DEVELOPMENT OF QUALITY PERFORMANCE INDICATORS FOR QUALITY MANAGEMENT IN CONSTRUCTION PROJECTS

Sang-Hoon Song[1], Hyun-Soo Lee[2], Moonseo Park[3]
song17@snu.ac.kr[1], hyunslee@snu.ac.kr[2], mspark@snu.ac.kr [3]
Dept. of Architecture, Seoul National University

ABSTRACT

The growing competitions among companies intensified by the rapid changes in business environments are forcing them to adopt a new managerial paradigm. The traditional production-oriented management focusing on higher productivity has transformed into the customer-oriented management aiming at achieving customer satisfaction. Under these circumstances, quality management is one of the critical concepts for innovating corporations and improving their competitive edge. Despite the companies' recognition of the significance of quality, most of them do not have a solid basis for quality management and substantial action programs. In the construction industry, there have been many attempts to adopt quality management as a tool for continuous improvement. They include Six-Sigma which has already been proven to be very useful for fostering quality innovation in the manufacturing industry. But these kinds of efforts are not sufficient enough to achieve organizational goals in quality management. It is essential to also take into consideration the root causes of inefficiency in the quality management.

The low level of construction quality is mainly caused by the result-oriented quality management owing to the fact that quality problems can be detected only after they occur. Also, few systems provide the quality managers with numerical objectives or tangible goals.

This study suggests a data-based quality management as a solution to the foregoing problems and discusses the methods of measuring and analyzing the performance related to quality in a construction company. It establishes the quality indicators to measure quality performance objectively. The management objectives and CSFs are defined according to the three management levels: strategic level; project level; and operational level, and then the indicators to measure and manage them are listed. The indicators are assigned to each quality management level and the level of quality is expressed with Sigma values. Through this quality performance management, managers will be able to improve the construction quality by monitoring the major indicators of construction project success and ultimately increase the competitiveness of overall construction organization.

Keywords: Performance, Performance Indicators, Quality, Quality management

1. INTRODUCTION

The shifts in business environments have intensified competition among companies,

forcing them to adopt a new managerial paradigm. The production-oriented management that focuses on higher productivity is changing to a customer-oriented management focused at customer satisfaction. Under these circumstances, quality is one of the critical factors to increase their competitiveness, and quality management is one of the main issues for improving competitive edge of innovating corporations. However, most of the companies do not have a basis for quality management and substantial action programs even though they recognize the significance of quality.

Until now, quality has not been a priority factor considered in the construction project life cycle compared to other project management factors such as cost and schedule. Quality should be perceived as a critical success factor and be analyzed from a new perspective that considers the relationships with traditional key success factors in the construction industry. Recently, there have been increasing attempts to adopt quality as a tool for continuous improvement like Six-sigma which already proves its usefulness for quality innovation in manufacturing industry (Pheng 2004). The average level of quality of construction industry is comparatively lower than other industries like the textile and clothing industries and the electronics industry. The low construction quality is mainly attributed to the practice of result-oriented quality management.

This paper introduces some quality indicators for measuring quality performance objectively and with which to develop a quality performance management system to monitor the construction quality continuously. Through the quality performance management, managers will be able to improve the construction quality by monitoring the leading indicator that determines the success of a construction project and ultimately increase the competitiveness of the overall construction organization.

Quality management should be implemented in a more quantified and integrated manner to advance to higher managerial level as discussed in project management process maturity model (Kwak 2002). This paper suggests a method of measuring the quality level of project and enterprise by aggregating the quality of the respective works and materials, which is the lowest unit of quality management.

The scope to which the concept of quality can be applied in a construction company ranges from the management quality using TQM to the quality of material or labor on construction field. And quality data classified according to managerial levels should be aggregated and manipulated by those levels.

This paper limits the research scope to the quality of activity during the executing phase of the construction project. Among the quality concepts that shows diverse aspects according to project phases or customers by the delivery systems, the definition of quality is determined as "conformance to specification" in this paper. Subsequently, the degree of achieving construction quality of "conformance to specification" is defined as quality performance. The processes and results of this quality performance were analyzed with suggested indicators from the perspective of the main contractor undertaking overall field management during the construction stage.

