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Quality Assurance

Term Paper

Understanding and Measuring the Cost of Quality on Construction Projects

Submitted to
Dr. AbdulAziz Bubshait

Prepared by
Jihad Farhat
CEM Student
ID # 220120

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Abstract

One of the most effective tools for evaluating the success of a quality management program is the measurement of quality costs which are prevention, appraisal and failure costs. A systematic approach is needed for measuring quality costs. This paper presents a methodology for assessing the 'complete' Cost of Quality for construction projects and reports on the findings. In addition, it is necessary to identify the causes and costs of rework in order to improve the performance of projects. For this reason, an understanding of the causal structure of rework cost is needed so that effective prevention strategies can be identified and such effects are reduced or eliminated.

Introduction

In the continuing global race for success, quality will lead the way. What is quality and what does it cost? In fact, there are four basic quality rules: (1) Quality is defined as conformance to requirements; (2) The system for causing quality is prevention of defects; (3) The performance standard is zero defects, and (4) The measurement of quality is the price or cost of non-conformance (Thorne, 1990).

In recent years, increasing attention has been given to improving the overall quality of construction works. Due to the success of total quality management (TQM) practices in the manufacturing industry, its application in the construction industry has received much attention. In order to quantify the benefits of TQM, quality must be measurable (Aoieong, 2002). In fact, recent research has found that effectively, QA does not improve an organization's competitiveness and performance. Only when a continuous improvement philosophy is used in conjunction with an effective QA system will organizational performance improve significantly. Without an effective quality cost system in place, performance improvements can be very difficult to identify and measure (Love, 2000).

Although there are numerous tools for measuring quality, the 'cost of quality' or quality costs is considered by both Crosby and Juran to be the primary one (Aoieong, 2002).

Studies showed that the deviation costs averaged 12.4% of the total project cost. With this high percentage of deviation costs, a slight reduction may result in significant savings. In order to do this, quality costs must be identified and assessed. Clearly, this points to the importance of knowing how and where quality costs have been incurred, so that remedial actions may be taken to prevent their recurrence, thereby reducing the costs of construction and benefiting contractors, clients and end-users. The same studies revealed that those who did measure noted that the cost of correcting defects was approximately 5% of the total construction costs. Similar results (about 5–6%) were also reported by Abdul-Rahman (Aoieong, 2002).

Objective

The objectives of this paper are:

- To introduce the reader to the Cost of Quality on Construction Projects.
- To develop a systematic approach for measuring quality costs.
- To assess the complete Cost of Quality for construction projects.
- To determine the causal structure of rework by quantifying the causes, cost, and magnitude of rework that might be experienced on construction projects.

Construction quality cost approaches by previous researchers

So far, only a few papers have been written in the context of construction on how quality costs could be determined (Aoieong, 2002). The COQ methodology is laid out broadly in British Standards BS 6143 – Parts 1 & 2 (BSI, 1990, 1992). These documents introduce the process cost model and prevention, appraisal and failures (PAF) model. They stress the link between cost and quality: 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 also is inappropriate (Hall, 2001).

Davis' approach

The cost of quality is defined as the cost of correcting deviations (rework) plus the cost of quality management activities. The Quality Performance Management System (QPMS) is based on the assumption that quality costs can be adequately tracked using 11 rework causes and 15 quality management activities (Aoieong, 2002).

Although the QPMS is simple and flexible, Abdul-Rahman stated that QPMS does not consider the effect of failure on time-related cost and knock-on cost, i.e. the cost to speed up work to make up for lost time. Moreover, the procedure does not show the specific source of problems (Aoieong, 2002).

Abdul-Rahman's approach

Abdul-Rahman developed a quality cost matrix to capture the cost of nonconformance during construction. The matrix lists such information as 'problem category', 'specific problem', 'when problem was discovered', 'causes of problem', 'extra duration needed to correct problem', 'additional cost of activity', 'amount of additional time-related cost', and 'any additional cost' (Aoieong, 2002).

