model" was recognized and included in British standards in addition to PAF model. CoC- is the intrinsic cost of providing goods/services by a given specified proven method in a fully effective manner BS 6143: Part I:1992.CoNC – cost of wasted time, material and capacity associated with a process in the receipt, production, dispatch and correction of unsatisfactory goods and services BS 6143: Part I: 1992.

IDEF (the computer aided manufacturing integrated program definition methodology) can be used to construct the process cost model for the process within an organization. In process cost model [BS 6143: Part 1] any process can be selected, a flow charts is made to identify all the activities and parameters associated with the process. The activities are allocated the costs (COC or CONC). The IDEF method is used for representing the complex system. It is an activity diagram and is made up of inputs and outputs. The cost report is prepared specifying all inputs, outputs, controls and resources. The report should specify means of calculation for each element of cost and source of cost data.

The old cost of quality model proposed by Juran was modified in accordance with concept of Kaizen and Six sigma (Juran & Gryna 1993). The process variability is a factor that decides the percentage defects. The increase in the expenditure on prevention activity will reduce process variability. It has been depicted that increase in the prevention cost will decrease defect rate percentage and increase in appraisal cost will initially increase the defect reduction rate at a higher rate but eventually the effect of increase in the appraisal cost will result only in incremental increase. It has also been discussed that an increase in the appraisal cost will increases the defect detection rate to a certain limit i.e. 100 percent defect detection is not possible even with 100 percent inspection (Burgess (1994)).

Goulden and Rawlins (1995) proposed three level hierarchical model and used process model to make flow chart for depicting various activities in an manufacturing organization.. The amount of time spent on conformance and non-conformance activities is calculated and is used to calculate the cost. There are two costs of quality one for desired level of quality in operations and the second account for the cost of process improvement. The defect in design will only be reflected as external failure.

It has been discussed that the most of COQ models assume static environment. They do not take into account the effect of learning and training of employees on the quality of product /services and the effect of quality improvement by competitor organization. Prasad and Tyson (1995) have proposed a dynamic model in Fig.3 which incorporates influence of learning and influence of competitor's improvements on voluntary (prevention & appraisal costs) and involuntary costs (internal & external failure costs).The learning process reduces voluntary costs and competitor's improvements increases intangible failure costs. This model needs to be validated by empirical study. Burgees (1996) gave the concept of dynamic quality cost model which clearly matches the empirical data obtained from companies. Chang *et al.,* (1996) proposed a mathematical model using for calculation of quality costs in a multistage manufacturing system.

In Xerox (Tsai, 1998) quality cost have been divided into 3 categories (i) CoC (Prevention and appraisal) (ii) CoNC (Internal Failure and External Failure) (iii) Cost of lost opportunities

Sandoval-Chavez and Beruvides (1998) included three opportunity loss components (1) Under-utilization of installed capacity (2) Inadequate material handling (3) Poor delivery service.

Harrington (1999) proposed a poor quality cost system which includes direct and indirect quality costs. It says that prevention, appraisal, non-value added costs, internal & external error costs and equipment poor

quality cost are direct poor quality cost. Customer dissatisfaction, loss of reputation and lost opportunity are indirect poor quality cost. This model helps to make an employee aware of the loss due to the error, as errors are expressed in terms of money the problem solving efforts are made, helps to measure impact of corrective action.

Czuchry, *et al.*, (1999) proposed an approach that includes customers view to improve the quality . Customer's perception about the quality helps the company to make strategic decision on investment for quality improvement.

An approach which is combination of BS6143 Part2 and IDEF method was proposed. This approach helps in calculation of various costs, process analysis & improvement **(**Giakatis and Rooney, 2000**)**. Proposed a model to optimize inspection process of electronic industry and found that the inspection cost will depend upon the probability of acceptance. This model helps to compare different inspection strategies (Opperman, *et al.,* 2001). Giakatis *et al.*, (2001) analyzed difference between quality cost and quality loss.A model which suggests that if with the increase in quality the cost of quality increases then the organization should take into account the market oriented aspects like economies of scale, sales volume, etc., (Mendez and Narasimhan , 2002**).**

Weheba (2003) proposed a model to analyze various costs and their relationship to process parameters. In this model the concept of reactive cost of quality which has quality related costs incurred to maintain a desired level of operation and proactive cost of quality are costs which are incurred to plan & implement process for attaining improved level of conformance. The improvement costs defined by Waheba,( 2003) include (i)Identification of new conformance level for better customer satisfaction (ii) Reduce variation in output.

