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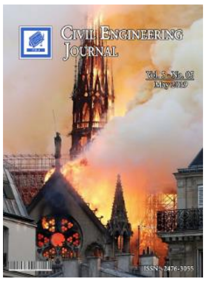

Prioritizing the Main Elements of Quality Costs in Design-Build Mass-Housing Projects

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Abstract

Reducing the cost of quality in mass-housing projects can reduce the overall cost and can also result in increasing profitability or the possibility of getting more projects due to the lower price offered in the tenders. The first step to reduce the cost of quality is to identify different elements, determine their impact on the final product quality and then prioritize them. In this study, questionnaires and structured interviews with experienced construction professionals were employed to identify and prioritize the fundamental elements using the P-A-F (prevention, evaluation, and failure) method, one of the most well-known methods for categorizing quality costs. The results indicate a high impact of preventive activities and the low impact of external failure activities on final product quality. According to the results, the use of experienced specialists and skilled workers is more effective than in-service training of inexperienced forces. Corrective actions of non-conformities and design improvements have a significant impact on final product quality. The new approach to COQ elements ranking, used in this research, can help decision-makers to prioritize the most effective activities in construction projects to increase final quality with an optimum quality cost.

Keywords: Cost of Quality; Construction Projects; Mass-housing; Quality Management; PAF Method.

1. Introduction

In recent decades, the increasing need housing in developing countries resulted in mass-housing or complexes projects managed government's authorities. For example, several multi-million housing plans in Iran have been designed and implemented in the form of mass-housing construction projects within large cities suburbs [1]. In such circumstances, it is essential for construction companies to reduce the cost of housing without losing the expected quality to attend in bidding competition. COQ (Cost of Quality) identification not only provides the opportunity to quantify and record costs, but also makes it possible to identify poor quality products and thus reduce costs by better and more appropriate use of resources and facilities. In addition, COQ can identify the areas where the total cost of quality can be optimized to increase quality level [2] and also can be useful as an overall measure of organizational performance [3].

Many companies consider quality as the core value of their organization and a critical factor for success in the competitive bids [4]. The research results have demonstrated that efforts to improve quality lead to an increase in product or service costs so that the quality improvement has its own costs. As a result, it is very important to conduct COQ analysis as an input to financial evaluation of quality improvement programs [5].

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The COQ is greatly important because of its extensive scopes [6]. Lam et al. (1994) claimed that the COQ could account for 8% to 15% of the total cost of the construction projects [4]. However, the literature review indicated that COQ, as an important quality management tool, is not applied in most quality management programs [7, 8].

According to research by Josephson et al. on construction projects, errors and problems computed 4.4% of total construction costs. In addition, these errors are equal to 7.1% of the working time or 34 minutes of a working day per person [4]. In 1978, these costs were estimated by the UK government at around 10% of the gross national product [9]. In the United States, direct costs due to reworks were estimated over 12% of the total cost of construction [9]. In Australia, it was concluded that every 1% more investment in prevention activities can reduce the total construction costs of failure from 2% to 10% [10].

The COQ measurement is not necessarily effective in improving quality. The COQ helps managers to evaluate their investment outcomes and will prepare their quality strategies and projects. The appropriate measuring instrument should be identified to measure the COQ. One of the most commonly used models for categorizing, detecting and measuring the COQ is the PAF approach, presented by Crosby in 1979 who divided the COQ into prevention, appraisal and failure costs. His work shows the relationship between failure costs and prevention and appraisal costs [4].The RAF approach classifies the components as follows [4]:

- **The prevention costs:** the sum of all costs to avoid deficiencies before implementation including identifying the cause of the defect, undertaking corrective action to eliminate defects, personnel training, product or system redesign, the provision of new or altered equipment [4].
- **The appraisal costs:** the costs of monitoring, testing, or other costs incurred to ensure quality requirements and conformance of the product or process [4].
- **The internal failure costs:** the costs incurred due to product defects within the company and costs associated with defects found before delivering the product or service to the customer, including reworks, wastes, and repairs [4].
- **The external failure costs:** the costs incurred due to product defects after presenting by the company, including replacement of the product during the warranty period, loss of reputation of the company, handling of complaints and product repairs [4].

