ANALYSIS AND UTILIZATION OF QUALITY COST IN CONSTRUCTION PROJECTS

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Abstract:
In the customer-focused paradigm, high quality products or services can strengthen competitiveness, raise market-share, and provide a basis for long-term relationship with owners. But in most cases, the lack of quantitative data makes it difficult for managers to judge the current status of quality appropriately during a construction phase. Although quality is one of the critical success factors for evaluating a construction project, there is no practical guideline for measuring quality. As a solution to this problem, this study proposes a method to measure and analyze quality cost in construction projects. Quality cost plays an intermediate role in managing quality from a cost perspective and consequently contributes to the success of the construction project.

Keywords:
Quality, Quality Control, Quality Cost, Multi-Dimensional Analysis

1. INTRODUCTION

1.1 Background and purpose

Due to the diversification of customer needs and the emergence of multi-functional buildings in recent years, the tasks of construction companies have changed from being producer-centered to customer-centered. With this shift in the business environments, construction companies are pursuing continuous quality improvement to meet customer demand. They are putting great efforts to improving their quality by recognizing the limitations in the existing quality control mechanism which are mainly centered on performing inspection and test of finished work and restructuring process to prevent defects during the construction and operational phases.

Maintaining good quality is one of the main objectives of construction management in addition to meeting designated schedule and cost. In addition, quality is one of the important factors considered when determining the success of a project.[1][2] So most construction companies are now in search for a new method to achieve target quality at the most optimal time and cost.

In this study, we found a method with which effectiveness can be enhanced in terms of quality control and ultimately the overall construction management process. Here, we propose measuring and analyzing cost related to quality in construction phase of project. Executing quality control based on quantitative data is expected to contribute to achieving construction projects' various goals, that is, quality, schedule, and cost.

1.2 Scope and method

Quality in construction projects can be classified in various ways. There are various objects and methods of quality control according to phases of the project life cycle, and project participants tend to evaluate these results according to their own targets and criteria.

In this study, we have limited the research scope to the construction process where the physical product of construction work is made with resources. Here, we identified quantitatively measurable costs among the quality cost categories, comprising quality control cost and failure cost and then reviewed the method to measure and utilize those costs in quality control.

This study was executed as follows.

1) The overall quality and quality cost were examined.

2) The definition and measurement method for quality cost in a construction process was reviewed based on previous researches and cases.

3) The measurable quality cost items were selected and a method of collect such data was developed.

4) A new process of measuring quality cost based on existing quality control work process was re-established.

5) A method to analyze quality cost multi-dimensionally was developed.

6) A method to utilize analysis results in quality control and other construction management areas was considered.

2. LITERATURE REVIEW

2.1 Quality control in construction projects

Quality control in construction projects can be described as organized efforts in maintaining and improving quality of buildings to produce buildings on a more economic level. Quality is defined as "conformance to established requirements".[3] By avoiding dealing with the degree of goodness or satisfaction, this definition provides a basis for measurement, i.e. the requirements are either met or not met. This definition is well suited with the objective of identifying costs associated with quality problems.[4] Furthermore, it implies that understanding requirements thoroughly is important to proper quality management.

In general, quality is measured based on whether the expected levels of quality by the owner, design quality of the designer, and construction quality of the contractor on site are achieved. So in each phase, it is important to investigate these requirements by the executing parties.

Figure 1 shows a general quality control process in a construction phase. According to Figure 1, quality control task is executed along with work progress. If the finished work has no problem, quality control task is performed along the middle area of the Figure 1. But if defects are found, additional works described on the right side of the figure are carried out. If the qualities of resources and finished works conform to the specified standards, the results of the inspection and test will be stored for future reference in other projects.

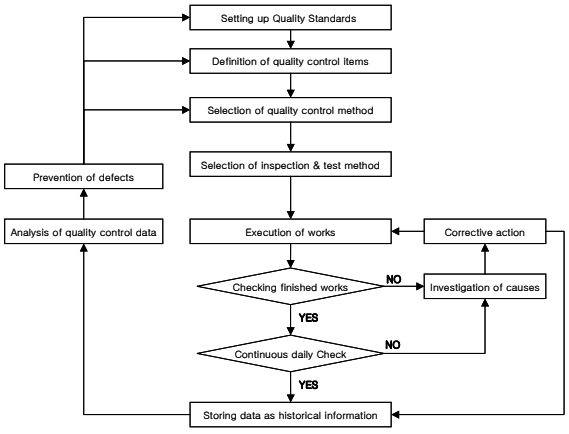

Figure 1. General Quality Control Process in Construction Phase

2.2 Quality costs

1) Concept and structure of quality costs

PMI(2000) defined cost of quality as all the efforts to acquire the quality of product and service, and these efforts include every work needed by requirements and rework.[5]

Quality costs can be classified as conformance costs and non-conformance costs(failure costs). Conformance costs are the costs for achieving satisfactory quality and non-conformance costs are the costs originated from low quality level. Table 1 shows the general classification and explanation of quality costs. Conformance costs include prevention costs and appraisal costs, and non-conformance costs are composed of internal-failure costs and external-failure costs.