Chiadamrong (2003) proposed a model which says that total quality cost is sum of visible, invisible & opportunity costs. Omachonu and Suthummanon (2003) discussed that there are three inputs to every quality cost i.e. material, machine & human. The material quality is measured in terms of conformance to company specifications , quality of machine is measured in terms of its operating time. This model is a static model as it does not take time into account. The model proposed by Freiesleben (2004 (b)) described the behavior of prevention and appraisal costs at a fixed failure cost. The old CoQ models are not fit to determine the optimal quality level as they just tell about the relationship between prevention, appraisal and failure cost at a fixed quality level. A model developed by Freiesleben (2004) (Fig.2) proposed a dynamic COQ model which can predict optimal prevention and appraisal cost for current quality level. This model gives relationship between prevention and appraisal cost and total cost of quality but not with failure costs.

Setijono & Dahlgaard (2006) proposed two quality cost measurement models. First model includes relative changes in the failure costs with the relative changes in prevention and appraisal costs and changes in the customer's judgment regarding the quality over a defined period of time. The second model considers the change in the percentage of the produced products that conform to the specifications with the relative changes in the prevention, appraisal and failure costs. Liu, (2007) gave a dynamic COQ model (Fig.4) which suggests a relationship between prevention and appraisal cost and failure for different quality levels. The failure cost decreases with the increase in quality level. This is theoretical model which needs to be verified by empirical data**.**

Tannock and Saelem, (2007) have proposed 'PAFD' model. The disruption Quality cost is the cost incurred due to any disruption in the manufacturing process (D) will count towards this component. It has four cost components (i)Difference in operating cost (ii)Difference in utilization cost (iii)Difference in WIP interest charges (iv)Difference in WIP handling and storage cost.

It works on the concept that manufacturing system has to work for more time to make required good components. The total disruption cost is significant when conformance to quality is low but approaches the level of internal failure cost at high conformance levels. There are hidden costs associated with the

disruption of manufacturing process. The behavior of disruption cost is similar to internal failure cost.

Kim & Nakhai (2008) proposed a dynamic model to determine the relationship between quality cost & quality level over a period of time. The quality level is determined by the effectiveness of the effort of organization to improve quality. The activities which are part of the quality improvement program includes "quality related training, supply chain management, quality planning, design for quality, process design and planning, process control, etc.," This model depicts the diminishing effect of improvement efforts upon quality over a period of time. Yang (2008) improved the list of quality activities by adding two new categories (1) "Extra resultant cost"; - incurred due to operational errors and can be quantified (2) "Estimated hidden cost" – difficult to analyze and quantify.

There is a strong connection between manufacturing cost and tolerance design as they are inversely related. A mathematical model has been proposed (Omar, *et al.*, 2010**)** to calculate acceptance sampling cost, expected quality related cost, non-quality related activities cost (like upgraded computer software cost, space cost, tool costs), expected opportunities cost (setup cost, idle cost, inventory cost, waiting costs and external failure costs) . By using simulation it has been shown that as the defect rate decreases the total cost of quality decreases. This model has been validated by empirical data. This model supports the model proposed by Waheba (2004).

Omar, *et al.*, (2011) modified the model developed by Chiadamrong (2003) by including Type I and Type II error and adding new components like inventory cost, cost of acceptance sampling and cost of deviation. This model has been verified by using empirical data.

