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EFFECTIVE FRAMEWORK FOR CHANGE ORDER MANAGEMENT IN CONSTRUCTION INDUSTRY

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Abstract

Construction is a multi-trillion-dollar industry with a very complex nature involving a balanced combination of many human, non-human and other factors. The change orders are a practical reality of the construction industry irrespective of the magnitude, type or nature of the projects. The purpose of this project is to propose a framework for the change order management in the construction industry by studying and analyzing the various causes of change orders and their impacts on the duration, cost, and quality of the projects.

The data for this project was gathered by a survey among construction industry professionals which was analyzed through statistical techniques of RII and Spearman's Correlation coefficient as well as multiple-objectives decision modeling technique of AHP. The results indicated that due to differences in relative importance of project objectives from one project to other, the rankings for the causes of change orders are different as well.

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 research project possesses special significance for the international and local construction industry where massive infrastructure and stadium projects are underway to serve the goals and vision of nations.

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Chapter 1 – Introduction

Construction is a multi-trillion-dollar industry in the world which is a major contributor in the economy of a country. The versatile nature of construction industry varies from development projects 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.

This chapter presents historical background and importance of the change order management in construction industry. This chapter also explains the objective and importance of the research, scope and limitations with the outline of report structure.

1.1 Historical Background:

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.

Changes in a project can be because of several reasons resulting into the modification of the project duration, project quality, project cost, and project scope. These changes may be initiated from any of the parties involved in the

project but the approval to execute these changes in the project must be authenticated and authorized by the owner or owner's authorized representative.

A variation or change can be defined as the deviation from the pre-defined and agreed upon project cost, scope, duration and schedule of works between the client and contractor as per the contract. A variation/change order is the formal document that is used to modify the agreed contractual agreement and becomes part of the project documents [1].

The major problem associated with change order management is the time actually taken to analyze the potential effects to the various project deliverables. While the key to successful change order management is to timely analyze the downstream effects of any change order. Focusing on the current scenario emergent in the GCC region, the countries are undergoing major economic development and a lot of focus has been put on the urban development. Qatar specifically has ambitious plans to host FIFA World Cup in year 2022. In view of this, huge Qatar has planned an investment of $40 billion in the development of infrastructure, top class stadium and tourism facilities. Similarly, UAE plans to host World Expo in year 2020 and has similar plans to upgrade and develop its existing infrastructure. In view of the above and construction industry dynamics of the region, it is high time that an effective framework of change order management process is required to support the national vision.

1.2 Aims & Objectives:

This research project aims to analyze and study the various causes that result in the change orders in the infrastructure development construction projects like

roads, highways, utilities development, schools, hotels and residential complexes. Although, the construction projects are diverse in nature, a ray of hope that helps in simplifying issues is the common project objectives of achieving the predefined cost, duration, quality and scope of works.

The goals of this project can be summarized as given below;

- Study and analyze the causes of change orders that result in modification of the contractual agreement between the owner and the contractor.
- Develop a ranking of the causes of change orders based on their impact on different project objectives
- Use AHP to develop a ranking of multiple objectives in the decision criteria to obtain hierarchy of the causes that result in change orders on the construction projects.
- Investigate the effects of the change orders on the duration, cost and quality of the construction projects.
- Suggest improvements for the effective management of change orders on construction projects to reduce their impact on the project objectives like cost, duration and quality.

1.3 Scope of the Project

Construction projects using project delivery systems (PDS) like Design-Bid-Build, Design-Build, Architect/Engineering are considered while the Public Private Partnerships (PPP) are excluded from this research due to limitations on utilization of such systems in this region as well as the limited data available on

this PDS. Also, the number of contracting parties with available history in successful execution of PPP projects is not in abundance.

Furthermore, changes arising during the warranty period or operations and maintenance of the project after the completion/handing-over are not considered. The project analyzes the roles and responsibilities of parties like owner, project management organization, designer, consultant and contractors to assess the importance of their role in change order management process. The contractual agreements between main contractors and their subcontractors are excluded to limit the complexity.

The pre-bidding phases such as feasibility study and financial estimation before the owner makes go or no-go decisions are not considered. Also, the bidding phases such as floating tenders, solicitation of bids, and changes in the tender documents before contractual agreements are not included. Hence, the research focuses on the phase of construction projects after finalization of contractual agreement between the owner and the contractor.

1.4 Importance of the Research Project

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. In addition, it is predicted that Middle East and Africa region will take over the place of fastest growing construction industry due to the huge investments in infrastructure and buildings by Saudi Arabia, Qatar and UAE.

Considering the above and other adverse effects of change orders like the increase in cost of projects, delay in schedules, adversarial relationship between contracting parties and the cost of arbitration and law suits, it becomes evident that process of change order management needs to be handled more effectively.

1.5 Outline of the Report

Chapter 1 of the report gives brief introduction about the construction industry and the holistic view of change orders in the construction industry.

Chapter 2 of the project provides the summary of studies done in the past on the causes of construction industry highlighting the positive aspects and short comings of these studies. This chapter also explains how this research project would add a value to the diverse existing knowledge of change order management processes.

Chapter 3 explains in detail the methodology of research of current project and how the positive aspects of previous studies were utilized to come up with most common reasons of change orders. The chapter also discusses how the survey was designed to obtain feedback from a group of professionals playing different roles involved in construction industry.

Chapter 4 focuses on the design of analysis technique for the data obtained through the survey. The technique used to analyze the survey data was Analytical Hierarchy Process (AHP). This chapter also describes why AHP was used in this research project as compared to other statistical analysis techniques used in the literature and how AHP would be beneficial to come up with concrete solutions based on multiple objectives decision criteria.

Chapter 5 discusses the research results based on the analysis of data obtained through the survey. The logical deductions produced by applying techniques of RII and AHP in chapter 4 are presented and discussed in this section.

Chapter 6 focuses on the recommendations and conclusion of this project. The chapter provides suggestions on how to improve the existing construction change order management process. These suggestions derive their basis from the academic literature review and also the respondents view and experience. This chapter also concludes by mentioning how this research project can be extended in future to add further value.

Chapter 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.

2.1 Change Orders and their Characteristics

The term change order has always received a notorious reputation among the owners in the construction industry. This is because the term change order comes with effects that disrupt the equilibrium of construction project objectives like time, cost and quality. Irrespective of the defame associated with change orders and despite the extensive and well thought planning conducted for the construction, change orders are a matter of practical reality.

Change orders can be defined as a change, alteration or addition with respect to the original plans, specifications or other contract documents, as well as a change in cost, which follow the creation of legal relationship between client and contractor (Choy and Sidwell, 1991; Wallace, 1994).

A change order must be in the written form and shall be authorized by the owner or the owner's representative. A change order can also be defined as the "written authorization provided to a contractor that approves a change from the original

plans, specifications, or other contract documents, as well as a change in the cost" (Hanna and Russell, 1998).

The construction process is influenced by variety of factors which may result in change orders. Contracting parties in a construction project act as different sources stimulating the change. Considering the complexity of relationships, Cox (1997) has identified three kinds of change orders based on the initiator of these requests:

1) A formal change order, which is an actual document called 'change order' issued by a client which modifies the contract terms, plans or specifications;

2) A constructive change order, which is an extra contract work performed pursuant either to oral or implied owner directives, or as a result for problems for which the owner is responsible;

3) A cardinal change order, which may occur whenever there is a substantial amount of work required outside the scope of the original contract.

Hadikusumo, (2003) summarizes the initiation, review and approval process of formal change orders and constructive change orders as shown below in figure 1.

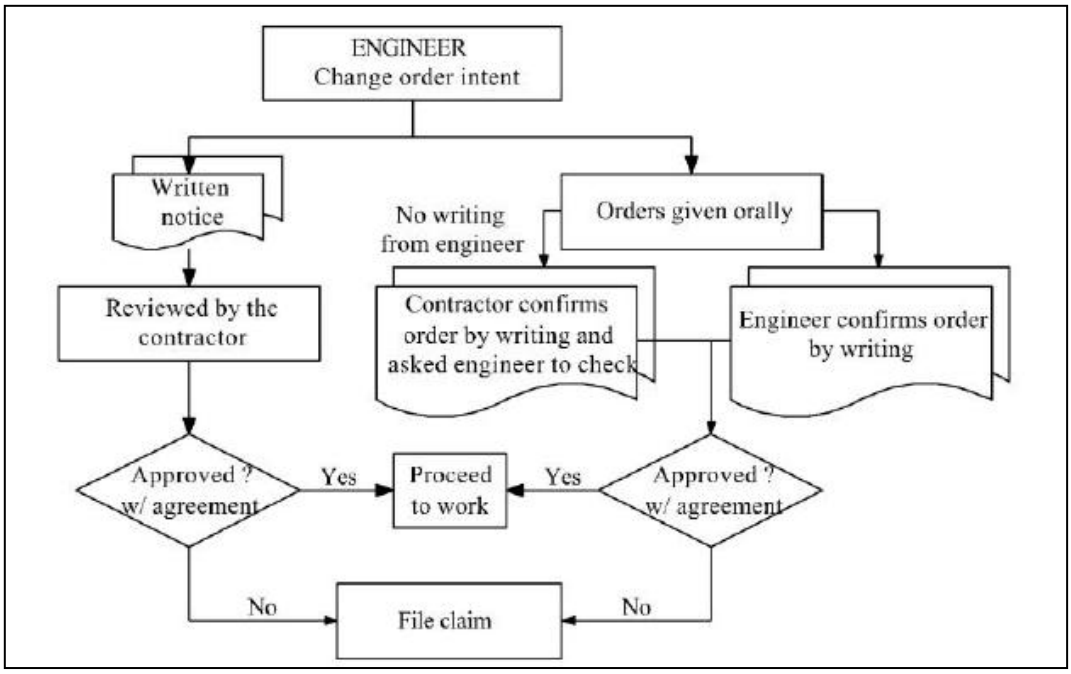

Figure 1- Summary of Initiation of Change Order by Hadikusumo, (2003)

2.2 Causes of Change Orders in Construction Projects

Extensive research has been conducted in the literature to investigate the causes of change orders in the construction projects. One of the effective ways to classify these causes is as per the contracting parties involved in the construction projects. Hence the causes have been grouped into three categories for the contracting parties: owner related variations, consultant-related variations, and contractor related variations.

Change of scope: Change of plan or scope of the project is one of the most significant causes of variation in construction projects (CII 1990b), and is usually the result of insufficient planning at the project definition stage, or because of lack of involvement of the owner in the design phase (Arain et al.2004)

Changes due to financial problems of owner: The owner's financial problems can affect project progress and quality (Clough and Sears 1994; O'Brien 1998). This problem can lead to changes in work schedules and specifications, affecting the quality of the construction.

Change in specifications by the owner: Changes in specifications are frequent in construction projects with inadequate project objectives (O'Brien 1998). Should the owner decide to change the specification of a design or requirement, then this may lead to variations in the construction phase.

Change in material or procedure by the owner: The replacement of materials or procedures may lead to variations during the construction phase. The substitution of procedures includes variations.

Conflicts among contract documents: Conflict between contract documents can result in misinterpretation of the actual requirement of a project _CII 1986_. It is essential that contract documents are clear and precise. Insufficient details in the contract documents may result in delays to the project completion or cause variations in cost.

Value engineering: Value engineering should ideally be carried out during the design phase (Dell'Isola 1982). Value engineering carried out during the construction phase can become an extremely costly exercise and may result in variations.

Errors and omissions in design: Errors and omissions in design are a significant cause of project delays (Arain et al. 2004). Dependent upon the timing of the errors in the project, delays and variations may occur.

Owner’s requirement to expedite project schedule: Fast-track construction requires an organized system to concurrently carry out independent project activities (Fisk 1997). Should this organized system not be in place during a fast-track construction process, there is a higher risk of variations to the project occurring.

Poor knowledge of available materials and equipment: Knowledge of available materials and equipment is an important factor for developing a comprehensive design (Geok 2002). If the consultant has a poor knowledge of available materials or equipment that can be used in the construction process, variations are more likely to occur during the construction phase. Unavailability of equipment: Unavailability of equipment is a procurement problem that can affect the project completion (O’Brien 1998).

Unavailability of skills: Skilled manpower is one of the major resources required for technological projects (Arain et al. 2004). Variations and delays may occur due to shortages of skilled labor. Poor workmanship: Defective workmanship may lead to demolition and rework in construction projects (Fisk 1997;

O’Brien 1998). This may lead to delay and increased cost.

Lack of strategic planning: Proper strategic planning is an important factor for successful completion of a building project (Clough and Sears 1994). The lack of strategic planning is a common cause of variations in projects where construction starts before the design is finalized (e.g., in concurrent design and construction contracts) (O’Brien 1998).

Health and safety: Safety is an important factor for the successful completion of a building project (Clough and Sears 1994). Noncompliance with safety regulations may result in variations in the design aspects of a project.

Change in economic conditions: Economic conditions are one of the influential factors that may affect a construction project (Fisk 1997). Should the economic climate change during a construction project, variations may occur to reduce the construction cost.

Contractor's financial difficulties: Construction is a labor intensive industry. Whether the contractor has been paid or not, the wages of the worker must still be paid (Thomas and Napolitan 1995). Should a contractor experience financial difficulties during the course of a project, variations may result and the quality and progress of the project may be severely affected.

Desired profitability: Variations may occur due to the desired profitability of the main contractor carrying out the works. Variations are considered a common source of additional work for the contractor (O'Brien 1998). Variations can be seen as additional financial reward for the contractor.

Unforeseen problems: Unforeseen conditions are usually faced by professionals in the construction industry (Clough and Sears 1994; O'Brien 1998). These conditions, if not resolved, may result in variations to the project.

Unfamiliarity with local conditions: Familiarity with local conditions is an important factor for the successful completion of a construction project (Clough and Sears 1994). Should the contractor not be familiar with local conditions, it would be more difficult to carry out the work, possibly leading

Lack of communication: A lack of coordination and communication between parties may cause major variations that could eventually impact the project adversely (Arain et al. 2004), causing demolition and rework affecting work progress.