Low and Yeo's approach

This approach proposed a construction quality cost quantifying system (CQCQS). The cost system is basically a documentation matrix that accounts for quality costs expressed as prevention, appraisal and failure costs. The headings of the matrix are ‘cost code’, ‘work concerned’, ‘causes’, ‘problem areas’, ‘time expended’, ‘cost incurred’ and ‘site record reference’ (Aoieong, 2002).

Barber et al.

Barber et al. developed a method to measure costs of quality failures. It was based largely upon work-shadowing. Personnel on-site were shadowed for a period of time and the quality problems encountered were recorded. Only direct costs of rework for the failures and the related costs of delay were included in the study (Aoieong, 2002).

Love and Li

They quantified the causes, magnitude and costs of rework. Data were collected from the date on which construction commenced on-site to the end of the defects liability period. A variety of sources such as interviews, observations, and site documents were used to collect the rework data, and only the direct costs of rework were included (Aoieong, 2002).

Others’ Approach

Research undertaken by Cnuddle determined the failure costs in construction by investigating the amount of non-conformance that occurred on-site. Cnuddle found the cost of non-conformance to be between 10% and 20% of the total project cost. Furthermore, it was found that 46% of total deviation costs were created during design, compared with 22% for construction deviations (Love, 2000).

Hammarlund and Josephson suggested that a large part of the failure costs found in construction projects are attributable to the poor skills of site management. From their study they found the major causes of quality failures in order of precedence to be: 1) defective workmanship, 2) defects in products, 3) insufficient work separation, 4) inadequate construction planning, 5) disturbances in personnel planning, 6) delays, 7) alterations, 8) failures in setting-out and coordination failures. They found quality failures to be as high as 4% of actual project production cost. 51% of these failure costs were design related, while 26% were related to poor installation of materials and 10% to material failure (Love, 2000).

Quality Costs

Understanding and calculating the cost of quality are a key step in building the foundation for quality improvement (Thorne, 1990).

Quality in construction is directly related to time, performance and cost, and vice-versa. A poor quality managed project can result in extra cost and time extensions. Similarly, a poor time and cost controlled project can affect the conformance of requirements, i.e. quality. It is therefore vital for project managers to understand the client's requirements in terms of cost, quality and time, and produce realistic estimates that match those requirements. 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 means to prevent poor quality. The use of prime cost as a control is limited due to its overall character. It merely exposes loss figures and does not address its nature. Cost control, an important function in construction project management, goes further. The objectives of cost control include the detection of potential cost overruns before they occur. It should be noted that traditional cost control systems used in construction do not consider the quality function and do not consider variance resulting from say, rework owing to poor quality work. Top management is usually reluctant to establish a rework account. Mistakes are buried and the extra costs incurred are treated as poor productivity. This act indicates poor management attitudes and takes away any room for improvement. On the contrary, quality costing allows cost quantification of failure events. Traditional cost control procedures needs modification to accommodate quality costing because costs used for cost control purposes can be utilized in quality costing. The quality cost concept illustrates the importance of prevention rather than merely handling failure. The implication of quality cost and its information in construction is that any decision taken early in the project will have an influence on the project quality (Abdul-Rahman, 1997).

The above literature suggests that quality management involves all aspect of a project and must be an integral component in the management of a project (Abdul-Rahman, 1997). Therefore, in order to improve quality and profit, designers, consultants, contractors and also subcontractors must do more than merely provide a minimum level of assurance to their clients. They must aim at reducing cost without sacrificing quality (Aoieong, 2002).