Although in the ASQ (American Society for Quality) references as a general guideline to all industries, most of the elements affecting the COQ are listed according to the above-mentioned classification system, these elements are presented in general, regardless of the type of project or construction system. In addition, the effect of each element on the final product quality is not determined separately [11].

Therefore, there is always a need to provide an appropriate platform for specifying, categorizing, and ranking the main COQ elements in mass-housing projects. Moreover, the determination of each parameter effect on final quality can help project managers to prioritize the parameters and elements affecting the COQ their associated costs.

In this study, the main parameters contributing in the COQ were listed on the basis of previous studies and semi-structured interviews with experienced experts and researchers in construction industry of Iran. Then, the impact of each parameter on final quality is determined and ranked in a comparative manner based on the Likret scale system from 1 to 5 [12].

The results of this research could be used as a basis for determining the quality costing system in the mass-housing projects. The ranking of COQ elements based on the impact on final quality can help decision-makers to focus on the most effective activities and it can result in increasing final quality and decreasing the quality costs.

2. Research Background

2.1. The COQ Studies and Implementation Analysis

As previously mentioned, the COQ is a tool for evaluating and measuring the efficiency of an organization or a process. Some organizations use COQ as a tool for weakness recognition and performance improvement consequently [13]. Moreover, some researchers exploit the COQ to evaluate a particular process or the performance of a system [14].

Al-Tmeemy and Rahman (2012) conducted a statistically qualitative survey to compare the benefits of implementing COQ and the requirements for conducting it between involved the parties. They divided the barriers into three cultural, systemic, and corporate classes, and stated that "management attention and increased quality awareness" are the highest advantages of measuring the quality costs [15].

Kiani and Shirovi Nezhad (2009) used a dynamic system for modeling the COQ [16]. Applied empirical studies were used to initialize their model. The study evaluated the impact of the costly factors on quality and came up with the following conclusions:

- In general, the prevention activities have a greater impact on the COQ reduction compared to the appraisal activity.
- The prevention and appraisal activities are more effective in reducing the total COQ than when these activities work individually.

Sower and Quarels (2007) studied the role of COQ and quality growth in organization implementation. In their research, more than 30% of companies examined the COQ, in line with the previous research findings. They concluded that "the total quality of COQ will be reduced as processes of quality improvement, but the decreasing trend will be reduced" [17].

Omar et al. (2009), as well as Tye and Abdul Halim (2011), conducted studies on the implementation of COQ in the Malaysian construction industry. They evaluated the COQ levels and effects on the quality of achievements in the relevant industry unit. Their findings showed a high proportion of COQ to reduce the cost of non-functional and organizational level development [18].

2.2. The COQ Studies in Construction Industry

Although the COQ study has a history of more than 60 years, it is far newer in the field of construction industry, due to two main reasons:

1. Projects and, in particular, construction projects are unique, and it is difficult to establish a steady trend in these projects.
2. The time-consuming nature of the construction projects generally leads to costly and extensive research as a case study in this regard.

In the following section, the main studies have been reviewed in the field of the construction industry, and in particular mass-housing, focusing on newer studies.

Johnson (1995) probably conducted the first series of studies on the COQ in the construction industry. This study examined the methods for calculating the COQ in the construction industry implemented by a well-known government contractor in US, aiming to identify existing measures for costs of non-conformance functions in engineering operations and to suggest the best solutions applicable for use in the engineering employer unit. The information was gathered using the literature and telephone interviews with quality practitioners from major US corporations. Finally, different methods for measuring the costs of conformance (COC) and non-conformance (CONC) were evaluated. In addition to suggesting optimal methods, the role of the accounting unit, methods for collecting COQ data, subset reporting mechanism, and the findings of the interviews were also discussed [4].

