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Effective Framework for Change Order Management Using Analytical Hierarchy Process (AHP)

Murat GUNDUZ[1,*] , Omar Hafeez KHAN[1]

[1] *Qatar University, Department of Civil and Architectural Engineering, P.O. Box 2713, Doha, Qatar*

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Abstract

Construction projects are of very complex nature and come along with an intrinsic but undesirable property of change orders. The purpose of this paper is to propose an effective framework for the change order management in the construction industry. This is achieved by investigating and identifying various causes of change orders and their impact on project objectives like project duration, cost, and quality. The data for this project were gathered by conducting a survey among the professionals like owners, project management consultants, design/supervision consultants and contractors in construction industry. The survey respondents were requested to provide feedback on the impact of change orders on project duration, cost and quality. Initially, the data collected from 105 professionals was analyzed through Relative Importance Index (RII). Furthermore, multiple objective decision technique of Analytical Hierarchy Process (AHP) was applied to rank the causes of change orders according to their impact on project duration, cost and quality considered collectively. According to AHP, the top three causes of change orders with highest cumulative impact on project duration, cost and quality were, "Change in specifications by the owner", "Change of plans or scope by the owner", and "Poor project planning by the contractor". This paper also suggests improvements for the existing change order management processes and ranks these suggestions according to their role in reducing impact on project duration, cost and quality. The proposed framework can be adjusted to suit individual construction projects with different relative importance of project objectives.

1. INTRODUCTION

Construction Intelligence Center (CIC), which is a group of fifty (50) largest markets in the world have estimated that the global construction industry currently values at US $8.5 trillion (2016) which is expected to grow at a yearly average rate of 3.9% from year 2016 to 2020. The versatile nature of construction industry varies from the development of power plants to infrastructure of cities. Also, wherever there is an existence of a human establishment, construction in one of its forms is inherent. On a similar note, wherever there is construction, it comes along with its intrinsic property of changes and change orders.

Construction projects are of very complex nature involving a balanced combination of many human, non-human and other factors contributing towards the success. Considering these various factors and complex relationships of information flow between different parties involved in the construction project, the scenarios of change orders are imminent. Change orders are a practical reality of the construction industry irrespective of the magnitude, type or nature of project. A change can be defined as "the deviation from the pre-defined and agreed upon project cost, scope, duration and schedule of works between the owner and contractor as per the contract. A change order is the formal document that is used to modify the agreed upon contractual agreement and finally becomes part of the project documents" [1]. The change orders may affect the project performance in a negative manner [2].

*Corresponding author, e-mail: mgunduz@qu.edu.qa

In view of the above and the construction industry, it is high time that an effective framework for change order management process is required to avoid cost overruns, schedule delays, lower quality and productivity in the construction projects to achieve the project targets.

2. LITERATURE REVIEW

The issue of managing change orders in the construction industry has received a lot of attention by the researchers. On a similar note, various causes and happenings in construction industry that result in change orders have also been studied in a systematic manner. These articles describe the impact of change orders on project objectives like duration, cost, scope and quality. Despite an extensive discussion in the academic literature for the causes and effects of change orders, the analysis of a change order impact on multiple project objectives, considered simultaneously, remains under examined.

In this study, the causes of the changes are studied extensively. The causes of change orders identified from the literature are summarized with their corresponding literature references in the Table 1 as given below. Thirteen major causes of changes are presented in Table 1.

Table 1. *List of Reasons for the initiation of Change Orders and their corresponding literature references*

