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Nonlinear Analysis for Ranking and Evaluating the Singular and Collective Impacts of Project Delay Factors in Saudi Arabia

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Nonlinear Analysis for Ranking and Evaluating the Singular and Collective Impacts of Project Delay Factors in Saudi Arabia

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This thesis has been approved and accepted in partial fulfillment of the requirements of the degree of Ph.D. in Engineering [in Industrial Engineering]

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Abstract

Abstract— One of the biggest engineering concerns in the Middle East is the major delays in infrastructural projects which impact on both their quality and cost. A significant number of projects do not finish on time, are subject to cost overruns and are not completed to the specified quality. The Kingdom of Saudi Arabia (KSA) claims losses of the order of $ 40 Billion per annum as a result of these issues. Information on the factors contributing to project delays was studied. A literature review which determined the main project delay factors was first carried out. An online survey incorporating 66 of these was then developed with the purpose of identifying the most critical factors contributing to project delays. The survey was administered to over 200 specialists in the area of project engineering. This cohort included; Consultants, Business Owners, Project Directors, Project Engineers, Safety and Quality Managers and Contracting Managers. The resulting critical delay factors were ranked in order of priority based on a Relative Important Index (RII) incorporating dimensions of Frequency and Severity. The non-linear relationships between 'Project Performance Measures' (PPMs) and 'critical delay factors' in construction projects were modeled using a 'House of Quality Tool 'with an innovative double roof. The method enabled the identification of the top 20 critical delay factors with respect to the following PPMs; "Time, Cost, Quality, Safety and Environment". An extended survey corresponding to the top 20 critical factors was conducted on a real mega-project. The results were used to validate ranking of the individual delay factors and to determine the gaps identified. The highest ranked factors which impacted on all the PPMs were; the unrealistic contract duration by client, the shortage of technical professionals by contractor and inadequate design and specifications by consultant. The lowest ranked factors included; contractor cash flow problems and slow decision making by the client. Group factors of delay were analyzed, ranked, and their impacts evaluated and then verified using Fuzzy Logic. The research confirmed that the contractor is mainly the first party responsible for the delay followed by the client. A proposed management protocol based on the results of the research was developed by using projects classification matrix. It is recommended that this protocol be used by a higher authority of projects for both the public and private sectors. (Abstract)

Keywords— Project Management, Project Phases, Factors of Delays, Ranking Factors, House of Quality, Quality Function Deployment, Relative Importance Index, Nonlinear Analysis, Classification Matrix, Process validation and Fuzzy Logic.

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Dedication

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Published Works

The following is a list of papers presented and published based on or associated with the work presented in this thesis:

Abdulwahab Abukwaik, Enda Fallon and Pat Donnellan, "The Analysis of Project Delay Factors Using the Double-Roof House of Quality", published in the Fifth International Conference on Advances in Civil, Structural and Environmental Engineering - ACSEE 2017. Copyright © Institute of Research Engineers and Doctors. All rights reserved. ISBN: 978-1-63248-122-1 doi: 10.15224/ 978-1-63248-122-1-12.

Abdulwahab Abukwaik, Enda Fallon, and Pat Donnellan, "A Proposed Projects' Overrun Management Protocol Using Projects Classification Matrix", accepted by the program committee (ICITM, 2018) and published in the Journal of Advanced Management Science, Vol. 6, No. 3, pp. 169-173, September 2018. doi: 10.18178/joams.6.3.169-173.

Abdulwahab Abukwaik, Enda Fallon, and Pat Donnellan, "Edible Oil Bottle Redesign for Automated Assembly and Productivity Improvement ", published in the IMC33 the 33rd International Manufacturing Conference - University of Limerick, Ireland 30th August – 1st September 2016.

Glossary

- ***Cause and effect:***

A cause is the event that gives rise to the alleged delay. The effect is the alleged period of delay that the event causes. There must be a demonstrable link between the two.

- ***Consultant:***

The party who is in charge of the design of the project components and the supervision of the contractor's work and ensures that the project is constructed in full compliance with the project documents.

- ***Contractor:***

A person, company or firm who holds a contract for carrying out the works and/or the supply of goods in connection with the project.

- ***Contract Disputes:***

Disagreement between the parties. This may occur during contract execution or at completion and may include misinterpretation of technical requirements and any terms and conditions or due to changes not anticipated at the time of contract award.

- ***Completion date***

The date calculated by which the project should finish, following careful estimating.

- ***Critical activity***

Any activity on a critical path. Most commonly determined by using the critical path method.

- ***Critical Factors of Delay:***

The factors that affect the progress of the entire project or extending the project completion date.

- ***Critical Path Schedule:***

A critical path is the sequence of project network activities which add up to the longest overall duration, regardless if that longest duration has float or not. This determines the shortest time possible to complete the project. There can be 'total float' (unused time) within the critical path.

– ***Date for completion***

The date stated in the contract when practical completion is to be achieved.

– ***Project Plan:***

A formal, approved document used to guide both project execution and project control. The primary uses of the project plan are to document planning assumptions and decisions, to facilitate communication among stakeholders, and to document approved scope, cost, and schedule baselines.

– ***Projects Performance Measures:***

They are the set of measures for analyzing or evaluating and/or reporting information regarding the performance of an individual and group of factors involved in a project. They are usually represented by time, cost, quality, safety and environment.

– ***Project Management office (PMO):***

A project management office (abbreviated to PMO) is a group or department within a business, agency, or enterprise that defines and maintains standards for project management within the organization. The PMO strives to standardize and introduce economies of repetition in the execution of projects. The PMO is the source of documentation, guidance and metrics on the practice of project management and execution.

– ***Key Performance Indicators (KPIs):***

It is a measurable value that demonstrates how effectively a company is achieving key business objectives. Organizations use KPIs to evaluate their success at reaching targets.

– ***Owner:***

The party legally responsible under the terms of a contract for financing the project.

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List of Abbreviations & Equations

ABBREVIATIONS:

AHP	Analytical Hierarchy Process
AIA	American Institutes of Architects
CA	Customer Attributes
CCD	Contractor Caused Delays
CD	Concurrent Delays
CPM	Critical Path Method
CPEF	Cost plus Percentage of Cost
CPPC	Charity Project Entertainment Council
CPIF	Cost plus Incentive Fees
CPS	Critical Path Schedule
CR	Contractor Related
CSF	Critical Success Factors
DA	Delay Analysis
DAMs	Delay Analysis Methodologies
DAM	Delay Analysis Method
DRHOQ	Double Roof House of Quality
EC	Engineering Characteristics
ECAMJ	Engineering Construction and Architectural Management Journal
ED	Excusable Delays
ECD	Excusable Compensable Delays
ENCD	Excusable Non-compensable Delays
FI	Frequency Index

EF	External Factor
FL	Fuzzy Logic
FFP	Firm Fixed Price
FPI	Fix Price Incentive
FIDIC	International Federation of Consulting Engineers
GCC	Gulf Cooperation Council
IAP	Impacted As-planned
IAC	Impacted Activity Code
IDT	Isolated Delay Type
IJPM	International Journal of Project Management
IPD	Integrated Project Delivery
JCME	Journal of Construction Management Economics
JME	Journal of Management in Engineering
KPI	Key Performance Indicator
KSA	Kingdom of Saudi Arabia
LPS	Last Planner System
NCD	Non-concurrent Delays
NED	Non-excusable Delays
OCD	Owner Caused Delays
OCP	Overall Contractor Performance
OR	Owner Related
OT	Over Time
RCC	Rank Correlation coefficient
RII	Relative Importance Index
RIW	Relative Importance Weight

PM	Project Management
PPM	Projects Performance Measures
TAI	Total Adjusted Index
TD	Time Delay
TIA	Time Impact Analysis
TPCD	Third Party Caused Delays
UAE	United Arab Emirates
HOQ	House of quality
SI	Severity Index
SOW	Scope of Work
SWOT	Strength, Weakness, Opportunity and Threat

EQUATIONS:

$$\textbf{RII} = \sum_{i}^{N} \left(\frac{Wi}{A\ x\ N}\right) \text{ --- (1)}$$

$$\textbf{Frequency Index (F.I.) (\%)} = \sum_{1}^{N} a\ x\ \left(\frac{(n)}{N}\right) x\ 100 \text{ ------------------------ (2)}$$

$$\textbf{Severity Index (S.I.) (\%)} = \sum_{1}^{N} a\ x\ \left(\frac{(n)}{N}\right) x\ 100 \text{ --------------------------- (3)}$$

$$\textbf{Importance Index (IMPI) (\%)} = \left(\frac{(\textbf{F.I.}\ x\ \textbf{S.I.})}{100}\right) \text{ ---------------------------------- (4)}$$

$$\textbf{RWC} = \frac{HVF + \left[BD\ x \sum_{1}^{N} \left(\frac{(F1+F2+F3......)}{N}\right)\right]}{FMV}\ x\ 100 \text{ ---------------------------------- (5)}$$

$$\textbf{OAR\%} = \sum_{1}^{5} \left(\frac{(\text{Relation Degree}-1\ x\ \text{PM weight}-1) + (\text{Relation Degree}-2\ x\ \text{PM weight}-2) + \cdots)}{\text{Total PM weight } (0.78+0.67+0.59+0.64+0.4)=3{,}09}\right) \text{ -- (6)}$$

CHAPTER 1: INTRODUCTION

1.1 Introduction

It is almost axiomatic of construction management that a project may be regarded as successful if the building is completed on time, within budget and is of the desired quality (Kazaz et al., 2008). It is commonly said, however, that two out of those three often cannot be achieved due to the complexities involved in a construction contract and, in particular, the many different trades and professions commonly involved. Realistic construction time is now increasingly prevalent as it often serves as a crucial benchmark for assessing the performance of a project and the efficiency of the project organization (Kumaraswamy & Chan, 2002). A fundamental specification of the construction contract is the project term or date of project execution, which is stated prior to bidding. Executing construction projects successfully and keeping them within estimated costs and prescribed schedules depends on methodologies that require sound engineering judgment.

For the owner, project completion means making use of the new assets on time through habitation, renting or selling. Any delay in project completion will disturb his or her plans as the client will not be able to make use of the property, and any business will be affected in almost all aspects, especially finance. For the contractor, any delay in completion of the project gives rise to indirect overhead expenses and additional payments to the project staff and workforce. It could also mean compensation claims or even cancellation of the next project as a result of delays in the present one. Furthermore, future opportunities may be compromised due to loss of reputation and credibility. The consultants and all other parties involved may also suffer a loss if the project is delayed. They will at least lose time, which may mean losing money.

Despite the great effort dedicated to the evolution of construction project planning and control during the last four decades, delay is still a very common feature of construction projects, and most projects experience extensive delays. These often result in adversarial relationships between construction stakeholders (clients, contractors, consultants, etc.) in addition to distrust, litigation, arbitration, cash-flow problems and a general feeling of apprehension towards each other (Ahmed et al., 2002; Mohamad, 2010).

1.2 Research Problem Statement

Delays in the completion of projects cause a negative effect on all aspects of projects as well as all parties involved therein. The negative effects of delays are reflected in the cost of developments, the revenue from projects and the quality of those projects. The more time taken to complete the job, the higher the cost of construction as delay means more staff members, more hours of work, more equipment, more plant, more direct and indirect overheads, potential claims between owner and contractor as well as more interest paid to financial institutions (Alaghbari et al., 2007; Ssemwogerere, 2011; Owolabi et al., 2014).

In addition, rental or sale revenues will be lost for the duration of the delay. Other consequences include delays in initiating new projects as well as loss of reputation and credibility. Delays may also affect both quality and safety of the work because attempting to push the project activities forward to overcome delays can lead to quality and safety concerns being neglected (AbuKwaik et al., 2018). The construction industry has a consistently poor record with respect to the poor quality, over budget, missing timelines, unsafe construction and client dissatisfaction (Ibrahim et al., 2010; Kashiwagi et al., 2012; Hai et al., 2014; Xiong et al., 2014). According to Duran (2006), the construction industry has a very bad reputation for coping with delays. Delay analysis is either ignored or done subjectively by simply adding a contingency. As a result, many major projects fail to meet the deadlines of the schedule. The performance of construction projects may differ based on the size, duration, objectives, environment, uncertainty, complexity, deadlines, financial intensity, organization structures and some other dimensions (Zou et al., 2007; Keung & Shen, 2013).

In construction, delay could be defined as the time overrun either beyond the completion date specified in a contract, or beyond the date that the parties agreed upon for the delivery of a project. It is a project slipping over its planned schedule, and this is a common problem in construction projects (Assaf, 2006). Construction delay, meaning the non-completion of the project within the specified duration in the contract, is considered to be one of the most recurring problems in the construction industry (Mahamid et al., 2012). Delays may cause adverse results to project parties. The common adverse results of delays are late completion of the project, increased cost, work disruption, loss of productivity and quality, third-party claims, disputes and abandonment or termination of contracts (Majid, 2006; Mahamid et al., 2012; Luu et al., 2015). Therefore, delays in construction projects give rise to dissatisfaction to all parties involved (Majid, 2006).

To the dislike of owners, contractors and consultants, many government projects experience extensive delays and thereby exceed the initial time and cost estimates (Odeh & Bataineh, 2002). Completing projects on time is an indicator of efficiency, but the construction process is subject to many variables and unpredictable factors, which result from many sources. The sources are the performance of parties, resources availability, environmental conditions, involvement of other parties and contractual relations (NEDO, 1988; Assaf, 2006). Contractors are primarily concerned with quality, time and cost, but the majority of construction projects are procured on the basis of only two of these parameters, namely time and cost (Bennet & Grice, 1990; Al-Sulami et al., 2014).

When projects are delayed, they are either extended or accelerated and, therefore, incur additional cost (Sambasivan & Soon, 2007). The normal practices usually allow a percentage of the project cost as a contingency allowance in the contract price, and this allowance is usually based on judgment (Akinsola, 1996; Ssemwogerere, 2011). Although in the contract the parties may agree upon the extra time and cost associated with delay, in many cases there are problems between the owner and contractor as to whether the contractor is entitled to claim the extra cost (Sambasivan & Soon, 2007). Such situations result in questioning facts, causal factors and contract interpretations (Alkass et al., 1996). Therefore, the owner needs to trust a consultant who will operate in his best interest. The separation of the contractor and the owner reduces the owner's influence on the project, making the owner dependent on the consultant. Therefore, delays in construction projects cause dissatisfaction to all parties involved, and the main role of the owners is to make sure that projects are completed within the budgeted time and cost (Al-Sedairy, 1994; Assaf & Al-Hejji, 2006).

Cost and schedule overruns occur due to wide range of factors. If project costs or schedules exceed their planned targets, client satisfaction would be compromised. The funding profile no longer matches the budget requirement and further slippage in the schedule could result (Kaliba et al., 2009). Delays on construction projects are a universal phenomenon (Ahmed et al., 2002; Sambasivan & Soon, 2007; Owolabi et al., 2014). The schedule delays and cost overruns are among the most common phenomena in the construction industry (Koushki et al., 2005). Delays are usually accompanied by cost overruns. These have a debilitating effect on contractors and consultants in terms of growth in adversarial relationships, mistrust, litigation, arbitration, cash-flow problems and a general feeling of trepidation towards other stakeholders (Ahmed et al., 2002). This problem is not unique to developed countries and is being experienced in most of the developing economies. Especially in developing countries, the construction industry has some shortcomings such as poor understanding of the project, lack of modern equipment, incompetent contractors, etc. This problem can easily occur in these countries and lead to a negative impact on the result of the project as cost overrun, poor quality and lack of safety (Luu et al., 2015). Sambasivan & Soon (2007) stated that *"the effects of delays in construction projects can be country-specific"* whereas other studies have shown that project characteristics may even be region-specific. In a comparative study done by Ramanathan et al. (2012), it was found that the majority of the studies assigned different weights to the ranking of project delay factors. They concluded this was due to the fact that factors causing delays are country, location and project specific and, accordingly, there are no root causes that can be generalized between all studies.

1.2.1 Gulf Construction Industry

Construction industry markets such as the Gulf Region, however, are typically characterized by high levels of complications, uncertainties, and unique risks that are beyond those experienced by local projects (Ozorhon et al., 2007; Hastak & Shaked, 2000; Luu et al., 2015). Examples of risks associated with projects delay include fluctuations, interest rates changes, inflation, business risks related to political factors, the economy and the cultural environment in the host country (Lee et al., 2011). These risk factors, if not properly identified, evaluated, and managed, can result in poor project performance in terms of budget, schedule, quality, and safety, and can significantly affect the company's overall performance (Ahsan et al., 2010; Andi, 2006). The Gulf construction market is fraught with a unique set of risks, which should be identified and managed adequately to overcome any unfavorable overruns or impact on projects' performance (Al-Sabah et al., 2012).

The construction industry in the Gulf Region has been experiencing unparalleled growth during recent decades. The merits of high oil prices, attractive business opportunities and liberal government policies have attracted substantial capital investment into the region (Al-Sabah et al., 2012). In 2009, there were 3,339 projects estimated to be worth in excess of $2.8 trillion underway in the region (Arab World Construction, 2009). The value of the projects awarded to construction companies in the Gulf region reached a high of $163 billion (Middle East Economic Digest [MEED], 2010b). A massive wave of projects in this region has turned it into the world's biggest construction industry for plant and industrial machinery, vehicles and equipment, the demand for which is expected to grow over the next few years (Al-Sabah et al., 2012).

1.2.2 Construction Industry in Saudi Arabia

The construction sector in Saudi Arabia is the largest and fastest growing market in the Gulf Region (MEED, 2010b; Samargandi et al., 2013). Ongoing construction projects in the Gulf are valued at US$1.9 trillion (SR7.1 trillion), and one-quarter of the developments are located in Saudi Arabia (MEED, 2010a). A number of positive economic, demographic and geographic factors, as well as continued government support, have combined to help Saudi Arabia weather the current economic downturn better than most of its Gulf neighbors. According to industry experts, in the first two quarters of 2009, 34 contracts, each with a value of over US$500 million (SR1.9 billion), were awarded. These contracts represent a combined worth of US$50.1 billion (SR187.9 billion) (MEED Projects, 2017).

Good management practices and organizational performance in Saudi Arabia have been slow to develop (United Nations Development Programme, 2003; United Nations Development Programme, 2009). According to Althynian (2010), the UN Development Programme Report cited problems encountered by 850 out of 1035 construction projects in progress between 1992 and 2009. Among them, 41% experienced cost overruns, and 82% did not meet the scheduled delivery time. As a result, problems due to incomplete or inaccurate engineering details often became serious and costly and sometimes the problems are not discovered until the project has been completed. These problems included cost and time overruns, disputes between parties, omissions, errors, ambiguities in planning, reduced life span of the construction products and increased maintenance costs (Al-Kharashi & Skitmore, 2009).

An official Saudi Arabian report indicated only 14% of the current projects are finished on time, and 44% of them exceed 6% of their budgets. The report also showed 66% of the projects underperform due to major delays. Targets have been set to accelerate the ongoing projects and to improve the delivery and on-time completion from 14% in 2017 to 70% by 2020 (Ministry of Economy and Planning, 2018).

