COST OF QUALITY IN CONSTRUCTION INDUSTRY

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Abstract *In quality management, the use of cost as a measure of performance has been recognized and this is usually known as the Cost of Quality (COQ) or Quality Cost. The usefulness and importance of knowing the Cost of Quality in manufacturing are well known. This is not so in the construction industry. Since there are differences in the nature and characteristics of the processes and environments of the two industries, it is difficult to assess whether similar quality cost concepts can be used in construction. One can only speculate that if the manufacturing industries can get benefit from quantifying quality costs then there should also be benefit to construction. Theoretically, it seems easy to apply the quality cost concept into the design and construction phases of a civil engineering project. In practice, it is quite complex and can be difficult. This paper initially presents a methodology for assessing the 'complete' COQ for construction projects. It also presents COQ model for determining optimum level of quality cost. Finally, techniques to reduce the COQ in construction industry are investigated.*

Keywords: *Quality Costs, Cost of Quality, COQ Models.*

Introduction

In order to improve quality, an organisation 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 possible cost. This can only be obtained 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 as an important issue for achieving quality excellence (Vaxevanidis and Petropoulos, 2008).

In the construction industry, the organisations generally do not have in place an effective organisational learning mechanism that can be used to stimulate best practice, primarily because quality management principles and tools have been neglected. Therefore, little is known about quality cost and the impact it has an organisation's performance and competitiveness. With respect to work, it is suggested that most organisations have learnt to accept it as part of their own and a project's performance. As a result, it has become an endemic problem in the construction industry.

In Australia, the Construction Industry Development Agency (1994) has estimated the cost of rework to be 12 percent of project cost. Thus, if a 12 percent rework value is applied to the annual turnover of the Australian construction industry, which is estimated at $A32 billion per annum (Construction Expert Group 1993), then the cost of rework can be approximated at $A4 billion per annum. With rework so large, the net benefits of building and implementing best practice are substantial (Love, 2000).

The construction industry lacks exposure to the tools and methods, which have been applied successfully in the manufacturing industry to promote the management of quality. Existing tools involves a cycle of measuring, comparing and action. None of the tools provides a mean to prevent quality failures. Researches have found that the absence of a quality focus throughout the construction often results in rework, which invariably takes the form of changes, errors, and omissions and as a result adversely affects project performance (Song and Lee, 1990).

Definition of Cost of Quality

Considering that there are different views on quality and what it is that actually causes costs, there are different concepts for the quality costs, additionally; each concept is defined differently by many authors/ researchers.

One author who uses the concept of quality cost is Campanella, who defines quality cost as "the total cost incurred by (a) investing in the preventing of non-conformances to requirements, (b) appraising a product or service for conformance to requirements, and (c) falling to meet the requirements (Campanella J, 1990). He has the opinion that quality costs, and therefore all costs connected to working with quality are called quality costs.

Lund et al. also discuss quality costs, and their definition is, "the time and those other resources that a company must use in order to preset requirements". They divide the quality cost into two categories where the first one is cost needed to ensure that quality requirements are upheld, and the second category is costs that are a result of deviations from the requirements (Song and Lee, 1990).

American quality consultant Philip Crosby's approach begins with discrediting the assumption that there is a correlation between quality and cost. Crosby stresses the price of conformance and the price of non-conformance classification. He defines the Cost of Quality 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 things that are done right the first time and the price of nonconformance is the money wasted when works fails to conform to customer requirements. (A. Schiffauerova and V. Thomson, 2000).

Abdul Rahman (1995) also discusses quality costs, and their definition is "cost incurred to ensure quality requirement and evaluate that the quality requirement are being met" and "any other cost incurred as a result of poor quality being produced."

Cost of Quality Categories

In the early 1960's Armand Feigenbaum categorized quality costs into the categories: prevention, appraisal, internal failure, and external failure, and then number of author has followed his reasoning. Figure 1 indicates COQ Categories given by Feigenbaum (Feigenbaum, 1983).