Causes for the Change Orders	References
Change of plans or scope by the owner	[1, 3-21]
Changes due to owner's financial problems	[1, 3-4, 6-7, 12-13, 16, 18, 22-27]
Change in specifications by the owner	[1, 3-4, 11-12, 14-16, 19-20, 22, 25, 28-33]
Changes in material and procedures by the owner	[1-7, 22-23]
Conflicts among contract documents (i.e. specs. vs. drawings)	[1, 3, 5, 7-8, 10-12, 14-15, 17-20, 22-26, 28-31, 33-36]
Value engineering proposals by Designer	[1, 7, 11, 15, 17-20, 22-23, 25, 29-30, 33, 36-36]
Errors and omissions in the design	[1, 4-5, 8-10, 12-15, 19-20, 22-23, 28, 30-31, 35, 37]
Owner's requirement to expedite project schedule	[1, 3, 5, 7-8, 11-13, 15-20, 25-28, 33-37]
Equipment and labour problem of the contractor	[1, 6, 9-10, 14-16, 24, 26-27, 31-33, 35, 37]
Poorly project planning by the contractor	[1, 3, 14-20, 22, 25, 28, 35, 37]
Additional requirement from owner/government	[4-5, 7-11, 14-16, 23-24, 26-27, 29, 31-32, 34-35]
Financial problems of the contractor	[1, 5-8, 11-13, 16-17, 19, 22-23, 25-28, 30, 32-33, 34, 36-37]
Unforeseen problems	[1, 3-4, 6, 8-10, 13, 16-17, 19-20, 22, 26-29, 33, 35-37]

Each cause of change orders affects the construction projects in one way or the other. There are many studies in the literature about change orders and their causes and effects. The rework and demolition are frequent occurrences due to variations in construction projects [38]. This scenario results in the delay of project completion dates and increase in the project cost. The delay in project completion and increase in project costs lead to claims. These effects on the project can be classified under the categories of impact on project duration, cost, quality and scope of work. In addition, the change orders may result in the reduced productivity of the labor.

Moreover, the improvements suggested by the literature are summarized in Table 2 below with the corresponding references from the literature.

Table 2. *List of improvements shortlisted from the literature*

Suggested Improvements	References
Introduction of a contract statement for timely response of the owner for contractor claims.	[1, 3-6, 9, 11, 14-17, 19, 22, 24-25, 28, 30-36]
Advanced documentation system to assist the owner in evaluation and administration of change orders	[1, 5, 9-12, 14-16, 19-20, 22, 25, 27, 30, 32-37]
Change in culture - Owners shall not develop an adversarial relationship with a contractor after claim	[1, 6, 12, 14-18, 25, 30, 32, 35]
Standardized forms & templates for submission of contractor claims	[5, 7, 11-12, 14-17, 22-23, 25, 28-29, 32-36]
Database development to utilize lessons learned for better planning of change orders.	[1, 6, 9-10, 12-13, 16, 20, 22-24, 27-28, 30, 32, 33, 36-37]

3. METHODOLOGY

The aim of this paper is to identify and analyze causes of change orders in the construction industry on the basis of their impact on project duration, cost and quality. Moreover, the research aimed at suggesting improvements to the change order management process.

To meet the above-mentioned goals of research, the process was initiated by reviewing available academic literature. Based on the thorough review of vast literature available in the construction change orders field, thirteen major causes of change orders and their effects were obtained. From a construction management perspective, the overall objectives of projects carry element of similarity, which is to achieve the project within the pre-defined target of duration, cost and quality.

A questionnaire based online survey was designed to obtain feedback from the construction industry professionals. These questions were carefully classified under three parts in the questionnaire; personal background, causes of change orders and their respective impacts and lastly, the suggested improvements in the change order management process and their role in reducing the impact. The scale utilized to indicate the impact of each factor comprised of numbers from "1 to 9" with "1" representing "no importance" and 9 representing "extremely important".

4. DATA COLLECTION & DEMOGRAPHICS

The online survey was distributed among 126 construction professionals who were working as different contracting parties in different geographical regions. The distribution of survey to the selected individuals allowed for easy follow-up for responses. A survey response percentage of 82% was achieved which means 105 professionals worldwide provided answers to all the required questions.

The number of survey responses received is well divided among different contracting parties. Out of 105 completed responses, 15% respondents were working as Owners, 30% respondents were PMCM (project management/construction management), 15% respondents were supervision consultants, 10% respondents were designers, 22% were working as contractor and 8% respondents were working as subcontractors/suppliers.