This research was executed according to the following procedure. 1) Review the current status and problems of the quality management in construction project through

literature review and establish the solution to them. 2) Analyze quality management process, and identify the problems and critical points in measuring and analyzing the quality performance. 3) Discuss the characteristics of performance indicators and systems, and develop the quality performance indicators linked to organization's strategies and quality objectives. 4) Find the data collecting method according to the established indicators, and plan the architecture for continual quality data accumulation. 5) Develop construction quality performance management process

2. QUALITY IN CONSTRUCTION

Quality management, which is a concept that had referred to simple inspections in the early 20th century, has continued to evolve to TQM, Six-sigma, and so on. Recently, quality places emphasis on the strategic direction, systematic approach, and organizational efforts.

There is a difference between a producer's perspective and customer's perspective with respect to quality. Quality from the producer's perspective is the quality of conformance, making sure that a product or service conforms to the described design standards and quality specifications. Normally the design activities, the starting point of quality management, are completed before the products are manufactured, and design standards and quality objectives are set up according to the corporate strategy and customer needs. To assure that the quality is maintained throughout the whole product life cycle and not confined to a simple product quality, quality of goal achievement and quality of conformance to meet the specification can be applied for the construction project management.

According to Ledbetter (1994), quality is defined as the conformance to the established requirements and the requirements are regarded as the characteristics of product, process, or services specified by the contracts.

Quality Management Process

Prior to developing the quality performance indicators and continuous measurement system, the currently used quality management process should be analyzed as a preliminary work. Quality performance management practice, related organization, and incurred data can be reviewed during this process analysis.

Quality management process of the main contractors in a construction project is composed of four sub-processes, and they are quality planning, quality check, quality action, and quality analysis. In quality planning stage, a quality management plan that includes quality goals and organization on the project level and inspection and test plan(ITP) on the activity level are prepared. The tests and inspections for materials and finished works are executed according to the designated schedule in the quality plan during quality check stage. Items requiring additional managerial efforts are identified by the inspection results, and non-conformance reports are issued to the related sub-contractors during the quality action stage. In the quality analysis stage, the inspection results are periodically analyzed and used to evaluate the level of project quality. Non-conformance items are classified along with building types, project types, or trades, and managers assess the performance by comparing actual values to the original goals.

Quality inspections are classified into the factory inspection, material inspection on delivery, work-in-process inspection(surveillance), and final inspection, all of which have the common process of 'planning - executing - processing'. Quality action includes the measures to handle non-conforming materials or works along with the process of 'identifying - action-taking - confirmation' as shown in Figure 1.

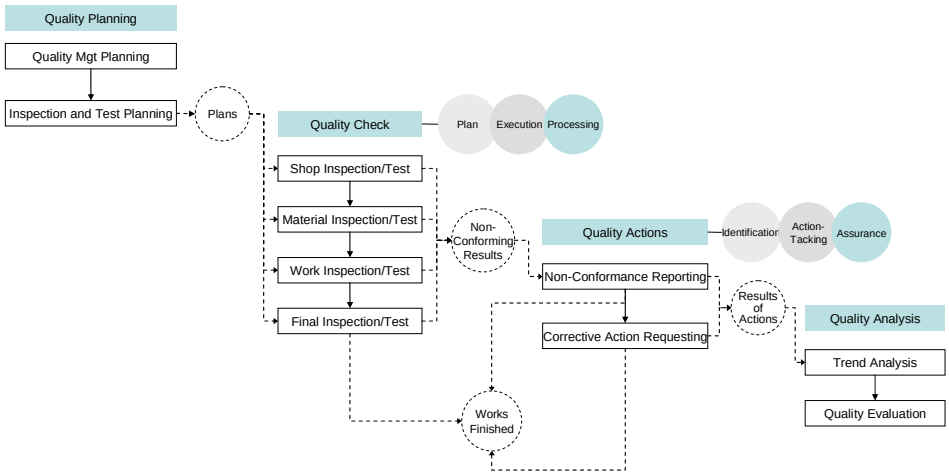

Figure 1. Process of quality management

Characteristics of Quality Management in Construction

Quality management is achieved by defining requirements based on organization's vision, and executing activities to satisfy them. The quality objects to be achieved through quality management in construction projects vary according to various factors such as types of customer, project phases, participants, construction methods, and so on. These factors are determined by the characteristics of project and influence the quality management system and contents. The quality level of the construction project tends to depend on whether proper quality control system is developed considering project characteristics and organizational capabilities. The quality performance should be evaluated continuously based on these factors.

Current quality management is focused on the results of works, and materials scheduled to be installed. Though other resources put to activities on construction site like labors or equipments affect the productivity and quality (Lee 2004), normally they are not included in the scope of quality management.