Love and Irani (2003) developed prototype project management quality cost system (PROMQACS) in the construction projects. The results investigated and suggested the structure and information required for COQ classification system. To identify the information and management tools required to develop the PROMQACS system, the suggested system was tested and applied in two construction projects using a computer program. The proposed system was also used to determine the costs and the causes of the rework generally occurring in the projects. This research recommended that the project participants and particularly construction contractors can utilize PROMQACS to detect short comes in their project-related activities and consequently make the best decision to improve their project management system in the future. The advantages and limitations of this system were also identified in these studies [19].

Kazaz et al. (2005) investigated a mass-housing project in Elazığ, Turkey. The project included 3100 housing units, the construction of which lasted over 4 years. Their study revealed that the total COQ was averagely 32.36% of the total project cost. They also considered this value to be very high, which could be attributed to the poor executive project management and the lack of internationally certified contractors [20].

Newton and Christian (2006) evaluated the COQ of construction projects and the impact of quality on construction costs. To this end, data related to the design costs, construction costs, operation costs, maintenance costs of 215 buildings were collected from all available databases from the Canadian Department of National Defense (DND). A measurement scale was developed to measure quality at all stages of initial building design, construction, operation and maintenance throughout the life cycle of the project. Analysis of variance (ANOVA) of the total annual costs in the first 20 years of the life cycle of buildings clearly indicated that the quality would have the greatest effect on total costs when the impact of other potential parameters, particularly the life cycle, was minimized or eliminated. It was also concluded that the quality and especially design quality would have the most significant impact on the maintenance costs [21].

Abdelsalam and Ghad (2009) investigated a mass-housing project in Dubai, UAE. The project included the construction of 291 multi-storied residences. The results revealed that the total COQ represents an average of 1.3% of the total costs of the projects. However, they could not calculate the external failure costs because their project was not yet handed over to the client. They also stated that the percentage of 1.3 is very low, and the reason could be that the employer monitored the execution of the work on a daily basis using project management tool (PMT) and a consultant. This not only elevated the accuracy of contractors but also reduced their appraisal and prevention costs [13].

Love and Jafari (2013) assessed the effectiveness of a quality program during the initial 18 months of a monorail project in Iran. In this project, the quality cost system was operationally implemented. Ultimately, the failure cost was calculated to be 5% of the project's contract value. Implementation of quality management program reduced this value down to about 2.78%, and 2.32% of the project's contract value was attributable to appraisal costs. The major factors in reducing COQ in the failure subscale were the use of full-time quality management teams and repetitiveness of the activities. The active performance management and appraisal team and contractor monitoring have led to detect the errors and problems of the initial design before implementation. This raised the efficiency of the quality management system and improved the cost-cutting mechanism. In this project, the experiences of the contractor in the field of operations and analysis of COQ have proven to be promising in providing learning opportunities for other companies and consequently implementing quality improvement programs [22].

Jafari and Heravi (2014) investigated quality-related activities using 77 structured interviews in 60 mass-housing construction projects in Iran. In this study, the most important quality-related activities and COQ components were first identified. A model was developed to evaluate the total COQ of the studied projects by fitting the third-ordered curve to the extracted data. Then, cost-cutting potentials as the result of quality management obtained by COQ optimization were estimated based on the developed model. In fact, this research has taken a major step in comprehensive quality management (CQM) by developing the appraisal COQ model and suggesting an optimal COQ in mass-housing projects. Moreover, this model provided an optimal level of COQ and could yield significant cost-cutting in COQ and thus the total costs of the project [1].

Robfeld et al. (2015) evaluated the effectiveness and efficiency of quality management system indicators in some reputable German companies. They concluded that the high cost of data collection, problems of cost and benefit isolation, the lack of benefit expectancy, the lack of knowledge of methods, and the hard process of quantification of the quality-related benefits are the main problems in COQ implementation systems [23].

Alglawe et al. (2017) used the system dynamic approach to examine the effects of incorporating the opportunity cost into quality costing calculations in order to build a general framework within the supply chain. They concluded that when the opportunity cost is considered in the COQ model, the number of new customers and production units in supply chain decreases, which highlights the importance of the opportunity cost analysis in making decisions for the quality management strategies [24].