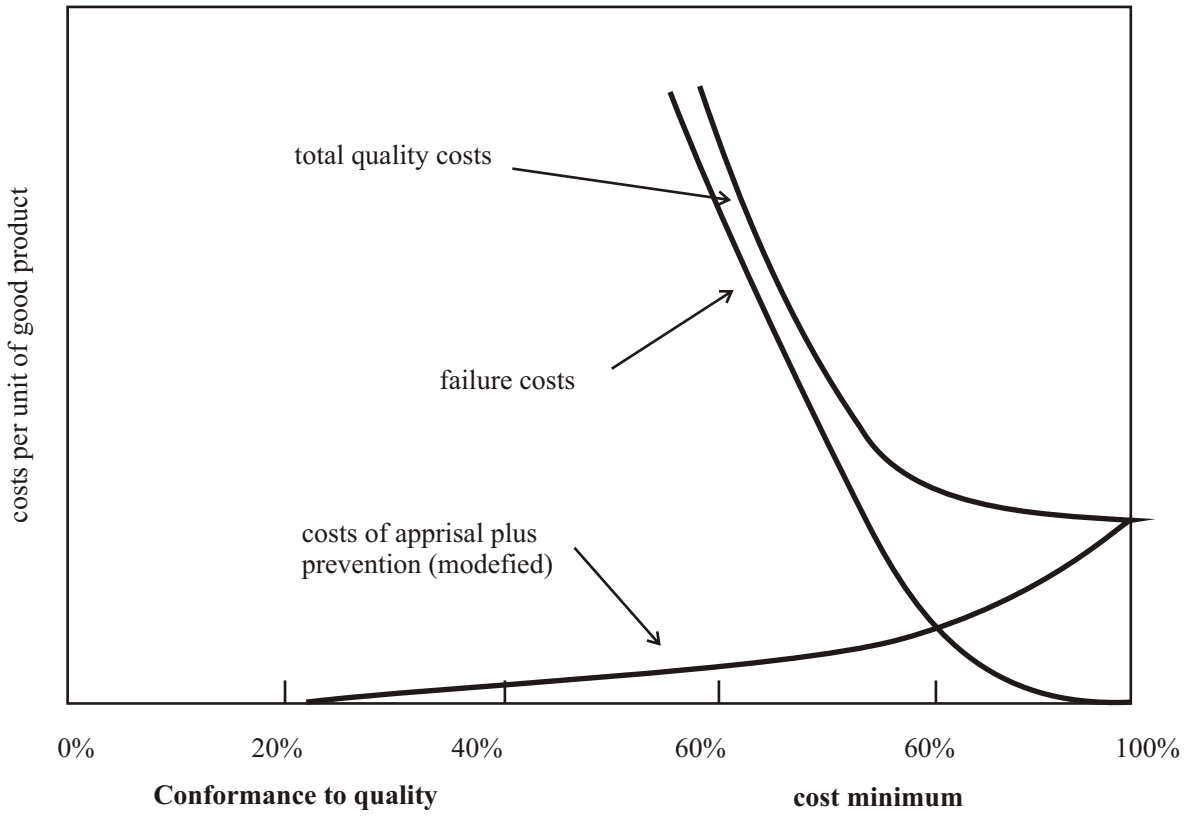


**Figure 1:** CoQ Model – Modern

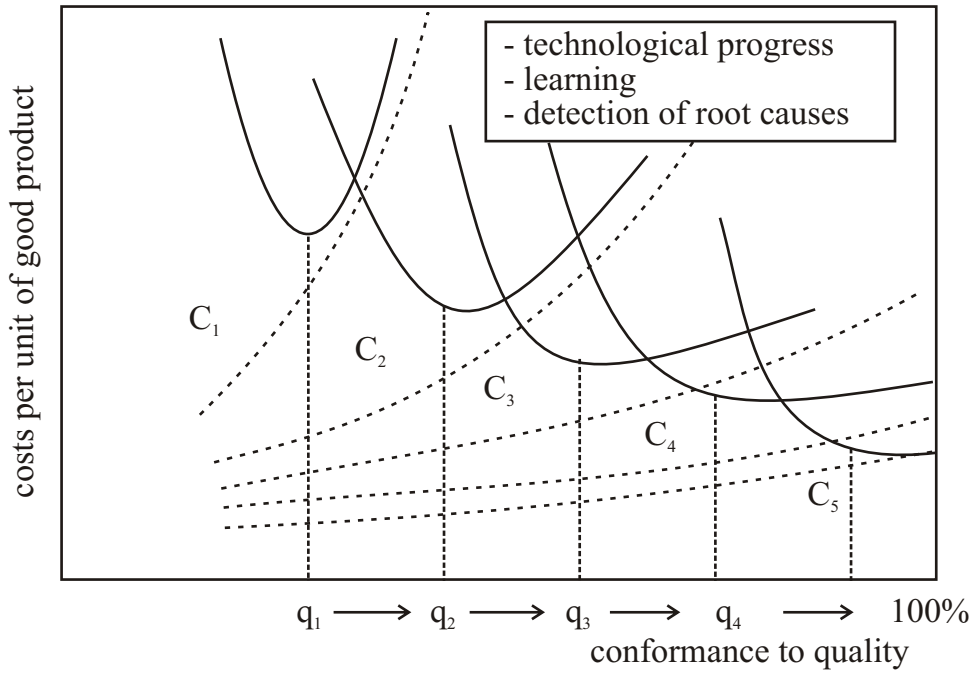


**Figure 2:** Model Proposed by Freiesleben, J (2004).

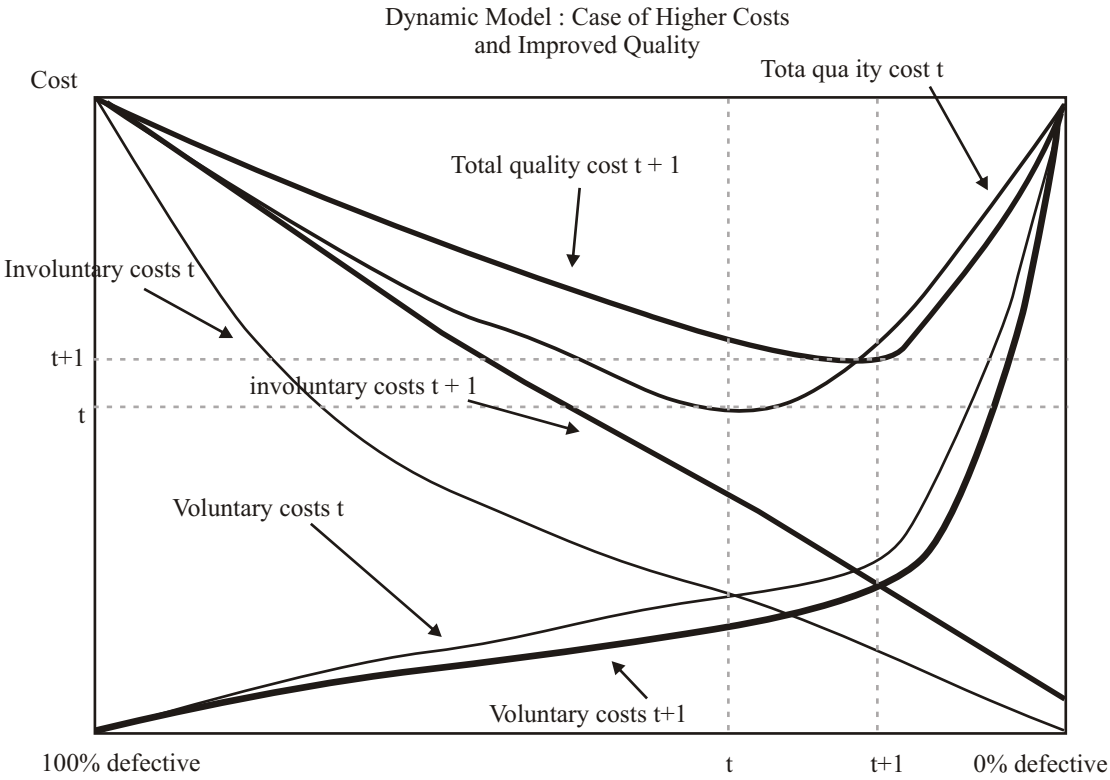


**Figure 3:** Model by Prasad.S and Tyson.T, *(1995).*

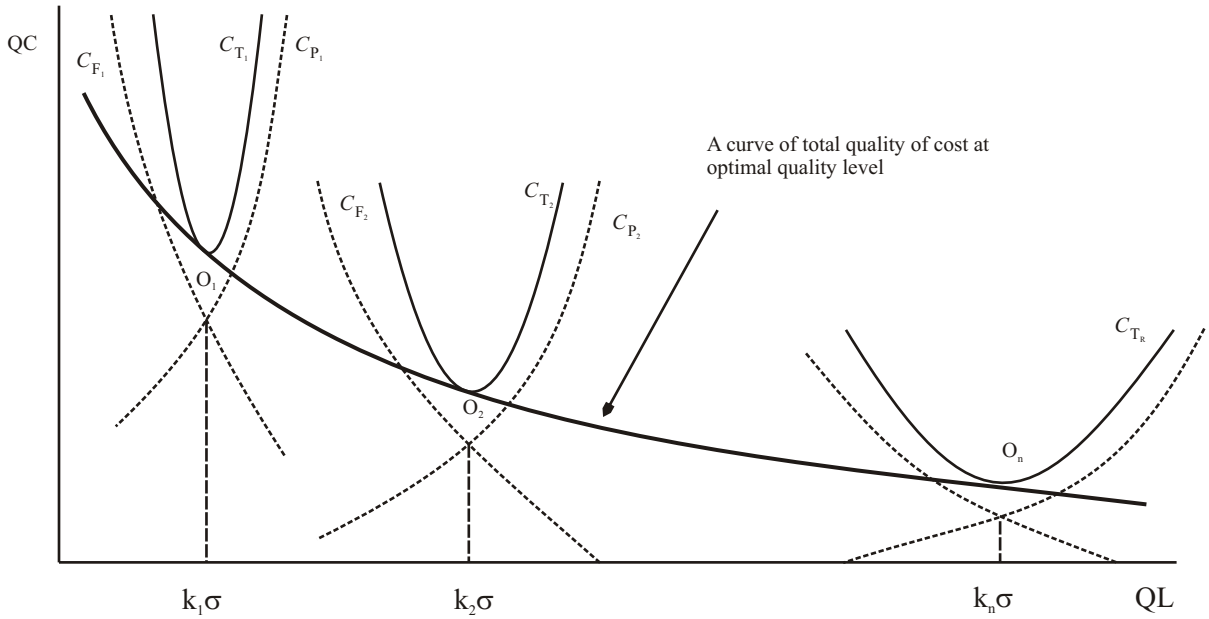


**Figure 4:** The COQ model on different levels.

**Model proposed by Yumin Liu (2007)**

*Advantages and Disadvantages of various CoQ models*

PAF model of measuring CoQ has been used successfully by various organization (Campanella 1999, Purgslove & Dale 1995, 1996).

It has been discussed that the focus of P-A-F is cost reduction. The PAF model needs to be complemented by other approaches quality costing like JIT and SPC (Porter & Rayer,1992). The failure cost should include the 'cost of losing a customer' as the product has failed to meet the expected performance level. The success of this model will depend upon the interdepartmental co-operation.

Most of CoQ measurement systems used do not trace quality costs to their sources which prevent the management from identifying the area where improvement in quality is possible (O'Guin, 1991). In PAF model the quality activity is identified solely with QA, inspection and test departments. There are various prevention activities which are required to be under taken for ensuring quality but are not part of defined prevention costs. The PAF model does not include intangible cost. Some quality cost cannot be classified easily as per the PAF model (Porter and Rayner, 1992).