Quality costs are just one type of measurement that can provide management with information about process failures and the activities that need to be designed to prevent their occurrence (Love, 2000). Estimates of the cost of quality (or, more accurately, the cost of poor quality or nonconformance with specification) vary across industries and between companies. In general, unless focused efforts are taken to minimize them, they are estimated to fall between 10% and 30%, with most analyses putting them at around 20% (Hall, 2001). The price of conformance will always exist, while the price or cost of non-conformance which is usually the far greater number, can be greatly reduced, through systematic quality improvement. Clearly, extremely significant improvements in corporate profits are possible by greatly reducing the price of non-conformance. Before the start of an ongoing quality improvement program, the price of non-conformance is the major element of a firm's cost of quality – typically averaging about 20% of sales. It is the cost of doing things wrong, and it needs to be eliminated. Often it equals or exceeds a firm's before-tax profits -- meaning that profits could double by doing everything right the first time (Thorne, 1990).

Costs associated with failure arise from both internal and external sources. Internal poor quality costs increase an organizations cost of operations, for example, rework, material waste, and other avoidable process losses. However, external poor quality costs result in loss of profits: for example, contractual claims, defect rectification (rework), and the loss of future business (Love, 2000). Consistency is the most important requirement of the COQ system - even more important than absolute accuracy (Thorne, 1990).

Quality experts agree that the key to improving quality and profitability is prevention. In fact, prevention dollars can be recovered many times over through reduced appraisal and failure costs. According to the classic cost of quality model, there is an inverse relationship between prevention and appraisal (P & A) effort and failure cost/deviation correction, i.e. as more is spent on P & A, less has to be spent on correction. This is theoretically true up to a point, in that there is an "optimal level" of quality conformance that minimizes total quality cost at a conformance level less than 100 per cent good (Willis, 1996). Please refer to Figure 1.

Identifying the Causes of Poor Quality

In a very real sense, quality costs money only if we do things wrong. We need to make sure we know what we're doing before we do it. Most people don't realize how much money companies spend in doing things over again (Thorne, 1990).

Quality costs can be used to identify the causes of poor quality and to develop estimates of their direct and indirect costs. Then this information can be used to determine quality improvement initiatives, which can be directed at achieving significant cost savings and quality breakthroughs for organizations (Love, 2000). For instance, rework is waste and to improve quality it is necessary to understand the root causes of rework (Mandal, 1999).

All personnel, from top management to site staff, should be made aware of the usefulness of quality cost data to the company. The top management should also do their best to remove any negative views on the system (Aoieong, 2002).

Oberlender summarized quality costs as follows. 'Quality costs consist of the cost of prevention, the cost of appraisal, and the cost of failure: (Aoieong, 2002; Oberlender, 1993).

- Prevention costs result from quality activities used to avoid deviations or errors,
- While appraisal costs consist of costs incurred from quality activities used to determine whether a product, process or service conforms to requirements.
- Failure costs are those resulting from not meeting the requirements, and can be divided into two aspects. Please refer to Figure 2.

- Internal failure costs which are the costs incurred on the project site due to scrap, rework, failure analysis, re-inspection, supplier error, or price reduction due to non-conformance.
- External failure costs which are costs that are incurred once the project is in the hands of the client. These include costs for adjustments of complaints, repairs, handling and replacement of rejected material, workmanship, correction of errors, and litigation costs.'

Studies found that quality failures accounted for 5.84% of the contract sum while prevention, appraisal and other activities accounted for 12.68% of the contract sum. This meant that the 'value adding' proportion of the contract sum was 81.48% (Hall, 2001). Researches found that the cost of quality failures increases steadily as the project progresses until the final two months, where a sharp rise in the cost of quality failures would be evident. There are a number of explanations for this phenomenon. First, the finishes were undertaken during this period, which represented a concentration of quality failures in a short space of time. Second, supervision (prevention and appraisal costs) was scaled down during this period as staff moved to different projects, thus providing greater scope for errors and mistakes to occur (Hall, 2001).

The quality failures can be analyzed to determine cause and divided into the following categories: 1) Communications, e.g. poor information control, Misunderstandings; 2) Plant and equipment, e.g. breakdowns, punctures; 3) Personnel, e.g. carelessness, lack of training, poor workmanship, sickness; 4) Design, e.g. mistakes that 'get on to' the construction site; 5) Management, e.g. lack of planning, errors, poor organization; 6) Suppliers (including subcontractors), e.g. poor selection, errors and mistakes; 7) *Force majeure*, e.g. third parties, weather, ground conditions (Hall, 2001).

