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QUALITY COSTS MANAGEMENT IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

A major portion of the country's budget is annually allocated to the implementation of developmental projects. Different deficiencies and problems cause prolonged duration of projects and other issues. One of the causes of delay is mismanagement of costs and duplications that occur during construction. Using the management techniques of cost reduction, these costs can be reduced considerably, so that the quality is increased and the final cost of construction is reduced. PAF model is one of the methods for management of quality cost which is a common way for evaluation of construction costs. The present paper aimed to study the importance of quality costs in construction and its role in reducing the construction costs. First, the quality costs related to construction were discussed and PAF model was introduced. Finally, appropriate strategies for management of construction costs were proposed based on this model.

Keywords: Quality costs; Costs management; PAF model; Construction industry

1- INTRODUCTION:

Construction sector has a special position in topics related to economic development because of its interaction with other economic sections. In a realistic analysis of the status of construction projects in our country, it can be easily inferred that the construction industry needs to be deeply studied and discussed in terms of quality, time, and cost. Therefore, an analytic study of three factors of quality, time, and cost in construction industry will be helpful and effective if a correct approach to each of these parameters is introduced. Quality is defined as compliance with requirements. In order to recognize and measure quality, different aspects of requirements should be

understood. Given the long life of products of construction industry, quality will not be realized without a prospective thinking and dealing with components of quality based on tastes is doomed to fail. The main point in costs management is to balance the costs of a building over its life cycle or, in other words, to optimize the total cost.

Improvement of total quality has attracted more attention in the construction industry since the 1980s. In the construction sector, quality is defined as the ability to meet the items and cases promised to customers [1]. Quality should be based on the project scope, time, and cost. Hence, only meeting the requirements listed in the contract for the project scope, time, and cost is not enough and the needs and views of the owners of the houses should be taken into account in adjusting these items [2]. The quality standard of a project is as important as its level of defect, because lack of a clear definition of quality level will cause variations between different sub-projects. Achieving a high quality requires spending large costs which brings a high profitability over time [3]. Quality cost inspection is one of the most important parameters for achieving a high quality. Quality spending cuts will lead to poor quality and increase in unnecessary spending decreases the profit margin. To determine the optimal level of quality costs, information related to quality costs should be completed [1].

2- Quality cost:

Juran and Armand Feigenbaum were the first ones who proposed models for evaluation of quality costs [4]. The quality cost is usually defined a total costs of compliance and non-compliance. Non-compliance costs refer to poor quality costs which is caused by wrong offerings and is spent on replacement by standard offerings [2].

Due to the rapid growth of construction, quality cost is necessary to be estimated. In order to improve the quality, costs associated with the pursuit of quality should be considered. Hence, achieving a quality product not only attracts customer satisfaction but also minimizes the quality cost and reduction of these costs is possible when they are defined and measured. Therefore, measuring and reporting the quality costs will lead to a better and more correct management [5].

According to studies, the best value for quality cost is 1% of total value of a project [3]. The numerical value of quality cost equal to 1% of the total cost of a large sub-project is clearly more than 1% of quality cost in small sub-project. This suggests the importance of considering the size and value

of each sub-project when evaluating the performance based on quality cost [6].

According to data of quality costing system, some items can be inferred such as identification of the inefficiency of the quality system, dependence between the quality and the cost of quality improvement, elimination of organizational activities which do not lead to quality improvement, a tool for assessing the operational efficiency and improvement of method based on current spending, providing financial justification for future quality initiatives, and a tool for management in order to assess costs and strengthen the information related to strategic decision-making.

Some of the benefits of measurement and classification of quality costs in the construction industry are as follows:

1- Quantitative expression of the total quality cost in construction projects
2- Providing the managers with accurate information about the project progress
3- Ensuring the fulfilment of tasks during the project execution
4- Identification of the items reducing the total construction costs
5- Providing a correct definition of failures costs and prevent the reallocation of irregular spending
6- Proposal of a proper strategy for management of costs

Based on these studies, unnecessary spending is identified and parameters of optimum level of services are introduced. In fact, improving the quality of products and reducing the costs are two main duties of managers of organizations. Based on the determined level of quality, managers should try to reduce the costs as much as possible and this is not practical unless by revealing and documenting the information of costs.