1.3 Research Gaps

It is clear the majority of construction projects suffer delays, and these delays are more concentrated in the developing countries due to the volatility, relatively unskilled labour forces, low levels of productivity, poor infrastructure, fraudulent practices, certain financing characteristics typical in these countries and government influence (Mankiw, 2010; Dakhil, 2013; Luu et al., 2015).

Tables 2.1 and 2.2 in Chapter 2, section 2.3.1, show an overview of 44 studies related to projects delay that were carried out between 1991 and 2017. The dates in the tables were prepared and organized from oldest to newest in order to facilitate the understanding of progress over time. Furthermore, the studies in the tables were categorized into five categories, with each category indicating the level of analysis from the basic stage-1: (Identification of delay factors) to the most advanced stage-5: (Identifying the factors, Grouping the factors and Ranking the factors according to more than two measures). Throughout these studies, conducting surveys was the most commonly method used for the delay factors identification and evaluation. Relative Important Index (RII) was found highly recognized as an effective tool for the data analysis collected from the survey. There were a few studies where other tools have been used such as ANOVA or PLS-SEM modeling, mutable regression and time impact analysis.

The majority of the studies referred to the evaluation of the delay factors in construction projects to a one specific performance measure or maximum of two, from time, cost and quality. However, very few projects attempted to evaluate and rank the delay factors according to more than two performance measures (Xiong et al., 2014; Al-Sabah et al., 2012; Saiful Haq et al., 2014; Arentes et al., 2015). Despite the fact that these studies have concerned their analysis and evaluation of delays to additional performance measures, they still failed to include other vital measures such as safety and environment. According to Al-Sulami et al. (2014), although the three traditional basic performance measures of time, cost and quality are still relevant and important, they do not individually reflect overall project performance and, therefore, are considered insufficient measures. Generally, the assessment measures for a project include cost, time, quality, environment, safety, etc. The new trend is to emphasize a more comprehensive evaluation approach of the delay factors where possible to include productivity, risk containment and security (Cha & O'Connor, 2006).

Figure 1.1: Previous Studies Stages, Scopes and Gaps

Figure 1.1 Illustrates the research gaps identified from previous studies in the literature. The figure explains the analytical levels of studies that were found, and the evaluations of delay factors progress from one level to another. However, many of the delay factors have not been well recognized and evaluated at a comprehensive level in numerous studies (Cha & Kim, 2011). Therefore, project performance evaluation with respect to budget, schedule, quality, and safety is a common occurrence. The need to evaluate these performance measures can be offset by the project managers expertise and knowledge of the host countries' characteristics (Andi, 2006). In order to establish an effective list of performance measures, project performance is defined to reflect the goals of a project, and potential indicators are collected through literature review, case studies and practical quantitative assessment examples (Costa et al., 2003; Cox et al., 2003; Cha & Kim, 2011).

As a result, the previous studies were diverse and widespread; however, many of them were concerned with identifying and ranking the factors of delay according to one or two performance measures, while very few included additional measures in the evaluation process.

The literature listed in tables 2.1 and 2.2 (1991-2017) has neither presented any attempt at evaluating the factors of delay according to the five main Project Performance Measures (PPMs) nor to any interrelationships between the factors of delays that could impact the evaluation and ranking of the delay factors. In other words, interrelationships could contribute to radical changes in the importance of factors of delay. These interrelationships could be embedded between the factors of delay on one side and attributed to the projects' performance measures on the other side. The behavior of the delay factors doesn't stand alone; indeed, they are affected and influenced by these interrelationships that are very important to identify and analyse. Another observation was that various previous studies in the list were lacking any mechanisms employed to evaluate or assess the impact of the group delay factors according to these measures.

Several studies have been undertaken to identify factors causing delays and cost overruns, and affecting quality, safety and productivity, etc., as well as specific problems in special types of projects. These studies usually focused on specific aspects of project performance mainly time and cost overrun. Practitioners need to develop the capacity to foresee potential problems likely to confront their current and future projects. Identification of the common problems based on past projects in their construction business environment is a good option (Long et al., 2004).

1.3.1 The Research Gaps Summary:

In order to address the research gap with respect to the evaluation and ranking the project delay factors, a number of issues relevant to the research arise that have to be identified, evaluated and analyzed. These issues are clarified by a set of goals that are listed in section 1.7. On the other hand, some points particularly are specified in research gaps 4, 5 and 6 below. They need more verification to create focus and to employ a suitable research analysis and methodological approach. These points are critical to the analysis of the research and listed briefly by a set of hypotheses in section 1.8.

Research Gap-1: Factors of delay identified in previous studies are very generic and are not focused on a particular geographic area. Special attention to these factors in the developing counties in general and to the Gulf region in particular is recommended due to unique risks, certain characteristics, typical environment, uncertainty, complexity, deadlines and financial intensity of the region, as indicated by (Zou et al., 2007; Keung & Shen 2013; Al-Sabah et al., 2012; Luu et al., 2015). Effects of delays in construction projects can be country-specific or may even be region-specific due to common project characteristics (Sambasivan & Soon, 2007; Ramanathan et al., 2012).

Research Gap-2: The delay of projects impacts all parties involved (Majid, 2006; Mahamid et al., 2012; Luu et al., 2015). The literature presented a wide variety of factors involved in the project delay. However, some that are common and others that are key are not observed in the ranking lists. This is possible due to the involvement of a single party in the delay of projects. The participation of other parties is necessary to be measured, to avoid subjectivity and to generate a wider perspective.

Research Gap-3: Factors of delay in the literature were generally assessed by one or two performance measures; they are mainly time and cost. Very few studies have tackled the issue of delay by adding additional measures. Including important measures such as quality, safety and environment are critical to the project delay (Cha & O'Connor, 2006; Al-Sulami et al., 2014). These measures are essential for effective ranking and evaluation.

Research Gap-4: The approach to the evaluation of delay factors in the literature was generally attributed to only one or two performance measures that are isolated from others. Including more measures of evaluating these factors at the same time could create a different form of relationship or nonlinear behavior among the five PPMs. This nonlinear behavior must be verified in order to employ suitable tools of analysis.

Research Gap-5: The contractor, consultant and owners are the main parties involved in projects. The main party responsible for delay has been a subject of controversy in previous studies. However, some studies did not address effectively the factors for which the contractor was responsible, such as those related to labour and equipment, planning and site management, construction methods or the adequacy and capability of the contractor. Hence, it is essential to determine whether the contactor is or is not the main party responsible for delay.

Research Gap-6: Many factors of delay are observed to be interrelated with each other. The interrelationships between these factors of delay may be minor or major, which may contribute significantly to the evaluation and ranking of project delay factors. This

approach was not applied in the previous studies referenced in this research. Therefore, it is worthwhile to verify and examine these relationships, if any, during the analysis stage.
Research Gap-7: During the analysis and evaluation of individual factors of delay with respect to the PPMs, consultants, experts and project practitioners within the focus group sessions realized that the impact of groups of delay factors does exist. The collective impact of these groups of factors was anticipated to be higher compared to the individual factors. This basis should be included in the study.

The current research was carried out to address and examine these points by involving experts from different construction fields using the appropriate methods. The ultimate goal of the research was to develop a guidance to reduce the impact of factors of delay in major construction projects in Saudi Arabia.

1.4 Research Motivation

For every finished project, several deficiencies or delay factors occurred and continued to occur in subsequent projects, either in the exact same fashion or in a slightly different form (Alkhathami, 2005). Occasionally, completely new problems would develop. Despite numerous efforts to improve project delays and subsequent cost overruns, these problems have persisted. While a body of research exists identifying factors of project delays in many countries, no research in the literature was found analyzing in extensive detail the relationships between critical delay factors and the five main PPMs. The factors generally were attributed to only one measure such as time or cost, in isolation from other measures as per tables 2.1 and 2.2 in Chapter 2. This research adopts for the first time a novel approach for evaluating the collective impact of groups of delay factors on the PPMs. Guidance in the form of a practical protocol could help to control project time and cost overrun.

1.5 Novel Aspects of the Research

The literature review did not reveal any studies that considered and discussed in a single study the relationships between project delay factors and other PPMs such as time, cost, quality, safety and environment. Moreover, these studies have not addressed the impact of groups of delay factors on construction projects. In this study, this impact has been evaluated through the application of a systematic research methodology developed from the industrial engineering prospective.

1.6 Importance of the Study

Common contractor and client problems include: project delay, where the project is not completed within the specified period; reduced quality levels; exceeded budgets; use of unspecified materials; unqualified employees; selling the projects after they are awarded; unrealistic joint ventures; unrealistic contract duration; project withdrawals and failures; future maintenance problems due to improper construction methods and safety problems such as project site accidents (Kaliba et al., 2009; Luu et al., 2015; AbuKwaik et al., 2018).

Whether they realize it or not, owners exhibit deficiencies as well, either directly or indirectly, due to limited experience or insufficient investigation. Owners face problems beginning with the design phase; for example, some projects designed outside of Saudi Arabia could be mismanaged if the designer failed to visit the project's actual site and examine its conditions. Additionally, some of the owners or their representatives are less than generous with contractors, limiting the amount of profit they could make on their projects; other owners or service organizations exercise bureaucratic authority over the contractors and make unrealistic special requests and orders after the contract has been signed (Bubshait & Kamal, 1996; Assaf & Hejji, 2006; Al-Kharashi & Skitmore, 2008).

Some of these demands include requesting specific subcontractors or materials and cutting the costs of any additional work. Furthermore, the owners sometimes do not perform necessary prequalification procedures and fail to rely upon valid contractor information. Instead, they blindly trust documents submitted by contractors and make no effort to verify that previously executed projects were genuinely and carefully executed by the contractor (Sambasivan & Soon, 2006). These problems all have a negative effect on the parties involved, generate a great deal of loss for everyone, threaten the general safety of construction projects and eventually affect the economy as a whole. In light of these points, this research investigated such problems and pinpointed the risk involved in both the critical delay factors and the necessary group of delay factors that could help to prevent or eliminate them in construction in general, with a specific focus on Saudi Arabia, where this case study was conducted.

1.7 Research Objective:

The main objective of this study was to rank effectively the critical factors of delay according to the main Project Performance Measures (PPMs) in extensive detail in the field of construction and industrial projects in Saudi Arabia. These critical factors of delay were identified from the literature and were sorted, evaluated, examined and ranked according to their impact on improvement and control of the Projects Performance Measures (PPMs). In reality, a group of delay factors may have a collective impact as well, which contributes more strongly to the PPMs compared to the effect of an individual or Singular delay factor. This research aimed to identify, analyse and evaluate their effects in extensive detail. These objectives have been tested and examined using Saudi Arabian construction projects as a case study. Finally, the result of the research aimed to develop a practical protocol for both public and private sectors to mitigate the critical factors' effects and to improve the project time and cost overrun.

1.7.1 Research Goals:

As pointed out in the last part of the research gap in section 1.3, some issues arise and must be identified, evaluated and analyzed. These issues concluded with a set of goals as follows:

Research Gap-1: This gap was addressed by the following goals:

1- To provide a general overview of construction delays from previous studies.
2- To identify the main factors of delay in construction projects in the Kingdom of Saudi Arabia (KSA) and other developing countries facing considerable construction booms that have similar geographical and cultural characteristics so efforts can be made to rank these factors and to provide more control over the PPMs.

Research Gap-2: This gap was addressed by the following goals:

3- To identify the extent to which the contractor, consultant and owner agree on the ranking of the importance of delay factors.
4- To measure the frequency of occurrence, the severity of impact and importance of construction delay factors in KSA.

Research Gap-3: This gap was addressed by the following goal:

5- To evaluate and build membership functions between the most critical delay factors and PPMs (time, cost, quality, safety and environment).

Research Gap-6: This gap was addressed by the following goal:

6- To identify and evaluate, if any, the inter-relationships between the most critical factors of delay to achieve more rational ranking.

Research Gap-7: This gap was addressed by the following goal:

7- To evaluate the grouped factors of delay (Critical Chains) with PPMs.

Research Objective: This gap was addressed by the following goal:

8- To propose a practical protocol to enable both public and private sectors to control the projects in the initiation, planning, execution and handover stages.

1.7.2 Research Goals Plan:

The research gap analysis in Chapter1, section 1.3 and the overview of the construction industry in Chapter 3, section 3.3 are presented to address Goal 1.The identification of critical delay factors from previous studies established in the construction field in Chapter 2, sections 2.3.2, 2.3.3 and further analysis in Chapter 4, section 4.5.1 are presented to address Goal 2. A quantitative method that involved administrating a survey is presented in Chapter 4, section 4.5.2 to achieve research Goal 3. This survey aimed to measure the frequency of recurrence and the severity of impact of the project delays by applying the Relative Important Index (RII) in Chapter 4, section 4.5.3 table 4.3 to address Goal 4.

The relationships between the factors of delays and performance measures were determined by the focus group. Similarly, the embedded relationships between the factors of delay were also identified and presented in Chapter 4, sections 4.5.4 to address Goal 5 and 6. An empirical formula was developed for evaluating the collective impact of delay factors in chapter 4, section 4.5.4.4 to address Goal 7. A proposed management protocol was developed by the author to enhance and improve the public and private projects execution in Saudi Arabia and is presented in Appendix-I to address Goal 8.

1.8 Research Hypotheses

The present study generated a number of hypotheses in section 1.3 that needed to be examined and verified to fulfill the research's objective and to conclude meaningful results. Determining the party most responsible for projects delay is crucial to dedicate efforts towards studies targeting them and to highlight the delay factors attributed to their deficiencies. Moreover, relationships between the delay factors and PPMs are also important to be verified to identify an effective ranking process. Accordingly, four main hypotheses were generated to be examined and verified as follows:

Research Gap-5: This gap is verified by Hypothesis 1

Hypothesis -1: The contractor is the party most often responsible for delays.

Research Gap-4: This gap is verified by Hypothesis 2 and addressed by Goal 5

Hypothesis -2: Delay factors have non-linear relationships with PPMs.

Research Gap-6: This gap is verified by Hypothesis 3, 4 and addressed by Goal 6

Hypothesis -3: Delay factors have effective inter-relationships with each other.
Hypothesis -4: The ranking of delay factors may encounter changes based on hypothesis 2 and 3.

1.9 Research Scope & Limitations

The focus of this research was the effective ranking of delay factors within the field of construction and industrial projects in Saudi Arabia. The focus included the collective impact of the delay factors and investigated their contribution to the PPMs. The research scope was limited to the following points:

1. Only the critical factors of delay and the 5- PPMs: (Time, Cost, Quality, Safety and Environment) were used.
2. Only construction and industrial projects were considered; projects of other types were not included.
3. Only projects built in KSA were considered; others were not included.
4. Only delays that occurred during the initiation, planning, control and execution stages of construction projects were considered.

1.10 Research Methodology

- All the range of delay factors were selected from the literature review and then categorized into groups. The list of critical factors of delay were sorted, merged, grouped and formally presented by conducting brainstorming sessions in a focus group with experts working in the project or consultation fields.
- For prioritizing the list of the factors of delay, a detailed questionnaire was developed and administrated, both on-line and manually. In Chapter 4, section 4.5.2.1 the questionnaire aimed to identify the severity and frequency of each factor using a group of specialists in engineering and the project management field. The sample size created was based on five main criteria: population size, margin of error, confidence level, standard deviation and response distribution.
- Based on the selected data, the relative important index (RII), a common analytical tool in the literature, was used to prioritize the data according to their severity and frequency.
- Quality functional deployment represented by the house of quality (HOQ) with an innovative double roof was used to identify and evaluate the relationships between factors of delays (Inputs) and the performance measures (Outputs) in the fourth stage.
- In the fifth stage, after the data were collected, a process of verification using Fuzzy Logic and ranking validation was applied for evaluating the reliability of the ranking process and the authentication of results.

1.11 Summary

This thesis covers the following seven chapters:

- Chapter-1: Introduction
- Chapter-2: Literature Review
- Chapter-3: Construction in KSA, Project Delay Classifications and Factors Grouping
- Chapter-4: Material and Methodology
- Chapter-5: Analysis and Results
- Chapter-6: Research Discussions
- Chapter-7: Research Conclusions and Recommendations

In Chapter One, seven topics are covered, starting with the problem definition and ending with the research methodology. This chapter provides a general background to the research problem, the purpose of the research from the identified problem and why it deserves special attention and extended time to solve it. The scope of the work is clearly defined and identified with research limitations to avoid-losing focus in meeting the core objective of this research. It is also important to give an indication on which methodologies could be used in the research to be ready from an early stage of the analysis and to develop new skills and methods if required. All assumptions are clarified in detail, and the present research critically analyses the assumptions at later stage in Chapter Four.

Previous related studies are reviewed in Chapter Two. This chapter provides a general, holistic view to enable the author to add something new, innovative and novel in the field of the research. Chapter Three provides a general background on the construction industry and types of delays before discussing the factors of delays. This chapter also presents general theory of the principles of project delays while highlighting the types of delays and their common causes.

Chapter Four examines the practical findings and construction delay facts identified by administrating a corresponding questionnaire to specific experts (Projects Directors, Consultants, Contractors, and Projects Owners) in KSA who have been involved the field of project management. The outcome of the questionnaire provides rating values used and analysed by the Relative Important Index (RII) for the initial ranking of delay factors. The outcome also helps to verify the project quality performance, type of contract(s) and main party responsible for the project delay. Quality function deployment represented by the HOQ with an innovative double roof is taken into consideration for identifying and evaluating the relationships between factors of delays (Inputs) and the performance measures (Outputs).

The analysis is covered in Chapter Five, including the final results supported by the verification process using fuzzy logic and an extended survey applied for validating and authenticating the research findings. The highlights of the results as well as discussions comparing them to previous studies are covered in Chapter Six. The research conclusions and future studies for the research are included in Chapter Seven. A project management protocol, was developed to enhance and improve the public and private projects execution in Saudi Arabia and it is included in Appendix I.

CHAPTER 2: LITERATURE REVIEW

2.1 Chapter 2 (Literature Review)

Figure 2.1 below outlines the structure of the literature review.