The current quality assurance system does not provide a quantitative ground for quality management. For time management and cost management, time, cost, or ratios are provided to the managers to help them perceive intuitively the managerial objectives and status. But most of the objectives in quality management have qualitative attributes and there is no method to properly assess the quality. Quality problems are intrinsically difficult in detecting before they occur and they are identified when managers confirm them (Garvin 1984). So, quality management are likely to be result-oriented without a proper preventive system that converts quality's result-oriented characteristic to predictable values.

The characteristic of the construction industry that it depends on the field production

is one of the main obstacles in ensuring the performance (Kubal 1994), and CII (1994) summarizes problems of quality management in construction industry as follows.

- For end results rather than process steps; that is, most measurement processes are a non-predictive manner of measurement.
- Focused on isolated phases with minimum integration.
- Geared toward short-term improvements vs. long-term strategic goals.
- Seldom developed by the full project team (owner, engineer, and contractor).
- Not well-suited to benchmarking.

Literature Reviews on Quality Performance Management

Davis (1989) designed QPTS (Quality Performance Tracking System) and discussed the definition of quality, requirement analysis, and application to cost/schedule system. Ledbetter (1994) developed QPMS (Quality Performance Management System) for estimating quality costs based on labor costs. Love (2004) measured the quality costs with PROMQACS (Project management quality cost system) including problem types, related trades and organizations, quality cost types, and impact on schedule/cost. All these researches regard quality costs as the major indicator and discuss the measurement of quality costs and their actual proportion to project costs.

Cheung et al. (2004) developed PPMS (Project Performance Monitoring System) for monitoring quality by using the performance indicators shown in Table 1.

Table 1. Quality-related indicators (Cheung 2004)

Category	Performance indicators
Inspections	• Number of site inspections conducted
Non-Compliance Records	• Number of non-compliance records received • Number of non-compliance records closed • Total number of non-compliance records rectified • Average time to close out non-compliance records
Work Rejection	• Due to workmanship • Due to lateness
Survey (Samples) Rejection	• Due to workmanship • Due to lateness

Cheng et al. (2000) suggested the quality-related measures as shown in Table 2. Quality measures were developed to improve client confidence, increase client satisfaction, and increase construction durability, and rework is measured to reduce wasted work.

Table 2. Quality-related measures (Chung 2000)

Criterion	Measure	Measuring unit
Quality	Rejection of work	• % sample rejections
	Client satisfaction	• Number of claims by client
	Quality of work	• Number of claims by contractor
Construction Process	Rework	Rework MH/total MH

In UK providing and managing KPIs to measure and analyze the construction performance as a social system, quality issues are classified into three types: rejected; reworked; and compromised. The cost and time incurred to rectify quality issues are measured, and the sources of quality issues are also reported with the categories of workmanship, design/specification, defective materials, damage on site, and others.

Existing quality management systems in practice are focused on processing the quality management tasks, and provide a simple function of generating the periodical reports to monitor the quality status. To complement this shortcoming, various quality performance indicators need to be developed and settled in the performance management process. Also, the process that includes identifying the causes of quality problems, developing necessary actions to resolve them, and establishing the goals should be suggested in accordance with the general framework of performance management to overcome current systems' failure to trace the root causes in performance variation.

3. QUALITY PERFORMANCE OF CONSTRUCTION PROEJCTS

Quality Performance Management Process

Performance measurement means the process of evaluating performance relative to a defined goal, and performance metrics are defined as the analytical tools in the performance measurement process that take measurements, display results, and determine subsequent action (Rose 1995).

The performance measurement system in specific organization should have a balanced framework between cause and effect, efficiency and effectiveness, etc. In the measurement and analysis of the quality performance, it is important to identify the points needing improvement and formulating the solutions through the indicators able to analyze the process, taking into consideration that one of the drawbacks in traditional business is the result-oriented measurement (Pande 2001). As pointed out by Bassioni (2004), the feedback loops and subsequent decision-makings are required to transform measurement system into the management systems including decision-support functions.

In the construction projects, work progress is managed with process factors while the monitoring is based on the result factors. The managers on the lower level are interested in the process factors, while the upper management places more emphasis on the measures showing results. In this sense, quality performance can be regarded as the process measures, compared to the financial measures mainly demonstrating the cost status in the construction project.