Patrick (2010) presents a summary of causes of change orders classified under categories based on the contracting parties such as owner, contractor and consultant as shown in the figure 2.

Owner-related variations	Consultant-related variations	Contractor-related variations	Other variations
Change of plans or scope (CII 1990b)	Change in design (Arain et al. 2004; Fisk 1997)	Lack of involvement in design (Arain et al. 2004)	Weather conditions (Fisk 1997; O'Brien 1998)
Insufficient planning at the project definition stage, or lack of involvement of the owner in the design phase (Arain et al. 2004)	Errors and omissions (Arain et al. 2004)	Unavailability of equipment (O'Brien 1998)	Safety considerations (Clough and Sears 1994)
Owners' financial problems (Clough and Sears 1994; O'Brien 1998)	Conflicts among contract documents (CII 1986)	Skills shortage (Arain et al. 2004)	Change in economic conditions (Fisk 1997)
Inadequate project objectives (Ibbs and Allen 1995)	Technology change (CII 1994b)	Financial problems (Thomas and Napolitan 1995)	Sociocultural factors (O'Brien 1998)
Replacement of materials/ procedures (Chappell and Willis 1996)	Value engineering (Dell'Isola 1982)	Desired profitability (O'Brien 1998);	Unforeseen problems (Clough and Sears 1994; O'Brien 1998)
Impediment of prompt decision-making process (Sanvido et al. 1997; Gray and Hughes 2001)	Poor coordination (Arain et al. 2004)	Differing site conditions; poor workmanship (Fisk 1997; O'Brien 1998)	
Obstinate nature of owner (Wang 2000; Arain et al. 2004)	Design complexity (Arain et al. 2004; Fisk 1997)	Fast-track construction (Fisk 1997)	
Change in specifications by owner (O'Brien 1998)	Poor working drawing details (Geok 2002; Arain et al. 2004)	Poor procurement process (Fisk 1997)	
	Poor knowledge of available materials (Geok 2002)	Lack of communication (Arain et al. 2004)	
	Lack of required data (Arain 2002)	Lack of experience	
	Ambiguous design details (O'Brien 1998)	Long-lead procurement (Fisk 1997)	
	Poor design (CII 1990a; Fisk 1997)	Complex design and technology (Arain 2002)	
	Change in specifications (O'Brien 1998)	Lack of strategic planning (Clough and Sears 1994)	

Figure 2- Summary of Causes of change orders by Patrick (2010)

(Alnuaimi et.al. 2010) conducted a study in Oman to investigate the causes of variations, quantify their effects on the project, identify the contributing parties, and suggest remedies. As per the survey respondents, the five most important causes out of (26) overall causes for each contracting party were identified as summarized in the figure 3 below;

Rank	Client's respondents	Consultant's respondent	Contractor's respondents
1	Owner instructs additional works	Owner instructs additional works	Owner instructs additional works
2	Owner instructs modification to design	Nonavailability of construction manuals and procedures for project construction in Oman	Low consultancy fee or less experienced designers
3	Natural growth of the project was not anticipated at the design stage	Owner instructs modification to design	Unrealistic design periods
4	Design errors	Poor communication between relevant governmental units and the owner	Nonavailability of records of similar projects in Oman
5	The contractor misuses variations instructions	Nonavailability of engineering licensing for engineers in Oman to maintain the quality of consultancy services	Owner fails to make decisions or review documents at the right time

Figure 3- Five Most Important Causes of Change Orders summarized by (Alnuaimi et.al. 2010)

In addition to the above, the reasons of change orders with their references to their corresponding literature are mentioned as a summary below;

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

Reasons for the Change Orders	**References**
Change of plans or scope by the owner	[1] [4] [7] [8] [9] [13] [14] [16] [17] [20] [21] [23] [25] [26] [31] [32] [34] [37] [38] [39] [40]

Changes due to owner's financial problems	[1] [2] [4] [5] [7] [11] [13] [16] [13] [15] [16] [18] [19] [24] [25] [26] [28] [29] [34] [38] [42]
Change in specifications by the owner	[1] [2] [3] [4] [6] [7] [8] [11] [12] [14] [19] [22] [23] [24] [25] [30] [31] [32] [34] [35] [39] [40] [42]
Changes in material and procedures by the owner	[1] [2] [4] [5] [7] [9] [11] [13] [15] [16] [41]
Conflicts among contract documents (i.e. specs. vs drawings)	[1] [2] [3] [4] [6] [8] [9] [10] [11] [12] [14] [15] [16] [17] [18] [19] [21] [22] [23] [24] [25] [28] [31] [32] [33] [35] [36] [37] [38] [39] [40]
Value engineering proposals by Designer	[1] [2] [5] [6] [12] [14] [15] [16] [23] [24] [32] [33] [35] [36] [37] [38] [39] [40]
Ambiguous Details in the design drawings	[1] [14] [15] [17]
Errors and omissions in the design	[1] [2] [3] [7] [8] [9] [12] [15] [17] [20] [21] [22] [25] [26] [27] [31] [32] [33] [39] [40]
Owner's requirement to expedite project schedule	[1] [3] [4] [8] [9] [10] [11] [14] [16] [17] [23] [24] [25] [26] [27] [28] [29] [32] [33] [34] [35] [36] [37] [38] [39] [40]
Lack of equipment and labour of contractor	[1] [13] [14] [18] [19] [20] [21] [22] [27] [28] [29] [30] [31] [32] [33] [34] [35]

Poorly planning by the contractor	[1] [2] [3] [4] [19] [24] [27] [31] [32] [33] [34] [37] [38] [39] [40]
Desired profitability of contractor	[1] [5] [6] [10 [22] [25] [26] [27]
Additional requirement from owner/government	[6] [7] [8] [9] [10] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [28] [29] [30] [31] [32] [33] [34]
Financial problems of the contractor	[1] [2] [3] [9] [10] [11] [12] [13] [14] [15] [16] [17] [23] [24] [25] [26] [27] [28] [29] [30] [34] [35] [36] [37] [39]
Unforeseen problems	[1] [2] [3] [4] [5] [6] [7] [8] [13] [14] [17] [19] [20] [21] [26] [27] [28] [29]] [33] [34] [35] [36] [37] [39] [40]

2.3 Effects of Change Orders on Construction Projects

Change orders are a source of potential disputes among the contracting parties, along with the other negative impacts on the project objectives. This adds up the fact that change orders are an unwanted element in the construction industry from an owner's perspective. Owner in the construction industry reserves the right to make changes in the project during the course of construction. On the other hand, contractor needs compensation (in terms of extension of time or cost) for additional utilization of resources and efforts. Disputes take place in such a scenario because of contractor's perspective of not being fairly compensated for

additional works, while owner has a clear notion that contractor's demands are exceeding the fair price.

Cost-related effects: Rework and demolition are frequent occurrences due to variations in construction projects (Clough and Sears 1994; CII 1990). Delay in payment can occur (CII 1990), leading to an increase in project cost due to interest rates. Variations require processing procedures, paperwork, and reviews before they can be implemented (O'Brien 1998), leading to increased overhead expenses. Additional payments for the contractor can be a potential effect of variations on a construction project. Variations are considered to be a common source of additional works for the contractor (O'Brien 1998). Rework, demolition, and processing procedures due to variation can result in increased cost, affecting the profitability of the contractor. The owner can encounter difficulty in meeting additional financial requirements. Furthermore, parties may not agree on the mount of payment due to fuzziness in the contract.

Quality-related effects: Variations during the project may affect quality (CII 1994). Variations, if frequent, may affect the quality of work adversely (Fisk 1997). Variations can affect project completion time and may cause accelerated construction process affecting the quality.

Time-related effects: Variations that are imposed when construction is underway or even completed usually lead to reworks and delays in project completion (CII 1990). Variations during the project may affect the project progress (CII 1994a), which may in turn affect payment to subcontractors usually because the main contractor can't pay subcontractors until they have been paid by the owner themselves. Completion schedule delay is a frequent result of variations in

construction projects (Ibbs 1997). Logistics delays may occur due to variations requiring new materials and equipment (Fisk 1997).

The negative impacts of variation orders on construction projects have been reported by several authors. Variation orders adversely affect labor productivity (Thomas and Napolitan, 1995; Hanna et al., 1999, 2002a, b; Hanna and Gunduz, 2004). They can frequently cause significant disruptions to a construction project, which may decrease the labor productivity of the contractor and extend the project duration (Hanna et al., 2002a, b; Tse and Love, 2003). This results not only in material wastage (Motete et al., 2003) but also marginalizes project quality (Smallwood, 2000) Variations are the most frequent cause of claims (Zaneldin, 2005), which result in cost overruns (Sutrisna et al., 2003). They are also one of the commonest causes of delays (Odeyinka and Yusif, 1997) and disputes in construction contracts (Sutrisna et al., 2003; Chan and Suen, 2005). A study by Ayininuola and Olalusi (2004) has also revealed that frequent variation of works by building owners is one of the major causes of the high incidence of building failures in Nigeria. Perhaps, the most undesirable impact of variation is that, according to Transparency International (2005), it has become a source of bribery and corruption in international construction. The sum total of these impacts of variation orders is that they can cause substantial adjustment to both the contract duration and cost, i.e. time and cost overruns (Ibbs, 1997; Ibbs et al., 1998; Morris, 1998; von Branconi and Loch, 2004).

Design variations, according to Chan and Kumaraswamy (1996), always lead to poor time performance whether they are owner-initiated or consultant-initiated. In fact, it has been known for a considerable amount of time that owner-initiated

variations represent a primary source of time and cost overruns (Love and Edwards, 2004).

Patrick (2010) presents a summary of effects of change orders classified under the categories of cost, quality, time, organization and others. This summary is presented as shown below in figure 4.

Effects of variations and change orders	Cost-related effects	- Increase in overhead expenses (O'Brien 1998)
		- Additional payment for contractor (O'Brien 1998)
		- Rework and demolition (Clough and Sears 1994; CII 1990a)
	Quality-related effects	- Quality degradation (CII 1994a; Fisk 1997)
	Time-related effects	- Delay in payment (CII 1990a)
		- Procurement delay (O'Brien 1998)
		- Rework and demolition (Clough and Sears 1994; CII 1990a)
		- Logistic delay (Fisk 1997)
		- Completion schedule delay (Ibbs 1997)
	Organization and its reputation-related effects	- Tarnish firm's reputation (Fisk 1997)
		- Poor safety conditions (O'Brien 1998)
		- Poor professional relations (Fisk 1997)
		- Dispute among professionals (Fisk 1997)
	Other effects	- Progress affected without delay (CII 1994a)

Figure 4- Effects of Change Orders by Patrick (2010)

(Alnuaimi et.al. 2010) presents the overall respondents' opinions on the effects of change orders. The "delay completion date of projects" is the most important effect of variation. This would be expected as changes will mostly result in revision of plans, addition of works, more time for decision making, material re-sourcing, etc. In the case of omission, no delay would be expected, but due to some cost saving, the client will usually use the saving by adding works which will result in delaying the project completion.

The second important effect was found to be "variation would result in claims and disputes". This is one of the major effects, especially in developing countries, as many of the variations are not well-studied and lead to confusion and disruption, which results in claims and disputes, particularly in the case of introducing new

materials or work activities that were not in the original contract. Surprisingly, this effect preceded the cost overrun although with a small difference.

Attention should be given to the least important factor "adversely affect work quality." Practically, the work-rework and delay of projects disturb the plans of the client and the contractor and put both parties under extreme pressure to complete the work.

The client needs to utilize the facilities. The contractor faces problems in his future works, may not bid for new projects, and may be forced to delay other projects due to shortages in manpower and equipment that are being delayed in this project. This situation leads to the work being carried out in a hasty fashion with a low quality, especially during the finishing stage. However, few people would admit this and quality control measures are usually not strictly followed.

Summarizing, the effects are ranked as below (Figure 5) in the Omani construction industry.

Effect	RII	Rank
Delay completion date of projects	67.91	1
Variations would result in claims and disputes	67.91	2
Cost overruns	66.98	3
Adversely affect the performance and moral of labor	60.47	4
Most contractors incur additional costs due to variations	54.88	5
Adversely affect work quality	44.19	6

Figure 5- Effects of Change Orders by ranked in order by (Alnuaimi et.al. 2010)

2.4 Suggested Improvements from the Academic Literature

Chan and Yeong (1995) stated that quality contract documentation, and good communication and cooperation between building team members are two of several elements that can be used to manage change orders. The element of good documentation can be facilitated through the design of an effective change order system. Jacob (1978: 64–65) noted that 'lax attitudes and unfamiliarity with proper change order procedures have led to serious financial loss and insolvency'. A realization of the construction participants of the importance of documentation practice is one of the first components in the development of a change order system. The effective change order system can be designed by understanding the change orders process or workflow, which can be compiled from the standard forms of contract.

The second element, good communication, can be facilitated through providing information in a timely mechanism. This can be achieved by using Internet technology as the communication media, because the information can be accessed in a timely and accurate manner and may be accessed from different locations.

A study by Cox et al. (1999) found that in monetary terms alone, the direct cost of post contract design changes amounts to 5.1 to 7.6% of the total project cost.

The effective management of variation orders requires a comprehensive understanding of the root causes of variations and their potential downstream effects (Ibbs et al., 2001).

The construction industry has a complex communication nature because a lot of parties are involved in the business process. An example of this complex nature is

that multiple reports must be prepared to ensure that information is delivered to all organizations, departments or staffs using it. This can be a problem if a channel and mechanism of communication is not adequately designed.

The issue of learning from past projects in making timely and more informed decisions for the effective management of variation orders has not been explored much in the literature. National database system about soil, underground services and weather conditions should be developed and made available for all concerned parties.

A standard manual with a check list for design of projects should be developed to regulate all stages/steps including feasibility study, design, tendering, tender evaluations, and project awarding. This document should be implemented by a specialized governmental unit.

The client should prepare a well-defined brief document about his/her needs before entering the design stage. This can be done either by carrying out a feasibility study or circulating a questionnaire to the end users of the project and also conduct enough deliberation about the project's final intended use.