Tsai (1998) says that activity based costing (ABC) defines activities as value added or non-value added. It has been found that in most CoQ systems do not have appropriate method to allocate overhead costs to CoQ elements and it is difficult to identify the source of quality cost. ABC can help to overcome these difficulties. Freeman (1995) discusses micro-simulation approach to quality analysis. Freeman, (2008) discusses the use of available software packages for quality costing simulations using QCOST & TQMSS software. The PAF models can measure costs within the department but not between the departments. It is difficult to collect the cost of personnel other than quality department for quality related activities (De, 2009).

**Conclusion:** It is difficult to find a generic model that fits different kinds of industry. Further, it requires expertise to apply the given model to an industry. From the literature it is clear that the each industry is required to modify the available models as per the needs and ease of application.

*Measurement methods of Cost of Quality*

The critical aspect of quality is measurement and reporting the related costs. An organization generally does not attempt to collect data for quality related costs because of lack of understanding regarding the concept of quality costing, lack of proper information, lack of organizational support. The quality costing data is of immense help to the Managers in decision making and in calculating the effect of any decision in monetary term (Dale & Plunkett 1999, Halis and Oztas, 2002). Success of any quality management program needs proper planning and control. This requires CoQ reporting for performance measurement. The importance of quantification of CoQ has been highlighted in the literature (Juran 1952, Yang 2008, Krishnan 2000). To establish quality improvement efforts it is required to identify and organize quality related costs (Desai, 2008). According to Crosby (1979) the cost of not conforming to the quality may be 20% of the cost of sale for any