This analysis of the causes of the quality failures arising during the project should be viewed with caution. The categories simplify a more complex picture. For example, mistakes by specific individuals might be attributable to the main contractor's or suppliers' employees, and their 'root' causes were diverse, including lack of training and inexperience. Similarly, the 'root' cause of suppliers' errors may in fact have been poor selection of specific suppliers in the first instance, or poor co-ordination of different trades. This is an important point, as the tendency in viewing the figures is to attribute blame. However, their purpose is to provide an overview of the issues and indicate the direction for corrective measures (Hall, 2001).

Number of 'root' causes that indicates directions for possible improvement in the future and learning themes that, together, could lead to reduced quality failure costs on future projects includes (Hall, 2001):

- more careful selection of suppliers and subcontractors: selection on a basis of best out-turn value rather than lowest initial cost;
- in design and build contracts, a closer and earlier involvement of the main contractor in the design process with more consideration of build-ability issues;
- consideration of ways in which information from the planning stage could be transferred to the design and construction stages more effectively;
- More involvement of key suppliers and subcontractors in the design stage of the project which would mean an earlier commitment to those suppliers and subcontractors by the main contractor. This would suggest that, for certain trades and services, strategic partnering arrangements should be established;

- identification of common and recurring mistakes and errors that could be considered at the beginning of future, similar projects and where effort by site staff can be directed;
- better consideration of the training needs of suppliers' and subcontractors' employees and a coordinated, joint approach to setting training targets and seeing that these are achieved; and
- A long term strategic approach to tackling a culture of complacency that is identified to exist among suppliers of, for example, plant and certain manufactured products that are incorporated into the finished building.

Applying the Quality Cost Concept

In principle, applying the quality cost concept to the construction industry is straightforward. However, in practice, it is rather complex. In fact, it is rather difficult to measure quality costs without the implementation of an effective quality cost tracking system (Aoieong, 2002).

Unlike a production line in the manufacturing industry, the construction process is far more complicated. Due to the vast number of parties involved and the uniqueness of each activity in a construction project, straight application of the concept of quality cost based on a manufacturing setting is rather difficult. However, if the measurement of quality cost is beneficial to the construction industry, attempts should be made to design a measuring system applicable to and acceptable by the industry. Among the prevention, appraisal and failure costs, failure cost is the most difficult to identify and collect (Aoieong, 2002).

Some of the main features of an 'ideal' quality tracking system are as follows (Aoieong, 2002):

- The quality tracking system should be able to capture all components of quality costs (Aoieong, 2002).
- The use of a coding system in tracking quality costs is essential (Aoieong, 2002).
- The ease of use of the quality cost tracking system is essential. The system must be straightforward, because the people who would be collecting cost data are the personnel on site. Any extra workload created from the system must be kept to a minimum (Aoieong, 2002). In addition, an onerous or complex system would have alienated the staff, reducing their co-operation with the exercise and, consequently, its potential efficacy (Hall, 2001). Due to the highly competitive environment in the construction industry, it is impractical to implement any extra system that would result in much extra workload to site staff (Aoieong, 2002).
- The practicality of the quality cost tracking system is also essential (Aoieong, 2002).
- Measurement begins by training users to account for their time spent on the job. Time is classified in one of three separate categories: (1) normal work; (2) prevention and appraisal; (3) deviation correction (Willis, 1996).

TQM requires the management of processes, not just of outputs. In order to improve the quality and productivity of a process, top management must first identify specific processes with discrete activities that require improvement. Continual improvement of processes should be established as an organization's objective. Once a particular process is isolated, its boundaries must be properly defined so that all key activities will be included for investigation. Flowcharting will facilitate the identification of all the key activities and process owners within the process boundaries (Aoieong, 2002).