Table 1. Classification of Quality Cost

Category		Contents
Conformance Quality	Prevention Cost	- Cost arising from prevention measures - Cost related to education, planning, etc.
	Appraisal Cost	- Cost related to performing check on products or services - Cost for conducting inspection, lab test, on-site test etc.
Non-conformance Quality	Internal-Failure Cost	- Cost related to resolving problems prior to delivery of product to customer - Cost related to disposal, re-production, stand-by etc.
	External-Failure Cost	- Cost related to solving customer claims in connection with products or services - Cost related to maintaining quality assurance, exchange, refund etc.

2) Quality costs and quality level

If quality cost means the whole cost spent to assure quality in corporation, quality costs are estimated up to 20 - 40% of its revenue.[6]

This concept of quality cost has been revised from the traditional perspective where prevention cost and appraisal cost offset failure cost(see figure 2-A) to the concept whereby achieving quality and cost reduction together is more important.(see figure 2-B)

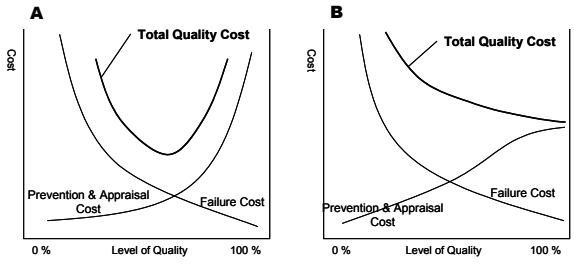

Figure 2. Relationship between Quality Cost and Quality Level

Quality manager should consider that increasing appraisal costs have no impact on the entire quality cost because internal-failure costs from rework or repair will still increase despite reduction in external-failure costs. So it is important that companies focus on cutting down failure costs by reinforcing prevention activities in the early stages.

2.3 Quality cost in construction projects

Quality control cost included in costs of construction projects is the costs required by related regulation and contract conditions for achieving quality of contractual object.

CII(1994) investigated 12 construction projects in U.S. and found quality control cost to be 8.1% of the entire contract sum[7], and PMI(1991) presumed that quality control cost was approximately 3-5% of entire project cost.

2.4 Related researches and cases

1) Researches on quality cost in construction

Davis(1989) classified the quality costs as the costs for quality control that comprise of prevention cost and appraisal cost and the costs for actions taken for deviation.[8] And Davis measured cost from quality control activities and rework by collecting labor working hours. He found that quality-related works took up 47.2% of all the design-related works. This study, however, appeared to have some vagueness in criteria by which 15 quality control activities and 24 rework-related tasks were selected, but showed that resources and costs required for quality control are not negligible

Burati(1992) traced causes of deviations and measured the cost incurred for correcting them.[4] In his study, Burati categorized causes of deviations into 5 areas: design, construction, fabrication, transportation, and operability, and each area had 3 types of deviation: change, error, and omission. Based on the data from 9 construction projects, Burati concluded that costs from deviation at the design phase and construction phase took up to 9.5% and 2.5% of the whole cost respectively. This study had its own significance in estimating internal-failure cost, but also showed limitations in its analysis in that it only defined data in the past.

Ledbetter(1994), who suggested Quality Performance Management System(QPMS) with Burati in CII, measured costs from quality control activities and rework.[7] The drawback was that QPMS could only be applied for estimating labor cost. With the framework of QPMS, Ledbetter analyzed data from 12 construction projects and found that labor-related quality cost was up to 11.2% of entire labor cost.

Love(2003) developed Project Management Quality Cost System (PROMQACS).[9] PROMQACS was constructed based on standard quality cost structure, and is useful in accumulating related data and sharing them with participants. But there exists no specific method for collecting quality-related data on construction projects. Also, his study did not provide detailed explanation about the relationship among quality, schedule, and cost though PROMQACS estimated the impact on schedule and cost.

The previous researches on quality control and quality cost in construction projects have demonstrated that there has been few effort to accurately measure quality cost incurred in the design and construction phases. In fact, most of these researches were focused on tracing the causes of defects and estimating cost from corrective actions based on data of the past.