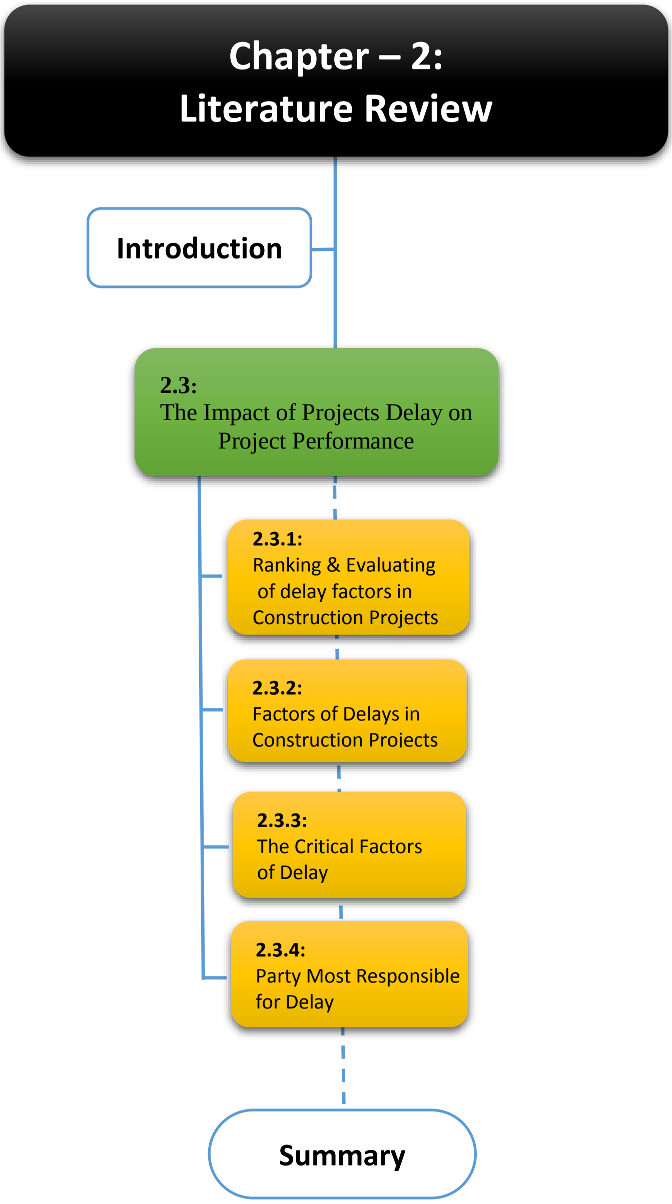


Figure 2.1: Chapter-2 General Layout

2.2 Introduction

This chapter presents a review of the research literature to discusses the delay impact that affects project performance and the factors of delay that contribute to projects delay (Projects overrun) during the initiation, planning and execution stages in construction and industrial projects. These factors of delay are described in relation to the time and cost overrun. This part of the review includes the identification of critical delay factors from studies established in the construction field to address Goal 2.

In order to address the second goal effectively, special attention is given to these factors in the developing counties in general and to the Gulf region in particular due to unique risks, certain characteristics, typical environment, uncertainty, complexity, deadlines and financial intensity of the regions. Hence, three main regions are targeted due to similarities in geographical and social nature, economic growth and witnessed severity of time overrun: Region 1 ‘Far East’; Region 2 ‘Middle East’; Region 3 ‘KSA and GCC’. The main factors of delay identified from the literature are sorted by region and analyzed according to the frequency of occurrence and repetition. As the main responsibility of projects delay has been a subject of controversy in previous studies, this analysis helps to conclude initially which party is often responsible for projects delay to verify Research Hypothesis 1.

The findings from the literature presented a wide variety of factors involved in the delay. However, some key factors were not observed in the ranking lists. This is possible due to the involvement of a single party in the delay of projects, mainly the client or the contractor. The participation of other parties is necessary to be measured to avoid subjectivity and to generate a wider perspective. This issue is addressed by Goals 3 and 4 are tackled through the questionnaire development in Chapter 4, section 4.5.1.2. Tables 2.1 and 2.2 present the methods used for evaluating and ranking the delay factors among key previous studies concerning the projects delay. They mainly deal with time and cost while other measures such as quality, safety and environment are important to be evaluated with the critical factors of delay. This issue is addressed by Goal 5.

2.3 The Impact of Projects Delay on Project Performance

Over 50% of the construction industry in most countries is the government (Okpala & Aiekwu, 1988). Unfortunately, many governmental projects experience extensive delays, causing them to exceed time and cost estimates (Odeh & Bataineh, 2002). This problem is more prevalent in traditional contracts in which the contract is awarded to the lowest bidder. One critical problem faced by the government is the frequent and lengthy delays in these types of projects. Zain Al-Abidien (1983) found 70% of projects undertaken by the Ministry of Housing and Public Works were delayed. Al-Sultan (1987) surveyed different types of projects in Saudi Arabia, finding that 70% of public projects experienced time overrun.

Procurement is a strategy used in a majority of the governmental projects in developing countries. Latham (1994) suggested that timely delivery of projects is one of the most important needs of clients in the construction industry. Big disputes can arise if projects take much longer than the projected project time frame (Bennett et al., 1999; Flanagan et al., 1986). Completing projects on time is the hallmark of an efficient construction industry (NEDO, 1988). Contractors are concerned primarily with quality, time and cost, but most construction projects are procured based on only time and cost Time is often seen as the main indicator of project success. (Bennet & Grice, 1990; Al-Sulami et al., 2014).

The construction process can be divided into project conception, project design and project construction, as stated in the research scope and limitation (Chapter 1). However, most project delays occur during the construction phase as many unforeseen factors can emerge (Chan & Kumaraswamy, 1997). In the field of construction, the delay could be defined as the time overrun either beyond completion date specified in a contract or beyond the date that the parties agreed upon for the delivery of a project. For the owner, delay can mean loss of revenue through lack of availability of production facilities and rentable space or a dependence on present facilities. In some cases, delay can cause higher overhead costs for the contractor due to the longer work period, higher material costs through inflation and labor cost increases. Completing projects on time indicates efficiency, but the construction process is prone to many variables and unpredictable factors from many sources such as performance of the parties, resource availability, environmental conditions, involvement of other parties and contractual relations. Due to these unknowns, the completion of a project within the specified time is rare (Assaf, 2006).

Cost and schedule overruns are caused by a wide range of factors. If project costs or schedules exceed their planned targets, client satisfaction would likely be decreased. The funding profile no longer matches the budget requirements, causing further delays in the schedule (Kaliba et al., 2009). According to Ahmed et al. (2002), delays in construction projects are universal, with road construction projects being no exception. Delays are usually coupled with cost overruns, which have a debilitating effect on contractors and consultants, leading to adversarial relationships, mistrust, litigation, arbitration and cash-flow problems (Ahmed et al., 2002). This problem is being experienced in both developed and developing economies.

When projects are delayed, they are either extended or accelerated, incurring additional cost. Normally a percentage of the project cost is budgeted as a contingency allowance in the contract price and is usually based on judgment (Akinsola, 1996; Sambasivan & Soon, 2007). Although the contract parties may agree upon the extra time and associated costs, in many cases problems arise as to whether the contractor is entitled to claim the extra cost. Such situations result in questioning facts, causation and contract interpretations (Alkass et al., 1996). Therefore, delays in construction projects lead to dissatisfaction for all involved parties. Very few studies have been undertaken regarding factors causing delays and cost overruns that affect quality, safety and productivity, especially specific problems in special types of projects. These studies usually focus on specific aspects of project performance. Practitioners need to develop their capacity to foresee potential problems likely to affect their projects. Additionally, identification of problems experienced on past projects in their construction business is invaluable (Long et al., 2004).

Frimpong et al. (2003) reported that project tools and techniques play an important role in effective project management. The Project Management Book (4^{th} edition) defines project management as the application of knowledge, skills, tools and techniques to the project activities so as to meet the project requirements (PMI., 2008). Project management involves managing the resources (Ramanathan, et al., 2012; Giridhar & Ramesh, 1998). While some projects are well managed, others are mismanaged, incurring delay and cost overruns. Any construction project comprises both the preconstruction phase, which is the period between the initial conception of the project till awarding of the contract, and the construction phase, which is the period from awarding the contract until completing the construction. Delays and cost overruns can occur in either or both phases; however, most project overruns usually take place in the construction phase (Frimpong et al., 2003).

Thus, project successes are not common in the construction industry, especially in developing countries. The evidence is clear that project overruns comprising delays and cost overruns occur most commonly during the construction phase. Therefore, professionals and scholars have been motivated to take steps to meet the challenge of reducing the overruns. Practitioners need to develop the capacity to foresee potential problems likely to confront their current and future projects. Identification of the common problems experienced on past projects in their construction business environment is a good option (Long et al., 2004).

2.3.1 Ranking and Evaluation of Delay Factors in Construction Projects

The second goal of this study was to critically review and identify the critical factors of delay in past local and international studies that affect and contribute to project performance measures (PPMs) in both private and public projects. This critical goal would be accomplished by reviewing articles published since 1991 in various project management journals e.g. *International Journal of Project Management (IJPM), Journal of Construction Management Economics (JCME), Journal of Management in Engineering (JME), Engineering Construction* and *Architectural Management Journal (ECAMJ)* and other similar research.

Many articles and studies conducted on ranking, evaluating and grouping the factors of delay in the field of construction projects have been reviewed locally, regionally and internationally. As indicated in Chapter 1, section 1.3 the problem of projects delay is not unique to developed countries and is being experienced in most of the developing economies. This problem can easily occur in these countries due to a certain shortcomings that lead to a negative impact on the result of the project as cost overrun, poor quality and lack of safety (Luu et al., 2015). Ramanathan et al. (2012) concluded from their comparative study that the weight of ranks of these factors varies between the studies. The effects of delays in construction projects can be country-specific or may even to be region-specific due to common project characteristics (Sambasivan & Soon, 2007; Ramanathan et al., 2012).

In this part of the literature, it is aimed to explore and overview the related research that concerns KSA and then review what was published about the Gulf Corporation Council (GCC) countries, including Kuwait and UAE. It is also recommended to follow the sequence of research afterward for the surrounding countries in the Middle East, including Egypt, Libya, Lebanon, Jordan, and Turkey.

This eventually will cover the developing countries in Africa and the Far East such as Ghana, Nigeria, India, Malaysia, Thailand, Hong Kong, Vietnam and Indonesia due to the relevant nature of construction activities and challenges. Figure 2.2 shows the main developing and emerging countries locations and their annual GDP growth percentage as per 2016.

The picture is withheld for a copy write.

Figure 2.2 Emerging Economies and GDP Growth in 2016
(Source: Focus-Economics, 2016)

Tables 2.1 and 2.2 show an overview of forty four studies related to projects delay which were carried out between 1991 and 2017. These tables present information related to the study's author, year of the study, publication, country of the study, scope, method of analysis and the performance measure(s) used for the overall evaluation. The date in the tables were prepared and organized from oldest to newest in order to facilitate understanding to the progress over time.

Furthermore, the studies in the tables were categorized into five categories; each category indicates different levels of analysis. These levels are presented as follows:

- **Level-1:** Identification of delay factors
- **Level-2:** Identification and ranking of delay factors to 1-PPM (Time or Cost)
- **Level-3:** Identifying, grouping or comparing the delay factors between main studies
- **Level-4:** Identifying, evaluating and ranking the delay factors to ≤ 2-PPMs (Time, Cost or both of them)
- **Level-5:** Identifying, evaluating and ranking the factors to ≥ 2-PPMs (Other measures including Time & Cost)

TABLE 2.1: MAJOR STUDIES COUNTRY, SCOPE, METHODS AND MEASURES (1991-2006)

Identifying
Identifying + Ranking
Case study or comparisons
Identifying + Ranking + Grouping (1/2 Measures)
Identifying + Ranking + Grouping (More > 2 Measures)

List of Major Studies Related to Causes of Delays in Construction Projects (1991-2006)

No.	Author/s	Year	Country	Scope of the study	Methods & Analysis	Measures
1	Ubaid	1991	Thesis - KSA	Discussed the contractor performance. Thirteen major measures were considered. These measures are related to contractor resources and capabilities	Survey	Contractor performance
2	Al-Barak	1993	Thesis - KSA	Ranking the main causes of failure in Construction industry in Saudi Arabia	Survey	Projects failure
3	Al-Ghafly	1999	Thesis - KSA	Ranking the delays in public water and sewage projects; as a result,60 causes of delays were identified and classified	Survey	Time
4	Assaf et al.,	1995	Journal - KSA	Outlined and ranked the main causes of delay in large building projects in KSA and their relative importance. The causes of delay were identified and grouped into 9 groups	Survey + Important Index	Time
5	Bubshait and Kamal	1996	Journal - KSA	Evaluated the contractor qualification and ranking the factors of delay with respect to contractor performance	Survey + Important Index	Contractor performance
6	Ogunlana et al.,	1996	Journal - Thailand	Evaluated the delays in building projects in Thailand	Survey	Time
7	Kaming et al.,	1997	Journal -Indonesia	Identified the most influencing factors on 31 high-rise projects in Indonesia. Analysis extended to evaluated the factors related to time and cost overrun	Survey	Time and cost
8	Chan and Kumaraswamy	1997, 2002	Journal - Hong Kong	Evaluated the relative importance of 83 potential delay factors which were grouped into eight major categories in Hong Kong construction projects	Survey + RII	Time
9	Odeyinka and Yusif	1997	Journal - Nigeria	Studied the causes of delays in building projects in Nigeria. They categorized the causes of delays as client-related, contractor-related and those related to extraneous factors	Survey + Grouping parties	Time
10	Noulmanee et al.,	1999	Journal - Thailand	Investigated the causes of delays in highway construction in Thailand	Survey	Time
11	Al-Momani	2000	Journal - Jordan	Investigated the construction delays in a 130 public building projects in Jordan, he carried out a quantitative analysis	Survey	Time
12	Odeh and Battaineh	2002	Journal - Jordan	conducted a survey to Identify the most important causes of delays in construction projects with a traditional type of contracts	Survey + RII	Time
13	Frimpong et al.,	2003	Journal - Ghana	Conducted a survey to identify the factors contributing to schedule and cost delays in Ghana groundwater construction projects	Survey + RIW	Time and cost
14	Hong Xiao and David Proverbs	2003	Journal - Japan, UK and USA	Compared the overall contractor performance (OCP) in Japan, UK and USA. The Overall contractor performance was defined to embrace construction cost, construction time, construction quality and sustainable development.	Comparisons, Multiple regression analysis	Time, cost, quality and sustainability
15	Long et al.,	2004	Journal - Vietnam	Developed a survey to investigate several issues relating to large construction projects focusing only on the problems experienced. Their comments were used to revise and prepare the final questionnaire. The analysis included ranking the	Survey + F.I. & S.I.	Time
16	Koushki et al.,	2005	Journal - Kuwait	Time-delays and cost-increases associated with construction of residential projects in Kuwait are determined	Survey	Time and cost
18	Sambasivan and Soon	2006	Journal - Malaysia	Identified the delay factors and their impact (effect) on project completion	Survey + RII	Time
19	Assaf and Hejji	2006	Journal-KSA	The most common cause of delay identified by all the three parties is “change order”. Surveys concluded that 70% of projects experienced time overrun.	Survey + RII	Time

TABLE 2.2: MAJOR STUDIES COUNTRY, SCOPE, METHODS AND MEASURES (2007-2017)

Identifying
Identifying + Ranking
Case study or comparisons
Identifying + Ranking + Grouping (1/2 Measures)
Identifying + Ranking + Grouping (More > 2 Measures)

List of Major Studies Related to Causes of Delays in Construction Projects (2007-2017)

No.	Author/s	Year	Country	Scope of the study	Methods & Analysis	Measures
20	Faridi and El-Sayegh	2007	Journal -UAE	Identified and assessed the significant risks in the UAE construction industry and addressed their proper allocation	Survey	Time and cost
21	Sweis et al.,	2007	Journal - Jordan	A case study was done in Jordon concerned causes of construction delays in residential projects. The causes were identified and classified	Survey + case study	Time
22	Alaghbari et al.,	2007	Journal - Malaysia	A survey was conducted among government bodies, main contractors, consultants and developers for ranking the delay factors	Survey + Mean Square	Time
23	Al-Kharashi and Skitmore	2008	Journal - KSA	Discussed the projects delays in the general public sector. The analysis reveals some considerable heterogeneity between the cause groupings and respondent groupings in terms of means and correlations	Survey + Grouping parties	Time
24	El Razek et al.,	2008	Journal - Egypt	Conducted a survey to identify the main causes of delay in construction projects in Egypt from the viewpoints of contractors, consultants & owners	Survey	Time
25	Le-Hoai et al.,	2008	Journal - Vietnam	A survey was conducted to elicit the causes of this situation by interviewing 87 Vietnamese construction experts	Survey + Imprt. Index	Time and cost
26	Hamad Raqraq	2010	Thesis - Libya	Aimed in his research to discover the most critical reason of projects delays in Libya	Survey + Grouping parties	Time
27	Songül	2010	Thesis -Turkey	Studied dwells on the importance of construction schedules in achieving the aim of producing good quality construction work within the specified duration	Time Impact Analysis Method	Time and quality
28	Mohd Rosazuad Bin Mohamad	2010	Journal - Malaysia	A survey was conducted to Identify the delay factors and the effect on the project completion. The study integrated an approach and attempts to analyze the impact of effects	Survey	Time
29	Azlan Shah Ali et al.,	2010	Journal - Hong Kong	Three objectives were formulated to identify factors contributed to delay in construction projects, to analyze and rank the causes of delay rated by contractors	Survey + SPSS software	Time
30	Fugar and Agyakwah-Baah	2010	Journal - Ghana	Grouping the delay factors in building construction projects in Ghana	Survey + RII + Grouping	Time
31	Helmy, Mohamed	2011	Thesis -Kuwait	Investigated the existence of critical success factors of PPP project in construction sector of Kuwait	Case study	Cortical success factors
32	Al-Sabah et al.,	2012	Conference USA / Gulf	Identified risks exposed to multinational firms in gulf region. Risks identified were categorized and ranked	Survey + RII + Grouping	Cost, Time, company performance
33	Ramanathan et al.,	2012	Journal- Major studies	Reviewed 41 studies around the world which has surveyed the delay factors and classified them into Groups	General Comparisons	Time and cost
34	Mahamid et al.,	2012	Journal - Palestine	Conducted a survey to investigate the time performance of road construction projects in the West Bank in Palestine to identify the causes of delay and their severity according to contractors and consultants	Survey + RII	Time
35	Nielsen, Yasemin	2013	Journal - Turkey	Studied the effects on delay on Turkey construction project	Survey	Time
36	Indhu and Ajai	2014	Journal - India	Identified the delay factors and the effect on the project completion by doing a case study in ongoing projects	Case study	Time
37	Dubem et al.,	2014	Thesis UK - KSA	Developed a framework for identifying and classifying causes of project failures in the Saudi construction industry	Survey + mean & stand. deviation	Projects failure
38	Saiful Haq et al.,	2014	Thesis - Pakistan	Measured the effects of delay in construction projects like cost, time, litigation and project abandonment	Survey + Various statistical tools (ANOVA Modeling)	Cost, time, litigation, project abandonment
39	Arantes et al.,	2015	Conference -Portugal	Identified the main causes for the delays in the Portuguese construction industry and its impact, with the purpose of increasing knowledge on construction projects	Survey + RII	Cost, time, disputes, arbitration, litigation, project abandonment
40	Luu et al.,	2015	Journal - Vietnam	Developed a conceptual model of delay factors and to analyze the level of impact of the delay groups on the completion of the government construction projects	Survey + Factors and regression Analysis	Group of factors vs. time
41	AbdulRahman et al.,	2016	Conference -KSA	The paper presents the development of PLS-SEM Model of delay factors of KSA construction industry focussing on Mecca City. A hypothetical model of delay factors was constructed where it consisted of 37 delay factors	Survey + PLS-SEM modelling	Group of factors vs. time
42	Mpofu et al.,	2016	Journal -UAE	The purpose of this paper is to identify the most significant causes of delays in the UAE construction industry. A survey was conducted targeting 3 key types of stakeholders, clients, contractors and consultants. Validity & reliability were achieved by first assessing the plausibility of construction delay variables	Survey + RII	Factors relation between parties vs. time
43	Lessing et al.,	2017	Journal - Newzealand	The purpose of this research was to establish the main factors causing delays on large construction projects in Auckland and compare results with the situation in other countries	Survey + RII	Time
44	Zidane and Andersen	2017	Journal - Norway	The paper identified the universal delay factors from an intensive literature review, supplemented by delay factors in major Norwegian construction projects based on empirical data. The study includes literature review, qualitative methods with interviews and survey questionnaires.The paper address frequency, and type of delay factors in construction projects in Norway and worldwid	Literature review analysis for the top 10 factors of delay. Most frequent factors among the studies	Time

As indicated in Tables 2.1 and 2.2, identifying the factors of delays in the project fields were basically the core work for most of the authors in their research. Many authors have worked to identify the factors of delay in construction projects in order to put forward effective solutions (Ogunlana et al., 1996; Kaming et al., 1997; Noulmanee et al. 1999; Al-Momani, 2000; Odeh & Battaineh, 2002; Frimpong et al., 2003; Sambasivan & Soon, 2007; Faridi & El-Sayegh, 2007; El Razek et al., 2008; Raqraq, 2010; Mohamad, 2010).