In addition to the above, the improvements suggested by the literature are summarized as below with the corresponding references for the literature.

Table 2 - List of improvements shortlisted from the literature and their corresponding literature references

Suggested Improvements	References
Introduction of a contract statement for timely response of the owner for contractor claims.	[1] [2] [3] [4] [5] [7] [8] [9] [10] [12] [13] [14] [18] [19] [20] [22] [23] [24] [30] [31] [32] [33] [34] [35] [36] [37] [39]
Advanced documentation system to assist the client in evaluation and administration of change orders	[1] [2] [9] [10] [11] [12] [20] [21] [23] [24] [25] [27] [29] [30] [31] [32] [33] [34] [35] [36] [39] [40]
Change in culture - Owners shall not develop an adversarial relationship with a contractor after claim	[1] [12] [13] [14] [24] [25] [30] [31] [32] [33] [34] [37] [38]
Standardized forms & templates for submission of contractor claims	[2] [3] [6] [9] [10] [11] [15] [16] [23] [24] [25] [30] [31] [32] [33] [34] [35] [36] [37]
Database development to utilize lessons learned for better planning of change orders.	[1] [2] [3] [11] [12] [13] [14] [15] [18] [19] [20] [21] [25] [26] [27] [29] [30] [34] [35] [36] [40]

Chapter 3 – Methodology

This chapter discusses the methodology used to obtain data from the international construction industry. A questionnaire was designed to obtain feedback from a group of professionals involved in the construction projects. The construction projects considered were of diverse nature which involved development and reconstruction of roads, highways, buildings, schools, infrastructure and utilities development.

3.1 Research Objectives

The aim of this research technique was to identify and analyze various causes of change orders in the construction industry on the basis of decision criteria which is comprised of multiple conflicting objectives. In addition, the research also aimed at forming decision criteria which would be used for the evaluation of cause of change orders resulting because of these causes. This decision criterion consists of impacts of change orders on most important project objectives like duration, cost and quality. Finally, the research aimed at suggesting improvements to the existing change order management processes generally implemented in construction projects around the world.

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, a huge number of causes of change orders and their effects were obtained. The huge number of

causes and effect is a result of versatile nature of scenarios faced in construction projects.

However, although the construction projects are diverse in nature, the overall objectives of construction projects carry huge elements of similarity across different projects. These project objectives shuffle among each other on a project to project. Similarly, these project objectives may shuffle between each other bases on phases of the construction project as well. Keeping this in consideration, the most common causes of change orders and their effects on various project objectives were identified and utilized to formulate the questionnaire, which was then used to obtain data from a group of construction professionals.

3.2 Survey Design

Based on the fact that analysis of the information from the industry professionals and any deductions from those results entirely depend on the reliable data collection, it was clear that the questions must be clear and concise. Also, the answers to these questions should be available from a wide range of professionals. The design of survey was hence considered as the most important pillar for the success of this research project. Hence, considerable time effort was expended to produce an inquisitive questionnaire. Considering the above-mentioned objectives, it was decided that questionnaire will be the convenient and effective medium to communicate these questions to wide range of professionals in construction.

An extensive literature review was conducted for formulating and drafting the questions in the survey. 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 respective improvement in avoiding the impact.

Each part of the questionnaire with its objective and design strategy is explained as below;

First part of the questionnaire comprised of questions related to the personal background of the respondents. This part aimed at knowing the diversity of the data under collection. The questions presented in this part asked the respondents about their relevant number of years experience in construction industry, the project delivery system being used in their current project and the role of their organization on the current project. Furthermore, first part of survey also asked the respondents about their location as well as the relevant discipline to know about the demographics of the data which would be analyzed.

An important consideration at this stage was to not ask the respondents about their personal name, organization's name or contact details to maintain their anonymity for confidentiality purposes. This consideration also helped to maintain the integrity of responses received.

Second part of the survey was developed focusing on the causes of change orders and their impacts on the project objectives. Based on the requirements of the analysis technique which was planned to be utilized, the goal here was to know the importance of impacts on different project objectives because of the change orders. These impacts on the project objectives constituted the decision factors in the decision criteria.

The project objectives used as factors in this decision criterion were project duration, project cost and project quality. These impacts on the project were shortlisted through the review of available academic literature. The respondents were requested to provide an opinion on the importance of each impact in making a go or no-go decision for a change order in the construction project. The application of analysis techniques on the survey responses would then provide the weights for each impact in the decision criteria.

The scale utilized to indicate the importance of each factor in deciding for a change order comprised of numbers from "1 to 9". This scale was selected to maintain consistency with the scale which was used in the survey to obtain the impact of causes of change order. The number "1" represented that decision factor has no importance in deciding for a change order while number "9" represented the factor as extremely important consideration for making a decision about the change order.

The scale from "1 to 9" was preferred over scales from "1 to 5" or "1 to 3" because of the number of causes of change orders which were presented in the survey. A total of thirteen causes were utilized. A scale from "1 to 9" provided a broader range of numbers to the respondents to depict their opinion about the impact and importance. A smaller scale from "1 to 3" or "1 to 5" would have resulted in the same impact score for many causes of change orders.

This survey question (Question No. 7) is given as below;

Table 3 - Decision Factors and their relative importance in deciding for a change order

Decision Factor	Importance in the Process of Making Decision for Change Orders								
Impact on Project Duration because of the change order	1	2	3	4	5	6	7	8	9
Impact on Project Cost because of the change order	1	2	3	4	5	6	7	8	9
Impact on Project Quality because of the change order	1	2	3	4	5	6	7	8	9

In addition to the above, the second part of the survey inquired the respondents regarding the causes of change orders which were obtained through the extensive literature review. Although the literature grouped and identified the causes of change orders based on their relation to the owner, consultants and contractors, the survey listed these causes in random sequence irrespective of their relation to different contracting parties. This technique was implemented in order to obtain unbiased researcher answers for their impacts and increase equal chances of participation from respondents representing different contracting parties.

Finally, in the second part, separate columns were developed for each member of the decision criteria. The individual columns for impact on project duration,

impact on project cost and impact on quality were equipped with the scale to obtain the respondents' inputs regarding the impact of each cause. This tabular design was developed considering the readability of the respondents.

A sample part of questions from this part of survey (Question # 8) are shown as below.

Table 4– Causes of change orders and their impact on project duration, cost and quality.

Causes for the Change Orders	Impact on Project Duration	Impact on Project Cost	Impact on Project Quality
Change of plans or scope by the owner	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
Changes due to Owners' financial problems	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9

Once again, an important point of consideration was the selection of scale to rank the impact on project objective because of each reason of change order. In addition to the reasons mentioned above for the selection of scale, the fact that Analytical Hierarchy Process (AHP) was utilized to come up with a multiple-objectives decision criteria, the scale from numbers "1 to 9" eased the transferring of survey ratings and scores to AHP scale. The number "1" was utilized to represent the impact as lowest on the decision factor because of the reason of change order while number "9" indicated the highest impact on decision factor.

Third part of the survey focused on the recommendations and improvements part of this research project. The respondents were presented with various suggested improvements for the change order management process which were developed based on the review of academic literature. These suggested improvements in the change order process management would reduce the impact on project duration, impact on project cost and impact on project quality. The separate columns for developed for reduction in impact on project duration, cost and quality were equipped with a unified scale for each suggested improvement. Again, a tabular design was developed for the respondents' easiness in putting the response.

The scale used here was based on numbers from "1 to 9", whereas the number 1 represented no improvement in reducing the impact while number 9 represented highest improvement in reducing the impact if the respective improvement is implemented in the existing change order management process. In addition to the above-mentioned reasons, this scale was selected to maintain uniformity along the whole questionnaire. Uniformity in the scale helped to avoid any confusion to the respondents regarding the interpretation of the ideas represented by each number. The table presented below shows excerpts from Question #9 of the questionnaire with some suggestions along with improvement scale to reduce the impact on project duration, cost and quality are given as follows;

Table 5- Suggested Improvements and their importance to reduce the impact on project duration, cost and quality.

Suggestions for improving the Change Order Management Process	Impact on Project Duration	Impact on Project Cost	Impact on Project Quality
Introduction of a contract statement for timely response of the owner for contractor claims.	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
Standardized forms & templates for submission of contractor claims	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9

The last and final question of the survey requested the respondents to provide additional suggestions that would be helpful in improving the existing change order management processes in different construction projects. These suggestions would also help in identifying any other causes of change orders that might not have been considered previously in the literature. Similarly, it requested the respondents to provide any solutions implemented in their projects to tackle ineffectiveness of change order management processes that would be valuable for use in other projects.

3.3 Strategy for Data Acquisition

The strategy used for acquiring data for this research project was to distribute the designed survey among a group of professionals involved only in the construction industry across the world. The professionals who were requested to provide the

feedback were working on the construction projects as different contracting parties such as Owner, Contractor, Architect/Engineer (Design/Supervision Consultant), Project Management Construction Management Consultants (PMCM) and Supervision Consultants.

These professionals were involved in construction projects utilizing different types of project delivery systems (PDS) such as Design-Bid-Build, Design and Build, Supervision & Design Consultancy. The audience was involved in major infrastructure development projects as well as small scale construction projects. The audience for this survey was present mainly in Qatar, other Middle East and North African countries, North America and Asia regions.

Based on the above-mentioned considerations, the survey was distributed among professionals to provide their experienced feedback on the research topic. The distribution of questionnaire only to the selected group provided a holistic feedback regarding the emerging situations in the construction industries around different regions of the world. The distribution of data to the selected individuals also allowed for easy follow-up for responses.

Once the criteria for profile of survey respondents was finalized, the next step involved computing the minimum number of respondents of that will be the sample population for this project representing the construction industry. The formula used to determine the sample size is presented as below;

Sample Size = $(\text{Z-score})^2 * (\text{Std-Dev})*(1-\text{Std Dev}) / (\text{margin of error})^2$

Where, z score and margin of error are dependent on the confidence level and confidence interval respectively.

- The confidence level for this research project was selected to be 90% (z score = 1.645)
- The confidence interval is 10% (margin of error= 0.1).
- Finally, the standard deviation of 0.5 has been used. This number ensures that the sample size would be large enough to represent the population.
- Based on the above figures, the sample size is 96.

To achieve the sample size for number of respondents, the survey was distributed to 126 professional out of which 105 professionals completed the survey with answers to all required questions. The survey response percentage was 82 percent.

3.4 Acquired Data

This section illustrates the demographics of the acquired 105 responses from the audience. The charts presented below represent the responses received to the first part of the survey which focused on the personal background of the respondents. The results for survey question no. 1 regarding the years of experience of the respondents in construction are distributed with the percentages as shown below in figure 6. The summary of responses is as follows;.

- 37 (35%) respondents had 15 or more years of experience.
- 25 (24%) respondents had 10-15 years of experience.
- 20 (19%) respondents had 05-10 years of experience.

- 23 (22%) respondents had less than 5 years of experience.

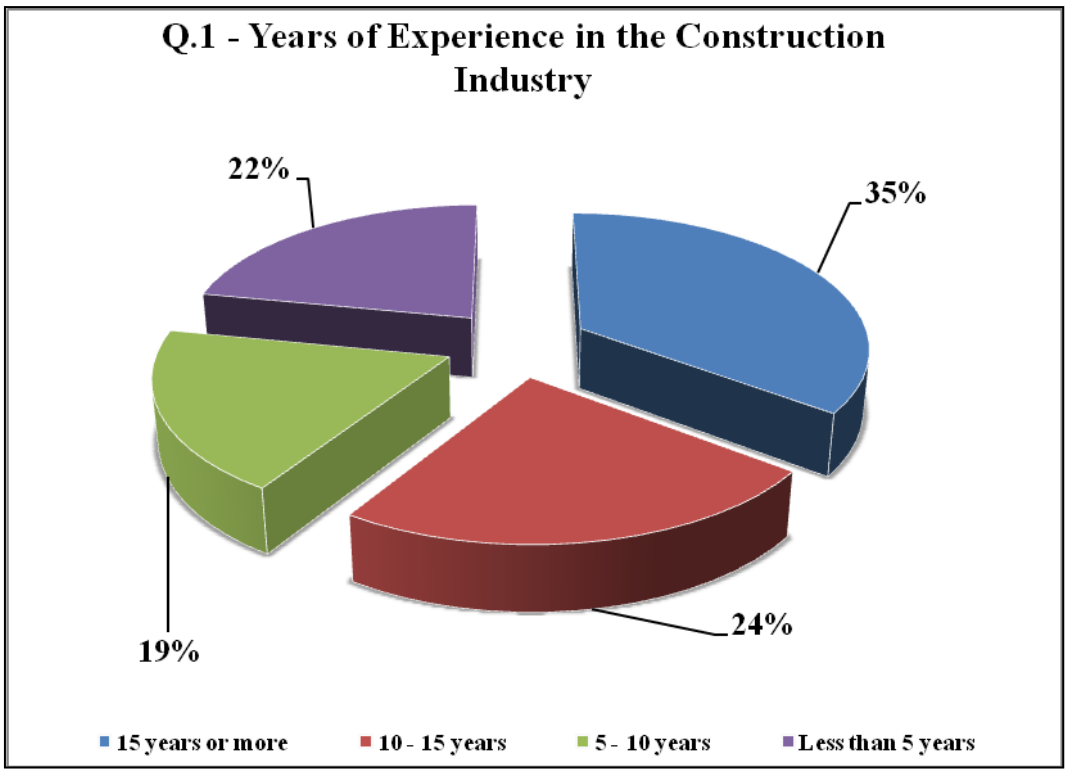

Figure 6- Years of experience of respondents in the construction industry

The question no. 2 in survey asked the respondents regarding the project delivery systems being used in their current construction project. The results of this question with the percentages of respondents from different project delivery systems are illustrated in figure 7, while the summary of responses is presented as below.

- 21 (22%) respondents were working in Design-Bid-Build Projects.
- 48 (42%) respondents were working in Design & Build Projects

- 32 (29%) respondents were working in Architect/Engineering Projects.
- 4 (7%) respondents were working in programs using a combination of two or more type of above-mentioned PDS.