The summary of responses based on the years of experience of respondents in construction industry as follows; 35% respondents had 15 or more years of experience, 24% respondents had 10-15 years of experience, 19% respondents had 05-10 years of experience and 22% respondents had less than 5 years of experience.

The summary of responses based on the background of respondents discipline in construction industry is shown in Figure 1. It can be easily observed that 37% respondents had civil & structural Engineering background; 30% respondents had electrical engineering background and 21% respondents had mechanical engineering background. The rest of the backgrounds are in oil &gas and others (electronics, control systems, transportation engineering)

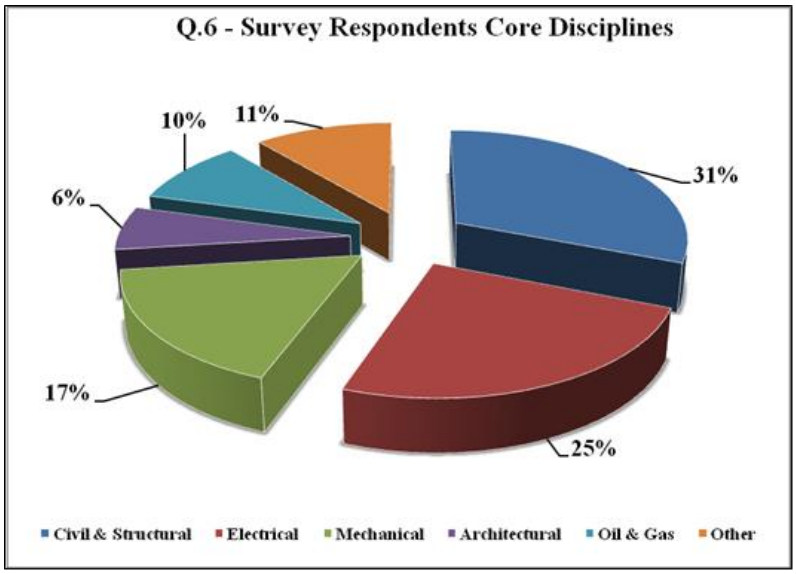

Figure 1. *Respondents' Backgrounds*

5. DATA ANALYSIS

The acquired data from 105 respondents was initially analyzed through statistical technique of Relative Importance Index (RII) for causes of change orders with respect to their impact on individual project

objectives. Initially, three separate rankings of causes of change orders were obtained based on their impact on project duration, impact on project cost and impact on project quality (Table 5). The scores provided by each respondent for all the listed causes of change orders were collated in the database for applying the mathematical computations of RII.

The technique of RII has been extensively applied by construction management research (CMR) community for the analysis of various factors. This paper uses the simplest but the most frequently cited form of RII equation. The equation for RII is given as below;

$RII = \sum W / A*N,$

Where:
W = weight given to each factor by the respondents (1 to 9).
A = the highest weight (in this case is 9).
N = total number of respondents

Then the factors were ranked based on the values of the RII. The value of the RII will vary from 0 to 1, the greater the value the higher the importance of each factor will be.

Finally, RII computations were performed on the survey data to obtain the rankings of importance of impact on project duration, impact on project cost and impact on project quality for making a decision regarding a change order. The RII values are shown below in Table 3.

Table 3. *RII for Importance of Impacts on Decision Criteria*

Impact on the Project	RII
Impact on project duration	0.6667
Impact on project cost	0.8889
Impact on project quality	0.4444

Similarly, RII technique was applied on the suggested improvements for the change order management process. This provided three separate rankings of the suggested improvements for their effect in reducing impact on project duration, impact on project cost and impact on quality.

The next step was the application of a multiple objectives decision-making technique known as Analytical Hierarchy Process (AHP) to obtain ranking of causes of change orders considering the decision criteria of project duration, cost and quality.

The goal of AHP for this paper can be graphically represented as shown in the following Figure 2.