Furthermore, there have been considerable efforts in other studies for the identifying and ranking the factors of delays for construction projects (Al-Barak, 1993; Al-Ghafly, 1999; Bubshait & Kamal, 1996; Long et al., 2004; Alaghbari et al., 2007; Azlan, et al., 2010; Mahamid et al., 2012; Dubem et al., 2014; AbdulRahman et al., 2016; Lessing et al., 2017). The information available is diverse and widespread, but the majority of the available literature concerns identifying and ranking the factors of delay to one PPM.

Some studies found are more concerned with grouping or classifying the factors of delay into sub-categories, which may help to distribute the responsibility for the delays among the parties involved in a project or be aware of these categories in advance for obtaining a better conclusion to their ranking analysis. To name few (Chan & Kumaraswamy, 1997; Odeyinka & Yusif, 1997; Assaf & Hejji, 2006; G. Sweis et al., 2007; Al-Kharashi & Skitmore, 2008; Fugar & Agyakwah, 2010; Ramanathan, et al., 2012; Moofu et al., 2016). On the other hand, only two studies have evaluated the ranked factors in their studies with other studies to test the similarities and differences (Ramanathan et al., 2012; Zidane & Andersen, 2017).

The majority of the studies referred to the evaluation of the delay factors in construction projects to one specific performance measure, or, at maximum, two among time, cost and quality. However, very few projects attempted to evaluate and rank the delay factors according to more than two performance measures (Xiong et al., 2014; Al-Sabah et al., 2012; Saiful Haq et al., 2014; Arentes et al., 2015).

Each and every study has a different scope and objective. Hence, different approaches have been used for the data collection and analysis. Conducting surveys followed by the Relative Important Index (RII) analysis were mostly used for ranking the factors of delay in the literature. There were a few studies where other tools have been used such as ANOVA modeling, mutable regression and time impact analysis (Dayı Songül, 2010; Xiong et al., 2014; Saiful Haq et al., 2014; Luu et al., 2015).

2.3.2 Delay Factors in Construction Projects

In the present study, it is aimed to effectively identify and rank the factors of delay which could help to create a practical protocol for both public and private sectors in KSA. The factors of delay were identified from key studies, mainly in the developing countries, where the issue of delay is more concentrated and relevant in nature as mentioned in Chapter 1, section 1.3, have been reviewed. This relevance was due to the volatility in the economy, the relatively unskilled labour force, low levels of productivity, poor infrastructure, fraudulent practices, government influence and certain financing characteristics typical in developing countries (Mankiw, 2010; Dakhil, 2013; Luu et al., 2015).

2.3.2.1 The Far East

The causes of construction delays in the Far East range from simple to complex. Delays may be due to unforeseen site conditions as found in Hong Kong construction projects (Chan & Kumaraswamy, 1997) or due to weather conditions (Mohamad, 2010; Indhu & Ajai, 2014). While these factors may be unavoidable, others are more focused on human resources, which might be perceived to be easier to control. However, several studies did report that labor shortages and lack of productivity contributed significantly to project delays. In Indonesia high-rise projects, poor labor productivity was identified as an important factor causing delays (Kaming et al., 1997). A study conducted by Sambasivan & Soon (2006) identified lack of a labor force as one of the top ten causes of construction delays. After conducting a literature review, Azlan et al. (2010) found that labor shortage was one of the seven most reported reasons. Mohamad (2010) more specifically identified a shortage of manpower to include skilled, semi-skilled and unskilled labour and also identified a problem surrounding productivity. After conducting a case study, Indhu & Ajai (2014) expanded this same perception of manpower shortage to include frequent change of staff.

Human factors come into play at the supervisory level. Chan & Kumaraswamy (1997) cited poor risk management and supervision. In a study of delays in highway construction in Thailand, Noulmanee et al. (1999) concluded that delays can be caused by all parties involved in projects, but the main causes come from the inadequacy of sub-contractors. Sambasivan & Soon (2006) also found subcontractors to be a problem. Three of the top ten causes of construction delays identified by Sambasivan & Soon (2006) pointed to the contractor, citing improper planning, poor site management and inadequate experience. Azlan et al. (2010) also reported poor site management to be a main cause for construction delays. Indhu & Ajai (2014) found not only poor site management to be a problem but also improper management of the engineers.

The client can also be a major factor resulting in construction delays for projects in the Far East. Chan & Kumaraswamy (1997) mentioned slow decision making and client-initiated variations. Inhdu & Ajai (2014) case study showed all delays involved either the contractor or the client. At times it could be that communication barriers are to blame as well. Even biases might exist that purposefully blame delays on other parties, as suggested by Kaming et al. (1997), while Noulmanee et al. (1999) found there were deficiencies existing between consultants and contractors. Sambasivan & Soon (2006) found lack of communication between parties as a top reason named for construction project delays.

The parties who are relevant to a construction project may also contribute to delays due to financial reasons. Sambasivan & Soon (2006) reported client problems due to inadequate financing and payments for completed work. Azlan et al. (2010) named contractors' financial difficulties as one of the three most important factors resulting in delays. Mohamad (2010) found contractor's payments to subcontractors can result from these difficulties. Inhdu & Ajai (2014) identified both delays in contractor's payments and delay in payment by the client.

Financial problems and delays are far-reaching and can lead to cost over-run. Kaming et al. (1997) found that cost overruns occur more frequently and are a more severe problem than time overruns. They pointed out that the major factors influencing cost overrun are material cost increase due to inflation, inaccurate material estimation and degree of complexity. Evaluating delays, researchers found that they are almost always accompanied by cost overruns (Yang et al., 2010; Saiful Haq et al., 2014). Mohamad

(2010) cited changes in materials and construction involve large amounts of money and is connected to cost overrun.

Functional and structural bases for delays can be due to planning and materials involved in the construction processes. In time overrun, important factors causing delays are design changes, inadequate planning, and resource shortages. In the Thailand study, Noulmanee et al. (1999) concluded that delays occur when an organization lacks sufficient resources, and is trying to work with incomplete and unclear drawings. Sambasivan & Soon (2006) further identified shortage of material, equipment availability and failure and mistakes made during the construction stage. Azlan et al. (2010) included construction mistakes and defective work, coordination problems, shortage of tools and equipment, and material shortage of highest importance were construction mistakes and defective works (Mohamad, 2010).

In addition to cost overruns, other negative effects can result from construction delays. Although schedule delays seem to be embedded in all projects, identifying the main causes and preventing these problems from occurring are better than resolving subsequent delay-related disputes. The main effects of delay include rescheduling and rearrangement, litigation, disputes, and arbitration (Mohamad, 2010). Saiful Haq et al. (2014) claimed delay in construction projects significantly leads to time overrun, litigation and project abandonment. The findings of their study also provided significant insights to the construction industry, so that they may formulate strategies in order to avoid delay and its consequences. Cost overruns, time overrun, litigation and project abandonment are the indirect outcome of causes of construction projects as discussed above. Since the agreement of projects is critical, it is recommended that a firm should decide how to deal with delaying factors in order to address the issues of extra cost and time, court cases and abandonment of the construction project. To overcome these negative consequences, construction firms should give a significant amount of consideration to the causes of delay in construction projects. Through addressing these delaying factors, construction firms can avoid extra costs and ensure their profitability. Moreover, the firm should avoid court cases and solve legal issues immediately once they happen. Not all delays can be rectified, but many of them can be overcome by improving management responsibilities.

2.3.2.2 The Middle East

While similar causes and effects of construction delays have been identified in the Middle East, there are significant differences. .Al-Momani (2000) investigated causes of delay in 130 public projects in Jordan and found one main cause to be weather and site conditions. However, Sweis et al. (2007), also investigating construction in Jordan, found severe weather conditions ranked among the least important causes of delays. Moreover, none of researched studies that were conducted in the Middle East identified labor issues as having an effect of construction delays. At the supervisory level, when Raqraq (2010) set out to determine the most critical reasons for projects delays in Libya that didn't meet the scheduled time, one finding that reported was poor planning by contractors. Clients were also targeted as the reason for delays in some Middle East construction studies. Al-Momani (2000) and Nielsen (2013) named user changes as a primary cause. Sweis et al. (2007) examined the causes of construction delays in residential projects through identification and classification according to Drewin's Open Conversion System. The most common causes were evaluated for residential projects by consultant engineers, contractors, and owners, and interviews with senior professionals in the field. Most correspondents agreed that too many change orders by the owner was one of the leading causes of construction delay.

Financial reasons were identified as well. Al-Momani (2000) found a main cause of delay to be economic conditions. In studies conducted by Sweis et al. (2007) and Raqraq (2010) the financial difficulties faced by the contractor was also named as a leading cause of construction delay. Raqraq (2010) also pointed to problems in Libya due to shortage of equipment, weak time scheduling, weak budgeting, the scope of work changes, negative cash-flow, weak project administering and supervision, old fashion equipment and poor planning. Nielsen et al. (2013) studied the effects of delays on a Turkey construction project and concluded that planning and scheduling, fluctuation of prices, rework due to errors and late delivery of material and complexity of project are all the major causes of delay.

A major difference also lies in the fact that more cohesive suggestions were offered in these studies to try to prevent or mitigate preventable delays. While Al-Momani (2000) also found delays were related to the designer and late deliveries, the study suggested that paying special attention to these factors will help industry practitioners in minimizing contract disputes. Songül (2010) dwelt on the importance of construction schedules in achieving good quality construction work within the specified duration. Continuously monitoring the interactive relation concerning delays in construction schedules and contractor demands is a complicated process. However, the simplest and basic approach is used because for both for owner and contractor, time is money and for this reason, construction schedule delays should be analyzed and corrective measures should be taken in a timely manner.

Based on this study, some general recommendations were presented, which could be useful in minimizing or avoiding the impacts of the construction delays. The design of the project should be finalized with all details before tendering the work so as to avoid change orders by the owners. The owner should allocate sufficient time and adequate finances for the design stage of the project. The selection of the contractor should be done through a pre-qualification of the firms. The owners should mobilize all resources and get the necessary permissions before signing the contract. The contract should include clauses of incentive for early completion. The schedule should be prepared and agreed on it by both the contractors and the consulting companies. The contractor should employ qualified work teams and provide in-house worker training in order to improve managerial and technical skills. The contractor should also have a project manager in his team to be able to check the progress of work and ensure timely delivery of materials. The last but most important issue is to establish a healthy communication between all parties in order to solve problems in a timely manner.

2.3.2.3 Saudi Arabia and GCC

In Saudi Arabia and the broader GCC, labour issues related to delays seem largely attributable to the level of management and to the contractors. Delays have strong relationships with failure and ineffective performance of contractors. Ubaid (1991) discussed the performance of contractors as one of the major causes of delay. Al-Barak (1993) analysed the main causes of failure in the construction industry in Saudi Arabia by surveying 68 contractors, concluding that lack of experience, poor estimation practices and decisions on regulating company's policy are significant factors, and a national slump in the economy are the severe factors.

Assaf et al. (1995) identified the main factors of delay in large construction projects. This is considered to be the first official study concerning project management within KSA. In this research, they concluded causes to include internal sub-contractors disputes due to schedule changes, slowness in making decisions, weak designs by the engineers and finally the shortage or low experience of the local labor force. Bubshalt & Al-Gobalt (1996) discussed contractor qualifications in Saudi Arabia. In their research, they identified the criteria, which should be considered in the pre-qualification of projects. In this research, they identified six delay factors, including experience of the contractor, project management and team capability. Al-Ghafly (1999) researched delays in public water and sewage projects, concluding that many important factors of delay are related to contractor performance. Faridi & El-Sayegh (2007) took a broader view by citing a general shortage in the labor supply.

Al-Kharashi & Skitmore (2008) carried out research in the field of projects delays in the general public sector. They claimed that no one has attempted to identify the extent to which improvements are possible in practice. They reported on the degree of effect on delays and the extent to which each can be practically improved. These are contained in seven delay factor groupings: client, contractor, consultant, materials, labour, contract and relationship related causes. The analysis of the survey revealed some considerable differences between these delay factor groupings and respondent groupings i.e. the client, the contractor and the consultant, in terms of mean values assigned to the delay factors by each group. Apparently, this partly was due to the lack of knowledge of respondents and the consultant's tendency to blame the contractors for the delays, and vice versa. The main results, therefore, are disaggregated to reflect the views of each respondent group concerning each group of causes. In general, however, they found that the most influencing current cause of the delay is the lack of qualified and experienced personnel – attributed to the considerable amount of large, innovative, construction projects and associated current undersupply of manpower in the industry. Dubem et al. (2014) developed a framework for identifying and classifying causes of projects failures in the Saudi construction industry. Respondents were mainly civil engineers, architects, quantity surveyors and building engineers who had years of experience in the management of infrastructure projects in Saudi Arabia. Findings revealed poor communication by management and poor risk management as critical failure factors for infrastructure projects.

Owners are not without blame in these member nations. Al-Ghafly (1999) pointed to owner involvement and delays in making decisions and giving approvals. Faridi & El-Sayegh (2007) found significant risks to include owner risks such as unrealistic construction schedules, improper intervention and changes.

As expected, finances also come into play. Dubem et al. (2014) cited budget overruns, while Al-Ghafly (1999) and Bubshalt & Al-Gobalt (1996) identified general financial problems. According to Assaf et al. (1995), the most critical factor of delay was financial difficulties, then approving the workshop drawings, payments delay and cash flow issues by the contractors. Faridi & El-Sayegh (2007) revealed that economic risks such as inflation and sudden changes in prices are significant. Dubem et al. (2014) identified factors to also include project management deficiencies, risk challenges, and government interference. Al-Ghafly (1999) found other important factors to be changes in design and scope, difficulties in obtaining work permits, coordination and communication problems. Al-Barak (1993) named a national slump in the economy as a severe factor.

2.3.3 The Critical Factors of Delay

This section aims to select the main factors of delay that have been identified in the literature. One hundred and thirty-six critical factors of delay were collected from sixteen different studies and applied for 10 countries in three main regions represented by KSA & GCC, the Middle East and the Far East in the field of construction projects. As discussed earlier, the present study was directed at these regions for the common economic growth, substantial construction boom, similarity of challenges and deficiencies in nature.

Tables 2.3, 2.4, and 2.5 illustrate the ranking of project delays that were carried out in the major studies in Saudi Arabia, United Arab Emirates, Turkey, Jordan, Libya, India, Pakistan, Indonesia, Hong Kong and Malaysia. The studies are listed below according to the region (R), country of research (C) and the date of publication.