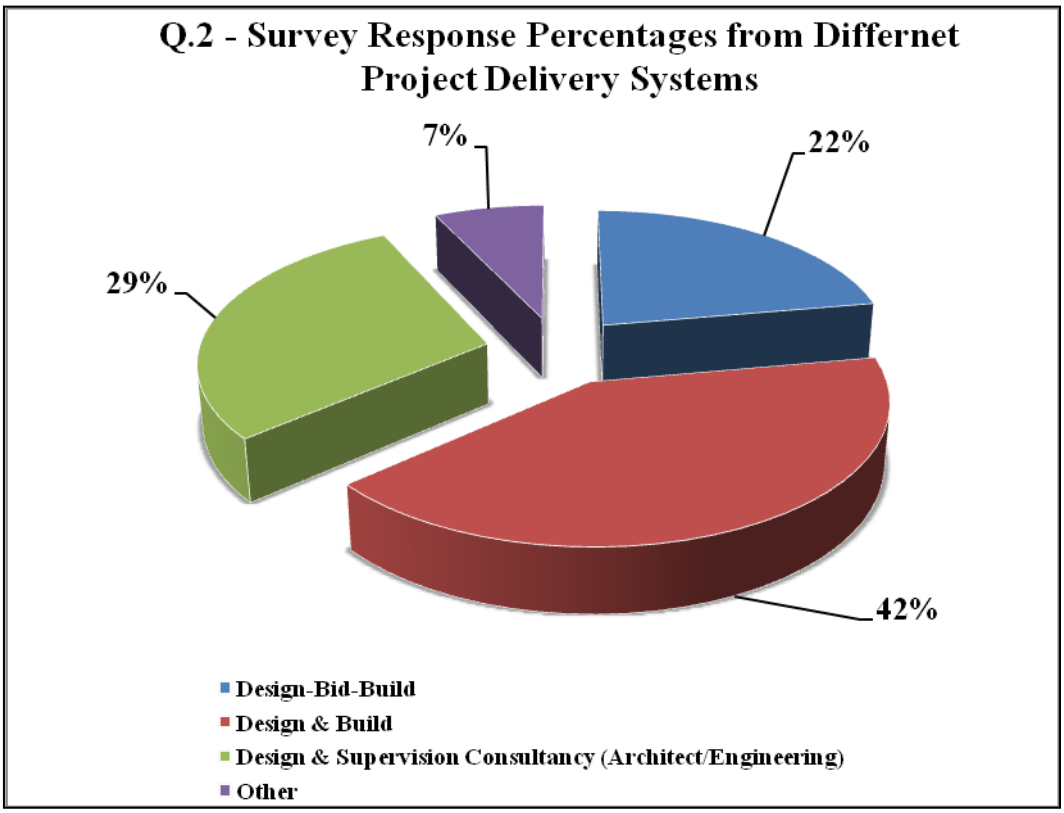

Figure 7- Years of experience of respondents in the construction industry

The question no.3 in survey focused on the roles of respondents as the contracting parties in the construction projects. The responses received for this question are summarized as below;

- 16 (15%) respondents were working as Owners.
- 31 (30%) respondents were working as PMCM.

- 16 (15%) respondents were working as Supervision Consultant.
- 11 (10%) respondents were working as Design Consultant
- 23 (22%) respondents were working as Contractor.
- 28 (8%) respondents were working as Subcontractors/Suppliers.

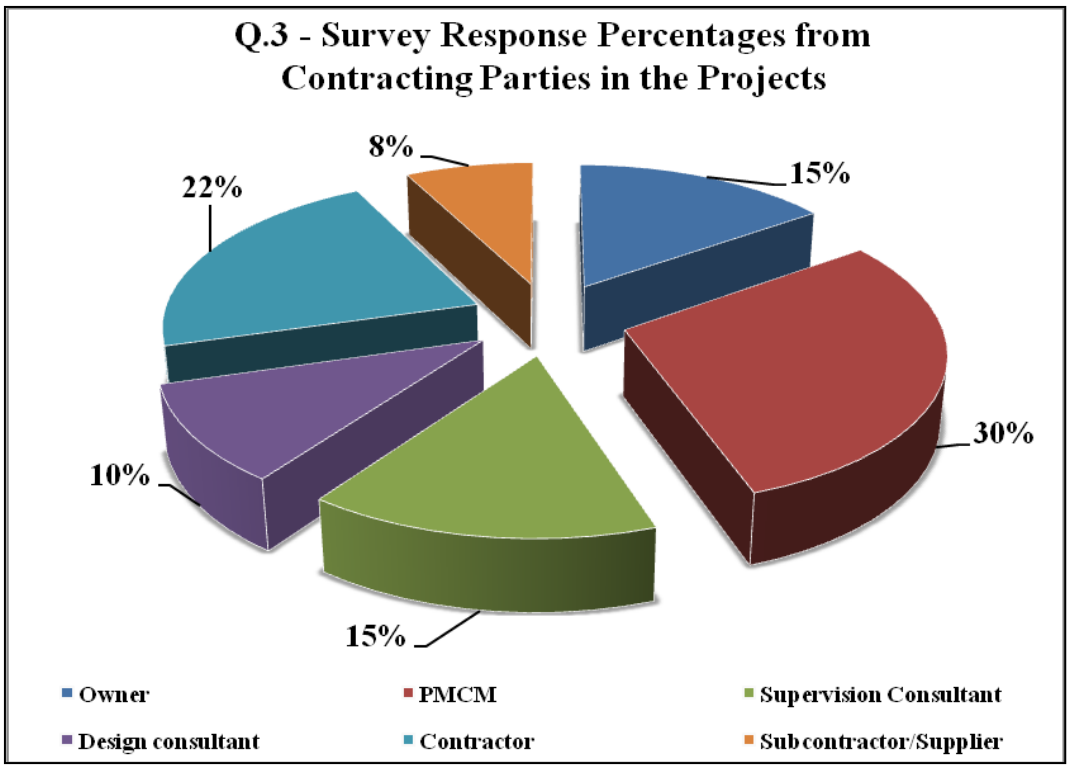

Figure 8- Survey response percentages from different contracting parties

The results of question no. 5 of the survey are one of the most important aspects of the research which show that the diversity of the data as well as validity of this research in different regions. This question requests the respondents to provide their current country of the construction project. The results are summarized as given in figure 9 with number of responses from each individual region.

- 36 (34%) respondents were currently based in Qatar
- 24 (23%) respondents were currently based in MENA Region (excluding Qatar).
- 30 (29%) respondents were currently based in North America (USA and Canada)
- 15 (14%) respondents were currently based in Asia (Pakistan, Malaysia)

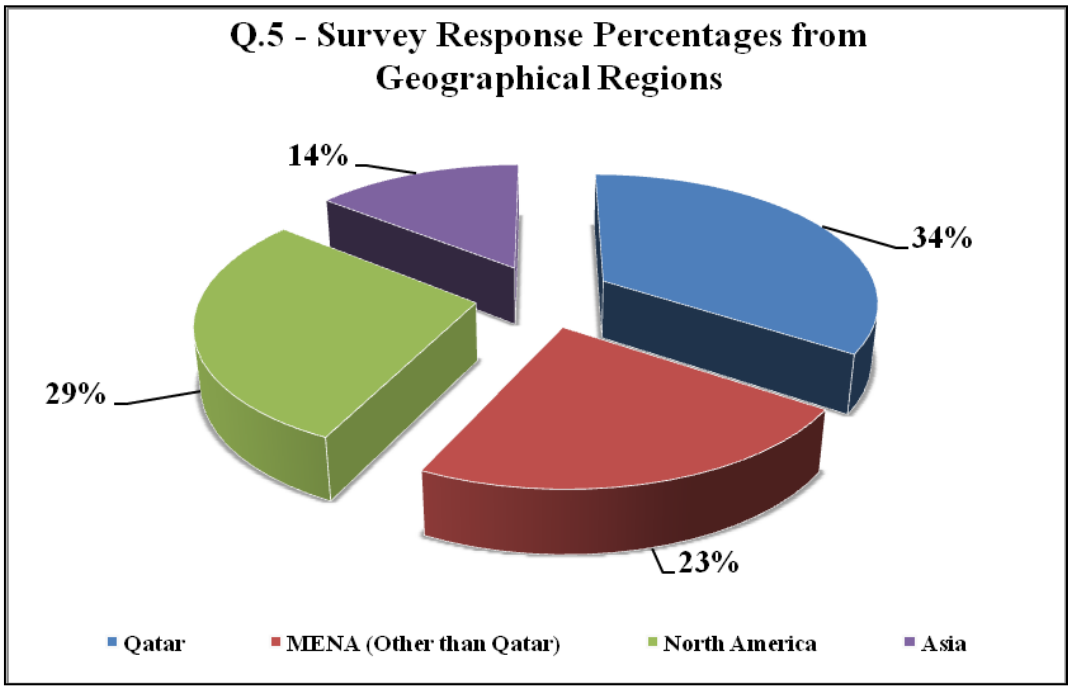

Figure 9- Survey response percentages from different Geographical Regions

The results of question no. 6 of the survey are presented in the following chart (figure 11). This question requests the respondents to provide their background engineering discipline. The results are summarized as given in figure 10 with number of responses from each individual region.

- 39 (37%) respondents had Civil & Structural Engineering background.
- 31 (30%) respondents had Electrical Engineering background.
- 22 (21%) respondents had Mechanical Engineering background.
- 8 (8%) respondents had Oil & Gas background.
- 12 (11%) respondents were involved in other engineering fields such as Electronics, Control Systems, Transportation Engineering.

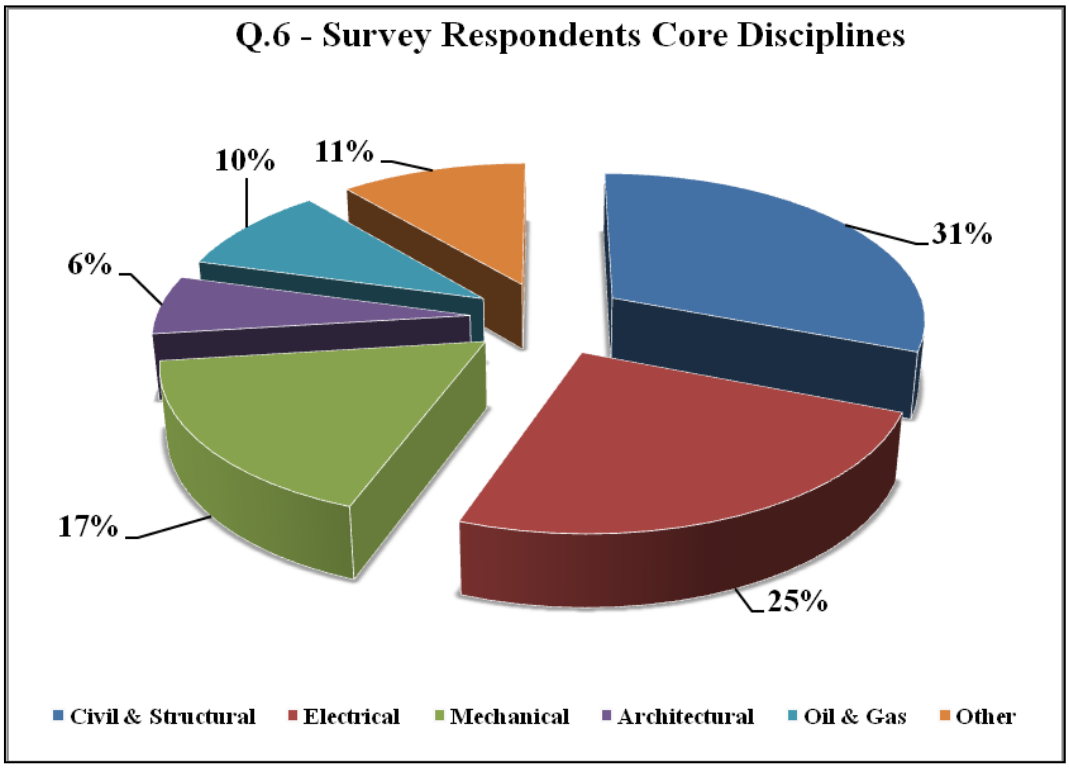

Figure 10- Survey respondents' core engineering disciplines

Chapter 4 – Analysis of the Data

This chapter focuses on the application of analysis techniques on the data obtained through the survey. The survey data was initially analyzed by applying statistical techniques to compute the relative importance indices (RII) of the causes of change orders. Secondly, decision modeling technique known as Analytical Hierarchy Process (AHP) was used to achieve the research objective. This chapter also describes why Relative Importance Index (RII) was used instead of other statistical techniques like computation of mean and standard deviations. Finally, this chapter explains the advantages of using AHP technique in this research project as compared to other techniques previously used in the literature. It also explains how AHP would be beneficial to come up with stratification of causes of change orders based on flexibility in the multiple objectives decision criteria.

4.1 Reasons of Change Orders Ranked as per Survey

The acquired data from 105 respondents was initially analyzed through statistical technique by obtaining relative importance index for each cause of change order with respect to impact on project objectives considered in this research. The scores provided by each respondent for all the listed causes of change orders were collated in MS Excel for applying the mathematical computations of RII. The impact of each of the cause of change order on the project objective was examined and ranking was developed in terms of their criticality as perceived by the respondents using RII.

The technique of RII has been extensively applied by construction management research (CMR) community for the analysis of various factors. Hence, the computation equation for RII has several forms in application. This research project uses the simplest but the most frequently cited form of RII equation (Okoroh et al., 2002; Zeng et al., 2005; Othman et al., 2005; Ribeiro and Fernandes, 2010; Chileshe and Dzisi, 2012). The equation for RII is given as below;

$RII = \sum W / A*N \ (0 \leq RII \leq 1)$

The symbols in this equation are explained as following;

W – the sum of scores awarded to a cause of change order from N respondents (Mathematically, it is the sum of "n" respondents selecting the impact number which is multiplied by the impact scale point's integer value. This is done for each integer on the selected scale)

A –the highest integer on the impact scale and;

N –the total number of respondents.