Glogovac and Flipovic (2018) expanded the level of knowledge about quality costing in active companies including both manufacturing and service-based companies. Their results confirm that companies which attribute to the fulfillment of certain requirements of ISO 9001:2015 for the adequacy of COQ management achieve better results [25].

2.3. Failure Costs Evaluation of the Construction Projects

The main researches carried out in the field of failure costs and especially rework costs in construction industry have been summarized in Table 1. As it is clear, the failure costs reported the table have not been estimated using the same method and each work has used its own method.

Table 1. Percentage of Failure Cost in Proportion to Total Project Cost in Previous Studies

Reference	Country	Studied projects	Sample size	Percentage	Failure cost	Data resources
Burati et al. (1992)	US	Industrial	9	12.4	Direct costs	field data collection + document inspection
Abdul-Rahman et al. (1996)	UK	Industrial	1	6	Cost of resources + time-related costs	Inspection of related documents
Josephson and Hammarlund (1999)	Sweden	Building	7	3.2-4.9	Direct costs	Field data collection
Hall and Tomkins (2001)	UK	Building	1	5.8	Direct costs + Delay costs	field data collection + document inspection
Kazaz et al. (2005)	Turkey	Building	3100	11.6	Internal and external failure costs	Inspection of related documents
Abdelsalam and Gad (2009)	UAE	Building	291	0.7	Internal failure costs	Inspection of related documents
Love et al. (2010)	Australia	Infrastructure	115	10.3	Direct costs + Indirect costs	field data collection + document inspection
Oyewobi et al. (2011)	Nigeria	Building	25	3.47	Direct costs	Inspection of related documents
Jafari and Love (2013)	Iran	Monorail	1	0.05	On-site costs	Field data collection
Jafari and Heravi (2014)	Iran	Monorail	1	0.05	Direct Costs	Inspection of related documents

3. Research Methodology

This research involved different stages and different methods at each stage. The main parameters affecting the COQ have been specified from literature review and previous studies. Then, using semi-structured interview, the main parameters having the most impact on COQ of mass-housing projects have been selected from the list. After that, the parameters ranked and prioritized based on their relative importance index. These four main steps have been shown in Figure 1.

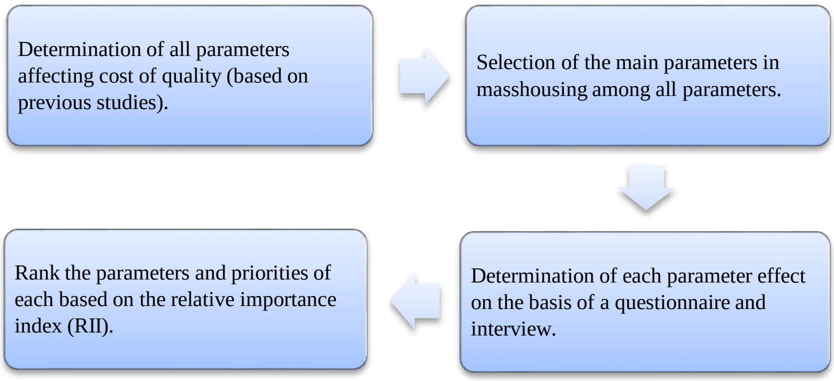

Figure 1. Research procedure

3.1. Semi-structured Interviews

To collect data associated with the parameters affecting the COQ in mass-housing projects, a thorough literature review was first carried out to identify a preliminary list of those involved. The studies reviewed all PAF elements in construction industries [1, 11, 19]. This resulted in the identification of an initial list of 64 parameters effective on the COQ. Semi-structured interviews were then conducted with 20 experts, consisting of three project manager, two deputy manager, four on-site discipline managers, four quality managers, and seven site engineer and experts. The reason for the combination of experts from different backgrounds was to provide a balanced view of the research topic. All these experts have sufficient working experience in the mass-housing industry and frequently deal with quality issues.

