IIOAB JOURNAL
ISSN: 0976-3104

ARTICLE

FUZZY ANALYSIS OF CONSTRUCTION COST OF QUALITY IN IRAN FOCUSED ON BUILDING MATERIALS QUALITY

Ashkan Khoda Bandeh Lou[1*], Alireza Parvishi[1], Rahad Sarami[2]

[1]*Doctor Of Philosophy Of Technical Sciences, Faculty Of Engineering,Civil Engineering Department,Urmia Branch,Islamic Azad University,Urmia, IRAN*

[2]*PhD Student Of Engineering Construction Management ,Faculty Of Engineering,Civil Engineering Department,Urmia Branch,Islamic Azad University,Urmia, IRAN*

ABSTRACT

Given the increasing quality expectations of human societies due to the use of technology and qualitative conception of modern human being to life it is necessary to observe qualitative aspects in all aspects of human life. One of most basic and the most important human needs is a shelter for living that has obtained major headlines in the long-term development programs and plays a significant role as the most dynamic areas of economic performance. Unfortunately, due to the lack of proper culture, inadequate control and supervision, short-lived investment in the construction sector, concerns about cheap construction and... in Iran there are poor quality buildings in terms of construction and severe financial and physical losses cause by earthquake in this country. In this paper it is attempted to recognize factors affecting the construction industry through relying on personal knowledge and experience, evaluating the information obtained from the distributed questionnaires and using fuzzy inference system and the predictable costs to improve the quality of buildings are considered by them and based on the costs of quality-oriented manpower and finally a pattern is obtained to reduce the costs.

KEY WORDS
construction cost of quality, housing, cost of quality management, challenges in the constructionindustryof Iran

Published: 15 October 2016

***Corresponding Author**
Email:
ashkan72@rambler.ru

INTRODUCTION

In fact, the costs of reworks include a considerable value of the total cost of the project; so in this sector there is a considerable room for improvement in the cost of the project that can reduce costs considerably. Obtaining the cost reduction depends on the ability to identify and collect the correct cost of quality (1). Without a program to measure the costs of quality, the units often cannot determine the quality problems (2). According to Davis et al. in 1989 without a formal and systematic quality management system in the place quality problems cannot be identified. As a result the information is lost and activities that are needed to reduce or eliminate reworks will not be detected (3).

All sectors of the construction industry can benefit from the analysis of quality measures. However, determining the cost imposed due to poor quality is essential in the design and manufacturing sector (1). In addition, analysis of the causes for the collected data could determine the root causes of quality problems which can identify ways to improve problems in future projects. Therefore, as a result of this work it is possible to reduce the cost of poor quality and rework (4).

The use of a system to determine cost of quality can have practical benefits. Including:

- It could justify future quality measures financially (5) and also used as a means to estimate the potential profit obtained for the lack of quality (2).
- It could be used as a means to evaluate performance and to evaluate the success of quality program (2) and find the weak points of the quality system (6).
- It could make the organization aware of the potential effect of poor quality on the performance of the organization's costs (7).
- It could help organizations to know where cost of quality occur (7) and where there are problems (2). Therefore, it can be used as a tool to determine the suitable areas for improvement (2).
- It could help to transfer the learned lessons to the future (3).
- It could help to focus on problems to make the staff aware of the problems. It can also detect the source of the nonconformities (such as manufacturing, engineering, marketing, etc.), and identify those who are responsible for additional costs (9); so it can make the employees to do their jobs more effectively (2).

MATERIALS AND METHODS

In this paper after a short analysis of quality management history by defining the cost of quality it is attempted to familiarize the reader with the subject of this article and then these costs are classified in the construction industry and its

Effective factors in the housing construction industry are detected and their impact on cost of qualifying system will be examined.

Then, statistical analysis is done on data obtained from questionnaires distribute among 60 civil engineers by IBM SPSS Statistics Software so that the fuzzy optimization of construction costs is performed in MATLAB application.
Finally, by analyzing the classic and dynamic models of the cost of the quality the results of earlier studies are addressed so that finally using these data recommendations are made to establish cost of qualitying system followed by high quality construction.

RESULTS

According to information obtained from the fuzzy inference system presented in this study, the relationship between the spent cost of quality and obtained quality by those costs. It is clear that in order to obtain a quality of 74.9% the lowest cost of quality for building materials is 8.81% and in fact optimal quality for residential buildings is located within this range. It is also possible to consider 8.81% of the total costs of a building to spend on the costs of quality in terms of manpower.