TABLE 2.3: RANKING OF DELAY'S FACTORS IN MAJOR STUDIES-1

Author	C	R	Major Factors of Delay	Party of Delay			
				Contractor	Consultant	Client	Others
Dubem et al., (2014)	Saudi Arabia - UK	1	Poor Risk Management	x			
		2	Budget overrun			x	
		3	Poor communication managmnet		x		
		4	Schedule delays		x		
		5	Poor estimation practices	x	x		
		6	Cash flow difficulties	x			
		7	Design discrepancies		x		
		8	Lack of effective change managmnet	x			
		9	Inadequate project stracture	x			
		10	Lack if teamwork	x			
				6	**4**	**1**	**0**
Al-Ghafly, (1999)	Saudi Arabia	1	Financial problems	x			
		2	Chnages in the design and scope			x	
		3	Delay in making decisions		x	x	
		4	Approval by the owner			x	
		5	Difficulties in obtaning work permits			x	
		6	Coordination and communication problems	x	x		
				2	**2**	**4**	**0**
Assaf et al., (1995)	Saudi Arabia	1	Financial diffculties	x			
		2	Approving workshops drwaings		x		
		3	Payments delay			x	
		4	Cash flow issues by contractor	x			
		5	Changes in the scope			x	
		6	Internal subcontractors disputes due schedule changes	x			
		7	Slowness in making decisions		x	x	
		8	Weak design by the engineers		x		
		9	The shortage or low experience of the local labors	x			
				4	**3**	**3**	**0**
Bubshait and Kamal , (1996)	Saudi Arabia	1	Experience of the contractor	x			
		2	Finanicial capablities	x			
		3	Project management	x	x		
		4	Team capablity	x			
		5	Past preferences			x	
		6	Quality preferences			x	
		7	The failure records			x	
				4	**1**	**3**	**0**
Faridi & El-Sayegh, (2006) Significant Factors Causing Delay in UAE construction	United arab Emirats	1	Shortage in HR resources	x			
		2	Shortage in material and labor	x			
		3	Shortage of equipment	x			
		4	Tight construction schedule			x	
		5	Change of design			x	
		6	Delays in approvals by government entities				x
		7	Performance and management of subcontractors	x			
		8	Delays of material supply by suppliers	x			
		9	Poor contract administration and management with subcontractors	x			
		10	Lack or departure of qualified staff from the contractor	x			
				7	**0**	**2**	**1**
Faridi & El-Sayegh, (2007) Risk Assessment & Allocation in UAE	United arab Emirats	1	Inflation and sudden chages in the prices	x			
		2	Shortage in material	x			
		3	Labor supply is signgicant	x			
		4	Unrelastic construction schedule			x	
		5	Improper intervention and changes in design			x	
		6	Politcal, scocial and cultural risks				x
				3	**0**	**2**	**1**

TABLE 2.4: RANKING OF DELAY’S FACTORS IN MAJOR STUDIES-2

Author	C	R	Major Factors of Delay	Party of Delay			
				Contractor	Consultant	Client	Others
Al-Momani, 2000)	Jordan	1	Planned duration of contract			x	
		2	Actual completion data			x	
		3	Design changes			x	
		4	Disputes		x	x	
		5	Notifications	x	x		
		6	Date of notice to proceed		x		
		7	Delays encountered during construction	x			
		8	Conflicts related to the drawings and specifications	x	x		
		9	Time extensions	x			
		10	Late delivery of material and equipment	x			
				5	**4**	**4**	**0**
Sweis et al., (2007)	Jordan	1	financial difficulties faced by the contractor	x			
		2	too many change orders by the owner			x	
		3	Severe weather conditions				x
		4	changes in government regulations and laws			x	
				1	**0**	**2**	**1**
Hamad Raqraq, (2010)	Libya	1	Shortage of equipment	x			
		2	Weak time scheduling	x			
		3	Weak budgeting	x		x	
		4	Scope of work changes			x	
		5	Negative cash-flow	x			
		6	Weak project administering and supervision		x		
		7	Old fashion equipment and tools	x			
		8	Poor planning by both owner and contractors	x		x	
		9	Contractor financial issues	x			
				7	**1**	**3**	**0**
Dayı Songül, (2010)	Turkey	1	Organizational deficiencies	x			
		2	Bureaucracy of the provincial municipality				x
		3	Lack of detail drawings during the municipality application		x		
		4	Lack of experience of the contractor	x			
		5	Problems in material procurement	x			
		6	Unforeseeable weather conditions				x
		7	Shortages of qualified employees of the subcontractors	x			
				4	**1**	**0**	**2**
Mohd Rosazuad Bin Mohamad, (2010)	Pakistan	1	Delays in contractor's payments to subcontractors	x			
		2	Shortage of material in construction	x			
		3	Delays in sub-contractors	x			
		4	Change in material	x			
		5	The weather condition				x
		6	Shortage of manpower (skilled, semi-skilled and unskilled labor)	x			
		7	Construction works which involve huge amounts of money				x
		8	Unpunctually material delivery	x			
		9	Labor productivity	x			
		10	Unavailability incentives for contractor to finish ahead of schedule			x	
				7	**0**	**1**	**2**
Azlan et al., (2010)	Hong Kong	1	Contractors’ financial difficulties	x			
		2	Construction mistakes and defective work	x			
		3	Labor shortage	x			
		4	Coordination problems	x			
		5	Shortage of tools and equipment	x			
		6	Material shortage	x			
		7	Poor site management	x			
				7	**0**	**0**	**0**

TABLE 2.5: RANKING OF DELAY’S FACTORS IN MAJO R STUDIES-3

Author	C	R	Major Factors of Delay	Party of Delay			
				Contractor	Consultant	Client	Others
Chan and Kumaraswamy (1997)	Hong Kong	1	Material cost increase due to inflation	x			
		2	Inaccurate material estimation and degree of complexity	x			
		3	Design changes			x	
		4	Poor labor productivity	x			
		5	Inadequate planning	x			
		6	Resource shortages	x			
		7	Inadequacy of sub-contractors	x			
		8	Organization that lacks sufficient resources	x			
		9	Incomplete and unclear drawings		x		
		10	Deficiencies between consultants and contractors	x	x		
				8	2	1	0
Indhu, B. & Ajai, P. (2014)	India	1	Delays in contractor's payments			x	
		2	Shortage of material in construction	x			
		3	Change in material	x			
		4	The weather condition				x
		5	Shortage of manpower (skilled, semi-skilled and unskilled labor)	x			
		6	Frequent change of staffs	x			
		7	Poor site management and improper management of the engineers	x			
		8	Delay in submission of drawings		x		
		9	Site space constraints				x
		10	Delay in payment by the client			x	
		11	Delay in material supply	x			
		12	Local problems like strikes	x			
		13	Change in labor allocation	x			
				8	1	2	2
Sambasivan and Soon, (2006)	Malaysia	1	Contractor's improper planning	x			
		2	Contractor's poor site management	x			
		3	Iadequate contractor experience	x			
		4	Iadequate client's financing and payments for completred works			x	
		5	Problems with subcontractors	x			
		6	Shortage of material	x			
		7	Labor supply is significant	x			
		8	Equipment availiblity and failure	x			
		9	Lack of communication between parties	x	x	x	
		10	Mistakes durining construction stage	x			
				9	1	2	0
Kaming et al., (1997)	Indonesia	1	Design changes			x	
		2	Poor labor productivity	x			
		3	Inadequate planning	x			
		4	Resource shortages	x			
		5	Material cost increase due to inflation	x			
		6	Inaccurate material estimation	x			
		7	Project degree of complexity				x
				5	0	1	1
			Party of Delay - 16 Studies	Contractor	Consultant	Client	Others
			Total Factors Related to Each Party of Delay	87	20	31	10
			Party of Delay Contribution %	58.8%	13.5%	20.9%	6.8%

The common factors of delay were obtained from Tables 2.3, 2.4 and 2.5 are grouped according to the emerging economics in three regions. The list included 13 factors of delay that were frequently presented in these studies. Level of occurrence selected ranged from 3 to 11.

Some of delay factors didn't appear in most of the studies while some were commonly presented, showing a high level of significance. For example, changes in the design and scope and delay in material delivery, followed by shortage or low experience of labours were reported as the main factors of delay among all studies, while unseen weather conditions and material cost increase were seen as the least important in the list.

The factors of delay, which were not observed in the literature's ranking lists, are important to be included and verified. This is possible due to the involvement of a single party during the evaluation of projects delay, mainly the client or the contractor. The participation of other parties is necessary to be measured to avoid subjectivity and to generate a wider perspective. This issue is addressed by Goals 3 and 4 in Chapter 4. Table 2.6 illustrates the most critical factors of delay, which were identified from the literature, categorised by region and ranked according to the number of occurrences or repetitions.

TABLE 2.6: OCCURRENCE OF DELAY'S FACTORS IN MAJOR STUDIES

	Major Factors of Delay (16 Studies)	Reigons			Total
		SA & GCC	M. East	Far East	
1	Changes in the design and scope	XXXX	XXXX	XXX	11
2	Delay in Material delivery	XX	XXXX	XXXX	10
3	The shortage or low experience of the local labors	XXXX	X	XXXX	9
4	Poor conrtact Management	XXX	XX	XXX	8
5	Coordination, planning, and communication problems	XX	X	XXXXX	8
6	Financial diffculties	XXXX	XX	X	7
7	Design discrepancies	XXX	XX	XX	7
8	Delay in making decisions	XXX	X	X	5
9	Unrealistic Time durtion	XXX	XX		5
10	Payments delay	X	X	XXX	5
11	Difficulties in obtaning work permits	XX	XX		4
12	Unforseen weather conditions		XXX	X	4
13	Material cost increase	X		XX	3

In Saudi Arabia and GCC, six main studies were conducted between 1995 and 2014, which indicates that the shortage of manpower skills, changes in the scope, financial difficulties and unrealistic contract duration were issues over 25 years ago and still exist. Unforeseen weather conditions, payment delay and material cost increase were the lowest reported among the factors of delay.

To a certain extent, the Far East region was found to be similar to the GCC region compared to Middle East with respect to the factors causing delay. Chronic suffering of labour shortage and weak planning and communication between the projects parties could be the main the reason for the similarity. Delay in material delivery and changes in the scope of work were common practices in the region. Bureaucracy and awareness of the client were not observed as an issue in the region. Obtaining works permits and providing a tight contract duration were not reported as reasons behind delays.

Changes in the scope of work and delay in material delivery were very chronic in the Middle East Region. The unforeseen weather conditions and financial difficulties were also reported as important and critical. Shortage of skilled labour and sudden material cost increases were found to be the least common factors causing delay from the list.

2.3.4 Party Most Responsible for Delay

Kometa et al. (1996) found the consultant was considered to be the key figure for Saudi Arabian construction projects, which tends to isolate contractors from clients. This polarity reduces the client's direct input on the project and increases client dependency on the consultant (Al-Sedairy, 1994; Assaf & Al-Hejji, 2006). Furthermore, government clients in Saudi Arabia side with consultants, even when a solution is contrary to their preferences (Alnuaimi & Al-Harthi, 2009).

Surveys conducted by Assaf et al. (1995) indicated the most important causes of delays in Saudi projects were due to client involvement in processes such as planning and design, along with slow decisions and approvals for materials. Al-Barak (1993) found the causes of failure in some construction projects stemmed from the client's lack of experience and project involvement. Similarly, Al-hajji & Assaf (2006) found delays in construction projects most commonly were based on client-related factors.

On other hand, Ubaid (1991) found contractor performance was one of the major causes of delay, specifically contractor resources and capabilities. Bubshalt & AI-Goball (1996) revealed that contractor experience, financial capability and management capability were critical to project delay. Al-Khalil & Al-Ghafly (1999) reported both weak contractor performance and slow client decision making were the major causes of project delay in Saudi Arabia. After investigating delays in highway construction in Thailand, Noulmanee et al. (1999) concluded delays could be traced to all parties involved in projects. Azlan et al. (2010) found the major delays caused by the contractor were due to construction mistakes and inferior work, coordination problems, shortage of tools and equipment and material shortage. Indhu & Ajai (2014) indicated the issues of delays were primarily due to the contractor capability, followed by client performance.

Table 2.7 presents 136 critical factors of delay resulting from the sixteen studies shown in tables 2.3, 2.4, 2.5, in three main regions referred to 11 countries between 1995 and 2014. The data presented in the table indicates the majority of delay factors are linked to the contractor. The analysis reported 87 factors of delay were related to the contractor, followed by the client with 31 factors, and the consultant with 20 factors. Others, such as government issues and weather conditions, had limited numbers of factors contributing to delay.

TABLE 2.7: PARTY OF DELAY RELATED FACTORS IN MAJOR STUDIES

	Party of Delay			
Party of Delay - 16 Studies, (136) Factors	**Contractor**	**Consultant**	**Client**	**Others**
Total Factors Related to Each Party of Delay	87	20	31	10
Party of Delay Contribution %	**58.8%**	**13.5%**	**20.9%**	**6.8%**

It is obvious from this comparison that the contractor, at 59%, is the main party responsible for delay. The client was found to be second at a much lower 21%, while the consultant was perceived as the least responsible party at 13%. These findings from the literature confirm the first research hypothesis, in which the contractor is the main party responsible for project delay in Saudi Arabia. Further analysis follows in the Methodology Chapter to verify this finding.

2.4 Summary

This chapter reviewed and presented research literature to address mainly the second goal of the present study. Accordingly, the author identified 136 critical factors of delay extensively reported in 16 different studies with similar construction booms, geographical features and cultural nature.

The analysis compared the critical factors of delay between the GCC, Middle East and Far East regions based on the frequency of occurrence discovered in 16 different studies. This analysis concluded the contactor was the first party responsible for project delay, which confirmed Research Hypothesis 1. The level of contribution to the delay was 59% by the contactor, followed by the client at 21%, while the consultant was found to be the least project's party responsible for delay at 13%.

Some key factors were not observed in the literature's ranking lists, so the involvement of all parties is necessary for the ranking process. Goals 3 and 4 emerged from this finding and are addressed in Chapter 4. Tables 2.1 and 2.2 presented several methods, technique and different analysis used by many authors in the field of project management for the identification, evaluation, grouping and ranking process. The ranking of delay factors was mainly assessed according to time and cost. Other important measures such as quality, safety and environment were not used in the majority of the previous studies where they are critical to the project delay. The evaluation of the delay factors according to these measures are addressed by Goal 5.

The next chapter is Chapter 3, which presents the second part of the literature concerning the importance of the construction industry and its status in Saudi Arabia where the scope of this research is focused. The general types and classifications of construction delays from the literature are presented to be used as a guideline for classifying and grouping the delay factors in the initial part of Chapter 4.

CHAPTER 3: CONSTRUCTION IN KSA, PROJECTS DELAY CLASSIFICATIONS AND FACTORS GROUPING

3.1 Chapter 3 (Construction in KSA, Project Delay Classifications and Factors Grouping)

Figure 3.1 outlines the structure of the Construction in KSA, Project Delay Classifications and Factors Grouping.

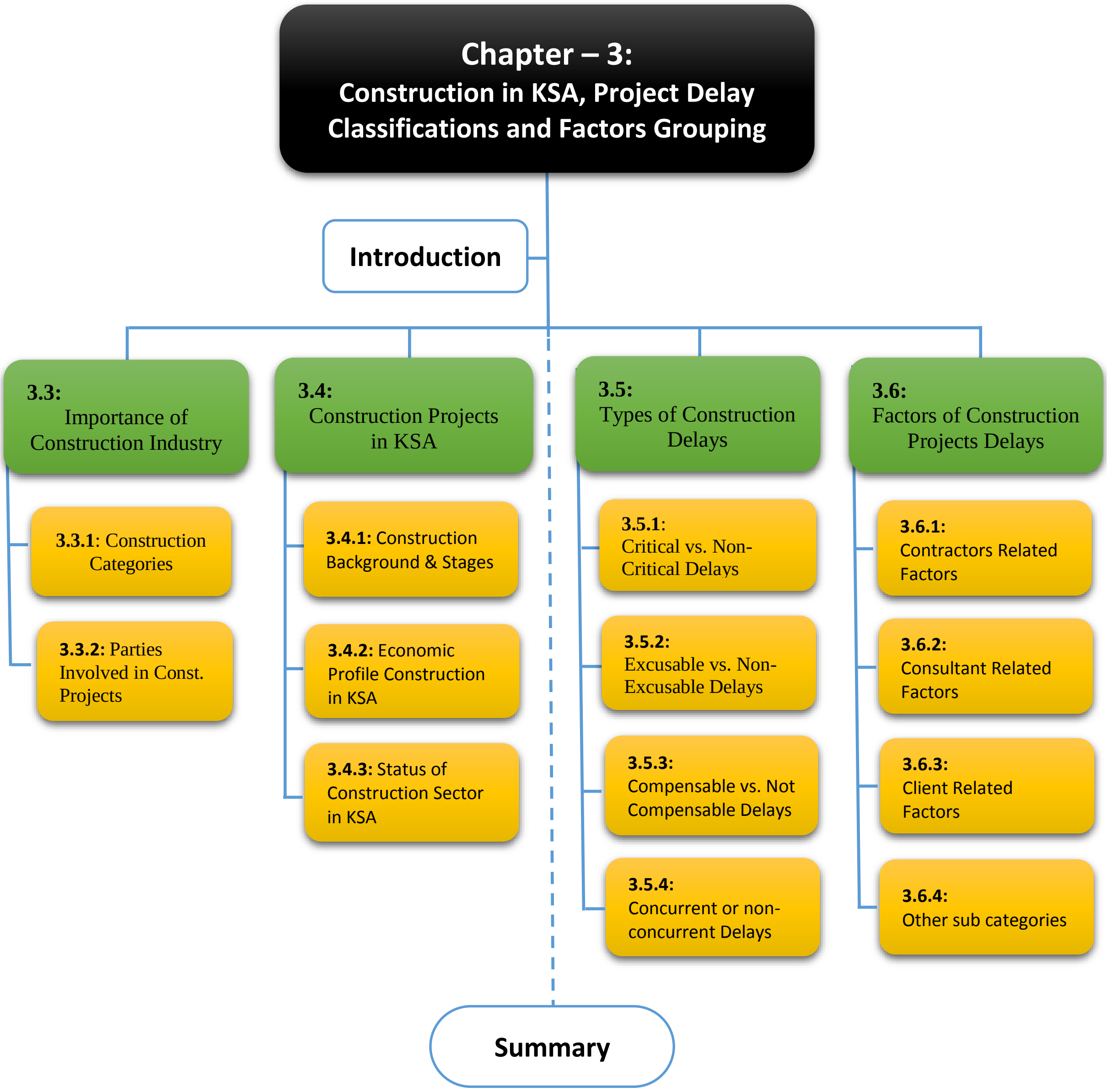


Figure 3.1: Chapter-3 General Layout

3.2 Introduction

The previous chapter overviewed 44 critical studies which were involved mainly in the identification, evaluation and analyzing the projects delay factors in developing countries. The Chapter concluded with the identification of 136 critical delay factors which were extensively reported in 16 different key studies with similar construction booms, geographical features and cultural nature.

This chapter overviews in the first two parts the construction industry and presented the relevant literature related to its importance in developing countries in general and KSA in particular. It also discusses the delay impact that affects project performance and the factors of delay that contribute to project delays (project time overrun) during the five stages in construction and industrial projects in KSA. It also aims to present, in the third part, the general types of construction delays and how they are categorized and classified according to the main contributors in the field of project management. The fourth part of the chapter discusses the classification of project delay factors in the construction industry. The section highlights that the logical classification is the liability of the construction parties and appears as the most appropriate for the present study.

The factors of construction project delays as identified for this study will be discussed through a wider perspective. In order to obtain a full understanding of the subject, major categories of construction project delays will also be considered on a case by case basis. This approach provides an opportunity for the author to select the factors from a number of previous studies most related to the research survey, providing a higher probability of covering all significant sources of delay.

3.3 Importance of the Construction Industry

The construction industry is incredibly important in all economies. In many cases, it is what drives the overall economy. In the United States, as well as other nations, construction is one of the largest economic sectors. In the United States, as well as other nations, construction is one of the largest economic sectors. Until the 1980s, construction was responsible for the largest percentage of the gross domestic product (GDP), and the highest dollar turnover of any U.S. industry. Construction was also the largest manufacturing industry in the United States in the 1990s, accounting for approximately 8% of the GDP (Halpin & Woodhead, 1998).

Even today, with expenditures reaching over $1.2 trillion, the US is the one of the largest construction markets worldwide. New construction put in place is forecast to reach over $1.4 trillion by 2021 (Statista reports, 2018).

Construction is one of the largest sectors of the UK economy as well. It contributes almost £90 billion to the UK economy (or 6.7%) in value added and comprises over 280,000 businesses covering some 2.93 million jobs, which is equivalent to about 10% of total UK employment (Department for Business Innovation and Skills, 2013). A study by the UK National Audit Office (2001) of the performance of government construction projects, which amounted to £7.5 billion expenditure, showed 70% of the projects were delivered late.

The construction industry, whether in developed or developing countries, faces conditions of uncertainty and risk. But sources of such risk are more concentrated in developing countries and include volatility, relatively unskilled labour forces, low levels of productivity, poor infrastructure, fraudulent practices, certain financing characteristics typical in developing countries and government influence (Dakhil, 2013). The construction industry in a developing economy is reflected in its economic growth (Mankiw, 2010). Specifically, infrastructure for housing and transportation is undertaken by the construction industry. Construction in developed countries, primarily those in Europe, became a foundation of their economies due to the need for reconstruction after World War II (Lopes, 2011). All countries depend on the construction industry to develop their economies, both in general and within specific sectors (Khan, 2008). These contributions are on the demand side, with short term economic growth dependent on increased demand (Wilhelmsson & Wigren, 2009). Because construction is largely labor intensive, a large number of workers are employed throughout developing countries, comprising 20-30% of the labor force (UNIDO, 2006). GDP can be used to investigate the role of the construction industry in economic growth (Laumas, 2007).