3- Different types of quality costs:

Studies conducted by Aoieong *et al*. [7] and Tang *et al*. [8] provided a comparative method for introduction and classification different models of quality costs. According to available information and references, prevention costs, appraisal costs, internal failure costs, and external failure costs are considered as quality costs items. There is no systematic collection or standard computations for the quality costs and making any decision on the structure of quality cost model depends on judgment of managers and the collected qualitative data [2, 4].

3-1- Internal and external failure costs:

Failure costs refer to spending for non-standard products and are divided into two categories of internal failure costs and

external failure costs. Internal failure costs are related to fixing the defects occurring before the product is delivered to customers and external failure costs are spent when customers are provided with a non-standard product [3]. One important point about external failure costs is that the cost of repairs after construction is higher than the cost of repairs during construction. Hence, as the customers have to pay higher costs for repairs, their satisfaction level would decrease [9].

3-2- Prevention and appraisal costs:

Appraisal costs involve all spending for measurement, assessment, and inspection of products in order to ensure that they in compliance with the requirements. Prevention costs are spent on qualitative activities in order to prevent distortions and errors in construction. Preventive activities aim to determine the reasons for problems and restrict them to resources. In other words, prevention costs can reduce appraisal and failure costs [10]. Appraisal costs are associated with income, while prevention costs are related to objectives. Both of them are unavoidable and construction companies and consulting firms should spend them in order to deliver their products and services at the specified time [3]. Table 1 provides examples of prevention and appraisal techniques in the construction industry [11].

Table 1: Examples of prevention and appraisal techniques in the construction industry

Activity	Description
Regulatory of quality system	**Promotion of quality improvement programs, setting the standards and objectives, and analysis and reporting of current activities**
Confirmation of suppliers	**Assessment of the ability of suppliers, vendors, contractors, and subcontractors foe doing the works in the best possible way, promotion of confirming system and scoring methods for evaluating the performance of suppliers**
Vetting of personnel, training, and testing	**Testing the ability of staff for getting things done according to certain standards, industrial vetting of individuals, and training them on quality control skills**
Acceleration of processes	**Defining the guiding activities to reach to a confidence that all items are purchase in time and equipment, services, and information are received**
Evaluation of the potentials of abuilding	**Activities which lead to effective design and planning methods, maximize the chances for success of a project, and increase the level of customer satisfaction, such as studies on building site layout, water supply, building structure, climatic conditions, regional potentials, etc.**
Feasibility, safety, and value assessment	**The design will be acceptable to the customer, government, and industry when some activities are dome for safety analysis, process risks, feasibility assessment, value engineering studies, and so on**
Internal test	**Assessment, inspection, observation, and testing the services are done within the organization. These assessments include reviewing the designs, plans, and documents, concrete and soil testing, hydraulic testing of pipes, and so on**
External tests	**Assessment, inspection, observation, and testing the services are done outside the organization. These assessments include inspection of incoming materials and equipment from suppliers, review of vendors' documents, evaluation of the performance of suppliers based on the provisions of contracts, and so on**

Gunneson proved that failure cost decreases with improvement in processes and this itself reduces the appraisal costs, because there will be less need for appraisal when the

quality of products is improved. High appraisal and internal failure costs would result in the production of poor products [12]. Increased costs of appraisal indicate high frequency of internal failures and paucity of external defects. When appraisal and internal failure costs are decreased and consequently prevention costs are increased, this eventually causes the total quality costs remain almost unchanged.

Unfortunately, a lot of costs are spent on troubleshooting, but the amount profit that is lost to achieve this acceptable level of quality is usually neglected. Preventing any non-compliance before a product is produced or before it is prepared to be delivered to customers is the best strategy for reducing the appraisal and failure costs, because it requires the minimum cost, time, and effort.

4- PAF model:

PAF is a model that is widely used for determining the quality costs. The basic assumption of PAF model is that investment in prevention and appraisal activities, failure costs, and more investment in preventive activities will reduce the appraisal costs. PAF model is used to find a quality level that minimizes the total quality costs. Figure 1 depicts a scheme of PAF model. There is an inverse relationship between efforts made for prevention and appraisal and failure costs.