The definition of cost of quality

The concept of cost of quality was first discussed by Juran (1951) in his book "Quality control handbook" and it was used in the early 50's in the manufacturing industry (10). In the manufacturing industry since the early1980s the organizations focused on increasing the quality of construction projects [11].
Simply put, the cost of quality is the one that is not spent if the quality is perfect. In summary the cost of quality is a cost that is related to achievement and non- achievement of the quality[3].
There are different definitions of the term cost of quality. For example, there are control costs and the costs of failure as stated by Juran (12), compliance and non- compliance costs as stated by Crosby[13], controllable variables and outcome variables as stated by Harrington [5] and the costs of quality management practices and the cost of repairing the damage as discussed by Davis et al [1].
The most common definition for the cost of quality is the definition provided by Philip Crosby. The cost of quality was one of Philip Crosby's definitions that stated "Quality is free" because it is the lack of quality that increases the cost (4). According to Crosby's definition cost of quality is considered as the sum of the costs of compliance are spent to prevent low quality and non- compliance costs are the costs of poor quality created by a defect in the product or service [14].

History of quality management and its cost The foreign literature

1951- Joseph Juran presents the concepts of costing quality, economy of quality and the graphic form of cost of quality model [14].
1956- Armand Feigenbaum presents the modern form of P-A-F model [19].
1978- The first edition of ISO 9000 Standard [quality management principles and terminology] was released to the world by the International Standards Organization [ISO].
1989- Construction Industrial Institute announces the costs relating to the quality of reworks in nine construction projects with total project as equivalent to 12.4% of the total cost of the projects [15].
1995- Johnson presents his suggestions for elements of cost of quality for engineering units [2].
2008- The fourth edition of ISO 9000 was published.
2009- Mills et al announces the costs of failure in construction about 4% of the total cost of the project [8].
2010- Love et al. announce the cost of reworks in the construction of infrastructure projects equivalent to 10% of the total cost of the project [15].

The literature in Iran

Iranian researchers have addressed the productive projects in the field of cost of quality and the cost of quality in construction projects is a new field in Iran and some of them are discussed below:
1983- Analyzing the impact of three factors of cost, quality and time on construction industry by the doctor Habibullah Bayat who has discussed the a result of his research as follows: quality is defined as the compliance with requirements thus first, for the recognition and measurement of quality it is necessary to understand the different aspects of the needs. Second with regard to the long life of the building industry product the quality is not achieved in the absence of foresight. Third, personalized dealing with quality components is doomed to failure. It is necessary to recognize the building components for all buildings by a systematic method and describe the components for cultural, social and climatic conditions of the country.
1998- Design and implementation of quality costing systems in a forging industrial unit by the doctor Kamran Rezaee and Alireza Nikdel that starts with the analysis of administrative procedures in the areas of manufacturing, mold making, quality and finance and they have identified all quality related costs and activities and after defining the elements of costs in each of the main levels and linking different activities

in company with each of them and collecting information and data, they have analyzed the elements of the cost.
2011- The analysis of the costs of quality in manufacturing industry with a focus on mass building projects by Amir Hossein Jafari which is a study conducted on 60 mass building companies according to which the costs of quality is equivalent to 5% of total construction costs.

Classification of cost of quality models

Schiffauerova and Thomson [2006] classified cost of quality models into four general models including: P-A-F or the Crosby Model, cost of opportunity models, cost of process models and activity based costing [ABC] models. They stated that models existing in the same group are not quite the same. In fact, their nature can be different and the proposed classification is made only in accordance with the basic rules and principles [14]. Elements of the abovementioned models are summarized as follows [17].

Table 1. Classification models of cost of quality

Generalmodels	Groups ofcost ofquality
PAF	Prevention + Appraisal +Failure
Crosby	Compliance + non-compliance
Cost of opportunityorinvisible costs	Prevention + Appraisal +Failure +Opportunity
	Compliance + non-compliance
	Invisible+ visible
cost of process	Compliance + non-compliance
ABC	Double value+without doublevalue

PAF or Crosby model

After studies on the subject matter it is prevention- Appraisal-failure of cost [P-A-F] model is widely accepted and it is the most widely used model to determine and classify costs of quality. P-A-F model is accepted by Quality Control Association of America [7] and Great Britain Standards Institute [17] and used by many companies that have put quality costing on their agenda [18].