They were requested to identify COQ elements according to their own experience in the mass-housing construction project. In these interviews, the effective elements on the COQ identified from previous studies were listed and then some of them were deleted by questions and answers. In addition to these elements, the other parameters offered by the interviewee were added to them or merged with another row. Finally, the final list was used along with the original list in the next interview. This list, after completing and achieving the final parameters, was sent to the interviewees once again for comment in order to obtain their opinion. Therefore, the final list was approved by all interviewees.

Two conditions considered in selecting parameters: 1) having the greatest impact on the quality and 2) having the ability to measure, analyze, and review. For example, since it is impossible to calculate the cost of discredit caused by poor quality, despite the mention of this case and acknowledgment of its high impact, it was removed from the list.

Finally, this resulted in the identification of 17 COQ main elements, as summarized in Figure 2. The elements were classified according to the PAF model [4]. The description of each parameter has been specified in Table 2.

Table 2. COQ elements description

No.		Item	Description	Symbol
1	Prevention	Project Quality management plan	Determination of requirements, expected quality level, tools and technics needed to reach this quality level, which will be prepared according to the nature and dimensions of the project at the beginning of the initial phase and before the start of the construction.	PR1
2		Work instructions, method statements and workflow design	Design and provision of the method statements, the operation flowchart, the work process and the order of the operation, as well as the quality control check points.	PR2
3		Quality management system	Determination, designing and producing of checklists, tolerances, inspection and test programs and and other tools for product quality control process.	PR3
4		Use of high-quality human forces	Finding and using experienced and high-quality experts for the construction process on the site.	PR4
5		In-service training of the project team	Includes all training for the purpose of improvement in the quality of personnel work and thus achieve a higher quality product.	PR5

6		Searching, evaluation and selection of competent suppliers and subcontractors	Evaluation, classifying and grading of the suppliers and contractors before using in the project. This will allow the use of quality materials as well as qualified contractors for quality work.	PR6
7		Quality control team activity in prevention	Preventive actions and other related works done by the quality control team to improve the product quality before construction	PR7
8		Design and Implementation of motivation system (reward and penalty)	Designing, launching, monitoring and controlling of an effective motivation system to conduct staff doing their works with maximum possible quality. This system will contain all materials (cash and both of reward and penalties.	PR8
9		Laboratory	Including all activities in planning, preparation, launching, producing test data, tests running and recording results, reporting, results evaluating etc. and generally all activities related to test of works done.	AP1
10	**Appraisal**	Quality control forces	It contains all quality control operations done with Quality staff.	AP2
11		Inspection and getting approve of External organizations	All inspections and quality control processes done with external organizations which have to approve the designs (like Firefighting organization, Construction engineering organization etc.) belong to this group.	AP3
12		Design correction	This section relates to services provided by the engineering department for designs correction due to computational or execution problems.	IF1
13	**Internal Failure**	Non-Conformances and related reworks	All works done due to low quality of products which cannot passed quality limits. It contains all destroying works done, corrective actions and reworks.	IF2
14		Re-evaluation and re-tests due to non-conformances	All appraisal works happen in the reworks which have not passed quality limitations first time.	IF3
15		Legal proceeding, complaints, and handling claims	All activities related to handling claims and complaints or courts that have been handed after the delivery of the product.	EF1
16	**External Failure**	Penalties for poor quality	Includes all penalties imposed by the employer due to poor quality of service.	EF2
17		Corrections and repairs in warranty period	All costs and activities incurred during the guarantee period by the contractor. Both of continuous costs (on-site staff during the guarantee period) or case costs (due to probable corrective actions.	EF3