Table 3.1 shows that construction contributes significantly to the GDP of a country. For example, the figures for 2009, 2010 and 2012 indicate the construction share of the GDP for Singapore, Hong Kong, Malaysia, KSA and Oman has increased. This significant construction reflects the use of the economic resources in these countries.

TABLE 3.1: CONTRIBUTION OF CONSTRUCTION TO GDP IN SOME DEVELOPING COUNTRIES, SOURCE: IMF COUNTRY AUTHORITIES AND STAFF ESTIMATES (2012)

CONTRY	2009	2010	2012
Singapore	29.1%	31.2%	43.00%
Hong Kong	9.5%	12.6%	15.5%
Malaysia	25.3%	33.1%	45.00%
Saudi Arabia	7.55	9.55	16.75
Oman	4.6%	5.4%	8.00%

Due to the importance of the construction industry in a nation's economy, it is worthwhile to ensure construction projects are completed successfully. There are a number of ways to achieve this; one way, which this research investigated, is based on the critical delay factors and their contribution to time and cost overruns. Many factors of delay result from poor management practices and lack of skills by managers involved in the project field. Providing managers with valuable skills can aid the successful completion of a project. The skills include tested methods of managing resources such as workers, subcontractors, equipment, the construction plant, materials, money and time.

As Nunnally (2001) noted, poor construction management practices usually result in one or more of the following issues:

- Project delays, which increase labor, equipment costs, overhead cost and insurance, often requiring the borrowing of additional funds.
- High cost of materials caused by inefficient handling of purchasing decisions.
- Increased subcontractor cost and poor contractor/subcontractor relations.
- High insurance costs due to material and equipment damage or a poor safety record.
- Low profit margin or loss on construction volume.

These issues will present themselves on a smaller scale to members of the project circle, such as contractors, owners, consultants, and subcontractors. However, on a larger scale, these issues will affect a larger factor of society, namely the economy.

3.3.1 Construction Categories

Strategies and operational relationships between construction project parties are directly related to the type of construction project. According to Halpin & Woodhead (1998) the three major construction categories are:

- Infrastructure: Transportation, such as highways, bridges, airports, pipelines, dams and tunnels.
- Nonresidential buildings: Institutional/educational buildings such as schools and government buildings, or industrial buildings such as factories, refineries or power plants.
- Residential: Single or multi-family homes.

Figure 3.2, 3.3 and 3.4 show construction industry distribution in the U.S., U. K. and KSA according to the previous categories. The activities in construction, infrastructure and the industrial sectors comprise more than half of the total projects in the construction industry for the three countries. The highest percentage was for US at 70%, followed by KSA at 63%, while UK at 55%. These figures are in line with the research objective which focuses on KSA and justifies the research's focus in the construction industry as represented in these sectors.

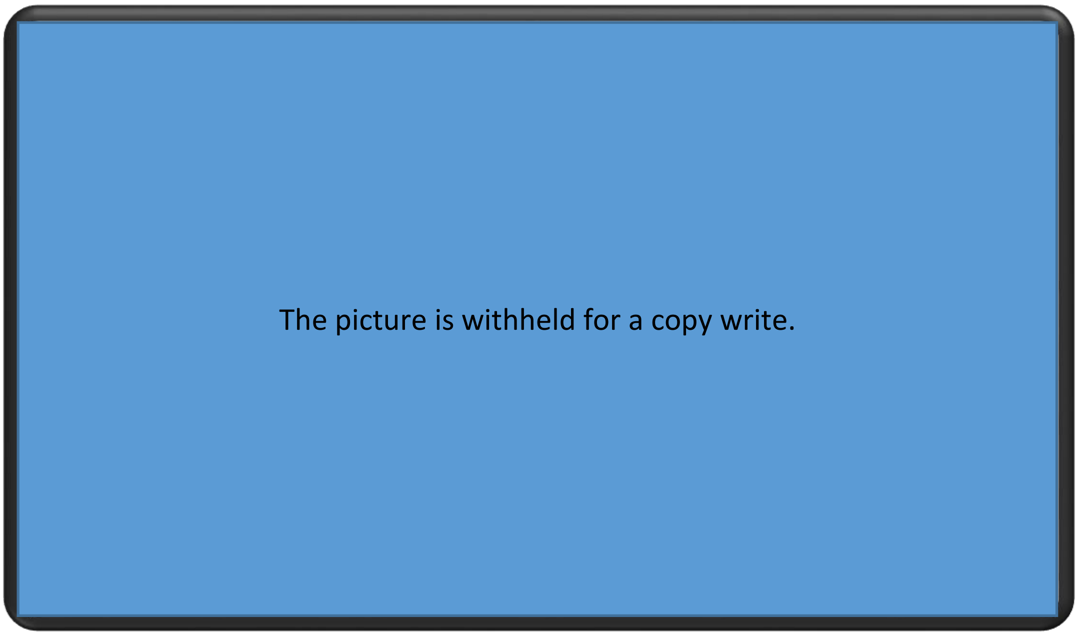


Figure 3.2 Construction Industry Breakdown in the United States
(Source: US federation office budget allocations, 2017)

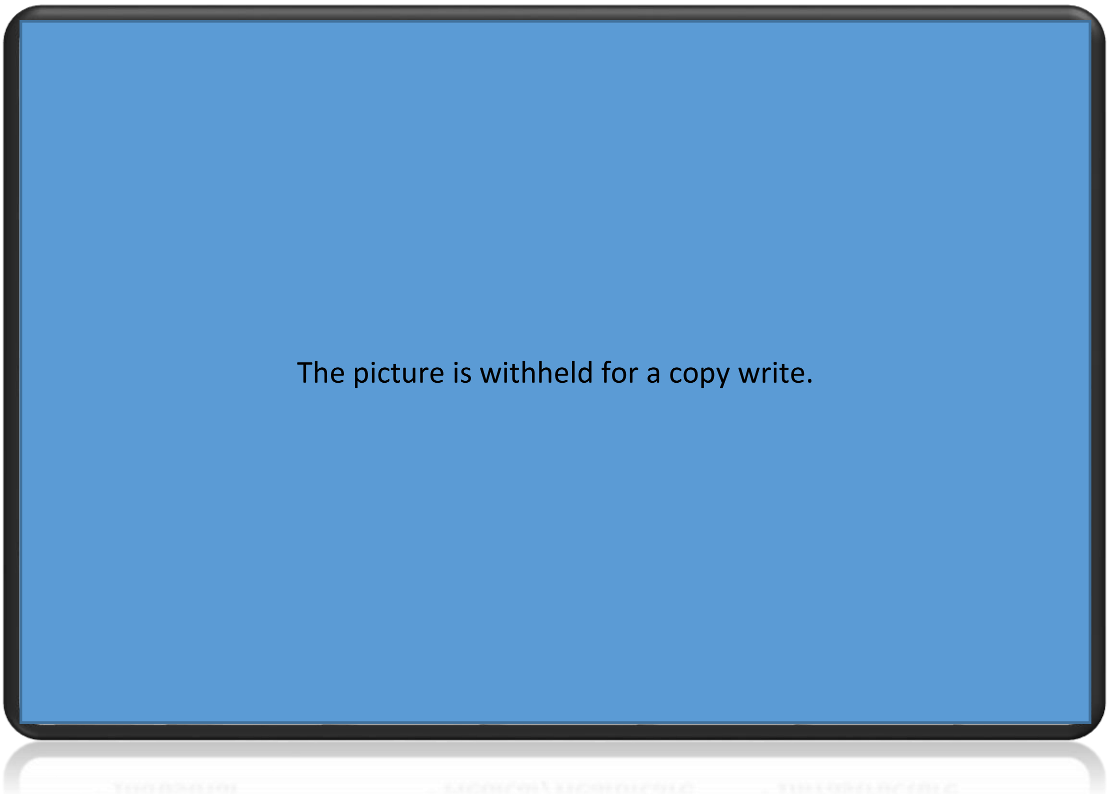


Figure 3.3 Contract Project Breakdown by Sector in UK,
(Source: AMA Research, 2017)

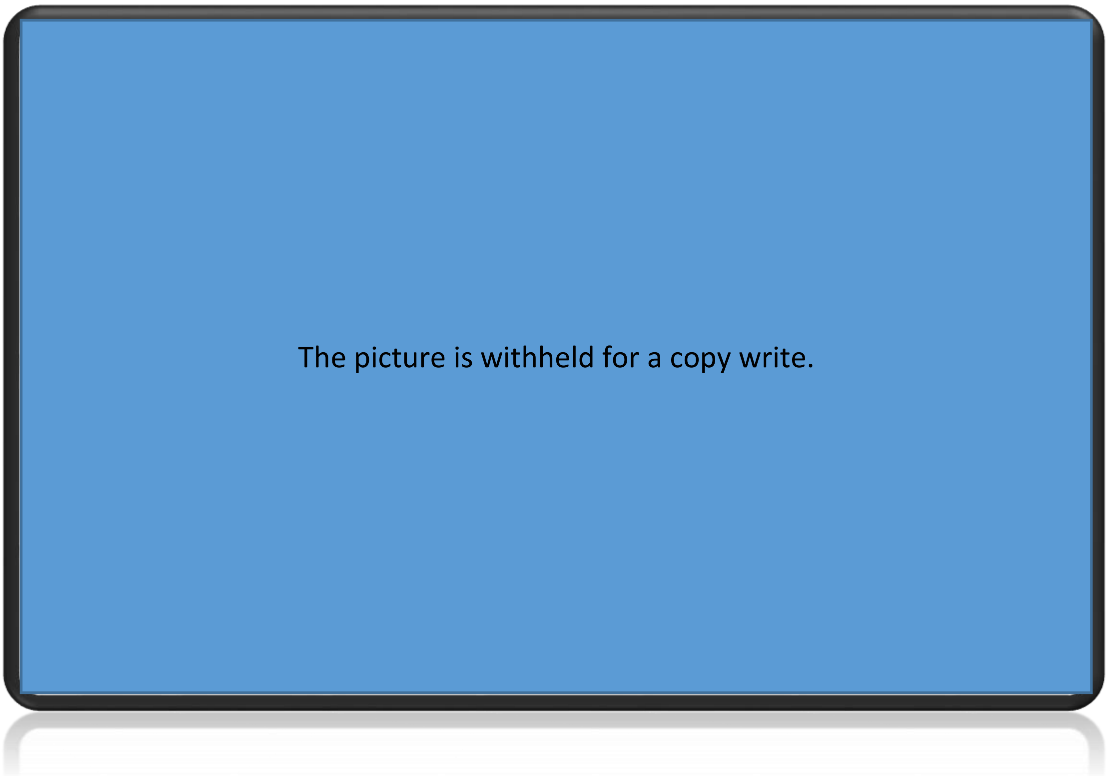


Figure 3.4 KSA Construction Industry breakdown
(*Source: Ventures Onsite MENA Projects, 2017*)

3.3.2 Parties Involved in Construction Projects

The parties involved in the construction process, such as owners, contractors, subcontractors and suppliers, are concerned with on-time performance and on-time payment. This section discusses delays in performance, which are, not surprisingly, among the most commonly litigated issues arising from construction projects. Construction projects involve expensive equipment, tremendous overhead, significant manpower and large payrolls for owners and contractors alike. The longer a job takes, the higher the costs and the greater the potential for litigation. Due to the high costs of untimely performance, contractors and owners usually require well planned and often complex schedules.

According to Winch & Kelsey (2005), to achieve great things, two things are needed; a plan, and not quite enough time. This is perhaps the view of some clients on construction projects. The completion date is not generally set by the specialist, i.e., the contractor, and based on a reasonable time to complete the scope of works within, but is often, instead, determined by the client based on commercial needs, sometimes without a full appreciation of the time needed. When assessed by contractors this tends to be shorter than the time they think it ought to take to carry out the works. Yet the contractor, and indeed the client, is often held to it.

Delay is a measurement of actual progress compared to the planned approach or, conversely, the assessment of delay events compared to the actual progression of the work. Delay analysis is necessary so the right to impose damages is protected if completion is delayed beyond the stipulated date (Ackoff, 1983). Delay analysis is generally considered to be a part of programming and planning, even though different skills are needed to perform delay analysis (AACE, 2007). An understanding of the philosophy of planning is the basis of grasping the context of delay analysis. Construction schedules serve several important purposes for both the owner and the contractor. Firstly, schedules are needed for planning and sequencing work. Secondly, the contractor could be protected from delay cost liability if a schedule is in place. Thirdly, the schedules could show delays were actually caused by a party outside of the contract. To serve these purposes, schedules should be constantly monitored and updated.

When work does not follow a project schedule, liability is often the outcome. In Jerry Bennett Masonry, Inc. v. Crossland Constr. Co., 171 S.W.3d 81, 92, for example, the court ruled against a subcontractor that "failed to live up to its obligation under the subcontract to adequately staff the job and add additional manpower at the request of the contractor, thereby creating delays in the months following commencement of the work on the project" (Masonry, 2005).

The primary construction project parties include:

a) Client (Owner)**:** Owners are most important to the construction project life cycle as they lay out the project requirements, functions and services while providing financial support to a project.

b) Contractor: Firms or individuals' contract with the owners to execute projects based on specific conditions.

c) Consultant (Architect/Engineer): A consultant is the third party for construction projects, tasked with interpreting the client's needs and creating a blueprint for the project. In some cases, the consultant also supervises the project during the construction phase.

A- Client Role:

The role of client could be split as projects can have different stakeholders and funders, each of whom will have different perspectives when involved in development and construction. Considering who takes on the roles of 'Client' and 'Employer' during the construction stage can have important implications for the project.

The client has a significant role in the process through appointing advisors and professionals, authorizing work and approving costs and timetables. Projects might have a community organization as the client, which could lead to difficulties with the role of employer due to potential liabilities.

At the contract stage, the client role is generally referred to as the employer and comes with specific liabilities. When the contract is ready to sign, the employer becomes responsible for payments to the contractor and other professionals and may also hand over land holdings. This may be beyond the financial capacity of a community organization. Depending on how the project is funded and who will own the land or buildings upon completion, a specific discussion on who will take on the client and employer roles during the process is critical (Robinson, 2011).

B- Contractor Role:

A contractor may be a self-employed individual, a sole proprietor or a business performing, managing or controlling construction work. Anyone directly engaging construction workers or managing construction work is a contractor, including companies that use their own workforce to do construction work on their own premises. The definition of contractor applies whether the workers are employees, self-employed or agency workers.

The main duty of a contractor is to plan and manage the construction so it is executed in a way that controls health and safety risks. A contractor also has a range of other duties dependent on how many contractors are involved. The duties may then entail coordinating their activities with others, especially through complying with directions from the principal designer or principal contractor. If there is only one contractor, this individual is responsible for preparing a construction phase plan and preventing unauthorized access to the site. If contractors are involved in design, including for temporary works, they then are carrying out duties as designers (Robinson, 2011).

C- Consultant Role:

A consultant engineer can be hired for both public and private clients, such as construction companies, government bodies, local authorities or factories. The projects could vary, for example, from a need for a factory re-design to coordinating bridge or road construction. The duties can vary from project to project as well, depending on the area of engineering expertise. A consultant engineering company will typically include employees from many engineering backgrounds so they can cater to virtually any type of project as they can be hired to plan, manage, supervise and even implement a project.

A consultant engineer may be hired to provide advice on a particular project element. For example, a business may be considering installing a new lighting system. The consultant engineer would be able to advise which lighting system would be most suitable for the business and the building. If the consultant engineer's line of expertise is CAD, then adjusting, creating or implementing designs and plans might be provided. Often, consultant engineers are hired as the points of contact between members of the project team. They can coordinate designers, architects, construction workers, suppliers, relevant authorities and the clients who have commissioned the project. They may also be hired to solve problems within a structure, such as persistent dampness, power failure, and lack of lighting or flooding. They can help with grants and applications, as well as ensuring certificates of compliance are obtained.

If green or sustainable energy solutions need to be incorporated in a building, consultant engineers could assist. They would thoroughly inspect the site and then suggest the most affordable and effective solutions and systems. Many countries now require that any property for rent or sale display its energy rating, and a consultant engineer may be able to certify the energy rating (Robinson, 2011).

Usually, a consultant engineer's responsibilities are needed in the early stages of a project, such as conducting a feasibility study, preparing estimated costs and assisting with securing plans. Their findings could lead to a project being terminated if it is too expensive, time consuming or simply not feasible. In other words, a consultant engineer could identify a problem or discover the most feasible, cost effective and efficient means of construction. Table 3.2 shows the relationship between project contract parties as discussed above.

TABLE 3.2 CONSTRUCTION PROJECTS PARTIES ROLES

CONTRACT PARTY	ROLES
Owner	➢ Determines whether it is necessary to build the facility ➢ Provides financial support to develop the project ➢ Determines the scope of work ➢ Most important player in the process
Contractor	➢ Creates the facility based on the consultant drawings and specifications ➢ Manages different resources during the project's development phase
Consultant	➢ Responsible for project design ➢ Fortifies the final project ➢ Determines which materials will be used and how they will fit together ➢ Develops the project's drawings and specifications

3.4 Construction Projects in Saudi Arabia

The construction industry in KSA faces a number of real challenges; some are unique to the kingdom, while others are inherent in any construction industry. However, owners share three primary concerns: spiraling costs, quality and time of completion. These challenges are compounded by the traditional 'sequential' approach to construction. The design, bidding and construction process are based on the assumption that the solution to a design problem can be embodied in a set of nearly faultless contract documents–capable of transmitting all the owner's needs to the general contractor (Bubshait & Al-Musaid, 1992; Althynian, 2010; Alsalim, 2013).

Construction experts have long recognized the extreme fragmentation of the industry, which comprises a variety of contractors, many of whom are small, undercapitalized and financially unstable. In most construction projects, using sub-contractors, whereby specialized tradespersons perform the majority of the work, has become common practice. There is also a general consensus among the construction teams that while the industry is large, it is diffused and, as a result, suffers from a high degree of incoherence (Assaf et al., 1995; Alsalim, 2013).

In the authors experience, facilities are constructed by a loose aggregate of independent design professionals, builders, land developers, financiers, manufacturers, suppliers and others, all of whom disperse on completion of a project. The owners find themselves in the position of having neither construction expertise nor control over their projects.

In view of the above-mentioned problems, the industry has adapted many tools and techniques from more advanced industries – mainly from the U.S. aerospace and defense industries. An approach that has found its way into the construction industry is referred to as the system approach. This includes the use of conventional, as well as more elaborate and technologically sophisticated techniques, for designing, estimating, organizing, planning, scheduling and controlling (Callahan et al, 1992).

