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Assessment of the expected cost of quality (COQ) in construction projects in Egypt using artificial neural network model

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Abstract Many definitions for quality were provided by experts. Among these definitions are: quality is the fitness for use [14], conformance to requirements [4], quality is a predictable degree of uniformity and dependability, at low cost and suited to the market [6].

Cost of quality is an essential element of the total cost of any construction project. Consequently, the accurate assessment of such cost of quality can materially affect the reliability of the estimated cost of any construction project. Stated differently, the accurate and reliable cost estimating for any construction projects is not really possible without the deep investigation for the expected cost of quality of this project. Cost of quality is generally affected by many factors. Any attempt to assess the cost of quality of any project should take the different cost of quality factors into consideration.

The main objective of this paper is to establish a neural network model that will enable the construction firms to assess cost of quality for any future building project. This will improve the company's performance and its ability to compete with other companies through the improvement of bids accuracy. The ''Neural Connection 2.0 Professional'' was chosen to generate the proposed model. The main factors affecting the expected cost of quality were clearly identified. The different sequences of the model development will be deeply investigated. Moreover, the validity of the proposed model will be evaluated using a number of case study applications.

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Introduction

COQ is usually understood as the sum of conformance plus non-conformance costs, where cost of conformance is the price paid for prevention of poor quality, and cost of non-conformance is the cost of poor quality caused by product

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and service failure. These COQ can be also broken down into the three categories:

- *Prevention cost:* the cost of any action taken to investigate, prevent or reduce the risk of nonconformity.
- *Appraisal cost:* the cost of evaluating the achievement of quality requirements.
- *Internal failure cost:* the costs arising within an organization due to nonconformities or defects at any stage of the quality loop.
- *External failure cost:* the cost arising after delivery to a customer/user due to nonconformities or defects which may include the cost of claims against warranty, replacement and consequential losses and evaluation of penalties incurred.

Cost of quality is an essential element of the total cost of any construction project. Cost of quality is generally affected by many factors, such as planned COQ for the project, awareness of quality for project team, supervision team experience, labor skills, suppliers, design errors, defected material, plan of improving quality, external factors, accident, equipment down time and project duration.

The objective of this study is to identify the most important factors affecting cost of quality and to develop an Artificial Neural Network model that can help cost estimator to arrive at a more reliable assessment for the expected cost of quality of any building construction project.

Literature review

COQ models were classified into five groups of generic models. These are: P-A-F model, Crosby's model, opportunity cost models, process cost models and ABC (Activity Based Costing) models. Porter and Rayner [19] make a more comprehensive survey of the published literature and present a detailed review of quality cost models, focusing again mainly on the P-A-F category and its limitations. The following is a summary for the main literature concerning the cost of quality topic:

1. Vernon et al. (1985) [23]
   Increases in construction planning during design and coordination across the design-construction interface are shown to have very strong effects on reducing construction time and increases in the former variable, which also included aspects of value analysis, reduce the cost of the building [21].
2. Tesfai (1987) [22]
   Developed a good quality culture. Owners, designers and contractors will take quality seriously, preventive disciplines will be widely used and camaraderie's will be observed throughout the industry [20].
3. Davis et al. (1989) [5]
   A quality performance tracking system (QPTS) has been developed to provide for the quantitative analysis of certain quality-related aspects of projects, by systematically collecting and classifying costs of quality. By defining quality as ''conformance to requirements,'' the cost of quality becomes measurable. It consists of two main parts, the cost of quality management efforts and the cost of correcting deviations [6].
4. Abdul-Rahman (1995)
   Stated that poor quality resulting from non-conformance during construction leads to extra cost and time to all members of the project team. The costs of rectifying non-conformance can be high and they can affect a firm's profit margin and its competitiveness. Construction-related firms can identify non-conformance information by employing a quality cost matrix as illustrated in a case study as a basis for improvement [1].
5. Abdul-Rahman (1996)
   Described the use of the quality cost matrix to capture the cost of non-conformance during a construction project and limited the Quality Performance Tracking System (QPTS) and developed a Quality Cost Matrix (QCM), which took into account the effect of a failure on time, particularly, the costing of accelerating work and specific causes of a non-conformance [2].
6. Abdul-Rahman (1997)
   Investigated the importance of client role in determining the quality of the end product; the usefulness of information on non-conformances in preventing failures and improving a process; problems with ground conditions; how most failure costs can be eliminated; how the contractor's role should include anticipating of problems; and how information on the cost of failures can be an indicator of weaknesses and assist in preventing the same failure in the future [3].
7. Low et al (1998) [16]
   Stated that there are three components that make up quality costs: prevention, appraisal and failure costs. Proper design and implementation of these work procedures would lead to reduced wastage as more work would be done right the first time [13].
8. Love (1999) [15]
   Determining the causal structure of rework influences in construction, contributes to study of quality in construction by capturing the complexity and dynamism of those factors that influence rework and project performance in a holistic manner. Rework is caused by errors made during the design process. These errors appear downstream in the procurement process and therefore have a negative impact on a project's performance [12].
9. Mwamila et al. (1999) [17]
   Stated that construction speed is impacted by the number and productivity of workers and can be increased by reliable equipment and early planning and design that maximize use of limited available resources. Building quality is dependent on standardization, product suitability evaluation, defect identification, and thorough planning. Labor costs are generally a small portion of total construction costs; however, labor is a key cost factor because it affects both quality and speed [14].
10. Heng Li et al. (2000) [12]
    Analyzed the causes and costs of rework projects and discussed. The findings reveal that the cost of rework for the case study projects was 3.15–2.40% of their project contract value. Changes initiated by the client and end-user together with errors and omissions in contract documentation were found to be the primary causes of rework [10].
11. Ofori et al. (2000) [18]
    Assessed the perceptions and expectations of contractors concerning ISO 9000 certification and the costs and ben-