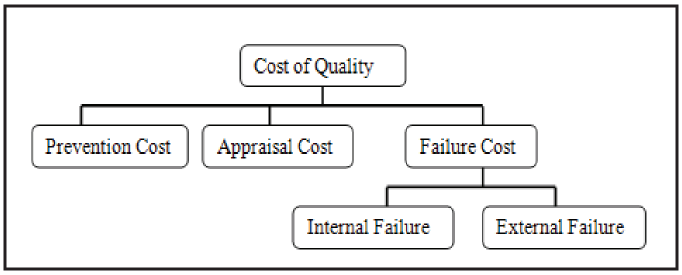

Figure 1. COQ Categories

Prevention Cost

Prevention Costs are costs related to all activities to prevent defects from occurring and to keep appraisal and failure to a minimum. These costs include new product review, quality planning, supplier surveys, process reviews, quality improvement teams, education and training and other like costs (P.E.D. Love and Z. Irani, 2003).

Appraisal Cost

The appraisal costs are those costs that occur because of the need to control products and services to ensure a high quality level in all stages, conformance to quality standards, and performance requirements. The control can take place before the production phase, during it or right afterwards. So, the appraisal costs are due to appraisal activities which hinder errors from being passed on to the next level in the process or to the customer. They do not reduce the number of errors, but they reduce the number of errors that reach the customer. These costs include first time inspection, checking, testing, process or service audits, calibration of measuring and test equipment, supplier surveillance, receipt inspection, cost for evaluation of business etc.,

Failure Cost

The failure costs are the costs resulting from products or services not conforming to requirements or customer/user needs, i.e. problems or errors have occurred and cause the product or service to be of poor quality. They are further divided into internal and external failure costs.

The internal failure costs are the costs caused by deficiencies found before delivery of products and services to external customers, which otherwise would have led to the customer not being satisfied. Deficiencies are caused both by errors in products and inefficiencies in process. Such costs can include costs for rework, delays, redesign, shortages, failure analysis, retest, downgrading, downtime, lack of flexibility and adaptability, poor competence, and poor management.

The external failure costs are the costs caused by deficiencies found after delivery of products and services to external customers, which lead to customer dissatisfaction. These can be costs for complaints, repairing goods and redoing services, warranties, extra costs for customers, bad will, and losses due to sales reductions and environmental costs (Logothetis, 1992)

Detection of Cost of Quality

There are numerous methods for calculating quality costs. For example, costs can be classified as either cost of conformance or non-conformance. Conformance costs include training, indoctrination, verification, validation, testing, inspection, maintenance, and audits. Non-conforming costs include rework, material waste, and warranty repairs. However, the most widely accepted method of determining quality costs in construction is the traditional prevention– appraisal–failure (PAF) model (ASQC Quality Cost Committee, 1974).

The COQ methodology is laid out broadly in BS 6143 – Parts 1 & 2 (British Standards Institute (BSI), 1990; 1992). These documents introduce the process cost model and prevention, appraisal and failures (PAF) model. Figure 2 illustrates the traditional theory underlying COQ and shows how cost and quality operate as a trade-off within the COQ methodology. They stress the link between cost and quality – that it is of little use to achieve the required quality at a cost that is prohibitively high and uncompetitive. Equally, achieving a competitive cost by degrading quality is also inappropriate. Together, costs that arise through the need for prevention and appraisal activities and costs due to failures represent the unnecessary additional cost incurred in the product if all processes could operate correctly the first time. (Mark Hall M, 2001)