Within this broad area of management techniques, the construction industry has developed some new concepts of its own. Industrialized or systems building, which proposes to replace handicraft field labor with sophisticated, mass-produced factory techniques, is one of these concepts. Another concept developed by the construction industry is phased construction, which refers to the overlapping of design and construction stages and the packaging of portions of construction work ready for contract before final plans are completed. This concept is sometimes used interchangeably with ‘fast-tracking,’ which covers all sequences of programming, design, documentation and construction. Finally, Construction Management (CM) is a concept that has already proven to be a significant technique for reducing construction time and overall project cost (Zhang et al., 2002).

The present study focused on improving projects to deliver them on time. Since the last economic boom took place in KSA in 2005, pressure from the government has emerged in treating high unemployment rates by facilitating many small and medium-sized contracting companies and implementing a Saudization percentage of 25%. These companies have started with low know-how in the construction fields, supported by ministries awarding them directly and indirectly “subcontractor” status to participate in this boom. Some contracts were applied to mega-projects with big international contracting companies with condition, specifying that Saudi local contractors should handle not less than 25% of the awarded–work (Al-Saleh, 2001; Council of Saudi Chambers, 2003).

These companies were so eager to contribute, even though the risk of failure was there, in order to generate profits and to grow by becoming qualified over the upcoming periods. The low workmanship and the limited capabilities of these companies have led to project time and cost overruns. It is worth mentioning that the number of these companies increased from 150,000 to more than 300,000 in less than seven years (Ministry of Finance, 2013).

On a positive note, this brave decision has helped to reduce the unemployment rate from 21% to around 14% in many sectors due to the pressure and support from the Ministry of Labor and the Human Resources Development Fund (HRDF). Pressure was maintained on the owners of these companies by applying additional fees to all foreign contracting companies; these additional fees have faced a lot of objections and has produced a big impact when maintaining these companies in the government’s qualification list. A reasonable percentage fall down in the black list, which prevents them from further contributing to any new bids (Ministry of Economy and Planning, 2013).

Officials in Riyadh and Jeddah started to rank the local companies based on the size of the organization, capital investment, the number of laborers, past project experience and successes, level of know-how and related experience, financial stability, qualification for bank guarantee, project portfolio management capabilities and adherence to safety and quality. This ranking has helped greatly by eliminating unqualified companies from participating in critical future projects. Furthermore, the successful companies that were able to execute old projects with minimal disturbances were allowed once again to bid with limited conditions, offering more facilities and advantages (Ministry of Economy and Planning, 2013).

Figure 3.5 shows the gross domestic product (GDP) in Saudi Arabia at current prices in Saudi Riyals for the construction sector from 2011 to 2017. In 2017, the GDP generated by the construction sector was about 154 billion Saudi Riyals, which represents about 8.5 % of the total GDP (International Monetary Fund (IMF) & Jadwa Investment, 2017).

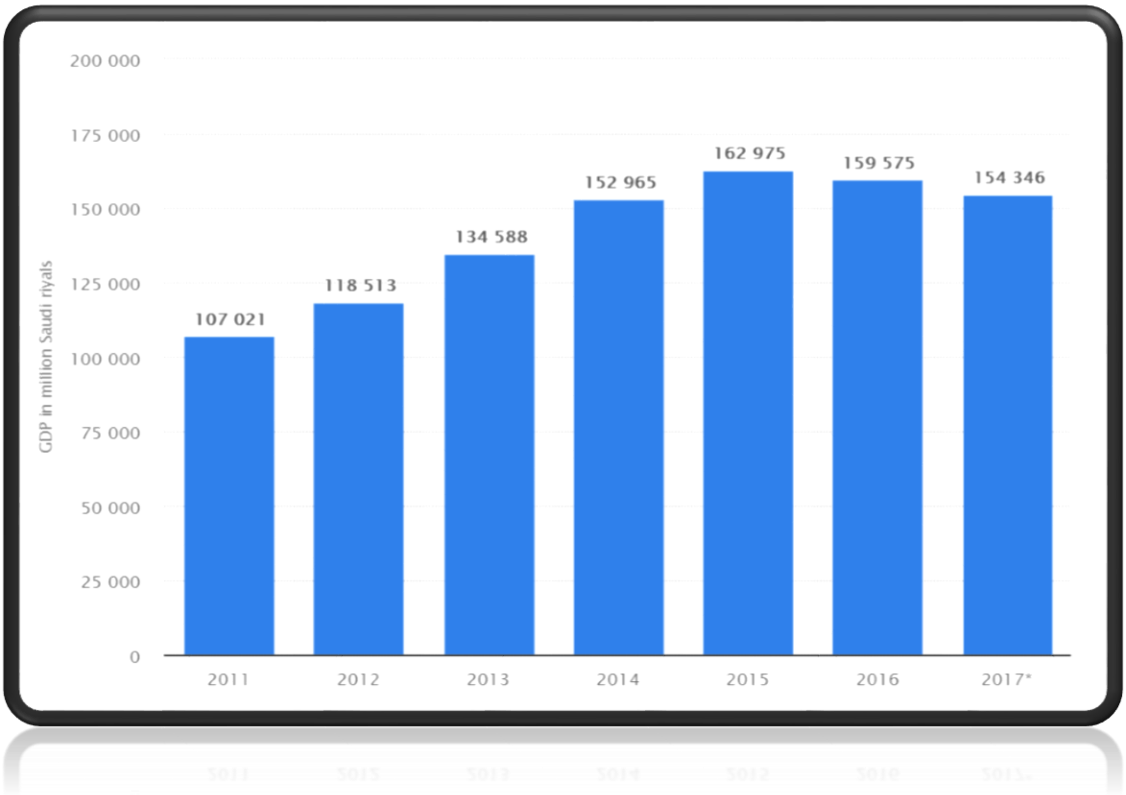


Figure 3.5 Gross Domestic Product of the Construction Sector in Saudi Arabia between 2011 and 2017 *(Source: Statistica reports, 2017)*

3.4.1 Background of Stages in Saudi Arabian Construction Industry

Historically, the Saudi Arabian construction industry has gone through a number of stages. The first stage began in the 1970s when the government introduced two 5 year plans. At that time, construction gained importance in Saudi Arabia alongside the more traditional industries, such as petroleum production. Through grants and interest-free loans, citizens were encouraged to build and invest in a variety of projects. Furthermore, an urgent need existed to develop the country's infrastructure. These initial years of growth were accompanied by a high level of economic prosperity, leading to the establishment of many firms that had a significant impact on the industry (Ministry of Economy and Planning, 2018).

The second stage spanned the first 5-year development plan that began in 1975. This development plan was established to stimulate construction of a modern Saudi infrastructure and to move towards its long-term strategic goals. During this decade, Saudi Arabia experienced a high level of activity that attracted construction professionals from all corners of the world. At this time, most of the infrastructure and major projects were built, such as military bases, airports, highways and hospitals.

The emphasis changed in the third stage that lasted from1980 to 1985. Infrastructure spending declined, but it increased for education, health and social services. Diversification and expansion of the productive sectors of the economy did not rise as planned; however, the construction of Jubail and Yanbu, cities built to produce steel, petrochemicals, fertilizer and refined oil products, was basically completed (Ministry of Economy and Planning, 2018).

In the fourth stage that lasted from 1985 to 1990, the country's infrastructure was basically completed, but education and training were still areas of concern. Private enterprise was promoted, as well as foreign investment through joint ventures with Saudi public and private companies. However, many construction companies shut down, and those that did not often merged with others. The private sector grew, rising by 1987 to 70% of non-oil GDP (Ministry of Economy and Planning, 2018).

The fifth stage, from 1990 to 1995, saw the government using previous experience and knowledge to implement industry regulations such as contractor prequalification, safety requirements, site supervision and consultant office regulations.

Contractors were forced to restructure their work methods, develop better plan strategies for future projects, recruit qualified workers and utilize new technology. These changes improved the competitiveness of Saudi Arabia's private companies. The period was noted for consolidation of the country's defenses after the first Gulf War, improved government social services, regional development and, most importantly, more private-sector employment opportunities for Saudis through the reduction of foreign workers (Ministry of Economy and Planning, 2018).

The sixth stage, lasting from 1996 to 2000, focused on lowering government service expenses and expanding educational training programs. There was a desire to reduce dependence on the petroleum sector by diversifying economic activity, particularly in industry and agriculture. This stage is noted as the first transformational period in the country's economy (Ministry of Economy and Planning, 2018).

Between 2000 and 2005, referred to as the seventh stage, the nation again focused on diversification and the private sector of the economy. During that time frame, the government aimed for a GDP growth 3.16% annually, based on projected private sector growth of 5.04% and non-oil sector growth of 4.01%. A further objective was to create 817,300 new jobs for Saudis and to improve the employment rate through private sector support, increased productivity and replacing non-Saudis with qualified Saudis. This strategy helped to lessen dependence on the oil industry by developing other natural resources and economic activities. (Ministry of Economy and Planning, 2018).

The eighth stage, encompassing 2005 to 2010, continued to focus on economic diversification, along with education and the inclusion of women. To support these goals, the plan sought to establish new universities and technical colleges. Privatization, a knowledge-based economy and tourism were targeted as means to achieve diversification. Implementing privatization policies fostered more ownership of productive assets, encouraged national and foreign investment, upgraded efficiency and enhanced national competitiveness (Ministry of Economy and Planning, 2018).

The ninth stage, spanning 2010 to 2015, had as its objectives poverty reduction and infrastructure development for medical services, education and residential housing. The Ministry of Housing was to invest approximately $ 67 billion to increase home ownership from 37% to over 50%.

The plan further aimed to increase real GDP by 15% over the five year period, along with government investment in human resource development, to decrease Saudi unemployment from 9.6% to 5.5% (Ministry of Economy and Planning, 2018).

The current tenth stage of 2016 to 2020, guided by the Transformational Plan of 2020, aims to enable the Vision of 2030. This stage includes enhancing the economic contributions of small and medium sized companies. The vision's model promotes efficient planning and collaboration by government agencies in order to achieve common national goals. It also guarantees timely project and initiative completion with sustainable action and impact through regular implementation reviews and performance evaluations (Ministry of Economy and Planning, 2018).

Strategic Objective (6)	Improve efficiency of projects and programs execution				
Relevant Vision 2030 Objectives	Achieve budgetary balance Achieve the highest levels of transparency and good governance in all sectors Improve performance, productivity and flexibility of public authorities				
Key Performance Indicators	Baseline	2020 Target	Unit	Regional Benchmark	International Benchmark
Percent projects completed on time	14	70	Percentage (%)	94	75
Percent projects that exceeded 6% of their budgets	44	3	Percentage (%)	Under study	0
Percent projects that are delayed more than 20% beyond targeted completion dates	66	20	Percentage (%)	6	Not Applicable

Figure 3.6 Projects Execution Program in KSA by 2020,
(Source: Ministry of Economy and Planning, 2018)

Figure 3.6, however, indicates that only 14% of the current projects in the tenth stage are finished on time, and 44% of them exceeded 6% of their budgets. The figure also shows that 66% of the projects underperformed due to major delays. Targets have been set to accelerate the ongoing projects and to improve the delivery and completion on time from 14% in 2017 to 70% by 2020 (Ministry of Economy and Planning, 2018).

3.4.2 Economic Profile of the Construction Industry in Saudi Arabia

The construction sector in Saudi Arabia is the largest and fastest growing market in the Gulf Region (Middle East Economic Digest [MEED], 2010; Samargandi et al., 2013). Ongoing construction projects in the Gulf are valued at US$1.9 trillion (SR7.1 trillion), and one-quarter of the developments are located in Saudi Arabia (MEED, 2010). A number of positive economic, demographic and geographic factors, as well as continued government support, have combined to help Saudi Arabia weather the current economic downturn better than most of its Gulf neighbors.

According to industry experts, in the first two quarters of 2009, 34 contracts, each with a value of over US$500 million (SR1.9 billion), were awarded. These contracts represent a combined worth of US$50.1 billion (SR187.9 billion) (MEED Projects, 2017).

Figure 3.7 shows the projects' expenditures in the Gulf countries for 2017, with Saudi Arabia's total capital investment exceeding $250 billion. This huge capital investment confirms the leadership position of Saudi Arabia, followed by UAE, in the construction industry.

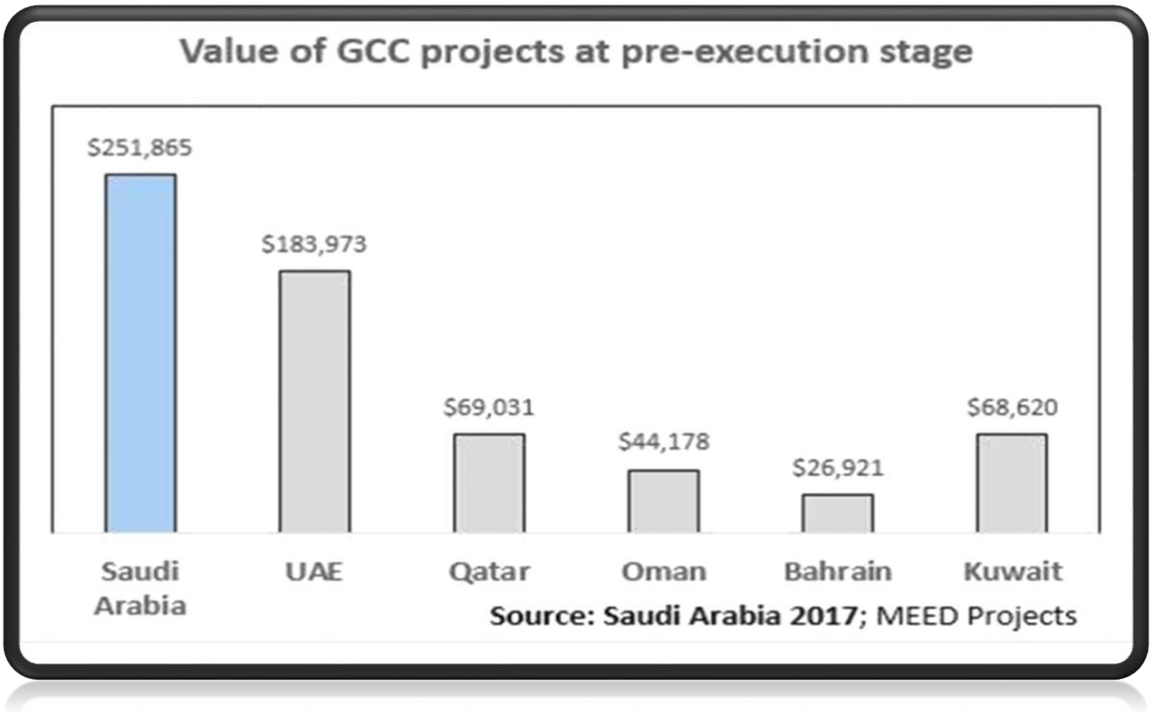


Figure 3.7 Value of GCC Projects at pre-execution stage in 2017,

(Source: Saudi Arabia 2017; Meed Projects)

To a large extent, the economy of Saudi Arabia depends on oil revenues, which constitutes around 75% of the kingdom's total revenues. Construction activities, therefore, have a direct relation to oil prices. This is reflected by the total value of publicly awarded construction contracts, which leaped by 26% to $3.36 billion in 2000 and fell by 6% to $3.14 billion in 2001. During the last 18 years, construction investment in KSA is estimated at $19.5 billion per year, peaking at $20.8 billion in 2000. After the 11 September economic slowdown, the government curbed its planned expenditure for 2002 by 20.8% to $ 54 billion compared to $ 68 billion in 2001. During the first five months of 2002, the total value of the awarded construction contracts increased by 60.7% to $2.13 billion, compared to $1.33 billion in the same period in 2001. This was largely due to the surge in construction activities of the industrial and urban development sectors, which rose substantially (SAMA, 2003; UK Trade & Investment, 2002 and the Saudi Ministry of Economy and Planning, 2003).

In early 2006, when oil prices rose and King Abdullah bin Abdul-Aziz was appointed, the first 5-years plan was set with an ambitious expansion in all fields, such as education, health, infrastructure and accommodations. This plan-created a big boom in these related fields, with an annual project investment in 2006 of around $ 70 billion, rising in 2012 to around $ 110 billion. Some of these projects are still in progress, i.e. King Abdullah Financial City, Jeddah airport, a highway-rail station, two holy mosques expansions and three mega-economical cities (Ministry of Finance Report, 2012).

Figure 3.8: World Oil Price and Target of Saudi Oil Price, 2000-2018,
(Source: World Prices, 2018)

In the last 15 years, the oil price has significantly increased and rose to levels above US$100, as shown in Figure 3.8. Saudi Arabia has the world's second largest oil reserves and is the world's second largest oil exporter, with a production of over 10.3 million barrels of oil per day. This productivity has had an enormous impact on Saudi Arabian income. The Saudi budget has had a surplus from 2004-2014, as shown in Figure 3.9. Therefore, Saudi Arabia has a strong economic standing globally. It is a member of the G20 forum for international cooperation on the most important issues of global economic and financial agenda (Ministry of Economy and Planning, 2018).

This strong economic position has encouraged the Saudi Government to take the opportunity to spend money on many public projects. The project capital spending rose around 25% annually, from the $ 80 billion per year (SR 300 billion) in 2004 to more than $ 254 billion per year (SR 950 billion) in 2014. This substantial boom resulted from the exceptional increase of oil prices that reached the level of $ 146 per barrel by the end of 2012. The capital spending was reduced dramatically by 15% for two years in a row (2014-2016), in tandem with movement in the price of oil, after which it partially recovered its momentum by the beginning of 2017 (Ministry of Economy and Planning, 2018).