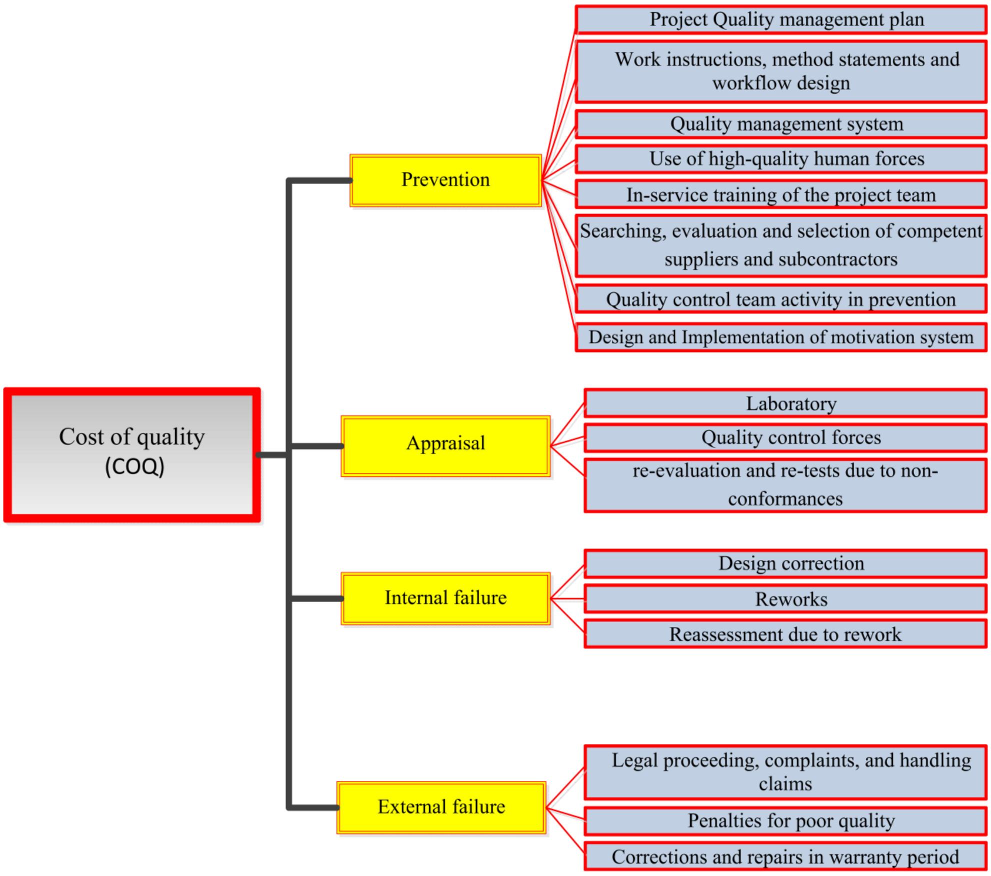

Figure 2. The main COQ elements specified in the mass-housing projects

3.2. Questionnaire Design

The questionnaire is divided into two main parts. The first part is related to general information about responder persons like their personal information, experience in mass-housing projects and their opinions about the COQ elements of mass-housing projects they have experienced. The second part includes the list of the identified COQ elements. The respondents were asked to score the elements based on the impact on the final quality cost of the related construction projects. The following five levels of scoring was adopted using Likert scale 'Very High Impact' (5 points), 'High impact' (4 points), 'Moderate' (3 points), 'Low impact' (2 points) and "very Low or no impact' (1 point) on final quality of the products.

A total of 200 questionnaires were distributed by e-mail, social networks, and project sites. Although the respondents asked to use the online questionnaire which was designed and launched in Google infrastructure, some experts preferred to use paper or word version for it. So the questionnaires gathered by e-mail or paper have filled in the related website by us. Over a period of 1 month, 148 questionnaires were returned, which comprised 72 online, 45 emails and 41 questionnaires collected from construction sites. Of these, 28 were discarded because of incomplete or invalid information provided by the respondents. The remaining 120 valid questionnaires are used for analysis, representing a very good response rate of 60% (Table – shows the details of related data), which is enough for a reliable analysis [26].

4. Results and Discussions

4.1. Method of Data Analysis

The Relative Importance Index (RII) method has been used to logically evaluate and rank the COQ elements according to their degree of importance. The impact on final quality will be measured using the formula presented in Equation 1 [27]:

$$RII = \frac{\sum W}{A \times N} \tag{1}$$

Where RII is the Quality index, W: weight of each element (determined by questionnaire and variable from 1: very low impact up to 5: very high impact), A: highest possible weight (here is 5), and N: the total number of respondents.