Most cost of quality models are based on P-A-F classification. For the analysis based on the phased need to classify each of the factors will be examined. Armand Feigenbaum [1943] performed an analysis of quality costing for the first time when they were developing the system for expense reports with their team. Later in 1951 Joseph Juran developed the concept of quality costing, quality economy and the graphic form of cost of quality model and then Armand Feigenbaum [1956] proposed the modern form of PAF for classification of cost of quality including the costs of prevention, appraisal and failure [including internal and external failure]. Cost classification of Crosby model in 1979 was similar to the P-A-F. Crosby saw quality as "conformance to requirements" and thus defined the cost of quality as the total costs of compliance and non-compliance [13].

Classifying costs of quality

The components of the PAF classification model are defined as follows:

1. Costs of planning, supporting and pursuit of quality:
   Including the costs of activities spent to prevent errors and failures in the building. Spending these costs reduce the errors and failure in planning to delivery stages.
2. The costs of quality assessment:
   These costs are spent for determination of compliance or non-compliance of the qualitative characteristics of building with the intended characteristics on the maps and technical documents.
3. Internal failure costs (Within the organization)
   These costs include the faults that occur at different stages prior to delivery to the customer and the organization through various ways, such as appraisal and testing by quality control department staff or external inspectors to discovers defects and attempts to remove them.
   External failure costs (outside the organization)

The group covers costs that arise after delivery to beneficiaries and they are not determined and discovered before utilization by the customer.

The definition of fuzzy variables in MATLAB

For the fuzzy analysis it is needed to classify each of the factors under examination.
In the analysis using Fuzzy Inference System, 4- input variables of construction, quality of materials, engineering knowledge and experience of workers as well as an output variable of cost of quality are defined.
According to the analysis based on fuzzy logic using MATLAB software, it is possible to achieve the desired classification in many ways. Among them the triangular or Trimf is used for middle classification and trapezoidal or Trapmf method is used for border classification.
The materials are classified into three classes with low, medium high quality. The engineers also classified into three categories: amateur, average and professional in terms of experience and knowledge. Labor force includes master, skilled workers and simple workers. The figures related to each classification are presented as follows.

Comparing the traditional model and the dynamic model of costs of quality

After developing the P-A-F model Juran presented the traditional relationship between preventive plus appraisal costs with cost of failure (10). In the P-A-F model, there is a different relationship between costs of quality that plays the key role in understanding the formation of the model [27]. The basic premise of P-A-F model is that addressing the prevention and appraisal activities reduces the costs of failure because the non- compliances will be detected at the earliest possible date [9,20]. Error! Reference source not found. Left Figure presents the traditional theory of the cost of quality and mentions how the cost and quality are linked together.
As it is clear from the Figure there is an inverse relationship between prevention and appraisal of the cost of failure. The optimal level of quality is where the rising curve of the prevention and appraisal costs meets the downward curve. Total costs of quality has the minimum level where the prevention plus appraisal costs is equal with the cost
of failure. The curve of total cost is the sum of two other curves and its minimum point is the optimal point of the cost of quality and thus it is completely dependent on the form of two other charts. This optimal point can be different based on the nature of the project (4).

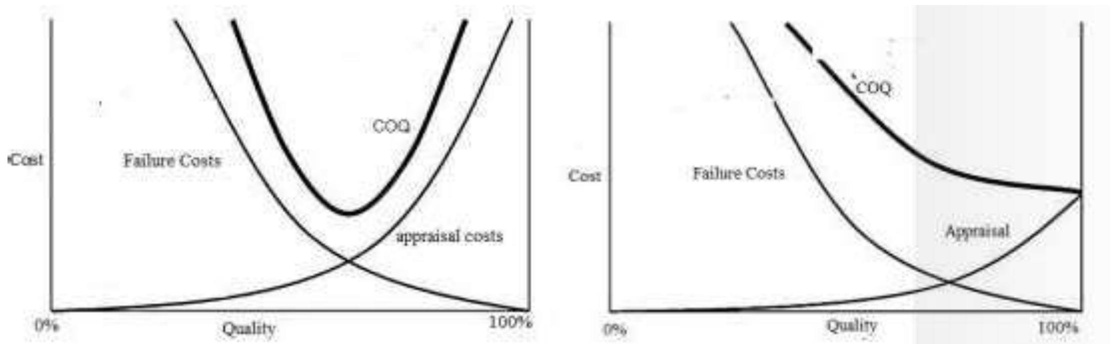

Fig: 1. The dynamic model (right Figure) and traditional model (left Figure) of the cost of quality
………..