manufacturing organization. Appraisal cost is about 20% and failure cuts about 70-80% of the COQ. The decision regarding the various elements of cost of quality varies from one organization to other. Crosby (1979) recommends that the management should analyze the various costs and quantify them under different headings as per the requirement. The identification of failure elements is unlikely to give complete cost of quality which was discussed by Crossby (1979). As the CoQ program evolves and matures the various elements will be developed, modified and clubbed together to suit a particular industry.

The cost of quality figures helps to generate the support of the top management and ultimately to involve people at all level for making improvements. The cost of quality helps in identifying type of defect, location of defect and cost (Bain, 1989). Thorne (1990) recommends some simple methods like collection the quality cost by defect/ labour time. Johnson (1995), Turney (1991) gave a cost assignment view to activity based costing. The quality costing system adapted by any organization should fit in organization's culture (Pursglove and Dale 1995).

Tsai (1998) discussed the measurement of cost of quality using activity based costing. (Petty 1997, Ross 1998) analyzed that most of the organizations do not have system of collecting CoQ from the available cost sheet. Some organizations don't have proper support from management for a collecting CoQ. Pursglove and Dale (1995) discussed that in some cases the collection of external failure cost involved a considerable amount of manual effort due to which organizations try to avoid these. The quality cost can be used for allocating resources for improvement, identify the areas and monitor quality targets (Pursglove and Dale 1995).