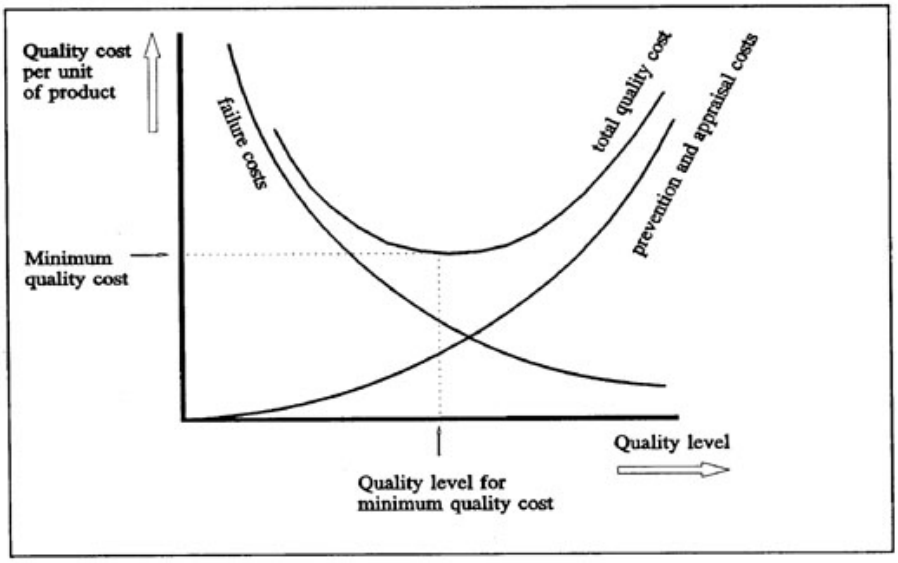

Figure 1: PAF Model

According to PAF model, the optimal level of quality or level of defect is the point where the incremental curve of appraisal and prevention costs crosses the decreasing curve of failure costs. Total quality cost becomes minimum at the point where prevention and appraisal costs are equal to failure costs. According to this model, it is assumed that

the optimum point obtained using calculations is exactly the same point where the curve of prevention and appraisal costs crosses the curve of failure costs. However, studied have shown that this assumption is not true [5, 6]. This can be due to the following items:

1- Drawing the curves based on real data
2- Supervision of project progress stages by quality control inspectors and project consultants with the aim of preventing the wrong works to be done

The position of minimum point on the curve of total quality costs often refers to the optimum point, although it may not be desirable in terms of profitability. The optimum amount of total quality costs is at the point that shows quality compliance less than 100% [13].

Some of the advantages of PAF model are as follows:

1- It is very easy for many construction firms to understand this model
2- This model can be easily used by the contractors who consider various parameters and their employees have different educational levels and experiences.
3- The data required for modelingare used based on the available documents of projects

Another important point is that quality costs should be evaluated in all phases of construction projects. The highest amount of prevention costs should be spent in phase of upper structure and the final phase, because the constructors try to build a structure in accordance with the standards and requirements. In addition, the highest amount of appraisal costs is spent in upper structure phase. On the other hand, failure costs are maximum in the final and troubleshooting phases, because many of hidden defects and problems are revealed in the final stages.

5- Modeling the quality costs based on PAF model:

Quality costs (C) is actually the sum of prevention costs (X), appraisal costs (Y), and failure costs (Z) that is shown as follows:

$C=X+Y+Z$	(1)

To model the quality costs based on PAF model, it is necessary to firstly determine all costs separately. Prevention costs include site personnel wages (X_1), site personnel training cost (X_2), and the costs related to traffic within the site (X_3) (Table 2). Each of these items are considered independent of other

expenses and prevention costs is a dependent variable which is calculated as follows:

$X=X_1+X_{2+}X_3$	**(2)**

Table 2: Prevention costs items

Variable	Description	Type
Site personnel wages	**Wages of contractors personnel and subcontractors personnel who are responsible for supervision, leadership, and control of the workers and do specific activities to achieve certain standards and specifications**	**Independent**
Site personnel training cost	**Education is an important pillar in helping the inexperienced staff in order to cause them get familiar with the project specifications and standards, quality standards, engineering plans, processes, and operations**	**Independent**
Costs related to traffic within the site	**In site with a very large area, Lack of means of transportation can have a huge impact on quality, especially in areas where the weather is very hot. This may reduce the frequency of inspection of remote buildings**	**Independent**