(Cost, total costs of quality, cost on compliance, cost on non- compliance, cost of failure, cost of prevention, appraisal, level of quality)

The traditional cost of quality model is appropriate for a specified time and limited conditions and in unlimited circumstances the dynamic model of cost of quality is preferred. In other words, traditional cost-quality relationship is completely correct and reflects the economic cost of quality in static conditions but in in dynamic mode, costs of failure can continue to reduce without an increase in cost of appraisal (14). Porter and Rainer (1992) stated that in some situations if enough preventive measures are taken, there will be no defect in the work and thus the cost of failure would be zero and there will be no need for appraisal. In these circumstances the optimal point will be faultless [18]. Error! Reference source not found. The right Figure indicates how it is possible to reduce the costs of failure by addressing the continuous improvement and preventive measures and bring the optimum quality cost to the level of 100%. This model is known as the dynamic model of quality.
According to the code of the design of buildings against earthquake (2800), residential buildings are in buildings with medium importance and thus the quality of 100% is not considered for the construction of a building. Accordingly in this study the traditional model of cost of quality is used and the obtained data are analyzed based on it.

IIOAB JOURNAL
ISSN: 0976-3104

Optimizing the quality costs using Fuzzy Inference System

One of the purposes of quality costing system is to minimize quality costs to the lowest possible. Quality costing could be a growing trend. In other words, as long as the savings and profits from reducing the costs of failure exceed the cost spend for a quality management, extra attention to the quality management is justified [1] To demonstrate the cost of quality features and find the optimal level of significance,
many mathematical and economic models have been developed. These models are quite different in terms of purpose but only few of them have practical application [21].
Thus, to achieve a functional model, the collected information is analyzed in MATLAB software and using Mamdani Fuzzy Inference System and then compared to confirm by the traditional curve of the cost of quality.
According to the classifications made on the quality of materials, engineering knowledge and experience of workers 135 rules are defined in the Fuzzy Inference System that finally the level of significance of these rules is defined and defined in [Fig. 2]

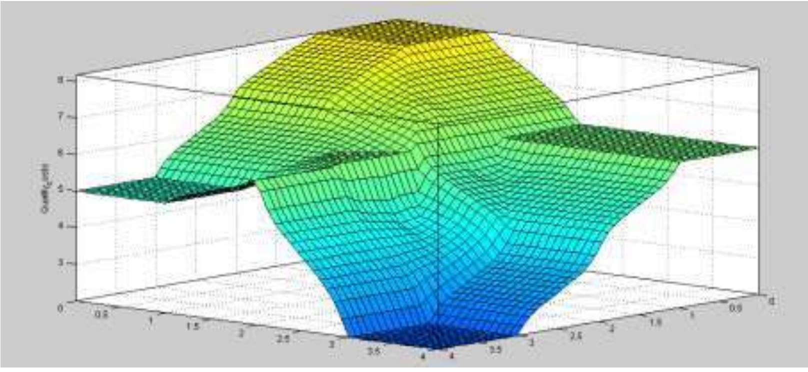

Fig: 2. Level of significance of rules defined in fuzzy inference system

………..

In [Fig. 3], the data obtained from the Fuzzy Inference System and information obtained from questionnaires indicate the relationship between cost and obtained quality based on those expenses. Accordingly it is clear that in order to achieve a quality of 74.9% the lowest cost of quality is about 8.81% and in fact the optimal quality for residential buildings in this range.