2) Case study on quality cost in construction

Company A has a category of quality-environment management cost in control budget. Table 2 shows the relevant items taken into account in quality control in that category. Prevention cost and appraisal cost are seen to have been included as indirect cost, but failure costs are not included.

Table 2. Cost for Quality Control

Category	Items
Quality Control Direct Cost	Curing / Line -setup Material cost / Waterproof test Lightings in basement
Quality Operation Cost	Testing lab Test equipment / Cost for test
Quality Control Labor Cost	Tester Labor cost
Quality Control Material Cost	Material reserved (tiles, floor materials, windows, hardware etc.)
Others	Regular test / Project record Print Survey / Other Design cost

Company B uses a Quality Cost Estimation System and has its own quality cost structure as illustrated in Figure 3.

Quality cost data from each project are collected through the internet based on quality cost structure.

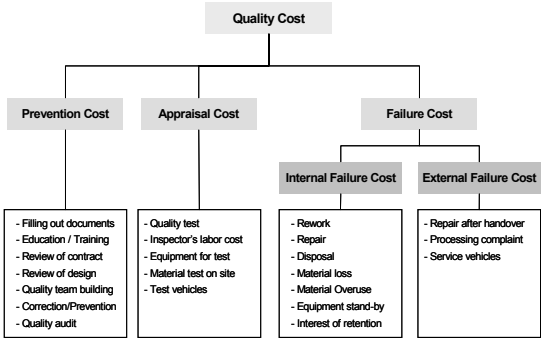

Figure 3. Classification of Quality Cost (Example of Company B)

By using the Quality Cost Estimation System, a quality manager can judge the status and time-series trend of quality cost. Figure 4 shows a user interface of quality cost status on project level.

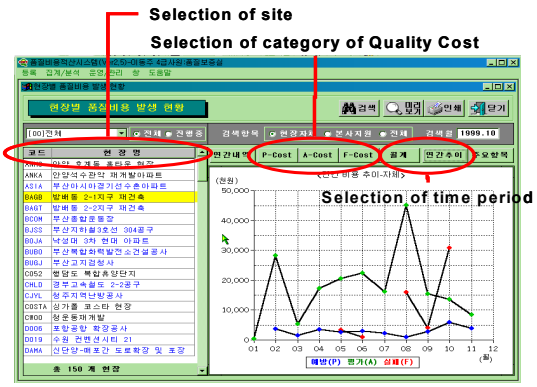

Figure 4. Example of Quality Cost System

2.5 Measuring quality cost

As the scope of quality cost has expanded, it has become more difficult to obtain an accurate measurement and evaluation of quality cost. In many cases, it is difficult to quantify quality cost and to separate it from indirect cost or fixed charge.

To collect related data and estimate quality cost accurately, it will be necessary to set up and operate a quality control process, especially process of inspection and tests.

Costs incurred in connection with quality managers at the head offices and sites and workers can hardly be estimated. The fact that companies tend to avoid revealing failure cost is also an obstacle in data collection.

3. METHOD FOR MEASURING AND ANALYZING QUALITY COST

3.1 Selection of quality cost items

Definition and scope of quality cost are different for each literature and author, and in some cases companies have specific quality cost items that is considered internally. These factors should be taken into account when selecting quality cost items in construction projects. In addition, items should have objectivity in order to use them in the public sector.

And items should have standardized structure to prevent confusion because the structure of quality cost will influence the aggregation in analysis process and the connection with schedule and cost data.

Normally quality control costs composed of prevention cost and appraisal cost are included in project budget as required by the relevant regulation and can be estimated with the processed data from the site. And data related to external-failure cost are collected through the various computer programs supporting the maintenance and operational activities. Thus, in this study, we focused on the measurement and analysis of internal-failure cost incurred from rework.

3.2 Method to measure quality cost

In case of manufacturing industry, most of the data related to quality cost were gathered from the accounting data. And the quality costs were estimated by product or by production line in accordance with the predetermined criteria.

Quality cost incurred from rework in construction was estimated by various ways from additional direct cost such as cost related to labor, material, and equipment to indirect impact on project such as schedule delay or cost overruns. This study considered the method below for substantial measurement of internal-failure cost during construction phase.

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 labors and equipment 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 process shown in part of Figure 1.

3.3 Analysis of quality cost

Managers in charge of performing construction site check status and direction of quality control activities by analyzing measured quality cost from various viewpoints. In addition, they refer to those results in making decisions for other construction management areas such as schedule and cost management. This study employed the concept of multi-dimensional analysis. Figure 5 shows an example of dimensions in analyzing quality cost. All the dimensions are designed to have a hierarchy and quality cost data can be aggregated according to this hierarchy. The structure of dimensions is utilized in creating cubes in multi-dimensional analysis and when using other analysis tools.