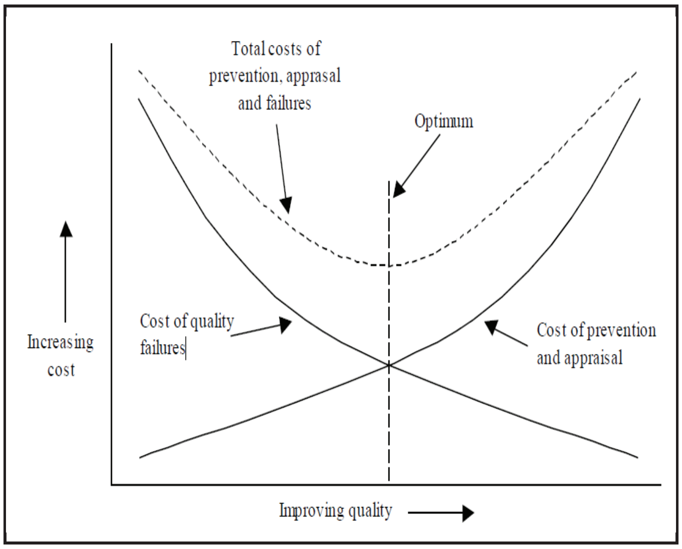

Figure 2. Traditional PAF Model

The optimum defect level shown in Figure 2 is where the increasing cost of the prevention and appraisal curve converges with decreasing failure cost curve. This optimum point will vary according to the nature of the project: the more severe the consequences of failure, the higher the requirement for quality performance. The quality axis should be defined more precisely as percentage conformance to specification and then one should recognize that, while the relationship in Figure 2 is broadly appropriate for expressing static relationships, one must, over a longer time-frame, recognize the dynamics of changing technology and knowledge and how even the acceptable degree of compliance with specification can change.

Recognizing these dynamics, the objective is not just to estimate the cost curves for prevention and appraisal and failures in order to find the optimal level of quality, but to link identified failures and their causes with technological or work process improvements such that failure costs are driven, over time, to be as near zero as possible (perhaps also with a tighter agreement on specifications). If materials and processes can be relied upon to radically reduce the incidence of failures, this would enable a reduction of prevention and appraisal activities such that almost all the PAF costs could be removed (although there will always be some prevention costs associated with, for example, health and safety regulations) (Mark Hall M, 2001).

For calculating the cost of quality, the data related to prevention, appraisal, and failure costs should be collected based on discussion and interviews with key personal and documentary sources such as, variation registers site instructions, request for information, audit reports, progress reports, non- conformance reports and customer compliant register, monthly performance reports, test reports, and observation. Background information about project is obtained from the discussions with quality assurance manager, quality system engineer, site engineer and project manager. Subcontractors are interviewed at the work face to obtain details relating to failure events. Direct observation and documentary sources provided by the contractor, customer, subcontractor, and supplier are also used to derive data. In estimating the failure costs, three elements need to be considered. These are man, material, and machines. Materials are estimated relatively easily based on the extent of the failure. The price of materials needed to rectify the quality problem is determined from the bills of quantities or the prevailing market prices. Man and machine costs are calculated based on the time estimated to rectify the problem. Then Cost of Quality (COQ) can be calculated using following equation.

Total COQ = PC+AC+IFC+EFC

where PC- Prevention Cost

AC- Appraisal Cost

IFC- Internal Failure Cost

EFC- External Failure Cost

The most construction firms have not measured all three cost categories; instead prefer to concentrate only on failure costs.

Numerous studies have attempted to quantify the rework costs in civil engineering projects. Generally field engineers inspect finished work and measure the quantity of rework if required on site. Rework cost is estimated through mathematical operation of measured rework quantity and unit cost below.

Internal-failure quality cost unit price = Demolition unit price + Disposal unit price + Rework unit price

Demolition unit price is determined by cost from labour and equipments required for removal of defective finished work. Disposal unit price, if deemed required, is estimated based on the actual expense. Unit price specified in the control budget or contract document is applied as the rework unit price. Measurement of rework cost basically follows the quality control process. (Song and Lee, 1990)

The organisations in construction industry spend money for prevention and appraisal, but the magnitude of these costs are very less when compared to the total cost of the project. It is widely believed that if prevention and appraisal costs are more, i.e., cost of conformance is more the failure or the non-performance cost will be less. Typically while the conformance costs are controllable variables, the non-conformance costs are the resultant variable (Mukhtar Che Ali, 2010).

Reduction of COQ

Many organisations consider improving quality as the best way to enhance customer satisfaction, to reduce manufacturing costs and to increase productivity. For this, the COQ must be reduced. Monitoring and controlling COQ are becoming critical activities of quality improvement programs (Lionel Boxer, 2004).

It makes no difference if this is done by reducing all three components or by increasing some and decreasing others enough to lower the total cost. To have a significant impact on the total cost; the cost of failure must be reduced, and the usual strategy for achieving this objective is to spend more on prevention. This concept is given in Figure 3.