4.2. Analysis and Ranking of COQ Elements

The survey's results have been analyzed with the Statistical Package for the Social Sciences (SPSS Version 17.0) Statistics [28]. Cronbach's test is used to measure the internal reliability of the questionnaire. The values of alpha for prevention, appraisal, and internal and external failure-related activities groups are 0.714, 0.702, 0.729, and 0.763, respectively, which were all higher than the acceptable threshold of 0.7 [27].

The RII calculated for all elements in each PAF groups from the questionnaires which are described below.

4.3. Prevention Elements Ranking

Table 3 shows the RII and ranking of each COQ elements in the prevention activities group. 8 elements were considered in this group. The table shows that the top three elements which have more impact on final product quality in mass-housing projects are: quality management system (RII = 90.9%), using of high-quality human resources (RII = 89.8%) and selection of competent suppliers and subcontractors (RII = 88.0%). As expected, the prevention activities have the most impact on quality in construction projects. The items related to this group ranged from 73.9% to 90.9% (severity level ranges from high to very high).

The results indicate that using high-quality staff could be more effective than the training of ordinary staff. The results also prove the fact that motivation systems cannot guarantee the low-quality product removing.

Table 3. Ranking of COQ elements of mass housing projects in Prevention group

Rank	RII	Standard Deviation	COQ Element
1	0.90	0.67	Quality Management System
2	0.89	0.71	Using high-quality human resources
3	0.88	0.67	Searching, evaluation and selection of competent suppliers and subcontractors
4	0.85	0.81	Work Instruction, method statement and workflow design
5	0.85	0.66	Project Quality Management plan
6	0.80	0.62	Quality control team activity in prevention
7	0.79	0.82	In-service training of the project team
8	0.75	0.97	Design and implementation of motivation systems
	0.84		

4.4. Appraisal Elements Ranking

Table 4 shows the RII and ranking of each COQ elements in the appraisal activities group. 3 elements were considered in this group. The table shows that laboratory activities (RII = 82%), have more impact on quality costs compared to quality control processes (RII=74%). The reason can be related to the reality that the most impacts of quality control process on quality costs have been considered in prevention activities in the item of "Quality Control team activities in prevention". As it is clear, the "Assessment of external organizations" has not most impact on final quality.

Table 4. Ranking of COQ elements of mass housing projects in Appraisal group

Rank	RII	Standard Deviation	COQ Element
1	0.82	0.64	Laboratories
2	0.74	0.68	Quality control processes
3	0.66	0.94	Assessment of external organizations
	0.74		

4.5. Failure Elements Ranking

Table 5 shows the RII and ranking of each COQ elements in the failure activities group. Each failure group (internal and external) has 3 elements and totally 6 elements were considered in this group. Although as it was expected, this group has the least impact on COQ, some activities in the internal failure group may play a very important role in final product quality. The table shows that "Redesigns and design corrections" as well as "Reworks", are the most important items in the failure group (RII=79%). The items related to this group ranged widely from 58% to 79% (severity level ranges from low to high).

From the table, it is quite clear that although "Legal proceeding, complaints, and claim handling" could be very costly in the projects, their impacts on quality evaluated lower than other elements.

Table 5. Ranking of COQ elements of mass housing projects in the Failure group

Rank	RII	Standard Deviation	COQ Element
1	0.79	0.84	Redesigns and design corrections
2	0.79	0.79	Reworks
3	0.72	0.77	Reassessments and inspection due to rework
4	0.69	0.91	Corrections and repairs in warranty period
5	0.66	1.24	Penalties for poor quality
6	0.58	0.97	Legal proceeding, complaints, and claim handlings

4.6. Overall COQ Elements Ranking

The relative importance index and ranking of all investigated 17 COQ elements in Mass-housing construction projects are listed in Table 6. As it was expected, the prevention activity group elements have the most impact on quality compared to other groups.