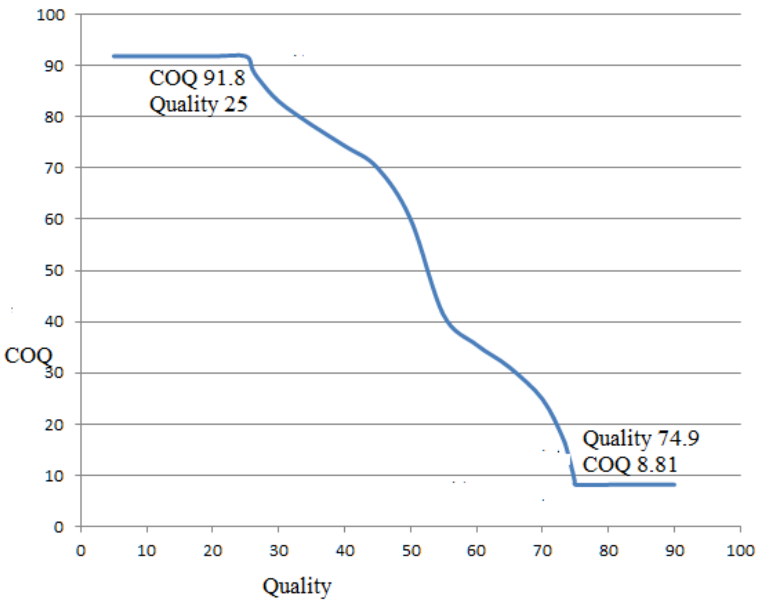

Fig. 3 : Relationship between quality and the cost required to achieve it Cost of quality/ quality

………..

Analysis of the effect of Fuzzy Inference System inputs on the cost of quality

[Fig.4] presents the charts that present the effect of each of the factors listed above one the cost of quality based on fuzzy inference systems. As the Figure 4 suggests and based on the slope of the curves the engineers and workers have the least effect on the costs of quality.

Also the scope of changes in the average cost of quality for each factor is obtained for each of the factors from the number 3 that is the cost of assessing by the contractor to number 6 which is the output failure which presents the proximity of these relations to the cost of quality based on the traditional theory.
The relationship between the input variables on the costs of quality indicated the same result. Figure 4 indicates the effect of changes in quality of building materials and expertise of human resources (engineer or worker) on costs of quality. It should be noted that in all these figures the optimal and acceptable sector for cost of quality is the bottom of the cost of quality charts that is specified with a dark blue and includes the quality of above 85%.

As the [Fig. 4] – a suggests the slope of the chart in the building material axis is more than the slope of the chart in the axis of the engineering expertise which indicates the higher effect of the building materials than engineering expertise such that in case of using the low quality materials the costs of quality are tilted towards the costs of internal failure and in case of using the engineers with low expertise these cost of quality lead to the internal failure costs with less slope.

The relatively gentle bilateral slope of this graph that starts with the input quality range of 20% shows the similar effect of these two factors on costs of quality because in the charts of Figure 4-b and c the slope of the graph matching the experiences of workers' axis is far more than engineering expertise or quality of building materials that shows limited range of input factors and this indicates the high effect of these two factors (quality of building materials and engineering expertise) on the costs of quality.

Also according to these two graphs, the slope of the graph in the materials and engineers axis is fixed50% to the bottom and this means that as the experience of workers in increased in the construction industry it is still not possible to used low quality materials or engineers with little expertise.

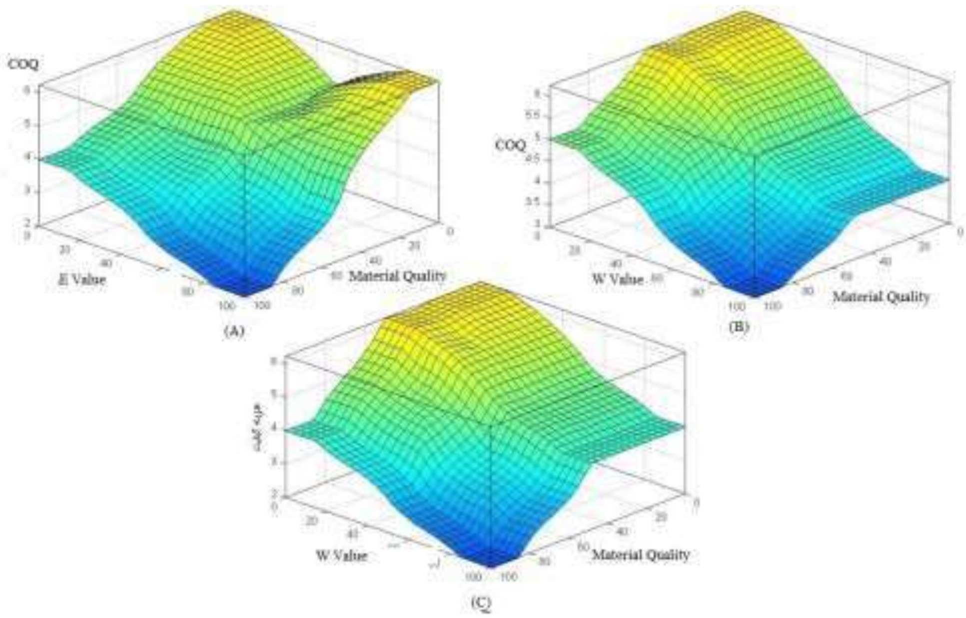

Fig: 4. The three-dimensional charts of the effect of materials and staffing on costs of quality