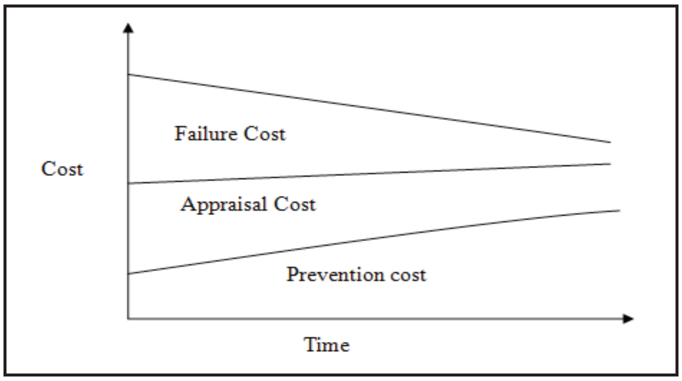

Figure 3. Reduction of COQ

Spending more on prevention and appraisal costs will reduce the failure cost over the time. Further spending on prevention will reduce the appraisal cost also. As Figure 4 indicates, spending on prevention also prevent poor quality pays. Therefore most failure costs can be eliminated with little investment in prevention and with timely inspection.

John R Parker describes 1:10:100 rule for reducing the Cost of Quality. According to him, one dollar spent on prevention will save $10 on appraisal and $100 on failure costs. This rule helps one to prioritize expenditure on prevention, which is sure to bring in greater returns (Parker, 2009).

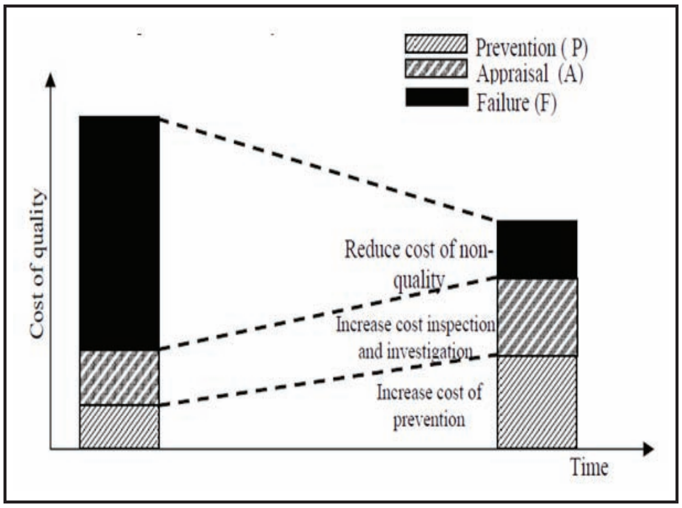

Figure 4. Prevention of poor quality pays

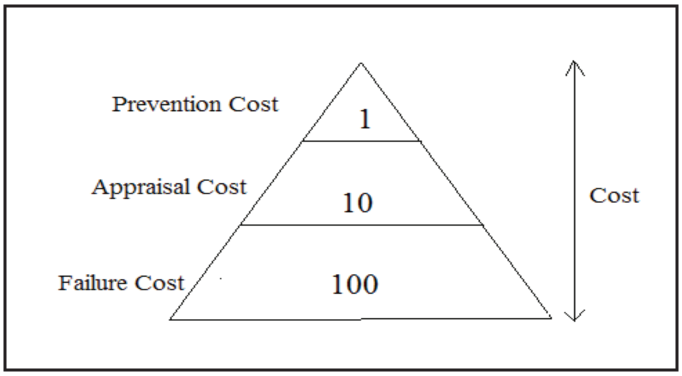

Figure 5. 1:10:100 Rule

According to Dale and Plunkett (1991), 95 percent of quality cost is usually expended on appraisal and failure. The expenditure on appraisal adds little to the value of building work. It only serves to increases the cost of construction. The failure cost, at least, may be regarded as avoidable. Reducing the failure cost by eliminating causes of non conformance can also lead to substantial reduction in appraisal cost (Dale and Plunkett 1991).

If a company wants to reduce defects and by this reduce the cost of poor quality, the cost of good quality would have to be increased, meaning higher investments in any kind of checking, testing, evaluation, training of operators, etc. Following the Six Sigma philosophy, however, of building quality into process, service and products and doing things right the first time, the increase of the cost of good quality, while striving for zero defect performance, can be smoothed if processes get better.