Table 6. Overall COQ elements ranking in mass housing projects

Rank	Group	Standard Deviation	COQ Element
1	PR	0.66	Project Quality Management plan
2	PR	0.67	Quailty Management System
3	PR	0.71	Using high-quality human resources
4	PR	0.67	Searching, evaluation and selection of competent suppliers and subcontractors
5	PR	0.81	Work Instruction, method statement and workflow design
6	AP	0.64	Laboratories
7	PR	0.62	Quality control team activity in prevention
8	IF	0.84	Redesigns and design corrections
9	IF	0.79	Reworks
10	PR	0.82	In-service training of the project team
11	PR	0.97	Design and implementation of motivation systems
12	AP	0.68	Quality control processes

13	IF	0.77	Reassessments and inspection due to rework
14	EF	0.91	Corrections and repairs in warranty period
15	AP	0.94	Assessment of external organizations
16	EF	1.24	Penalties for poor quality
17	EF	0.97	Legal proceeding, complaints, and claim handlings

PR: Prevention Group Elements
AP: Appraisal Group Elements
IF: Internal Failure Group Elements
EF: External Failure Group Elements

The following results can be derived from the values shown in Table 6:

- As expected, the prevention and external failure activities had the highest and the least effects on the quality, respectively. However, the impact of internal failure costs on the final product quality has been particularly high.
- According to the interviewees, the quality management system from the prevention activities has identified as the most effective element, and trials, complaints and claims handling from the external failure section as the least influential element in the final product quality.
- As a result of interviews, the use of specialist and high-quality human forces is far more effective than in-service training of regular and inexperienced forces.
- Based on the results of the interviews, the design and implementation of the incentive system will not have much effect on the final product quality.
- The activities related to quality control operations by the quality control team will have a significant impact on the final product quality.
- According to the results obtained, the evaluation of external organs has no particular effect on the final product quality, and the internal sensitivity of the company has far more effect on providing high-quality of the product compared to the appraisal of external organizations.

4.7. Group Ranking

The ranking of the main groups of COQ in mass-housing construction projects and comparison of the results with Jafari and Heravi (2014) is shown in Table 7. Unexpectedly the internal failure group ranked better than appraisal group. It happened due to the low impact of "Assessment of external organizations" which has decreased the average RII for the appraisal group. This factor has not been considered in Jafari and Heravi (2014). So the rank of appraisal group in that work has been evaluated more than the present study. In addition some effective factors in prevention group like "Using high-quality human resources" which has evaluated as a high impactive factor on final product quality has not been considered in Jafari and Heravi (2014). On the other hand, the activities of quality control staff has been divided into two main group of "Quality control team activity in prevention" which has been considered in prevention group, and "Quality control processes" which has been considered in prevention group. Hence, the weight of prevention activities has been raised in the present study compared to the mentioned work.

Although some internal failure activity programs like "Redesigns" or "Reworks" could be very costly compared to prevention and appraisal activities, they can remove most of the low quality products and have a high impact on the final quality consequently.

Table 7. Relative importance index of COQ groups on final product quality of mass housing projects

COQ Group	Jarari and Heravi (2014)		Present Study	
	RII	Rank	RII	Rank
Prevention	0.73	2	0.84	1
Appraisal	0.81	1	0.74	3
Internal failure	0.72	3	0.77	2
External failure	0.51	4	0.51	4

5. Conclusion

In this article, the main elements of COQ were detected and extracted in mass housing projects. Subsequently, these elements were prioritized by experts in the industry using questionnaires and semi-structured interviews. Based on PAF method, the COQ elements classified under 4 groups: prevention, appraisal, internal failure, and external failure.

The results indicate that the prevention group has the most impact and external failure group elements have the least impact on the final quality of the products.

According to the results, the use of specialist and high-quality human forces is far more effective than in-service training of inexperienced forces. Corrective actions of non-conformities and design improvements have a significant impact on final product quality. Accordingly, the re-evaluation of corrective actions is far less important than the primary assessment of the activities undertaken.

The ranking of COQ elements based on the impact on final quality can help project managers to select the most effective activities in the limited budget conditions. This can help project managers to maximize the quality and minimize costs simultaneously.

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7. Conflict of Interest

The authors declare no conflict of interest.

8. References

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