The important points of consideration for utilizing the above-mentioned equation in this research project are the values of N and A. The value of "N" is 105 according to the total number of respondents for survey. Similarly, the value of "A" for this research project is 9 as impact scale utilized to obtain respondents feedback ranges from 1 to 9.

The RII score has been calculated for each reason by multiplying the impact intensity with the respective number of responses for each reason. Then this

number was divided by the total number of respondents and the highest integer on the impact scale as per the equation cited above to obtain the relative importance index for each cause of change order.

Appendix K shows the tables for number of responses for each integer on the impact scale for all the causes of change orders with respect to impact on the project duration, project cost and project quality. For example, 26 respondents replied that the impact on project duration would be extremely high due to the change in specifications by the owner. Similarly, the poor planning of the contractor would result in a high impact on project quality according to 22 respondents.

The computations of RII and stratification of causes of change orders considering the individual factors such as impact on project duration, impact on project cost and impact on project quality formed the basis for the application sophisticated technique of AHP. This stratification was used as the reference for assigning scores according to AHP scale in AHP pairwise comparisons of the causes of change orders. This pair-wise comparison for relative importance of the causes of change orders was carried out for each factor in the multiple objectives decision criteria. Finally, the ranking of reasons for change orders are obtained considering a collective impact on project duration, cost and quality.

According to the calculations shown in Appendix K, the RII and rankings of reasons of change orders as per their respective impact on project duration, impact on project cost and impact on project quality are shown as following tables.

4.2 Reasons Rankings as per Impact on Project Duration

Table 6 - RII Rankings of Reasons as per Impact on Project Duration

Reasons for the Change Order	RII	Ranks of Reasons as per Impact on Project Duration
(10) Poor project planning by the contractor	0.8529	1
(12) Financial problems of the contractor	0.8360	2
(1) Change of plans or scope by the owner	0.7979	3
(2) Changes due to owners' financial problems	0.7651	4
(9) Equipment and labor problems of the contractor	0.7640	5
(11) Additional requirement from owner/government agencies	0.7460	6
(8) Owner's requirement to expedite project schedule	0.7429	7
(4) Change in material and procedures by the owner	0.7354	8
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	0.7259	9
(3) Change in specifications by the owner	0.7238	10
(7) Errors and omissions in the design	0.7122	11
(13) Unforeseen conditions in the project	0.6751	12
(6) Value engineering proposal by the designer	0.6085	13

4.3 Reasons Rankings as per Impact on Project Cost

Table 7- RII Rankings of Reasons as per Impact on Project Cost

Reasons for the Change Order	RII	Ranks of Reasons as per Impact on Project Cost
(3) Change in specifications by the owner	0.8931	1
(1) Change of plans or scope by the owner	0.8910	2
(2) Changes due to owners' financial problems	0.7841	3
(8) Owner's requirement to expedite project schedule	0.7683	4
(4) Change in material and procedures by the owner	0.7630	5
(10) Poor project planning by the contractor	0.7354	6
(11) Additional requirement from owner/government agencies	0.7164	7
(7) Errors and omissions in the design	0.7122	8
(12) Financial problems of the contractor	0.7058	9
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	0.6529	10
(13) Unforeseen conditions in the project	0.5556	11
(6) Value engineering proposal by the designer	0.5312	12
(9) Equipment and labor problems of the contractor	0.5238	13

4.4 Reasons Rankings as per to Impact on Project Quality

Table 8- RII Rankings of Reasons as per Impact on Project Quality

Reasons for the Change Order	RII	Ranks of Reasons as per Impact on Project Quality
(8) Owner's requirement to expedite project schedule	0.887831	1
(12) Financial problems of the contractor	0.82328	2
(10) Poor project planning by the contractor	0.820106	3
(2) Changes due to owners' financial problems	0.708995	4
(9) Equipment and labor problems of the contractor	0.706878	5
(7) Errors and omissions in the design	0.701587	6
(4) Change in material and procedures by the owner	0.670899	7
(3) Change in specifications by the owner	0.637037	8
(6) Value engineering proposal by the designer	0.627513	9
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	0.62328	10
(13) Unforeseen conditions in the project	0.514286	11
(11) Additional requirement from owner/government agencies	0.48254	12
(1) Change of plans or scope by the owner	0.402116	13

4.5 Spearman's Rank Correlation

Since the data obtained through survey was from different demographical regions, it was necessary to check the accuracy and cohesion of responses from different regions. This test helped us to verify that similar project management attitudes are adapted by the organizations across different countries. To attain this objective, Spearman's Rank Correlation Factor is utilized. This test is preferred over the other techniques as it is a non-parametric test which does not require distribution normality and homogeneity in the data (Megha and Rajiv, 2013).

The Spearman's correlation has been used in this project to measure the strength of the relationship of ranks for causes of change orders between (Qatar + MENA) region with ranks of the causes of change orders for North America region. These ranks were initially obtained through RII calculations from the responses of survey respondents based in these regions.

The Spearman's correlation coefficient can be calculated by applying the following formula.

$$\mathbf{r = 1 - [6\Sigma d^2/(n^3 - n)]}$$

Where, r = Spearman rank correlation coefficient between two rankings,

d = difference between ranks assigned to causes for each location,

n = 13 which is equal to the number of causes which are ranked

The value of Spearman coefficient is between +1 and −1, where +1 implies a perfect positive relationship (agreement), while −1 results from a perfect negative relationship (disagreement)

The mathematical computations for Spearman's coefficient were conducted for three cases which are described as below;

- Comparison of rankings of causes of change orders with respect to impact on project duration for Qatar & MENA region versus North America region. The Spearman's correlation coefficient for this comparison was 0.5000 which shows agreement among the results.
- Comparison of rankings of causes of change orders with respect to impact on project cost for Qatar & MENA region versus North America region. The Spearman's correlation coefficient for this comparison was 0.3956 which shows agreement among the results.
- Comparison of rankings of causes of change orders with respect to impact on project quality for Qatar & MENA region versus North America region. The Spearman's correlation coefficient for this comparison was 0.3022 which shows agreement among the results.

The detailed comparison tables with mathematical computations for the Spearman's coefficients are presented in Appendix L

4.6 Importance of factors (Project Duration, Cost & Quality)

The survey requested the respondents to provide their insight on the importance of different impacts on construction projects because of any change orders. The resulting impacts due to change orders were considered in terms of extension in project duration, increase in project cost and lower project quality. For example, the question in the survey aimed to ask how important is the impact on project

duration while a change order is being evaluated for approval, negotiation or rejection. Similarly, the question also asked how important the impact on project cost and impact on project quality are during the assessment process of a change order. The survey responses from 105 respondents for this question are summarized in Appendix C.

Again, RII computations were performed to obtain the overall score in terms of importance of impact on project duration, impact on project cost and impact on project quality in deciding for a change order. This time the objective of applying RII calculations was to obtain the hierarchy of importance.

The average of responses for the survey was used to compute the initial rankings for factors in the decision criteria. The calculations as shown in Appendix C were performed by multiplying the intensity of importance with the respective number of responses for each impact type. Finally, the resulting number was rounded up to the closest integer to assist for further analysis in the AHP procedure. These calculations resulted in a score of 5.8666 (≈ 6) for the impact on project duration. Impact on project cost received the highest score of 7.8095 (≈ 8) and impact on project quality received a score of 5.3081 (≈ 5). The rankings obtained are summarized as shown in the following table 9;

Table 9 - Rankings for Factors of Decision Criteria based on the survey

Impact on the Project	Average Score	Rank
Impact on project duration	**6**	**1**
Impact on project cost	**8**	**2**
Impact on project quality	**5**	**3**

4.7 Application of Analytical Hierarchy Process (AHP)

The general methodology for applying AHP technique is described as below;

1. Determine the problem and define the goal.
2. Determine the criteria which influence the decision alternatives.
3. Determine the decision alternatives to find their rankings.
4. Construct a set of pair-wise comparison matrices (size n*n) for the decision alternatives. Here 'n' represents the number of decision alternatives. The pair-wise comparisons are done in terms of which alternative dominates the other.
5. Compare each element in the comparison matrix with each other. A total n(n-1)/2 are required to be done. It should be noted that the diagonal elements in the matrix are equal to 1 and the other elements will simply be the reciprocals of the earlier comparisons.

6. After the completion of pair-wise comparisons for decision alternatives with respect to the criteria, consistency of the comparison has to be checked. This is done by calculating the consistency index (CI) and consistency ratio (CR). The acceptable range of CR is less than 0.10. If the CR value is greater than 0.1, the matrix needs to be made consistent which is done by reassigning the judgement values as per AHP scale.
7. The normalized values of each alternative are then computed from decision matrices to obtain the hierarchy of the decision alternatives.

The survey rankings presented in the above sections were then used to execute the most critical part of AHP analysis which is the development of pair-wise comparison matrices. This part constituted of two steps. Firstly, the development of a pair-wise comparison matrix of the factors which formed the decision criteria was done. Secondly, the development of a pair-wise comparison matrix for reasons of change orders with respect to the individual factors in the decision criteria.

The decision making technique of AHP was used in this research project to obtain a hierarchy for reasons of change orders based on their impact simultaneously on the project objectives such as project duration, project cost and project quality. The goal of AHP for this research project can be graphically represented as shown in the following figure 12.

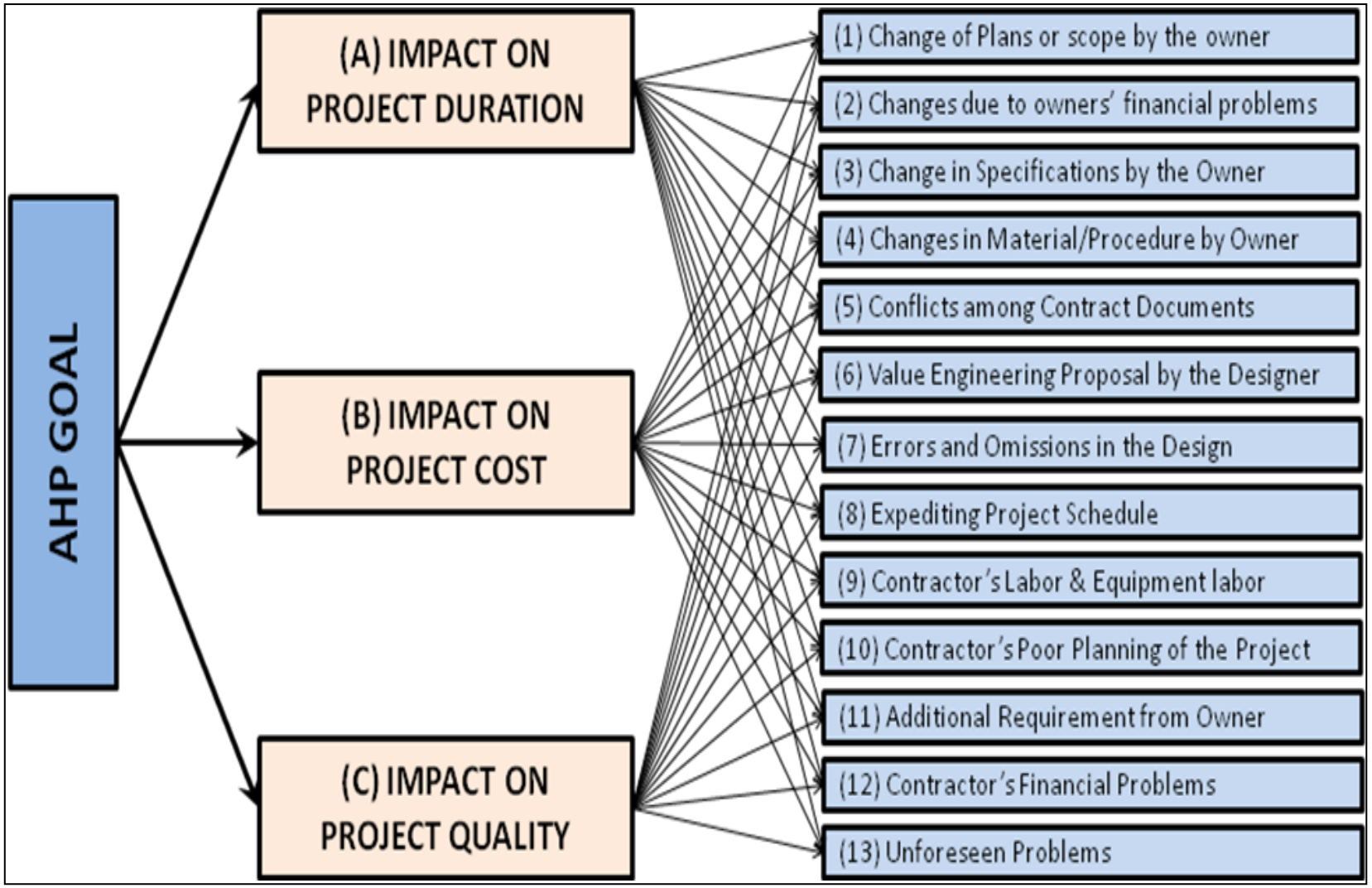

Figure 11- AHP Multi-Objective Model for the research project

The scale used for AHP in this project is presented in Appendix B. The sequential order of steps for the AHP conducted in this research project is explained as given below;

- Developed a pair-wise comparison matrix for the factors in the decision criteria (Appendix D). The decision criteria comprised of three factors which are given as follows;
    - Impact on project duration because of the change order
    - Impact on project cost because of the change order and;
    - Impact on project quality because of the change order.
- Computed relative weights for the factors in the decision criteria. (Appendix D). The AHP weights obtained after these computations are as follows;
    - Impact on project duration – $0.3237762 \approx 32.37\%$
    - Impact on project cost – $0.5869464 \approx 58.69\%$
    - Impact on project quality – $0.0892774 \approx 8.9\%$
- Developed a pair-wise comparison matrix for the reasons of change orders with respect to impact on project duration. (Appendix E).
- Computed the relative weights for the reasons of change orders with respect to impact on project duration. The complete calculations for the weights for each reason of change order are presented in (Appendix E).