Since construction processes are dynamic in nature, it is essential that the data collection process commences only after the construction processes become stable. Comparison with previous periods can then be made and areas for improvement identified. Failure costs, in particular, should be prioritized for improvement through reduction in cost of nonconformance. An excessive cost of conformance may suggest the need for process redesign. It is also essential that the process owners be involved in the improvement team (Aoieong, 2002).

In this case, the focus is no longer on capturing the 'total cost' of the quality of an entire project, which is rather difficult to do. Instead, specific processes in a project can be identified for monitoring and improvement (Aoieong, 2002).

In terms of measuring cost of quality failures during a construction project, the focus should be on the entire supply chain. Additionally, the data should be collected during the construction project, while all relevant parties are still available and focusing on the project in hand. Furthermore, the previous studies cited tended to concentrate on rework (Hall, 2001).

One difficulty in costing the failures lay in estimating the cost of delays to the construction process. It was established that such delays were relevant only where they affected the construction program's critical path. Two approaches were considered (Hall, 2001):

- Devise a proxy cost for each day of delay, related to the contract liquidated and ascertained damages (LADs).
- Estimate the costs related to accelerating aspects of the work to ensure the program remained unaffected.

The overall aim of the COQ exercise is to achieve a number of anticipated outcomes, as follows (Hall, 2001):

- A carefully constructed PAF model combined with a view of production as a process as outlined above. The goal is to produce a tool that could be used to support senior management decision making as an on-going improvement process.
- An investigation into and understanding of the causes of quality problems through causal analysis.
- An absolute figure for COQ failures, that might have a strong impact were it to be disseminated, and against which future projects could be compared, allowing measurement of the effects of learning, policy changes and continuous improvement initiatives.
- Perhaps most importantly, the effect of encouraging a cultural change among those who participate in the exercise, focusing their attention on quality issues generally and the importance of minimizing quality failures, both at a site level and along the supply chain.

Recommendations for future research

Further work on creating and testing cost models is recommended for the near future (Aoieong, 2002). In addition, if the industry is to improve its performance, all organizations involved in the project supply chain should implement quality management practices. In order to ensure quality in design documentation, construction companies and consulting firms should give greater attention to the following quality management practices (Love, 2000): (a) the requirements of the client and end-users; (b) producing correct and complete drawings and specification; (c) coordinating and checking design documentation (including inter-organizational coordination); (d) conducting design verification through design analysis reviews; (e) controlling changes (e.g. scope freezing); and (f) committing to providing a quality service. Also, special emphasis should be placed on the constructability of the project, so as to minimize design changes and errors that may arise during construction. It is suggested that giving attention to these preventive items may help improve design quality assurance and therefore minimize changes, errors, and omissions. If rework is to be reduced then significant improvement in the understanding of quality is required by both construction companies and consulting firms (Love, 2000).

Conclusion

This paper satisfactorily fulfilled the aims of the research. The reader was introduced to the Cost of Quality on Construction Projects. In addition, a systematic approach for measuring quality costs was addressed in details. The focus should always be on the entire system and the data should be gathered during the construction project. In line with this, the causal structure of rework could be determined by quantifying the causes, cost, and magnitude of rework that might be experienced on construction projects. Therefore, the complete Cost of Quality was assessed.

The costs of quality can be utilized in the identification of the causes of poor quality. Based on these causes, the quality improvement initiatives can be determined. As a result, this would achieve significant cost savings for companies.

Finally, Long-term benefits include ways of how to improve the P & A system and how to optimize the quality efforts of the entire project rather than each phase. Moreover, the root causes of deviation corrections can be identified and, hence, reduced on future projects.

References

1. Aoieong, R. (2002). “A process approach in measuring quality costs of construction projects: model development”. Construction Management and Economics. 20 (2), p179-192.

2. Hall, M. (2001). “A cost of quality analysis of a building project: towards a complete methodology for design and build”. Construction Management and Economics. 19 (7), p727-740.