In this research, the quality performance management cycle was composed with reference to the Deming cycle which comprise the plan, do, check, and action. The cycle comprises quality performance planning, quality performance measurement, quality performance review, and quality performance improvement. The management level is divided into three levels: the strategic management; project management; operational management. The tasks of each level in conducting quality performance management are listed to identify their major interests. Managers on the upper level must have data on matters such as cost or schedule as well as the quality to evaluate the quality performance of the construction companies. By synthesizing all these data from various management areas, managers can judge the quality status from a more integrated perspective.

The functions and tasks related to quality performance management for each management level are as follows:

- Strategic management level(S) : Review the quality management strategy and quality policy in the enterprise or department's perspective, and monitor the overall quality performance of the departments and sites
- Project management level(P) : Manage the quality assurance status, review the quality objectives and action plans, and monitor quality status of the site by analyzing and comparing quality data
- Operational management level(O) : Plan the inspections and tests considering the relationships with the schedule and resource allocation, determine whether to proceed to succeeding activities, and take necessary actions to handle quality problems

Figure 3 shows tasks and review items of the each management level along the quality performance management cycle.

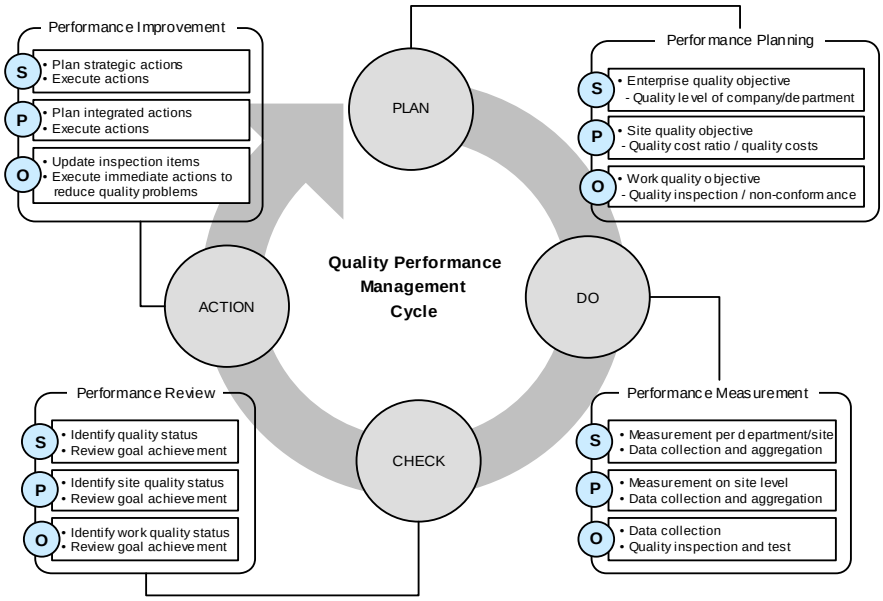

Figure 2. Quality performance management cycle

After determining the quality status, the causes for poor achievement should be traced to improve and enhance the efficiency of quality management. This research categorizes the causes of quality problems into work error, design error, defective material, damage on site, etc. Each inspection item is connected to the cause on the inspection checklist, and inspection results are input into the quality management system in a periodic manner.

Development of Quality Performance Indicators

The performance indicators are the objective standards developed based on the management policies and the critical success factors to assess the accomplishment of the policies in the companies.

Rose(1995) suggested the attributes of good metrics, and they are summarized as

follows.

- Good metrics are customer centered and focus on indicators that provide value to customers.
- They measure performance across time, which shows trends rather than snapshots.
- They provide direct information at the level at which they are applied, and no further processing and analysis is required to determine meaning.
- They are linked with an organization's mission, strategies, and actions.
- They are collaboratively developed by teams of people who provide, collect, process, and use the data.

Also, the what, why, when, how, and who to measure should be defined in developing quality-related indicators (CII 1994).

In this research, the management objectives and critical success factors (CSFs) were defined for each quality management level, and the indicators to measure and manage them were developed (shown in Table 3). The basic principles in developing quality indicators by CSFs are as follows.

- Upper management identifies the quality level and performance at a glance with a single indicator. The indicators cover the larger scopes in performance as the management levels are higher, and have the characteristics of financial indicator.
- The quality indicators are classified into effectiveness measures and efficiency measures. Efficiency measures are designed to measure the productivity of the quality management process, including quality cost ratio and each category of quality costs. Effectiveness measures are calculated using the data from the inspections and tests, including work quality ratio, NCR records, and goal achievement ratio.
- The achievement ratios are calculated by comparing the actual performance to the periodical quality goal for each indicator. These ratios show the effectiveness of quality management by comparing the actual results to the achievable level.
- The newly developed quality indicators enable management to monitor the processes, and not the results, and analyze quality from various dimensions in order to improve efficiency.