    - For example, with respect to impact on project duration, , the resulting weight for the reason of change order, " (1) Change of plans or scope by the owner", after pair-wise comparison is "0.124"

- Developed a pair-wise comparison matrix for the reasons of change order with respect to impact on project cost. (Appendix F)
- Computed the relative weights for the reasons of change orders with respect to impact on project cost. The complete calculations for the weights for each reason of change order are presented in (Appendix F).
    - For instance, with respect to impact on project cost, the resulting weight for the reason of change order, " (1) Change of plans or scope by the owner", after pair-wise comparison is "0.181"
- Developed a pair-wise comparison matrix for the reasons of change order with respect to impact on project quality. (Appendix G)
- Computed the relative weights for the reasons of change orders with respect to impact on project quality. (Appendix G).
    - For example, with respect to impact on project quality, the resulting weight for the reason of change order, " (1) Change of plans or scope by the owner", after pair-wise comparison is "0.012"
- Computed the overall score 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 (Appendix D) with the respective weights of the causes of change orders obtained in (Appendices E, F, & G). The table for calculations for score of each reason is provided in (Appendix H).

- The sample calculation for computing overall score of reason of change order," (1) Change of plans or scope by the owner", is given as below;

  AHP weight for "(1) Change of plans or scope by the owner" = 0.3237762*0.124 + 0.5869464*0.181 + 0.08592774*0.012 = **0.147**

4.8 Rankings of Reasons as per AHP

The ranking of reasons of change order based on the AHP multiple objective criteria is presented as below;

Table 10 - AHP Rankings for Reasons of Change Orders

Reasons for the Change Order	Average Score	Ranks of Reasons
(3) Change in specifications by the owner	0.169	1
(1) Change of plans or scope by the owner	0.147	2
(10) Poor project planning by the contractor	0.119	3
(2) Changes due to owners' financial problems	0.114	4
(12) Financial problems of the contractor	0.092	5
(8) Owner's requirement to expedite project schedule	0.088	6
(4) Change in material and procedures by the owner	0.079	7
(11) Additional requirement from owner/government agencies	0.047	8
(9) Equipment and labor problems of the contractor	0.046	9
(7) Errors and omissions in the design	0.035	10
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	0.026	11
(13) Unforeseen conditions in the project	0.023	12
(6) Value engineering proposal by the designer	0.016	13

Chapter 5 – Discussion of Results

The goal of applying statistical analysis technique (RII) and Analytical Hierarchy Process (AHP) to the survey results was to obtain a hierarchy of reasons of change orders based on their impact on project objectives. The project objectives considered in this research topic were project duration, cost and quality. Initially, the causes of change orders were ranked according to their impact on project duration. The rankings for the change orders for the impact on project duration were obtained based on the RII calculations of survey responses as shown in section 4.2. Similarly, the hierarchy for the reasons of change orders was obtained based on RII calculations of survey results for their impacts on project cost and project quality. These rankings are shown in section 4.3 and section 4.4 respectively.

It should be noted that the rankings of change orders obtained are different based on their impact on different project objectives. For instance, "poor project planning by the contractor" is the number 1 cause for change order in terms of impact on project duration. While, the same reason is ranked as number 6 with respect to its impact on the project cost and ranked as 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 impact on project duration and impact project quality. On the other hand, these reasons are ranked ninth, second and thirteenth for impact on project cost.

Moving on to the second stage of analysis in this research project, AHP was applied to the survey results which were initially analyzed by statistical technique. AHP goal for this project was to develop a stratification for the reasons of change orders based on their impact on project duration, cost and quality considered together.

An important point to be noted in the AHP procedure was the development of decision criteria and determining the weights of factors in the decision criteria. Project objectives were considered as the factors in the decision criteria. Impact on project duration, impact on project cost and impact on project quality were the three factors which constituted the decision criteria. The RII rankings for these factors were obtained based on survey question no. 7 and an AHP score was computed on the basis of their RII. As expected, impact on project cost was considered as the most important factor while any change order is being assessed. Following the impact on project cost, were the impact on project duration and then the impact on project quality. The detailed AHP calculations for the weights of factors are presented in Appendix D. The weights of impact on project duration, impact on project cost and impact on project quality in the decision criteria are 0.3237762 (≈32%), 0.5869464 (≈59%), 0.0892774 (≈9%) respectively.

In view of the above and the results of AHP, it is noted that when a multiple objective decision criteria was utilized based on the cumulative effect of different possible impacts of change orders, 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.

As some reasons of change orders had similar rankings while their impacts were considered separately, similar case was observed in AHP rankings of reasons and rankings of reasons based on impact on project duration, cost and quality. For instance, 'Change in specifications by the owner' and 'Change of plans or scope by the owner' were ranked first and second in AHP ranking and RII ranking for impact on project cost. Similarly, 'Changes due to owner's financial problem' was on the fourth rank according to AHP score, RII for impact on project duration and RII for impact on project quality.

A comparison table for the rankings is presented in Appendix I for all thirteen reasons of change orders according to their RII scores for impact on project duration, project cost and project quality and AHP score.

In view of the above discussion, it should be noted that the results of decision technique (AHP) and statistical technique (RII) provided an insight and understanding of the problem at hand. These results do not provide a model solution to fit all situations encountered in the change order management process.

Since change orders are inherent phenomena in construction industry, the ultimate goals in construction change order management are to avoid these change orders

and to mitigate any adverse impact on the project duration, project cost and project quality due to these change orders.

5.1 Owner Related Causes of Change Orders

The results for our AHP analysis on the causes of change orders are mentioned in Section 4.7. 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 impact on the project duration, cost and quality. It is also to be noted that "Owner's requirement to expedite schedule of project" and "changes in the project due to financial conditions of owner" are among the top six causes with most impact on project.

Considering this scenario, it is necessary for the owners to change their attitude towards the change order management process in construction projects. The owner's involvement in the early stages of design is extremely important. The owners need to be involved in the design stage of the project to avoid any changes of specifications, requirements and plans at the final stages of design or the construction of project.

The owner's role in hiring experienced project management consultant and design/supervision consultant also holds key role in the success of change order management process. The consultants are the eyes and ears of owner on the site. While evaluating any consultant for the required construction project, their experience in similar previous projects needs to be critically scrutinized. The owners may contact and request the previous clients of the contractor for feedback

regarding their performance in the project. A checklist can be developed by the contractor considering key performance factors to judge the performance based on feedback.

The decision by the owner to execute the project in required time and budget must be well studied and thought of. Sudden change in requirements by the owner to expedite project schedule results in the lower project quality and huge cost over-run. Such situations can be avoided only by strong determination of the owner to stick to the original cost and schedule baseline. The role of consultant in such scenario can also be critical as the plausible impacts of expediting project schedule need to be highlighted and demonstrated to the owner.

Another important owner related cause of change order is the change in material and procedures, which is ranked seventh in the AHP results. This issue is commonly observed in the finishing stages of the construction projects like buildings where the owner's perception of how the final finishes should be are changed. Such situations need to be avoided by requesting the contractor to procure the material only after review and approval of the sample by the owner itself.

5.2 Contractor Related Causes of Change Orders

Importance of contractor's role in the change order management process is second to none. The analysis results obtained in Chapter 4 indicate that scenarios like "poor project planning by the contractor", "equipment and labor issues of the contractor" and "poor financial strength of the contractor" are major causes which adversely affect the duration, cost and quality of project.

In real life construction projects, it is not rare that contractors are terminated by the owner due to extreme delays in project progress and poor quality of the work. Similarly, there are many instances where contractors have claimed bankruptcy during the ongoing construction. All such scenarios result in the delay of projects and cost over-runs accompanied by poor quality. These results come along with consequences like nasty reputation of the contractor among the clients with a possibility of contractor being blacklisted.

To avoid such issues, special care and attention is required from the contractors. Some measures recommended to the contractors include a need to establish proper coordination and communication with the consultants and owner to ensure that they are performing what is required by contractual scope of work. The misinterpretation of the contractual scope of work by the contractor is a leading cause of legal conflicts among the client. These situations arise because the contractor demands additional compensation for what they deem was required by scope of work while the owner has the opposite view.

The selection of subcontractors and the employees by the contractor according to specific project requirements needs to be done well. Financial stability along with required experience of the subcontractors should be a key element in scrutinizing subcontractors before hiring them. This is of critical important as any lack of performance on subcontractor's part is reflected on contractor. Also, the lack of funds, equipment and labor of subcontractors puts the main contractor under additional pressure. The equipment, labor and financial issues of contractor which result in change orders can be better handled by sharing the responsibility with

subcontractors. Furthermore, contractor has to ensure proper coordination among the subcontractors.

In addition to the above, the staff of subcontractors as well as the contractor needs to be properly experienced for the undertaken project. Furthermore, the contractor needs to be aware of all the contract clauses and special provisions to perform the work and avoid any conflicts between the oral instructions from the consultant and what is demanded as per the contract. Contractor's pro-active role is also important in terms of identifying any conflicts among the contract documents.

5.3 Consultant Related Causes of Change Orders – Discussion

The consultant related causes of change order which were identified through literature review and analyzed through statistical analysis and AHP in Chapter 4 are errors and omissions in the design, value engineering proposal and conflicts among contract documents. 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.

Since consultants are involved since the inception of a project, they need to understand the requirements of the client thoroughly. This is to ensure that the designed project reflects owner's aspirations and also helps to avoid late design changes which would not then not be required due to misunderstanding or misinterpretation of the owner's requirements.

Another important factor to be considered by the design consultant is the proper coordination among its own team members. It has been frequently observed on the

construction projects that different disciplines are not well coordinated with each other in the design drawings. For instances, the clashes between electrical and mechanical networks are not resolved before the transfer of issued for construction drawings to the contractor. Such scenarios result in frequent change orders requests from the contractors to the client.

The design consultants need experienced employees to properly develop a design which is constructible with least conflicts and clashes. Also, the design consultants need to be aware of all the latest specifications and standards of the local government authorities. This is also observed as a major cause of change orders in the construction projects in this region as the design consultants develop design drawings according to out dated standards. Such situations need to be strictly avoided as this exposes the client to potential change orders.

Chapter 6 – Conclusions and Recommendations

This research project which started by the extensive review of existing academic literature is now concluded in this chapter by presenting the deductions of the analysis done as part of this project. This chapter also mentions the contribution of this project to the diverse subject of change order management in the field of construction management research. Finally, the chapter and project are closed with few recommendations on improvement of the existing change order management process.

6.1 Conclusion

Construction is a global industry which exists in all the countries of the world in of its forms. This form could be either the development of new projects or reconstruction, renovation or refurbishments of existing buildings, roads or infrastructure. 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 research project were to investigate the causes of change orders in the construction industry. 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 project objectives which were being impacted by the change orders were the project duration, cost

and quality. A similar trend among the impact on project objectives was found by the researchers in construction management (Patrick and Begum, 2010) and (Alnuaimi et.al. 2010). An extensive literature review was conducted to shortlist the causes of change orders and their effects on the project objectives.

An online survey was conducted by distributing the questions among the professionals involved as different contracting parties in the construction industry to obtain a feedback on the effects of the causes of change orders with respect to their impact on the project objectives which were shortlisted during literature review. These project objectives were the project duration, cost and quality. The application of RII statistical technique provided the rankings of the causes of change orders in terms of their impact and Spearman's correlation factor provided consistency of respondents from different regions. AHP model and framework was then developed based on the survey results to obtain ordinal values of causes of change orders based on their collective impact on certain project objectives. The results indicated that different rankings of reasons of change orders were obtained when impact on project duration, cost and quality were analyzed separately. Similarly, the rankings of causes of change orders were different when AHP was applied to evaluate cumulative impact.

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. Similarly,

in some instances project quality is the prime and most important project objective while the project duration and project possess lesser importance.

An example of such scenario was faced by the developers of Sydney Opera House. The original budget for Sydney Opera House before the beginning of construction was $7 million and scheduled estimate for completion was year 1963. But the project was formally completed ten years later in 1973 and with a cost of US $102m. The development of residential complexes by private developers are examples of such project projects in which cost is the most important concern. The projects come to halt if the financial situation of investors is not viable to complete the project. On a similar note, the oil leakage few years ago in the Gulf of Mexico required the project to be executed in the shortest possible time irrespective of the cost due to its environmental repercussions.

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 or vice versa.. Hence, considering the differences in importance of project objectives from project to project, the rankings for the causes of change orders based on their impact and criticality would be different as well. This would require certain causes of change orders to be planned and accounted for more than the others. This inference is supported by previous research such as (Amr, 2007), (Alnuaimi et.al. 2010) and (Al-Dubaisi and Abdulghafoor, 2000).

AHP is a versatile tool which is flexible to be modified according to the relative importance of project objectives. As discussed above, the weights of impact in the

decision criteria may vary from project to project based on the priorities of project. For example, the quality of project might be the prime concern and may have the highest weight-age while the impacts on project cost and project duration have lower weights. Such scenarios would then result in the modification of rankings of change orders suited according to the project objectives.

The construction industry in MENA region is dominated by the construction projects which are adversely affected by delays and cost over-runs due to ineffective practices in change order management. This research project can be of great help to all the contracting parties to plan and develop better mitigations for risks and impacts due to change orders.

6.2 Recommendations

Thorough review of academic literature resulted in many suggestions for the improvement of existing change order management processes. The survey developed as part of this research project asked the respondents to provide their feedback for the effectiveness of those suggested improvements in order to reduce the impact on the project objectives. Again, different rankings for suggested improvements were obtained as per their respective contribution to reduce impact on duration, cost and quality of the project. The survey responses and the result computations for the rankings of suggested improvements are shown in Appendix K and Appendix J.

In addition to the suggested improvements retrieved from the literature review, some of the improvements in the change order managements can be summarized as below;

- It is important to ensure proper coordination among the contracting parties in construction projects. Depending on the phase of project and other characteristics, the development of a change order review committee with representation from all contracting parties to assist the client in evaluation and administration of change orders could be helpful in timely decisions for change orders.
- Carry an allowance in the construction budget because of plausible design errors.
- Impact of the change largely depends on the stage of the project. So, it is recommended that the design of the project has to be thoroughly reviewed and frozen to as much extent as possible before moving to the construction stage.