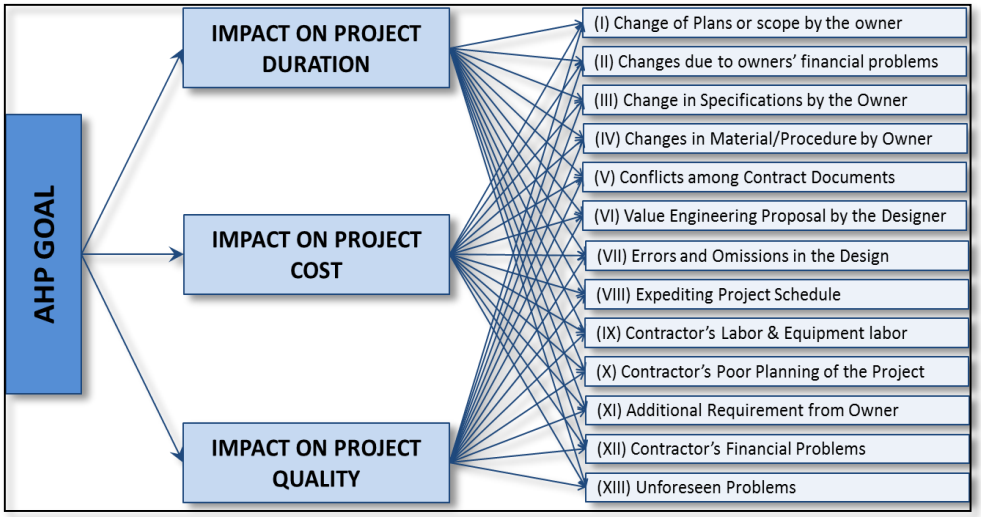

Figure 2. *AHP Multi-Objective Model for the study*

The rankings obtained through RII were then used to execute the most critical part of AHP analysis, which is the development of pair-wise comparison matrices. AHP scale from 1-9 points was utilized in the development of these pair-wise matrices.

The AHP utilizes three decision making steps:
(1) Given i = 1, …, *m* criteria, objectives etc., determine their respective weights *wi*,
(2) For each element *i*, compare the elements and determine their weights *wij* with respect to objective *i*,
(3) Determine the final element weights (priorities) by synthesizing [39].

This part constituted of two steps. Firstly, a pair-wise comparison matrix was developed for the factors, which formed the decision criteria. The results of this matrix after normalizing and computing row averages provided the relative weights of individual factors in the decision criteria as shown in Table 4.

Table 4. *Pairwise Comparison for AHP Relative Weights of Factors in Decision Criteria*

Decision Criteria	Impact on project duration	Impact on project cost	Impact on project quality	Row Average
Impact on Project duration	1	1/2	4	0.32378
Impact on project cost	2	1	6	0.58695
Impact on project quality	1/4	1/6	1	0.08928
Calculations	3.250	1.667	11.000	1

Secondly, pair-wise comparison matrices were developed for the reasons of change orders with respect to the individual factors in the decision criteria. The results of these matrices after normalizing and computing row averages provided the relative weights of each cause with respect to individual decision factors in the criteria. Finally, the overall score was computed for each reason of change order based on the collective effect of all factors in the decision criteria. These overall scores were obtained by multiplying the relative weights of the factors in the decision criteria with the respective weights of the causes of change orders obtained. The sample calculation for computing overall score of reason of change order,“ (I) Change of plans or scope by the owner”, is given as below;

AHP weight for "(I) Change of plans or scope by the owner" = 0.32378*0.124 + 0.58695*0.181 + 0.089278*0.012 = 0.1474.

The weights presented in Table 4 are used to calculate the AHP weight for each factor. This weight takes into account the weights of duration, cost and quality.

The scores for the causes of change orders obtained via RII and AHP are presented as given below in Table 5.