Dale & Plunkett (1999) listed the methods for collecting costs like Departmental interviews, process mapping, checklist of cost elements, etc. It was found during the collection of information regarding CoQ that line managers and operators respond honestly than senior managers (Roden and Dale 2000). The elements which contribute most to the failure cost are scrap & rework. The SPC is best method to reduce scrap & waste. In a case study by (Roden and Dale, 2001) in small engineering company it has been found that quality cost collection requires support from senior management. Expertise is required to collect cost of quality which is not always available in all organizations. Roden and Dale (2001) used Departmental interviews and departmental study for calculating cost of quality. Use of time sheets for all the workers resulted in improved reporting of quality costs.

Eldridge and Balubaid, (2006) discussed that ontology can be used as a basis for the knowledge management solutions that would support collection of quality costs.The ontology can be used by quality managers to collect and manage quality costs. The data collected using ontology can be accessed and used by the employees of the companies (Civi, 2000). The major steps for measuring cost of quality are to identify the activities due to poor quality, decide method to identify costs, collect data and estimate costs, analyze and decide the action to be taken for improvement (Defeo, 2001).

The hidden CoQ includes loss of customers due to poor quality and indirect labour cost. These kinds of hidden costs go unreported and not measured (Wheldon and Ross 1998). Hidden cost of poor quality can

be between three and ten times visible costs. Krishnan (2006) discussed that major part of Internal and external failures are difficult to record. Some amount of wastage is normally considered as part of the process and assumed to be unavoidable. Uyar ( 2008) in a case study found that 30% of the respondents had a view that creation of COQ system is responsibility of finance department, 30% said it is quality department, around 13% chase production and 11% production control. Yang (2008) states that most of companies are not able calculate the actual CoQ as their accounting system is not able to calculate all the quality related costs. Many quality managers fear misinterpretation of quality cost data. (Keogh *et al.*, 2003). Collection of cost of quality is a joint responsibility of finance/ accounting and quality departments (Mandal and Shah, 2002).Cheah *et al.*, (2010) has used various Techniques like interview, observation, documents available from various departments for collection of various quality costs. The quality cost available under the heading of prevention, failure, approval and the hidden quality costs like machine, cost of erroneous documentation, cost of holding extra inventory, loss of sale, claims made by customer under warranty, etc., were calculated using various methods.

It has been found that (i) the prevalent accounting system was not able to capture all the quality costs (ii) most of the employees tried to attach quality costs with quality assurance department. The cost which are impossible to measures/ their measurement will cause delay in the system should be avoided.

**Conclusion :** The collection of data for various quality costs is a cumbersome process. The industry needs to simplify the collection method. There needs to a clear understanding at all the levels in the industry that collected data will be used for the improvement in quality and reduction of cost. The support of the top management is required for collection of CoQ

*Relationship between various components of CoQ and Organization performance*

Quality cost analysis is the most important part of Quality cost management. The analysis will reveal the status and indicate the direction of improvement required in the process (Hou, 2011).

It has been found during the interaction with various companies that there is tendency to hide the quality costs because it will expose the inefficiency of the system (Gryna, 1988). The finding of hidden quality costs by the organization can be benefited only if some remedial measures are taken to reduce or estimate those costs. In an empirical study it has been found that that percentage identified non-conformance cost decrease by 50% over a period of six years (Porter and Rayner, 1992). The internal failure contributed maximum to the quality cost about 70%, external failure 14% and prevention and appraisal for 18% (Pursglove and Dale, 1995).

The quality related cost of the activities like rectifying errors, reprocessing, dealing with the customer complaint may be as high as 20% of sales (Schneiderman, 1986). Porter and Rayner (1992) discussed that for any manufacturing process it is always cost less to detect a fault at an earlier stage and cost of an error increases as we move ahead in a manufacturing process. It says that in case of computer program which has been released in the market, the cost of correcting the error is sixty times higher than the cost of correcting it in initial design stage. Burgess, (1994) using simulation has found that if prevention cost is varied we get optima at some point near to 99% conformance level. This means that any increase in the prevention cost will not result in the 100% defect free process. If prevention cost and appraisal cost are varied over a period of time w.r.t. conformance level of quality, the combination which gives minimum total quality cost and maximum possible conformance level is minimizing appraisal cost (~zero) and maximizing prevention cost. It has been found that 84% of the organizations measured both internal and external failure cost but only 50% measured prevention and appraisal costs. It is difficult to measure prevention and appraisal costs separately (Gupta and Campbell 1995)**.** Only 37% of the respondents made alterations in the accounting system to measure COQ accurately.