Construction management research community has put in a lot of efforts to understand the reasons and effects of change orders in the construction industry, yet we find a gap in the available academic literature and the data with construction industry. The lessons learned from previous construction projects have not been well documented in the educational sector to be utilized in future projects. The framework developed in this research project can be expanded to include more project objectives such as impact on HSE. Also, this framework can be adjusted to suit individual construction projects with different relative importance of project objectives at various phases of the project.

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Appendix – A: Questionnaire

Questionnaire – Effective Framework for Change Order Management in Construction Industry

We highly appreciate your time to complete the following survey. The survey is conducted as part of data collection for Masters Project at Qatar University.

Your responses are voluntary and will be confidential

You may contact the sender at (ok1404726@student.qu.edu.qa)

The survey consists of three parts and it should take about ten minutes of your time.

First Part – Personal Background:

1- Years of experience in the construction industry:

□ Less than 5 years □ 5 - 10 years

□ 10 - 15 years □ 15 or more years

2- Project Delivery Method being used in your current project:

□ Design-Bid-Build □ Design & Build

□ Architect/Engineering □ Other _____

3- Role of your organization in the current project:

□ Owner □ PMCM □ Supervision Consultant

□ Design consultant □ Contractor □ Subcontractor/Supplier

4- Your department in the organization at the current project:

□ Contracts Dept. □ Design Dept. □ Finance Dept.

□ Construction Dept. □ Projects Control □ Other _____

5- Your country of work:

□ Qatar □ MENA (Excluding Qatar)

□ North America □ Asia

6- Your discipline in the current project & organization:

□ Civil & Structural □ Architecture □ Oil & Gas

□ Electrical □ Mechanical □ Other _____

Second Part – Causes of Change Orders, their Impact on Project Duration, Cost & Quality

7- Please mark your response with (✓) from 1 to 9, for the importance of each factor in making decision for a change order in the construction project based on the following guidelines;

(1 - Not Important, & 9 - Extremely Important)

Factors in Deciding for a Change Order	Impact (Importance)
Impact on Project Duration because of the change order	1 2 3 4 5 6 7 8 9
Impact on Project Cost because of the change order	1 2 3 4 5 6 7 8 9
Impact on Project Quality because of the change order	1 2 3 4 5 6 7 8 9

8- The following question mentions various causes of change orders and the resulting impact on project duration, project cost and project quality. Please mark your response with (✓) from 1 to 9, for the impact of each cause of change order based on the following scale,

(1 - Lowest impact, & 9 - Highest impact)

Causes for the Change Orders	Impact on Project Duration	Impact on Project Cost	Impact on Project Quality
(1) Change of plans or scope by the owner	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(2) Changes due to owners' financial problems	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(3) Change in specifications by the owner	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(4) Change in material and procedures by the owner	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(6) Value engineering proposal by the designer	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(7) Errors and omissions in the design	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(8) Owner's requirement to expedite project schedule	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(9) Equipment and labor problems of the contractor	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9

(10) Poor project planning by the contractor	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(11) Additional requirement from owner/government agencies	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(12) Financial problems of the contractor	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
(13) Unforeseen conditions in the project	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9

Third Part – Suggested Improvements and their Role in Reduction of Impact:

9- Following are some suggestions for improving the Change Order Management Process in the construction projects. Please mark your response with (✓) from 1 to 9, for the effect of these suggestions to reduce time, cost & quality impact of change order process.

(1 - No Improvement, & 9 - Highest Improvement)

Suggested Improvements in the Process of Change Order	**Reduction in Impact on Project Duration**	**Reduction in Impact on Project Cost**	**Reduction in Impact on Project Quality**
Introduction of a contract statement for timely response of the owner for contractor claims.	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
Advanced documentation system to assist the client in evaluation and administration of change orders	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9

Change in culture – Owners shall not develop an adversarial relationship with a contractor after claim notification.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	6	7	8	9		6	7	8	9		6	7	8	9	
Standardized forms & templates for submission of contractor claims	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	6	7	8	9		6	7	8	9		6	7	8	9	
Database development to utilize lessons learned for better planning of change orders.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	6	7	8	9		6	7	8	9		6	7	8	9	

10- Please provide your valuable suggestion for any other improvements that should be considered in the Change Order Management Process

_____

_____

_____

Appendix – B: AHP Scale

The following scale AHP scale was used in the development of pairwise comparison matrices for the causes as well as the factors.

Preference Level	Numerical Value
Equally preferred	1
Equally to moderately preferred	2
Moderately preferred	3
Moderately to strongly preferred	4
Strongly preferred	5
Strongly to very strongly preferred	6
Very strongly preferred	7
Very strongly to extremely preferred	8
Extremely preferred	9

Appendix – C: Survey Responses for Criteria

Importance of Time, Cost & Quality Impact in Deciding for a Change Order

Survey Responses - Importance of Time, Cost & Quality Impact in Deciding for a Change Order										
Impact Type/ Impact Score	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Average Score**
Time Impact of the change order	2	1	7	14	19	25	17	9	11	**6**
Cost Impact of the change order	0	0	1	0	2	13	21	30	38	**8**
Quality Impact of the change order	5	10	12	14	15	8	15	14	12	**5**

Appendix – D: Pair-wise Comparison for Criteria

Importance of Time, Cost & Quality Impacts in Deciding for a Change Order

Determining the Relative Weights of Decision Criteria				
	Decision Criteria			
Decision Criteria	**Time Impact of the Change Order**	**Cost Impact of the Change Order**	**Quality Impact of the Change Order**	**Row Average**
Time Impact of the Change Order	**1**	**1/2**	**4**	**0.3237762**
Cost Impact of the Change Order	**2**	**1**	**6**	**0.5869464**
Quality Impact of the Change Order	**1/4**	**1/6**	**1**	**0.0892774**
Calculations	**3.250**	**1.667**	**11.000**	**1**

Inconsistency Ratio = 0.04237 < 0.1

Appendix – E: Pair-wise Comparison for Impact on Project Duration

Pair-wise Comparison for Reasons of Change Orders for Impact on Project Duration

Criteria 1- Impact on Project Duration for each reason of Change Order														
Reasons for Change Orders	**(1) Change of plans or scope by the owner**	**(2) Changes due to owners' financial problems**	**(3) Change in specifications by the owner**	**(4) Change in material and procedures by the owner**	**(5) Conflicts among contract documents (i.e. specs. vs. drawings)**	**(6) Value engineering proposal by the designer**	**(7) Errors and omissions in the design**	**(8) Owner's requirement to expedite project schedule**	**(9) Equipment and labor problems of the contractor**	**(10) Poor project planning by the contractor**	**(11) Additional requirements from owner/government agencies**	**(12) Financial problems of the contractor**	**(13) Unforeseen conditions in the project**	**Row Average**
(1) Change of plans or scope by the owner	1	2	4	3	4	7	5	3	2	1/4	3	1/3	6	**0.124**
(2) Changes due to owners' financial problems	1/2	1	3	2	3	6	4	2	1	1/5	2	1/4	5	**0.084**
(3) Change in specifications by the owner	1/4	1/3	1	1/2	1	4	2	1/2	1/3	1/5	1/2	1/4	3	**0.037**
(4) Change in material and procedures by the owner	1/3	1/2	2	1	2	5	3	1	1/2	1/4	1	1/3	4	**0.057**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	1/4	1/3	1	1/2	1	4	2	1/2	1/3	1/5	1/2	1/4	3	**0.037**

(6) Value engineering proposal by the designer	1/7	1/6	1/4	1/5	1/4	1	1/3	1/5	1/6	1/8	1/5	1/7	1/2	**0.013**
(7) Errors and omissions in the design	1/5	1/4	1/2	1/3	1/2	3	1	1/3	1/4	1/6	1/3	1/5	2	**0.025**
(8) Owner's requirement to expedite project schedule	1/3	1/2	2	1	2	5	3	1	1/2	1/4	1	1/3	1/3	**0.050**
(9) Equipment and labor problems of the contractor	1/2	1	3	2	3	6	4	2	1	1/3	2	1/2	5	**0.090**
(10) Poor project planning by the contractor	4	5	5	4	5	8	6	4	3	1	4	1/2	7	**0.210**
(11) Additional requirement from owner/government agencies	1/3	1/2	2	1	2	5	3	1	1/2	1/4	1	1/3	4	**0.057**
(12) Financial problems of the contractor	3	4	4	3	4	7	5	3	2	2	3	1	6	**0.189**
(13) Unforeseen conditions in the project	1/6	1/5	1/3	1/4	1/3	2	1/2	3	1/5	1/7	1/4	1/6	1	**0.027**
Calculations	11.01	15.78	28.08	18.78	28.08	63.00	38.83	21.53	11.78	5.37	18.78	4.59	46.83	1.00

Inconsistency Ratio = 0.05941 < 0.1

Appendix – F: Pair-wise Comparison for Impact on Project Cost

Pair-wise Comparison for Reasons of Change Orders for Impact on Project Cost

Criteria 2- Impact on Project Cost for each reason of Change Order														
Reason for Change Orders	**(1) Change of plans or scope by the owner**	**(2) Changes due to owners' financial problems**	**(3) Change in specifications by the owner**	**(4) Change in material and procedures by the owner**	**(5) Conflicts among contract documents (i.e. specs. vs. drawings)**	**(6) Value engineering proposal by the designer**	**(7) Errors and omissions in the design**	**(8) Owner's requirement to expedite project schedule**	**(9) Equipment and labor problems of the contractor**	**(10) Poor project planning by the contractor**	**(11) Additional requirement from owner/government agencies**	**(12) Financial problems of the contractor**	**(13) Unforeseen conditions in the project**	**Row Average**
(1) Change of plans or scope by the owner	**1**	**2**	**1/3**	**3**	**7**	**8**	**6**	**3**	**8**	**4**	**5**	**6**	**7**	**0.181**
(2) Changes due to owners' financial problems	**1/2**	**1**	**1/3**	**2**	**6**	**7**	**5**	**2**	**7**	**3**	**4**	**5**	**6**	**0.133**
(3) Change in specifications by the owner	**3**	**3**	**1**	**4**	**8**	**9**	**7**	**4**	**9**	**5**	**6**	**7**	**8**	**0.261**
(4) Change in material and procedures by the owner	**1/3**	**1/2**	**1/4**	**1**	**5**	**6**	**4**	**1**	**6**	**2**	**3**	**4**	**5**	**0.093**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	**1/7**	**1/6**	**1/8**	**1/5**	**1**	**2**	**1/2**	**1/5**	**2**	**1/4**	**1/3**	**1/2**	**1**	**0.020**

(6) Value engineering proposal by the designer	**1/8**	**1/7**	**1/9**	**1/6**	**1/2**	**1**	**1/3**	**1/6**	**1**	**1/5**	**1/4**	**1/3**	**1/2**	**0.014**
(7) Errors and omissions in the design	**1/6**	**1/5**	**1/7**	**1/4**	**2**	**3**	**1**	**0**	**3**	**1/3**	**1/2**	**1**	**2**	**0.031**
(8) Owner's requirement to expedite project schedule	**1/3**	**1/2**	**1/4**	**1**	**5**	**6**	**0**	**1**	**6**	**2**	**3**	**4**	**5**	**0.091**
(9) Equipment and labor problems of the contractor	**1/8**	**1/7**	**1/9**	**1/6**	**1/2**	**1**	**1/3**	**1/6**	**1**	**1/5**	**1/4**	**1/3**	**1/2**	**0.014**
(10) Poor project planning by the contractor	**1/4**	**1/3**	**1/5**	**1/2**	**4**	**5**	**3**	**1/2**	**5**	**1**	**2**	**3**	**4**	**0.065**
(11) Additional requirement from owner/government agencies	**1/5**	**1/4**	**1/6**	**1/3**	**3**	**4**	**2**	**1/3**	**4**	**1/2**	**1**	**2**	**3**	**0.045**
(12) Financial problems of the contractor	**1/6**	**1/5**	**1/7**	**1/4**	**2**	**3**	**1**	**1/4**	**3**	**1/3**	**1/2**	**1**	**2**	**0.030**
(13) Unforeseen conditions in the project	**1/7**	**1/6**	**1/8**	**1/5**	**1**	**2**	**1/2**	**1/5**	**2**	**1/4**	**1/3**	**1/2**	**1**	**0.020**
Calculations	**4.00**	**6.00**	**1.00**	**11.00**	**44.00**	**57.00**	**29.00**	**11.00**	**57.00**	**17.00**	**24.00**	**33.00**	**44.00**	**1.00**

Inconsistency Ratio = 0.03108 < 0.1

Appendix – G: Pair-wise Comparison for Impact on Project Quality

Pair-wise Comparison for Reasons of Change Orders for Impact on Project Quality

Criteria 3- Impact on Project Quality for each reason of Change Order														
Reason for Change Orders	**(1) Change of plans or scope by the owner**	**(2) Changes due to owners' financial problems**	**(3) Change in specifications by the owner**	**(4) Change in material and procedures by the owner**	**(5) Conflicts among contract documents (i.e. specs. vs. drawings)**	**(6) Value engineering proposal by the designer**	**(7) Errors and omissions in the design**	**(8) Owner's requirement to expedite project schedule**	**(9) Equipment and labor problems of the contractor**	**(10) Poor project planning by the contractor**	**(11) Additional requirement from owner/government agencies**	**(12) Financial problems of the contractor**	**(13) Unforeseen conditions in the project**	**Row Average**
(1) Change of plans or scope by the owner	1	1/7	1/5	1/6	1/4	1/5	1/7	1/9	1/7	1/8	1/3	1/8	1/4	**0.012**
(2) Changes due to owners' financial problems	7	1	3	2	4	3	1	1/3	1	1/2	5	1/2	4	**0.093**
(3) Change in specifications by the owner	5	1/3	1	1/2	2	1	1/3	1/5	1/3	1/4	3	1/4	2	**0.040**
(4) Change in material and procedures by the owner	6	1/2	2	1	3	2	1/2	1/4	1/2	1/3	4	1/3	3	**0.061**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	4	1/4	1/2	1/3	1	1/2	1/4	1/6	1/4	1/5	2	1/5	1	**0.027**