Lam et al (1994) claim that quality cost can make up from 8 to 15 percent of the total construction cost. In a publication by the Construction Industry Development Board (CIBD) entitled Managing Construction Quality, an average contractor is estimated to spend between 5-10 percent of the project cost doing things wrong and rectifying them.

Improvement strategy using COQ Data

Dennis Beecroft prescribed an improvement strategy using the Cost of Quality data. According to him, COQ data is useful as a measurement tool. This data can be used very effectively to identify and prioritize improvement opportunities and then, once a change is made, track the impact of the change. The strategy for using Cost of Quality data for improvement is to attack the failure cost and drive them to zero. Implementing this strategy, result in problem solving and improving or changing the process that produces the product or service. The money spent to investigate and correct the problems that result in the failure costs are prevention dollars. By capturing these dollars the organisation can determine the bottom line benefit of eliminating the failure cost (Beecroft, 1996).

Appraisal cost activities should be minimized, as they are non-value added. They are defined as non-value added as they do not change the quality of the product or service being evaluated. The more inspections or verifications conducted the less likely poor quality will be shipped to the customer. However these activities do not prevent the poor quality from being produced. By spending more money on prevention activities, appraisal activities can be reduced and this should also lead to lower failure cost (Beecroft, 1996). A Cost of quality model is shown in Figure 6.

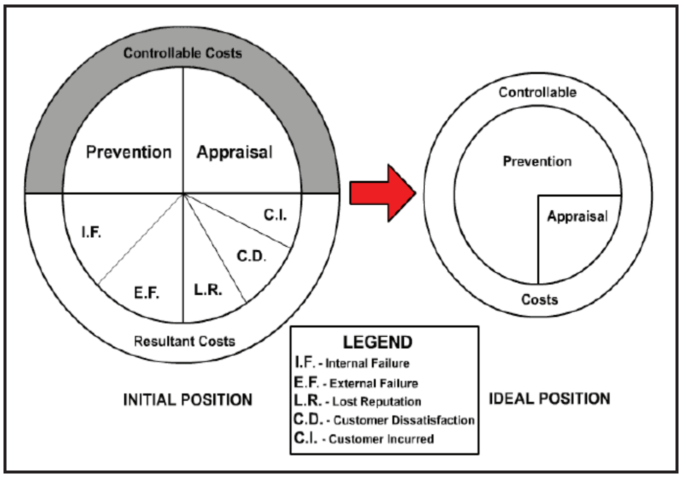

Figure 6. Cost of Quality model

The initial position shown on the left and the ideal position is shown on the right. The initial COQ model consists of both controllable cost (prevention and appraisal and resultant cost-internal and external failure, customer incurred, customer dissatisfaction and lost reputation cost). An ideal model has zero failure cost. By eliminating the failure cost the customer incurred customer dissatisfaction and lost reputation cost would also be zero. All the cost would now be controllable-prevention and appraisal with preventing being larger than appraisal. The ratio of prevention to appraisal would be very dependent on the type of business involved.

Conclusion

This paper attempts to address the concept of Cost of Quality, especially as an aid to identifying and reducing failures during construction of Civil Engineering Projects. Quality issue, as a central one from the point of view of user, nowadays, is a critical competition factor. Each serious effort to improve quality is not only to meet the user's demands as regards quality, but also to achieve this at least costs possible. Reduction of these costs is possible only if measures are also identified.

Quality cost provides management with an assessment of how quality has been managed and identifies problem areas. It can also be used as a tool to attract the attention to the presence of unplanned costs and the cost of failure. The study through literature review has brought out the importance of quality costs and how these can be captured in construction industry.

Some of the key conclusions that have been brought out by the study are the failure events could have been avoided had some preventive or appraisal actions been taken. The process of eliminating such failure costs reduces the need to appraise since lesser defects occur. In other words, the quality costs system is to help management to determine which area of operation requires preventive measures to be carried out so as to prevent the recurrence of defects. Therefore, knowing quality costs reduces quality costs. It is always cheaper to prevent than to rectify.

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