Table 3. Quality objectives and CSFs

Level	Objective	CSFs
Strategic Level	• Customer satisfaction • Assuring management quality	• Integrated quality management for projects in the company • Analysis and comparison of respective project quality
Project Level	• Internal customer satisfaction • Assuring project quality	• Review of the link with cost and schedule • Setting of the quality goals of project • Identification of the quality status of project
Operational Level	• Assuring work quality • Keeping work schedule	• Identification of the quality status of work • Identification of the causes of quality errors

The indicators are developed to measure the degree of achieving the CSFs listed in Table 3, and categorized into three groups below.

Work quality indicators

To assure the work quality, data from inspection results and non-conformance records

are analyzed on the operational level. Combining the inspection (test) results and the data from non-conformance processing enables manager to understand the result of quality management.

Quality cost indicators

The efficiency of the quality management is identified by measuring and analyzing quality cost on site. The Quality Cost Ratio (QCR) is calculated to check the comparative value of quality cost using interim expenditure. Among the many classification of quality cost, this research adopts the most prevalent PAF model using the classification of prevention cost, appraisal cost, and failure cost. The responsibility of quality cost incurred during construction can be varied according to the contract and delivery systems.

Quality status indicators

Quality status includes both reviewing the achievement ratio of quality goal and measuring the quality level. Sigma level is calculated by converting the yield or defects per million opportunities (DPMO) to determine quality level. In this research, the inspection items on quality checklists for work were regarded as opportunities, and DPMO and sigma values were computed using them.

In addition, quality training hours and the degree of participation can be the preceding indicators, and be analyzed in connection with other quality indicators.

As Bassioni (2004) discusses, performance management systems should be dynamic and flexible, with the ability to cope with the occurrence of relevant external and internal changes. In this context, this research adds the periodic review for measures to quality performance management process.

Table 4 shows the calculation formulas and data source for each indicator.

Table 4. Quality performance indicators for construction projects

Indicators	Management Level	Category	Calculations	Data Sources
Quality level	Strategic level	Status	Sum of company quality index multiplied by index weight	(computation inside system)
Department sigma level	Strategic level	Status	Sum of each sigma quality level of project multiplied by project weight	(computation inside system)
Quality cost ratio	Project level	Cost	Ratio of total quality cost to the periodic earned value	• Monthly project report • Payment report for sub-contractors
Quality cost	Project level	Cost	• (Prevention cost) Total cost for quality managers and trainings • (Appraisal cost) Total cost for quality inspection and test • (Failure cost) Total cost for rework and disposal	• Control budget • ERP (system) • Daily project report
Project sigma level	Project level	Status	Sum of each sigma quality level of work multiplied by work weight	• Work quality checklist
Work quality ratio	Operational level	Work	Ratio of the number of inspection passed to total number of inspection	• Inspection and test plan • Work quality checklist • Daily project

				report
No. of NCR	Operational level	Work	Numbers of NCR received and rectified in each period	• NCR(process) report
No. of CAR	Operational level	Work	Numbers of CAR received and rectified in each period	• CAR(process) report
Work sigma level	Operational level	Status	Converting defect ratio per inspection item to sigma level	• Work quality checklist
Goal achievement ratio	Every level	Status	Ratio of actual data to goal values	(computation inside system)

4. CONCLUSION

In the construction industry, there are more companies attempting to adopt quality as a tool for continuous improvement. These tools include Six-Sigma which has already been proven to be useful for quality innovation in the manufacturing industry. However, these kinds of efforts are not sufficient enough to achieve the organizational goals in quality management. The root causes of inefficiency in the quality management should be considered. The low level of construction quality is mainly caused by the result-oriented quality management due to the fact that quality problems can be detected only after they occur. Also, few systems provide the quality managers with the numerical objectives or tangible goals.

This study suggests the data-based quality management as a solution to the foregoing problems and discusses the methods of measuring and analyzing the performance related to quality in a construction company. It establishes the quality indicators to measure quality performance objectively. The management objectives and CSFs are defined according to the three management levels: strategic level; project level; and operational level, and the indicators to measure and manage them are listed subsequently. The indicators are assigned to each quality management level and the level of quality is expressed with Sigma values. Through the quality performance management, managers will be able to improve the construction quality by monitoring the major indicators of construction project success and ultimately increase the competitiveness of the overall construction organization.

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