Chauvel and Andre (1985) performed hypothesis testing related to relationships between quality cost components and found that the prevention activities have a direct and positive influence on the profit margin. Harrington (1987) says that as prevention cost increases, the total number of errors will decrease

resulting in reduced the total error cost. Investment in appraisal will help in detecting the error. Companies like Motorola and Xerox have achieved almost defect free production with a decrease in quality costs (Carr, 1992 and Flynn, 1992). The learning & maturity of quality system will result in lowering of costs.

Carr and Phnoemon (1994) in a study found out that internal failure cost is most expensive and prevention is the least expensive quality cost component. It has also been found that as the size of the company increases, the quality cost decreases. An improvement in quality conformance will result in the decrease in prevention, appraisal and failure costs (Thomas, 1994).

An increase in appraisal and prevention costs results in a reduction in failure cost which will subsequently result in improved level of quality and productivity ((Feigenbaum (1991), Gryna, (1999) and Harrington (1987)) . With the increase awareness about quality systems there is a general improvement in quality level and the need for inspection decreases. (Thomas,1994).

Process model was implemented and areas for improvement were identified by identification of non-conformances (Goulden and Rawlin, 1997). Lorente *et al.*, (1998) has shown that other factors remaining same the continuous prevention activity leads to improvement in quality and reduction in cost. The continuous prevention activity may not necessarily reduce costs over a period of time as external quality requirements may increase.

A certain percentage of rejection is considered as part of process and until the rejections go beyond the preconceived percentage, the failure cost is not calculated (Moen, 1998). There are four stages of quality management described as inspection, Quality control, Quality assurance and TQM. The author suggested that the cost of quality technique is being used by the organization when it reaches the advanced stage of the quality management. There is an increase in prevention activities and decrease in inspection activities in the TQM stage **(**Rapley *et al.*, 1999). A survey indicates that only 26% firms measures COQ. Some quality certified firms were not ready to adopt COQ reporting (Oliver, 1999).The author has used simulation model to calculate the cost of quality taking into account process variability. It has been found that the total CoQ is maximum when the detection rate is zero and it decreases with the increase in inspection (Krishnan *et al.*, 2000). It has been found that only 33% of the companies employing Quality program calculate cost of quality The survey showed that the trend of increasing use of Quality costing increases with the increase in the size and sophistication of the quality management practices of the organization (Prickett and Rapley 2001).

It is better to focus on internal & external failure cost than on appraisal & prevention cost (Shepherd, 2001). Appraisal and failure costs are avoidable and add to overall cost of product thus affecting competitiveness (Godden, 1996). Prevention cost is investment of an organization to do things right the first time. It includes the cost of finding the qualified vendors, training, developing quality producers, etc.,(Bain, 1989).The external failure cost will affect the reputation of the company and may result in loss of sales. The expected quality control technique costs, expected process control costs associated with the technique, product inspection cost and cost of deviation (Omar *et al.*, 2010).The management should promote the interdepartmental coordination for quality improvement studies and its evaluation **(**Halis and Oztas, 2002).

Only 10 to 15% of the Indian automotive organization use quality cost for improving quality performance (Khanna, *et al.*, 2002)**.** The survey conducted in the in six organizations found that PAF and process model was being used under different nomenclature. The feedback system is being used to take remedial measures and initiate preventive actions (Keogh *et al.*, 2003).An empirical study using Pearson Correlation Coefficient found that there is inverse relationship between (prevention cost + appraisal cost) and failure costs. There is an increase in quality if prevention cost + appraisal cost increases. Also as level of quality increases failure costs decreases. There is an inverse relationship between level of quality and appraisal cost. It has been found that quality cost is 3.67 percent total sale. The scrap costs are caused by

excessive tolerances, machine downtime and process changes (Omachonu and Suthummanon, 2003).Sower and Quarles (2003) discussed that the reason for not implementing quality cost systems were lack of knowledge and lack of management support. Miguel *et al.* (2003) conducted a case study to measure warranty costs. The warranty costs include cost of replaced components, repair cost, transportation costs, invoice cost and packaging costs. Banford (2004) conducted a case study in a footwear company. The cost of quality per pair of shoe was calculated. The COQ data was used to reduce major cause of footwear failure.

Schiffauerova and Thomson (2006) discussed about the quality cost practices of different industries belonging to different sectors. A telecommunication company uses activity based costing to determine cost categories , multinational microelectronic company does not measure CoQ, an aerospace company tracks all non-quality events, finds its root cause and takes corrective action. It has been found that all the companies strive for very high quality but a few apply formal CoQ method. Company using CoQ methodology successfully has achieved 40% reduction in the failure cut over 18 months.