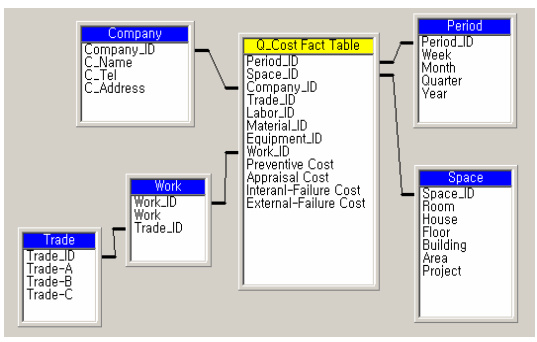

Figure 5. Schema for Quality Cost Analysis

And quality cost can be analyzed through other methods such as comparative analysis, trend analysis, and composition analysis described below.

1) Comparative analysis

Comparative analysis is performed to judge the quality level of a project by comparing quality costs against specified dimensions. Figure 6 shows the analysis of quality costs by periods and areas with pivot table function provided by Microsoft Office Excel.

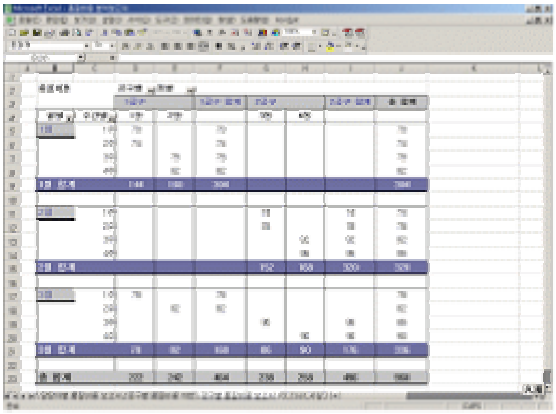

Figure 6. Analysis by Time and Areas

2) Trend analysis

Trend analysis is a method to evaluate current level of quality control activities by analyzing the trend of quality costs by time periods.

3) Composition analysis

Composition analysis is performed for analyzing the changes in proportions of each quality cost item. When applying this method, managers check the proportion of each item along with the changes of the overall quality cost.

3.4 Connecting Quality cost with schedule and cost

Quality cost is used as indicator to evaluate quality performance and influences companies' financial performance. To achieve the goal of quality control in construction project, not only quality but also other factors affecting project success such as schedule, cost, safety should be taken into consideration at the same time. Because quality cost during construction phase can have an effect on schedule and cost, the degree of influence should be reflected on the overall project cost and schedule at the planning stage.

3.5 Utilization of analysis results

Expected utilization of analysis results suggested in this study is as below.

1) Sub-contractor management

By providing rework cost and causes of defects, quality cost data can contribute to effective sub-contractor management. Quantitative information on the cost incurred in maintaining proper quality will enable managers to recognize the importance of quality control activities, to reinforce work control on site, and consequently to enhance overall quality level of the project. On the other hand, managers refer to historical quality cost data of the sub-contractors in selecting a specific sub-contractor for a certain project because high quality cost implies potential risk in labor control and finance.

2) Reinforcement of preventive activities

Quantification of quality control activities and analysis on causes of rework can contribute to the reduction of comprehensive cost by reinforcing preventive activities in future construction. Causes of rework can be reflected on quality plan, ITPs (inspection and test plans), and checklists. These information will be more valuable when only limited resources can be allocated in preventive activities on site.

3) Connection of quality with schedule and cost

By using schedule data and cost data in analyzing quality-related data, all the management areas are connected systematically, based on which a new management information can be derived.

4) Determining priority in quality improvement

As Crosby(1979) pointed out, measuring quality cost can help identify more benefit areas in cost through quality improvement.[6]

5) Feedback to design phase

By using non-conformance information from quality cost analysis in design phase, designers avoid works frequently causing defects.

4. CONCLUSION

Measurement of quality cost is important as a supporting tool to decide when, where and how to allocate resources on site. In general, quality issues are of less concern than meeting time schedule or cost requirements. In this study, a new method for achieving good quality control in terms of cost is suggested and ways to measure and analyze quality cost during construction phase were discussed.

Practically most of the cost and responsibility of rework are ascribed to sub-contractors, and so there is no additional burden on the contractors for handling quality-related problems. But it is important that all the participants pay more attention to non-conformance situations because they cause many secondary problems such as schedule delay, cost overruns, sub-contractor insolvency etc..

In the future, a physical system based on the concept suggested in this study will be developed, complimented by qualitative factors on quality.

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