Table 5. *RII and AHP Scores for Causes of Change Orders*

RII and AHP Scores for Causes of Change Orders				
Reasons for the Change Order	RII - Impact on Project Duration	RII - Impact on Project Cost	RII - Impact on Project Quality	AHP Score
Change of plans or scope by the owner	0.7979	0.8910	0.4021	0.1474
Changes due to owners' financial problems	0.7651	0.7841	0.7090	0.1137
Change in specifications by the owner	0.7238	0.8931	0.6370	0.1689
Change in material and procedures by the owner	0.7354	0.7630	0.6709	0.0785
Conflicts among contract documents (i.e. specs. vs. drawings)	0.7259	0.6529	0.6233	0.0263
Value engineering proposal by the designer	0.6085	0.5312	0.6275	0.0163
Errors and omissions in the design	0.7122	0.7122	0.7016	0.0346
Owner's requirement to expedite project schedule	0.7429	0.7683	0.8878	0.0881
Equipment and labour problems of the contractor	0.7640	0.5238	0.7069	0.0460
Poor project planning by the contractor	0.8529	0.7354	0.8201	0.1190
Additional requirement from owner/government agencies	0.7460	0.7164	0.4825	0.0470
Financial problems of the contractor	0.8360	0.7058	0.8233	0.0920
Unforeseen conditions in the project	0.6751	0.5556	0.5143	0.0230

The application of RII computations on the results of survey for the suggested improvements provided the following scores as given in the following Table 6.

Table 6. *RII Scores on Duration, Cost and Quality*

Suggested Improvements	RII – Reduction in Impact on Project Duration	RII - Reduction in Impact on Project Cost	RII - Reduction in Impact on Project Quality
Introduction of a contract statement for timely response of the owner for contractor claims.	0.7497	0.6570	0.6181
Advanced documentation system to assist the owner in evaluation and administration of change orders	0.7433	0.6947	0.6677
Change in culture - Owners shall not develop an adversarial relationship with a contractor after claim	0.6214	0.6494	0.6419
Standardized forms & templates for submission of contractor claims	0.6818	0.6224	0.6688
Database development to utilize lessons learned for better planning of change orders.	0.7174	0.7379	0.7325

6. DISCUSSION OF RESULTS

It should be noted that the rankings of change orders obtained are different based on their impact on different decision criteria. For instance, "poor project planning by the contractor" is the number 1 cause for change order with respect to impact on project duration. While, the same reason is ranked as number 6 with respect to its impact on the project cost and number 3 when its impact on project quality is considered. Similarly, "Change of plans or scope by the owner" is ranked third considering its impact on project duration, while it is ranked second based on impact on project cost and ranked thirteenth due to impact on project quality.

An interesting case of similar rankings is observed for few reasons of change orders considering impact on project duration and impact on project quality. For example, 'Financial problems of the contractor', 'Changes due to owner's financial problems', and 'equipment and labor problems of the contractor' are ranked second, fourth and fifth as per both impacts on project duration and project quality.

The results of AHP, it is noted that when a multiple objective decision criterion was utilized based on the cumulative effect of different impacts on project objectives, the ranking obtained for reasons of change orders was different. The ranking of 'poor project planning by the contractor' is third in the hierarchy list of AHP, while it is ranked as first, sixth and third for impact on project duration, cost and quality respectively. A comparison for the rankings of change orders is presented in Table 7 below.
AHP provides a powerful comparison of the causes of changes, because it converts decision criteria rankings to numerical values that can be used to rank the pre-determined change order causes.

Table 7. *RII and AHP Rankings for Causes of Change Orders*

RII and AHP Rankings for Causes of Change Orders				
Reasons for the Change Order	RII - Impact on Project Duration	RII - Impact on Project Cost	RII - Impact on Project Quality	AHP
Change in specifications by the owner	10	1	8	1
Change of plans or scope by the owner	3	2	13	2
Poor project planning by the contractor	1	6	3	3
Changes due to owners' financial problems	4	3	4	4
Financial problems of the contractor	2	9	2	5
Owner's requirement to expedite project schedule	7	4	1	6
Change in material and procedures by the owner	8	5	7	7
Additional requirement from owner/government agencies	6	7	12	8
Equipment and labour problems of the contractor	5	13	5	9
Errors and omissions in the design	11	8	6	10
Conflicts among contract documents (i.e. specs. vs. drawings)	9	10	10	11
Unforeseen conditions in the project	12	11	11	12
Value engineering proposal by the designer	13	12	9	13

A comparison for the rankings of suggested improvements with respect to the reduction in impact on project objectives is presented in Table 8 below.