3. Love, P. (2000). “Quantifying the causes and costs of rework in construction”. Construction Management and Economics. 18(4), p479-490.

4. Mandal, P. (1999). “Determining the causal structure of rework influences in construction”. Construction Management and Economics. 17 (4), p505-517.

5. Abdul-Rahman, Hamzah (1997). “Some observations on the issues of quality cost in construction”. International Journal of Quality & Reliability Management. 14 (5), p464-481.

6. Thorne, H. (1990). “The Cost of Quality”. *AACE Transactions, Q.3, AACE International, Morgantown, WV.* P1-5.

7. Willis, T. (1996). “A quality performance management system for industrial construction engineering projects”. International Journal of Quality & Reliability Management. 13 (9), p38-48.

8. Oberlender, G. (1993). "Project Management for Engineering and Construction". McGraw-Hill: New York.

Appendix A

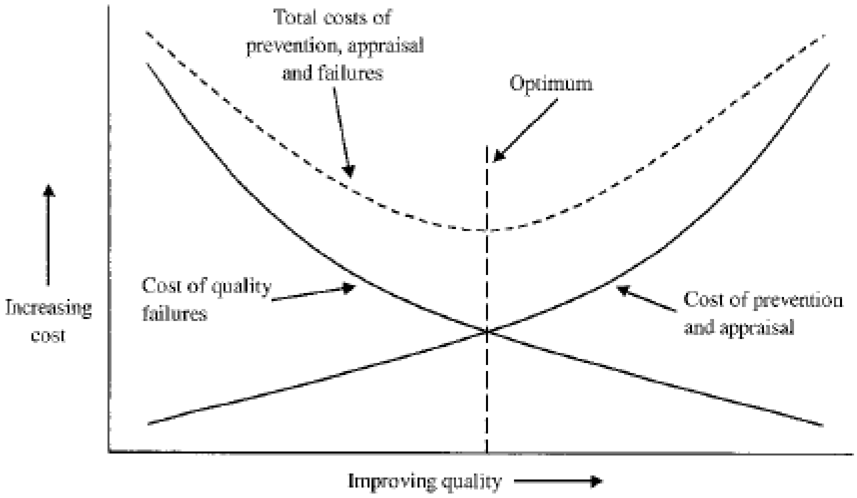

Figure 1. Optimization of quality and Cost (Hall, 2001).

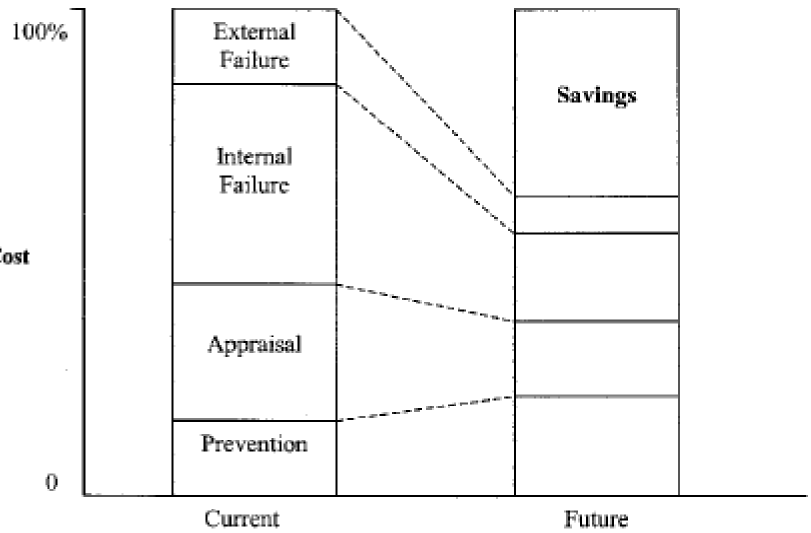

Figure 2. Total Quality Cost (Love, 2000).