Fuzzy logic was used to overcome the problems faced by the industry in quantifying the costs under various heads of PAF model. The study has helped the industry in reduction of non-conformance costs and optimal resource allocation (Sharma *et al.*, 2007).

Uyar (2008) conducted a study involving 500 companies in Turkey and found that 75% of the respondents had a perception that cost quality is around 5% of turnover while Willam *et al.,* (1999) found it 5 to 25 percent. Statistical analysis of survey data (Uyar, 2008) says that companies implementing CoQ system have higher sales, adopt TQM system and likely to have ISO certifications. In a case study it has been found that the total Cost of Quality decreases by about 25% on implementation of CoQ technique ( Desai, D. 2008).

Kiani *et al.,* (2009) has used system dynamics approach with the help simulation software to predict the future cost of quality. Results of an empirical study shows that an increase in the prevention cum appraisal cost will decrease the total cost of quality. With the increase in prevention cost the failure cost decreases which will result in the improved level of customer satisfaction. Arvaiova *et al.,* (2009) conducted a survey to investigate the use of CoQ programmes in telecommunication industries of UK. It was found that 39% companies which do not implement the quality cost systems have a view that their costing system is capable providing data on quality costs, 30% organization says that they have no concept of quality costs system. 33% organisations implemented quality costs systems to increase productivity, cost reduction, initiate improvement action and increase competitiveness.A study in a small company suggests that 55% of the prevention costs is derived from the time spent by the personnel. The cost of inspection and testing is more than all other appraisal costs added together. Scrap, rework and cost of design changes account for most of the internal failure costs. The scrap generated due to given allowances in the manufacturing process is not the part of the scrap generated due to quality failure (De, 2009). It has been shown in a study using simulation that the for a two stage manufacturing system the cost of quality is highest when inspection is done after completion of finished products (Omar *et al.*, 2009).

Cheah *et al.*, (2010) discussed the identification and analysis of hidden poor quality cost in a continuous process manufacturing company and in a case study found that the hidden cost of quality is most double than the CoQ normally calculated. In some cases hidden quality costs were more than three times than the CoQ normally calculated (Giakatis *et al.*, 2001). A case study undertaken in a continuous-process industry reveals that opportunity factors account for 83.08 percent of the total revenue lost.

A survey in small scale industries (Chopra *et al.*, 2011) for measurement of cost of quality using Pearson Correlation Coefficient found there is strong negative correlation between prevention cost and internal failure cost. Luther and Sartawi (2011) conducted a survey was conducted in 88 manufacturing firms in Jordan to find the best practice of quality costing. These best practices have been divided into three groups i.e. collecting, measuring and classifying data, analyzing report and classifying data, matrices.

**Conclusion :** It has been found that in the various case studies that if prevention and appraisal cost is increased the failure cost decreases. It is difficult to predict the exact relationship between various components of cost of quality as it depends on the type of industry, level of implementation of quality program, method of collection of data, interdepartmental coordination and top management commitment. To predict the behavior of the failure costs with the change in the prevention and appraisal cost requires complete understanding of the CoQ technique. The support from the top management and interdepartmental coordination is vital for successful implementation of CoQ technique.

**Conclusion and future direction**

The literature review suggests that although CoQ is considered to be the part of TQM process but finds a limited use in industry. The published case studies prove that use of CoQ technique not only helps in measuring the various components of quality cost but also helps in reducing the failure costs. Companies need to modify the basic models like P-A-F to suit their needs. The method of collection of quality costs depends on the type of industry. The cost of the components like hidden failure costs, effect of failure on the brand image of the organization are difficult to calculate. Detailed studies are required to simplify the process of collection and measurement of quality costs. Sector wise case studies should be undertaken to show the utility of the CoQ technique in reducing the cost and improving productivity. The CoQ technique will help to quantify both failure and improvement. Although the standards are available for defining the sub-elements of the quality costs but each industry uses its own methodology. The companies use different base for calculation of quality costs which causes inconsistency among the companies and comparison becomes difficult. The common base for calculation of cost elements should be made available to the organizations. The training of the employees at various levels and the support from the top management is required for successful implementation of CoQ technique. Further, very little work has been done to find the effect of different components of prevention cost and appraisal cost on failure cost. CoQ technique is not being used by the various organizations especially small & medium level due to lack of knowledge and limited resources. CoQ technique is an important part of the TQM. Top management should be made to understand that it is part Quality Management program and not just a costing technique.

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