Appraisal costs include wages of quality control personnel (Y_1), quality control personnel training cost (Y_2), inspection costs (Y_3), testing costs (Y_4), and cost of calibration of measurement and testing tools (Y_5) (Table 3). Each of these items are considered independent of other expenses and appraisal costs is a dependent variable which is calculated as follows:

$Y=Y_1+Y_{2+}Y_3+Y_4+Y_5$	**(3)**

Table 3: Appraisal costs items

Variable	Description	Type
Wages of quality control personnel	**The salary that is paid to quality control personnel by the major contractor or subcontractor**	**Independent**
Quality control personnel training cost	**Education is an important pillar in helping the inexperienced staff in order to cause them get familiar with the project specifications and standards, quality standards, engineering plans, processes, and operations**	**Independent**
Inspection costs	**Costs paid by the main contractor and subcontractors to a group of experts from outside the site who are recruited for inspection and performing some specific activities**	**Independent**
Testing costs	**Costs paid by the contractor for tests which include cost of testing equipment**	**Independent**
Cost of calibration of measurement and testing tools	**Costs paid for calibration and fixing the measurement and inspection tools**	**Independent**

Failure costs involve internal failures costs (Z_1) and external failures costs (Z_2) (Table 4).

$Z=Z_1+Z_2$	**(4)**

These variables are dependent on total cost of failures or duplication of materials and activities, labor and overhead costs associated with production, fixing the non-standard products or replacing them by standard and high-quality ones, cost of guarantee after the delivery of the building, and cost of services after delivery of the building.

Table 4: Failure costs items

Variable	Description	Type
Internal failures costs	**Total cost of failures or duplication of materials and activities, labor and overhead costs associated with production**	**Dependent**
External failures costs	**Delivery of product**	**Dependent**

To test the relationship between different variables and determine the trend of changes, Kendall nonparametric correlation analysis can be used [6]. The next step is modeling and determining the optimal point of quality costs. In summary, failure costs in a descending and appraisal and prevention costs in an ascending order should be arranged. Then, these two groups are put together and after taking derivation of a quadratic function, the obtained total cost of the optimum level will be determined.

When the obtained quality level is not equal to the intersection of prevention-appraisal curve and failure costs curve at two points, there are two alternatives: first, the intersection is located in the right side of the minimum point and second, the minimum point is located in the right side of the intersection. In the first case, failure cost is more than the quality cost at the minimum point. This means that more money must be spent on correction of products. In the second, failure cost is less than the quality cost at the minimum point and this means that more money should be spent on controlling the products. It should be noted that second case is more preferred.

The obtained point needs to be discussed based on the project conditions and then be used for strategic managerial decision-makings. For instance, low percentage of quality cost may be due to the supervision of quality control staff and project consultants. This allows the contractors to reduce prevention costs through reducing the number of quality control/quality assurance engineers in sub-projects. However, this is more dependent on foremen rather than engineers, because the daily activities of site are under the control of foremen. Involvement of these workers prevents any wrong work or problem as much as possible. They also control the way of exploiting the materials operation method which reduces the appraisal costs without any increase in failure costs or quality costs. Therefore, mere reliance on the obtained point is not enough.

6- RESULTS

Analysis of quality costs causes the activities improving management to be in line with customer costs and expectations and it can be observed that there is a direct relationship between reduced costs and increased profit for improving the quality. Therefore, the actual estimation of quality costs and improved profits- something that establishes a balance between the costs spent on compliance and non-compliance- is the basis of any management system.

The activists of construction industry well know that it better that they perform the

works correctly from the beginning, but they are not aware of the degree of compliance with standards. According to the procedure provided in the present paper, the average failure costs, prevention and appraisal costs and what percentage of the total costs of project is allocated to failure costs because of wrong performing of works from the beginning are expressed. Therefore, defects and duplications should be minimized. To achieve such a purpose, an optimum value must be considered for quality costs. PAF model is one of the most effective techniques which can be used by many construction companies because of its simplicity and ease of execution. By using this model, the optimum level and its related quality costs can be obtained. Drawing the charts specifies the current status of projects and all of these items will help the managers in better management of costs and taking more appropriate decisions.

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