Table 8. *RII Rankings for Suggested Improvements*

Suggested Improvements	RII – Reduction in Impact on Project Duration	RII Reduction in Impact on Project Cost	RII - Reduction in Impact on Project Quality
Introduction of a contract statement for timely response of the owner for contractor claims.	1	3	5
Advanced documentation system to assist the owner in evaluation and administration of change orders	2	2	3
Change in culture - Owners shall not develop an adversarial relationship with a contractor after claim	5	4	4
Standardized forms & templates for submission of contractor claims	4	5	2
Database development to utilize lessons learned for better planning of change orders.	3	1	1

By carefully observing the results, it is noted that causes of change orders, which are related to the owners, have grabbed the top spots. This indicates that the requirements of owner such as late "changes in the specifications", "change in plans or scope" have the most adverse impacts on change order management. Considering this scenario, it is necessary for the owners to change their attitude towards the change order management process in construction projects. Similarly, the consultant's role in the change order management process holds key importance as all the claims and notices of contractors are evaluated and validated by them. Unforeseen conditions in the project and value engineering proposal by the designer are ranked last in the AHP ranking.

7. RECOMMENDATIONS

Since the roles and responsibilities of all contracting parties in construction change order management possess unique importance, the recommendations are provided separately for owners, contractors and consultants. The owners need to ensure proper coordination among the contracting parties, develop a change order review committee, and carry an allowance in the construction budget for plausible design errors. The owners should also be involved in the early stages of design and must thoroughly review and freeze the design, to as much extent as possible, before construction stage.

On the other hand, the contractors also need to establish proper coordination with the project consultants and owner to ensure that they are performing what is required by contractual scope of work. Contractor's selection of the employees and subcontractors is critical and should be according to project requirements. The contractor needs to be aware of all the contract clauses and special provisions to perform the work. This helps the contractor to avoid any conflicts between the verbal instructions from the consultant and what is demanded as per the contract.

The project designer/supervision consultants need to understand the requirements of the owner thoroughly. This is to ensure that the designed project reflects owner's aspirations and helps to avoid late design changes. The cross-discipline coordination among different project teams is critical. The consultants also need experienced employees to develop a constructible design with least conflicts and clashes.

8. CONCLUSION

Construction is a global industry, which exists in all the countries of the world in various forms. Construction comes along with its intrinsic property of changes and change orders. The issue of change orders is complicated by the diversity of issues faced in the construction industry. In view of the above, the effective change order management becomes a key player in the success of any construction project. The main objectives of this paper was to investigate the causes of change orders in the construction industry and suggest improvements in the existing change order management processes. Despite the fact that unique circumstances may be faced in different construction projects, the overall goal remains the same. This goal is to achieve the pre-set project objectives like the planned duration, budgeted cost and quality standards. The most important fact, which should be noted here, is that the construction projects face diverse scenarios. The relative importance of project objectives may vary from one project to the other. Sometimes the project duration is the prime objective while project cost and project quality could of lesser concern. Hence, in construction projects it is a possibility that a change order could be evaluated based solely on its impact on project cost irrespective of its impact on project duration and/or project quality. These results do not provide a model solution to fit all situations encountered in construction change order management process. However, AHP provides a versatile framework, which is flexible to be modified according to the relative importance of project objectives. This paper examined the quantitative effects of thirteen major change order reasons on change order management system through AHP process. With the application of AHP, the combined effects of duration, cost and quality were captured in an effective manner. This study uses AHP with considering the weight of duration, cost and quality together to better capture and rank the causes of change orders.

9. DATA AVAILABILITY STATEMENT

Data generated or analyzed during the study are available from the corresponding author by request.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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