CONCLUSION

The relationship between the spent cost of quality and obtained quality by those costs.It is clear that in order to obtain a quality of 74.9% the lowest cost of quality for building materials is 8.81% and in fact optimal quality for residential buildings is located within this range. It is also possible to consider 8.81% of the total costs of a building to spend on the costs of quality in terms of manpower.
Also according to the results of this study the following points are mentioned:

- Optimization of costs of quality helps to reduce the negative risks of the project
- Optimization of costs of quality lead to the reduced cost of the entire project, reduced time of implementation of the project and improved construction quality

- Investment on the costs of compliance helps to reduce the cost of non- compliance
- Based on the results of this research achieving the optimum point of the costs of quality in construction projects is achievable by following the classical charts of the costs of quality

CONFLICT OF INTEREST

Authors declare no conflict of interest.

ACKNOWLEDGEMENT

None

FINANCIAL DISCLOSURE

No financial support was received to carry out this project.

REFERENCES

[1] Measuring Design and Construction Cost of quality. Davis, K., Ledbetter, W. and Burati, J 1 989, Journal of Construction Engineering and Management, p. 115.

[2] The Development of Measures of the Cost of Quality for an Engineering Unit. Johnson, M. 1,995th, International Journal of Quality and reliability Management, pp. 86-100.

[3] Quantifying the Causes and Costs of Rework in Construction. Love, P. and Li, H. the 2 thousandth, Construction Management and Economics, pp. 479-490.

[4] A Cost of Quality Analysis of a Building Project: Toward a Complete Methodology for Design and Build. Hall, M. and Tamkins, C. the 2,001th, Construction Management and Economics, pp. 727-740.

[5] Is a cost of quality system for you? Corradi, P. 1,994th, National Productivity Review, pp. 257-269.

[6] Principles of Cost of quality. Campanella, J. 1,990, ASQC Quality Press.

[7] A Process Approach in measuring cost of quality of construction projects: Model Development, International Journal of Quality and reliability development, 20 pp: four hundred seventy-nine to four hundred and ninety-two Aoieng, R., Tang, S. and Ahmed, S.

[8] Cost of quality in Dubai: An analytical case study of residential construction projects. Abdelsalam, H. and Grad, M. 2009, International Journal of Project Management, Vol. 27: 501-511.

[9] Quality-Related Costing: Findings from an Industry-Based Research Study. Plunkett J, Dale B. 1,998th, Engineering Management International, pp. 247- 257.

[10] Quality Control Handbook. Juran, J. 1951st, New York: Mcgrae-Hill.

[11] Cost-based Analysis of Quality in Developing Countries: A Case Study of Building Projects. Kazaz, A., Birgonul, M. and Ulubeily, S. in 2005, Building and Environment, 40, pp. 1356-1365.

[12] Quality Planning and Analysis, 3rd Edition. Juran, J. and Gryna, F. the 1,993th, New York: McGraw-Hill.

[13] Quality is free. Crosby, P. 1979, McGraw-Hill.

[14] A Review of Research on Cost of Quality Models and Best Practices. Schiffauerova, A. and Thomson, V. 2 006, International Journal of Quality and Reliability Management.

[15] The Effect of Project Types on the Occurence of Rework in Expanding Economy. Oyewobi, L., et al., Et al. 2,011, Journal of Civil Engineering and Construction Technology, pp. 119-124.

[16] Rework in Civil Infrastructure Projects: Determination of Cost Predictors. Love, P., et al., Et al. Two thousand and ten, Journal of Construction Engineering and Management, p. 136.

[17] Measuring the impact and the results of using the costs of quality tools- A Case Study in the suppliers of car parts, Hosseini Ashtiani M, Rezai , Kamran and Communion , Massoud , Master's thesis, Tehran University ,[2002]

[18] Strategic approach to housing and urban development in the country, Ghalibaf, Mohammad Bagher, Tehran, Institute of thinking and dynamic action

[19] Total Quality Control, Feigenbaum, A. [1961] New York: McGraw-Hill.