(6) Value engineering proposal by the designer	5	1/3	1	1/2	2	1	1/3	1/5	1/3	1/4	3	1/4	2	**0.040**
(7) Errors and omissions in the design	7	1	3	2	4	3	1	1/3	1	1/2	5	1/2	4	**0.093**
(8) Owner's requirement to expedite project schedule	9	3	5	4	6	5	3	1	3	2	7	2	6	**0.210**
(9) Equipment and labor problems of the contractor	7	1	3	2	4	3	1	1/3	1	1/2	5	1/2	4	**0.093**
(10) Poor project planning by the contractor	8	2	4	3	5	4	2	1/2	2	1	6	1	5	**0.143**
(11) Additional requirement from owner/government agencies	3	1/5	1/3	1/4	1/2	1/3	1/5	1/7	1/5	1/6	1	1/6	1/2	**0.019**
(12) Financial problems of the contractor	8	2	4	3	5	4	2	1/2	2	1	6	1	5	**0.143**
(13) Unforeseen conditions in the project	4	1/4	1/2	1/3	1	1/2	1/4	1/6	1/4	1/5	2	1/5	1	**0.027**
Calculations	74.00	12.01	27.53	19.08	37.75	27.53	12.01	4.24	12.01	7.03	49.33	7.03	37.75	1.00

Inconsistency Ratio = 0.02344 < 0.1

Appendix – H: AHP Calculations

Overall Score Computation based on Multiple Objective Decision Criteria

Computation of AHP Score for Reasons of Change Orders based on Multiple Objectives Decision Criteria				
Reason for Change Orders	**Impact on Project Duration**	**Impact on Project Cost**	**Impact on Project Quality**	**Overall Score of Each Reason for Change Order**
Decision Weights	**0.3237762 (from Appendix A)**	**0.5869464 (from Appendix A)**	**0.0892774 (from Appendix A)**	
(1) Change of plans or scope by the owner	0.124	0.181	0.012	**0.147**
(2) Changes due to owners' financial problems	0.084	0.133	0.093	**0.114**
(3) Change in specifications by the owner	0.037	0.261	0.040	**0.169**
(4) Change in material and procedures by the owner	0.057	0.093	0.061	**0.079**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	0.037	0.020	0.027	**0.026**
(6) Value engineering proposal by the designer	0.013	0.014	0.040	**0.016**
(7) Errors and omissions in the design	0.025	0.031	0.093	**0.035**

(8) Owner's requirement to expedite project schedule	0.050	0.091	0.210	**0.088**
(9) Equipment and labor problems of the contractor	0.090	0.014	0.093	**0.046**
(10) Poor project planning by the contractor	0.210	0.065	0.143	**0.119**
(11) Additional requirement from owner/government agencies	0.057	0.045	0.019	**0.047**
(12) Financial problems of the contractor	0.189	0.030	0.143	**0.092**
(13) Unforeseen conditions in the project	0.027	0.020	0.027	**0.023**
Calculations	--	--	--	1.00

Appendix – I: Comparison of Rankings for Reasons

Overall Comparison of Rankings for Reasons Based on the Decision Criteria

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

Appendix – J: Comparison of Rankings for Improvements

Overall Comparison of Rankings for Suggested Improvements Based on Reduction in Impact on Project Duration, Cost and Quality

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

Appendix – K: RII Calculations

Survey Responses - Impact on Project Duration for each Reason of Change Order										
Reasons for the Change Order	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**RII**
(1) Change of plans or scope by the owner	1	0	2	2	14	15	24	12	35	**0.7979**
(2) Changes due to owners' financial problems	3	1	4	5	17	9	17	13	36	**0.7651**
(3) Change in specifications by the owner	3	1	8	3	18	11	27	8	26	**0.7238**
(4) Change in material and procedures by the owner	1	1	4	9	16	20	17	8	29	**0.7354**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	4	4	4	6	16	13	14	14	30	**0.7259**
(6) Value engineering proposal by the designer	6	4	11	7	23	18	21	5	10	**0.6085**

(7) Errors and omissions in the design	6	0	6	6	19	13	16	11	28	**0.7122**
(8) Owner's requirement to expedite project schedule	2	6	4	4	13	12	21	11	32	**0.7429**
(9) Equipment and labor problems of the contractor	2	0	2	12	8	15	20	18	28	**0.7640**
(10) Poor project planning by the contractor	1	1	1	4	7	4	18	22	47	**0.8529**
(11) Additional requirement from owner/government agencies	2	3	3	8	12	15	19	14	29	**0.7460**
(12) Financial problems of the contractor	2	1	1	4	4	10	21	18	44	**0.8360**
(13) Unforeseen conditions in the project	2	4	7	11	19	13	20	11	18	**0.6751**

Survey Responses - Impact on Project Cost for each Reason of Change Order										
Reasons for the Change Order	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**RII**
(1) Change of plans or scope by the owner	0	0	0	2	2	6	19	29	47	**0.8910**
(2) Changes due to owners' financial problems	0	2	0	4	12	15	26	25	21	**0.7841**
(3) Change in specifications by the owner	0	0	0	0	1	11	17	30	46	**0.8931**
(4) Change in material and procedures by the owner	0	3	2	4	13	20	21	17	25	**0.7630**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	3	6	7	10	19	19	14	9	18	**0.6529**
(6) Value engineering proposal by the designer	5	14	17	14	14	15	12	8	6	**0.5312**

(7) Errors and omissions in the design	0	1	2	10	25	18	17	15	17	**0.7122**
(8) Owner's requirement to expedite project schedule	0	3	5	4	7	13	29	23	21	**0.7683**
(9) Equipment and labor problems of the contractor	6	14	13	14	22	17	6	5	8	**0.5238**
(10) Poor project planning by the contractor	2	3	9	7	10	13	15	15	31	**0.7354**
(11) Additional requirement from owner/government agencies	4	4	2	9	14	15	19	12	26	**0.7164**
(12) Financial problems of the contractor	6	4	4	9	16	7	17	14	28	**0.7058**
(13) Unforeseen conditions in the project	3	5	15	17	28	17	10	3	7	**0.5556**

Survey Responses - Impact on Project Quality for each Reason of Change Order

Reasons for the Change Order	1	2	3	4	5	6	7	8	9	RII
(1) Change of plans or scope by the owner	16	21	22	13	14	6	7	5	1	**0.4021**
(2) Changes due to owners' financial problems	6	8	4	5	11	9	15	21	26	**0.7090**
(3) Change in specifications by the owner	9	5	5	6	23	19	9	9	20	**0.6370**
(4) Change in material and procedures by the owner	6	5	12	3	13	15	14	16	21	**0.6709**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	9	8	9	7	17	11	14	10	20	**0.6233**
(6) Value engineering proposal by the designer	11	2	6	8	20	15	16	17	10	**0.6275**

(7) Errors and omissions in the design	4	4	6	8	18	10	14	16	25	**0.7016**
(8) Owner's requirement to expedite project schedule	0	1	1	0	3	5	18	30	47	**0.8878**
(9) Equipment and labor problems of the contractor	4	4	6	8	11	12	19	23	18	**0.7069**
(10) Poor project planning by the contractor	1	3	1	2	7	9	22	26	34	**0.8201**
(11) Additional requirement from owner/government agencies	10	13	21	17	14	9	8	8	5	**0.4825**
(12) Financial problems of the contractor	3	0	2	3	7	7	21	25	37	**0.8233**
(13) Unforeseen conditions in the project	7	8	13	21	24	17	5	7	3	**0.5143**

Survey Responses - Suggested Improvements to Reduce Impact on Project Duration										
Suggestion for Improvement	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**RII**
(1) Introduction of a contract statement for timely response of the owner for contractor claims.	2	1	4	4	13	20	19	15	25	**0.7497**
(2) Advanced documentation system to assist the client in evaluation and administration of change orders	3	2	5	3	11	13	27	18	21	**0.7433**
(3) Change in culture - Owners shall not develop an adversarial relationship with a contractor after claim	5	7	5	9	26	14	18	5	14	**0.6214**
(4) Standardized forms & templates for submission of contractor claims	6	5	6	7	10	16	19	15	19	**0.6818**
(5) Database development to utilize lessons learned for better planning of change orders.	4	1	3	9	16	15	19	13	23	**0.7174**

Survey Responses - Suggested Improvements to Reduce Impact on Project Cost										
Suggestion for Improvement	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**RII**
(1) Introduction of a contract statement for timely response of the owner for contractor claims.	**5**	**7**	**4**	**9**	**18**	**15**	**17**	**9**	**19**	**0.6570**
(2) Advanced documentation system to assist the client in evaluation and administration of change orders	**3**	**3**	**7**	**6**	**20**	**12**	**15**	**20**	**17**	**0.6947**
(3) Change in culture - Owners shall not develop an adversarial relationship with a contractor after claim	**6**	**8**	**4**	**6**	**21**	**13**	**17**	**10**	**18**	**0.6494**
(4) Standardized forms & templates for submission of contractor claims	**7**	**5**	**9**	**9**	**17**	**15**	**19**	**9**	**13**	**0.6224**
(5) Database development to utilize lessons learned for better planning of change orders.	**4**	**3**	**2**	**5**	**11**	**19**	**14**	**24**	**21**	**0.7379**

Survey Responses - Suggested Improvements to Reduce Impact on Project Quality										
Suggestion for Improvement	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**RII**
(1) Introduction of a contract statement for timely response of the owner for contractor claims.	10	5	8	8	15	15	17	12	13	**0.6181**
(2) Advanced documentation system to assist the client in evaluation and administration of change orders	8	4	2	7	17	12	26	13	14	**0.6677**
(3) Change in culture - Owners shall not develop an adversarial relationship with a contractor after claim	7	6	2	7	21	20	17	9	14	**0.6419**
(4) Standardized forms & templates for submission of contractor claims	8	4	7	6	13	13	19	14	19	**0.6688**
(5) Database development to utilize lessons learned for better planning of change orders.	5	2	5	4	14	16	11	18	28	**0.7325**

Appendix – L: Spearman's Coefficient Calculations

Spearman's Correlation Coefficient (Qatar & MENA) vs. (North America) RII Rankings for Impact on Project Duration				
Reasons for the Change Order	**RII-Qatar & MENA**	**RII-North America**	**d**	**d^2**
(1) Change of plans or scope by the owner	**10**	**10**	**0**	**0**
(2) Changes due to owners' financial problems	**12**	**12**	**0**	**0**
(3) Change in specifications by the owner	**1**	**1**	**0**	**0**
(4) Change in material and procedures by the owner	**2**	**8**	**-6**	**36**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	**11**	**9**	**2**	**4**
(6) Value engineering proposal by the designer	**9**	**4**	**5**	**25**
(7) Errors and omissions in the design	**8**	**11**	**-3**	**9**
(8) Owner's requirement to expedite project schedule	**3**	**3**	**0**	**0**

(9) Equipment and labour problems of the contractor	**4**	**2**	**2**	**4**
(10) Poor project planning by the contractor	**5**	**7**	**-2**	**4**
(11) Additional requirement from owner/government agencies	**7**	**13**	**-6**	**36**
(12) Financial problems of the contractor	**13**	**5**	**8**	**64**
(13) Unforeseen conditions in the project	**6**	**6**	**0**	**0**
Spearman's Correlation Factor				**0.5000**

Spearman's Correlation Coefficient (Qatar & MENA) vs. (North America) RII Rankings for Impact on Project Cost				
Reasons for the Change Order	**RII-Qatar & MENA**	**RII-North America**	**d**	**d^2**
(1) Change of plans or scope by the owner	**1**	**1**	**0**	**0**
(2) Changes due to owners' financial problems	**3**	**2**	**1**	**1**
(3) Change in specifications by the owner	**8**	**3**	**5**	**25**
(4) Change in material and procedures by the owner	**2**	**10**	**-8**	**64**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	**4**	**4**	**0**	**0**
(6) Value engineering proposal by the designer	**11**	**8**	**3**	**9**
(7) Errors and omissions in the design	**10**	**12**	**-2**	**4**
(8) Owner's requirement to expedite project schedule	**7**	**7**	**0**	**0**
(9) Equipment and labour problems of the contractor	**12**	**5**	**7**	**49**

(10) Poor project planning by the contractor	**13**	**11**	**2**	**4**
(11) Additional requirement from owner/government agencies	**5**	**13**	**-8**	**64**
(12) Financial problems of the contractor	**6**	**6**	**0**	**0**
(13) Unforeseen conditions in the project	**9**	**9**	**0**	**0**
Spearman's Correlation Factor				**0.3956**

Spearman's Correlation Coefficient (Qatar & MENA) vs. (North America) RII Rankings for Impact on Project Quality				
Reasons for the Change Order	**Qatar & MENA**	**North America**	**d**	**d^2**
(1) Change of plans or scope by the owner	**1**	**1**	**0**	**0**
(2) Changes due to owners' financial problems	**12**	**8**	**4**	**16**
(3) Change in specifications by the owner	**10**	**7**	**3**	**9**
(4) Change in material and procedures by the owner	**8**	**9**	**-1**	**1**
(5) Conflicts among contract documents (i.e. specs. vs. drawings)	**2**	**12**	**-10**	**100**
(6) Value engineering proposal by the designer	**9**	**10**	**-1**	**1**
(7) Errors and omissions in the design	**7**	**2**	**5**	**25**
(8) Owner's requirement to expedite project schedule	**4**	**4**	**0**	**0**
(9) Equipment and labour problems of the contractor	**3**	**5**	**-2**	**4**

(10) Poor project planning by the contractor	**6**	**3**	**3**	**9**
(11) Additional requirement from owner/government agencies	**13**	**6**	**7**	**49**
(12) Financial problems of the contractor	**11**	**13**	**-2**	**4**
(13) Unforeseen conditions in the project	**5**	**11**	**-6**	**36**
Spearman's Correlation Factor				**0.3022**