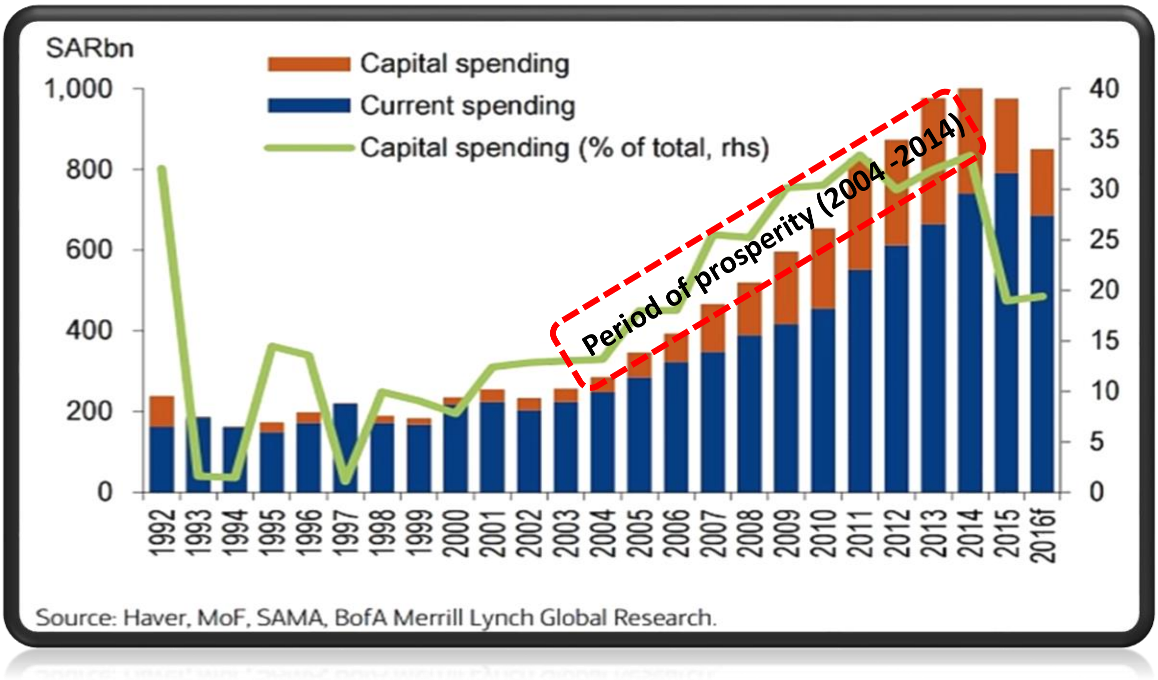


Figure 3.9: KSA Capital Spending vs. Current Spending, 1992-2016 *(Source: Haver, MoF, SAMA, Bofa Merrill Lynch Global Research, 2016)*

The Saudi Government is intent on fueling the growth of the construction sector. The government planned to spend an estimated US$400 billion (SR1.5 trillion) on large infrastructure projects from 2010 to 2015 (Ministry of Finance, 2010). In the period between October 2008 and April 2009, industry experts estimate that the Saudi Government invested nearly US$137 billion on construction projects. Since 2007, 29,640 projects with an approved cost of US$ 655 billion have been signed off by the government as set out in Table 3.3. However, according to the Gulf Project Index introduced by the Middle East Economic Digest, the total value of ongoing projects in Saudi Arabia in August 2017 was US$ 956 billion. This increase in number was due to the inclusion of some petroleum projects that are not under the control of Saudi Ministry of Finance (Ministry of Finance, 2018).

Table 3.3: PROJECTS APPROVED BY THE SAUDI GOVERNMENT SINCE 2007
(Source: Ministry of Finance, 2018)

Government-Approved Projects (*)		
Year	**No of Project**	**Cost (Billions US$)**
2007	3200	22.13
2008	2500	32
2009	2350	38.77
2010	2460	53.06
2011	2600	73.7
2012	2000	69.8
2013	1858	83.2
2014	2550	98.7
2015	2572	49
2016	2650	31.47
2017	2700	48
2018	Expected 2200	54.7
Total	**29,640**	**654.53**
(*) Ministry of Finance Reports (2007 to 2018)		

H.E. Amr Al Dabbagh, Governor of the Saudi Arabian General Investment Authority, stated that construction in Saudi Arabia will play a large part in the kingdom's massive industrial expansion through the National Industrial Cluster Development

Program (U.S.-Saudi Arabian Business Council, 2012). One of the most interesting steps in development plans in Saudi Arabia is the initiative to create six economic cities near the major regions of Tabuk, Madinah, Rabigh, Hail, Jizan and Eastern Province. These cities are expected to create 1.3 million jobs, and accommodate a population of 4.8 million, contributing to a value of US$150 billion in gross domestic product.

In July 2013, the Al-Riyadh Development Authority announced the winners of three turnkey contracts for the construction of a 176 km six-line driverless metro network in Riyadh. The overall budget for the metro is US$22.5 billion, making it one of the world's largest public infrastructure projects. The Saudi Government also plans to implement the same project in some other major cities such as Dammam and Jeddah (Ministry of Finance Report, 2014).

3.4.3 Status of Construction Sector in Saudi Arabia

In Saudi Arabia, construction project management practices vary as different nationalities of professionals have worked there since the 1970s (Bubshait & Al-Musaid, 1992). The quality of public projects among government agencies vary as well due to the different approaches employed (Al-jarosha, 2010; Althynian, 2010). Therefore, no general guidelines to describe the role of public agencies in construction project management exist. Moreover, varying degrees of client involvement in public construction could produce various levels of quality produced by different construction agencies (Assaf & Al-Hejji, 2006; Bubshait, 1994; MEED, 2010).

For Saudi projects, the consultant has traditionally been considered to be the major player in the construction project, which has served to isolate the contractors from the client (Kometa, Olomolaiye & Harris, 1996). To the point, the client needs to trust a consultant who will operate in the client’s best interest. The separation of the contractor and the client reduces the client’s influence on the project, making the client dependent on the consultant (Al-Sedairy, 1994; Assaf & Al-Hejji, 2006). Furthermore, the clients in government projects in Saudi Arabia believe consultants are correct even if a solution presented is different from the client's preference (Alnuaimi & Al-Harthi, 2009).

Good management and organizational performance in Saudi Arabia has been slow to develop (United Nations Development Programme, 2003, 2009). According to Althynian (2010), the UN Development Programme Report cited problems encountered by 850 out of 1035 construction projects in progress between 1992 and 2009. Among them, 41% experienced cost overruns and 82% did not meet the scheduled delivery time. The Anti-Corruption Commission (2013) updated these figures for 2013, with more than 3000 projects missing their deadlines. Alhammadi, chairman of the Committee of Contractors and board member of the Riyadh Chamber of Commerce, blamed the government for the delays in the projects due to the large number of projects being put forward, errors in the project design and weak supervision of all parties involved (Alsalim, 2013). One primary reason for these deficiencies is the lack of planning and design, caused by insufficient client involvement and inadequate consultant performance in the project processes (Althynian, 2010).

Construction projects in Saudi Arabia experience major delays (Al-Kharashi & Skitmore, 2009), and studies have been conducted regarding the causes of these delays. Surveys conducted by Assaf (1995) revealed the most important factors of delays in Saudi projects were related to client and consultant performance in project processes such as planning and design and slow responses when making decisions and granting approvals for materials.

Al-Barak (1993) found the causes of failure in some construction projects were based on the client's lack of experience and involvement in project activities. Similarly, Al-hajji & Assaf (2006) found delays in construction projects generally originated from client and consultant related factors. Al-Khalil & Al-Ghafly (1999) reported slow client decision outcomes were a major cause of project delay in Saudi Arabia. Overall, then, it seems the problems experienced in these construction projects are primarily due to low levels of client performance. Unfortunately, weak decisions made in the early stages of a project can lead to conflict between parties in the later stages. Therefore, client involvement during the early design stages of a project must be strong if a project is to be delivered on time, within budget and of the desired quality (Love et al., 1998).

Project success begins with positive planning and design involvement in the early stages of a project, with the client and appointed consultant playing a major role in these stages (Shen & Hui, 2004). Al-Sedairy (1994) investigated management conflict in public construction and found the conflict in public construction in Saudi Arabia occurred most often in the relationships between the contractor and the client or the contractor and the consultant. These conflicts occurred mainly in the later construction stages of a project. Moreover, low levels of experience coupled with a rapid economic and construction boom provided little time for the client norms to be stabilized (Assaf & Al-Hejji, 2006). As a result, problems due to incomplete or inaccurate engineering details often became serious and costly, and sometimes not discovered until the project had been completed. These problems included cost and time overruns, disputes between parties, omissions, errors, ambiguities in planning, reduced life span of the construction products and increased maintenance costs (Al-Kharashi & Skitmore, 2009).

A tragic example of the lack of progress in the Saudi construction sector took place in Jeddah in November 2009 when a flash flood killed 143 people and damaged 10,785 homes and over 10,850 vehicles. Saudi King Abdullah ordered an investigation, which revealed the disaster was compounded by corruption among top municipal officials, poor infrastructure planning, incompetence and lack of expertise and the negligence of some decision-makers (Arab News, 2010; Fatany, 2009). Therefore, the government of Saudi Arabia must increase professionalism in the construction sector and promote sound client and consultant performance in the project processes.

Very little research, however, has focused on effective client involvement in public construction projects in Saudi Arabia. A study by Bubshaite & Al-musaid (1992), emphasized the quality of owner involvement in the planning, design and construction phases in public construction projects in Saudi Arabia. The authors determined the construction phase included the most involvement by the owner. They also found that the most important phase was construction, followed by planning and then design. The study concluded that defining the important tasks during the project phases helped to optimise owner performance and maximise quality with minimum cost. In contrast, the aim of the present study was to investigate these problems and to pinpoint the risk involved in both the critical delay factors and the necessary group of delay factors that help to prevent or eliminate the delay impact in construction with a specific focus on Saudi Arabia. The investigation is extended to verify which party is the most responsible for delay in the project processes through the five project phases which are the planning, design, control, construction and handover. Accordingly, the conclusion would help to propose a protocol or mechanism to improve outcomes of the construction projects.

3.5 Types of Construction Delays

Construction delays can be categorized according to the liability of the construction parties, the occurrence and consequences of delay. General types of construction delays should be clearly examined before analyzing schedule delay factors. Schedule construction delays are categorized in many ways. According to Trauner et al. (2009), there are four main groups of construction delays:

- Critical or non-critical
- Excusable or non-excusable
- Compensable or non-compensable
- Concurrent or non-concurrent

Figure 3.10 presents a general overview of how construction delays can be categorized. Firstly, in the process of analyzing delay effects on the project, it should be stated if the delay is critical or noncritical as well as concurrent or non-concurrent.

All construction delays are either excusable or non-excusable as shown in the figure. Excusable delays are further classified into compensable or non-compensable. This figure presents only one interpretation as delays being excusable and compensable can change according to the contract.

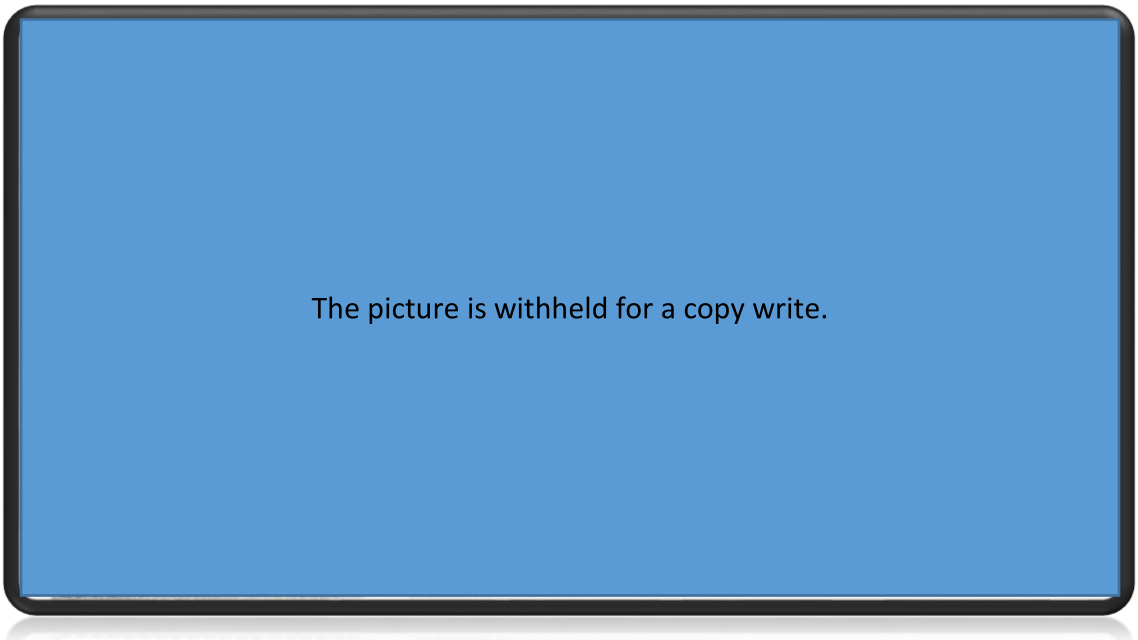


Figure 3.10: Delay Categories, *(Source: Trauner et al., 2009)*

In the study conducted by Yang, Yin, and Kao (2007), Figure 3.11, delays were classified in a different manner than in Figure 3.10, but similar to the concept of Trauner et al. (2009), as shown in Figure 3.12 in another study, Kartam (1999) classified project delays into three main groups according to their origin, timing and compensability as shown in Figure 3.12. These groups are as follows:

The picture is withheld for a copy write.

Figure 3.11: Delay Classification, *(Source: Yang, Yin and Kao, 2007)*

- Delays classified by their origin: Owner caused delays (OCD), contractor caused delays (CCD), and the third party caused delays (TPCD).
- Delays classified by their timing: These are concurrent delays (CD) and non-concurrent delays (NCD).
- Delays classified by their compensability: These are excusable delays (ED), which are also classified as excusable compensable delays (ECD) and excusable non-compensable delays (ENCD).

The picture is withheld for a copy write.

Figure 3.12: Project Delays Classification, *(Source: Kartam, 1999)*

3.5.1 Critical versus Non-Critical Delays

While several authors (Mubarak, 2005; Kelleher, 2005; Levy, 2006) categorize delays into three groups as Excusable versus Non-excusable, Compensable versus Non-compensable and Concurrent versus Non-concurrent, certain authors (Trauner et al., 2009; Callahan et al., 1992) added one more category, which is Critical versus Non-critical delays.

According to Trauner et al., (2009) and Callahan et al., (1992), the main focus in any analysis of project delays is on determining if the delay affects the progress of the entire project or the project completion date. The authors further stated delays that result in an extended date of project completion are considered critical delays, while delays that do not affect the project completion date are known as non-critical delays. Trauner et al., (2009) claimed the issue of critical delays emerges from the Critical Path Method (CPM) scheduling. All projects have a critical path and if these critical activities on the path are delayed, then the completion date of the project will, in turn, be extended. The criteria determining the project completion date are as follows (Trauner et al., 2009):

- The project itself
- The contractor's plan and schedule (particularly the critical path)
- The requirements of the contract for sequence and phasing
- The physical constraints of the project.

3.5.2 Excusable versus Non-Excusable Delays

Construction delays are basically either excusable or non-excusable. Callahan et al. (1992) and Trauner et al. (2009) claimed a delay is identified as excusable or non-excusable according to the terms and conditions of the contract. The authors further claimed standard contracts of construction stipulate types of delay that will allow the contractor an extension of time. For instance, in some contracts, unexpected or unusual weather conditions are not considered as excusable, so these contracts do not allow for any time extensions. According to Trauner et al. (2009), an excusable delay, in general, is due to force majeure events beyond the contractor's or subcontractor's control. The authors further explained delays resulting from the following issues are known as excusable:

- General labor strikes
- Fires
- Floods
- Acts of God
- Owner-directed changes
- Errors and omissions in plans and specifications,
- Differing site or concealed conditions
- Unusually severe weather
- Intervention by outside agencies,
- Delayed action by government bodies, such as building inspection.

In another study, Levy (2006) added two more excusable delays to the above list, which are:

- Illness or death of one or more of the contractors,
- Transportation delays over which the contractor has no control.

Moreover, Kelleher (2005) supplied the above list with two more delays:

- Epidemics
- Quarantine restrictions.

Mubarak (2005) defined non-excusable delays as "delays that are either caused by the contractor or should have been foreseen by the contractor". He also pointed out a non-excusable delay does not entitle the contractor to either a time extension or monetary compensation. Trauner et al. (2009) enumerated some examples of non-excusable delays as follows:

- Late performance of subcontractors
- Untimely performance by suppliers
- Faulty workmanship by the contractor or subcontractors
- A project-specific labor strike due to the contractor's unwillingness to meet labor representatives or due to unfair labor practice.

In another observation, Mubarak (2005) added other examples to the above list:

- Contractor cash-flow problems
- Accidents on the site caused by contractor's negligence or lack of preparation
- Late delivery of the contractor's furnished materials and equipment.

As stated in the excusable delays, again, only the contract specifies whether or not a delay is considered non-excusable. Therefore, Trauner et al. (2009) warned contractors that when signing a contract, it should be clearly understood and comprehended which delays are defined as excusable and which as non-excusable.

3.5.3 Compensable versus Not Compensable Delays

Some studies (Callahan et al., 1992; Kartam, 1999; and Mubarak, 2005) claimed an excusable delay can be classified as "excusable compensable" or "excusable non-compensable". Mubarak (2005) stated compensable delays are usually caused by the owner or the designer (engineer or architect). The contractor is typically entitled to a time extension, recovery of the costs related to the delay or both. Factors specified in the contract resulting in delays, such as differing site conditions, changes in the work scope and difficult site access are examples of compensable delays. According to Trauner et al. (2009), only excusable delays may be compensable. Trauner et al. (2009) emphasized a delay is basically defined as compensable or non-compensable according to the terms of the contract; the contract lays down the types of delays in detail and the delays for which the contractor is entitled to time extension or monetary compensation.

3.5.4 Concurrent Delays

Mubarak (2005) stated a concurrent delay includes a combination of two or more independent factors of delay occurring within the same time frame. According to the author, a concurrent delay often includes an excusable delay and a non-excusable delay. Another definition presented by Callahan et al. (1992) is "more than one delay contributed to the project delay, not necessarily occurring at the same time". Although this type of delays seems like a simple issue, there is really no clear and accurate definition of concurrent delays. According to Trauner et al. (2009), concurrent delays are simply defined as "separate delays to the critical path that occur at the same time". Levy (2006) named this type of delay as overlapping. Nguyen (2007) pointed out that simultaneous delays, commingled delays, and intertwined delays are other names used for concurrent delays.

Levy (2006) further indicated that concurrent delays may be generated by the contractor or by the owner, but if both parties are responsible and these delays overlap, then neither party can be liable for damages.

3.6 Factors of Construction Projects Delays

It has been shown that a large number of factors arising from different parties and resources may lead to delays in construction projects. These factors are, in a sense, countless as each construction project has its own characteristics, circumstances and environment. Efforts have, therefore, been made to identify the most significant causal factors of delay in construction projects.

In this section, the factors of construction project delays as identified for this study will be discussed through a wider perspective. In order to obtain a full understanding of the subject, major categories of construction project delays will also be considered on a case by case basis. These factors are be grouped into four major categories as follows:

- Contractor-related factors
- Consultant-related factors
- Owner-related factors
- Others

3.6.1 Contractor related factors

The contractor is the party responsible for carrying out the work scope of the project and generally bears most of the responsibility for construction works. The majority of the previous surveys conducted to detect the responsibility for delay found that blame, for the most part, lies with the contractor. As a matter of fact, the contracting profession is extremely complex and demanding, compared to other professions. All contractors are familiar with the difficulties of fluctuating work. The main contractor is often expected to take full managerial responsibility, not only for his own work and for safeguarding the owner from delay, but also for liaising with other contractors. However, the level of contractor responsibility differs according to the type of contract.

Setting a workable schedule that resolves all constraints is not an easy task. After evaluating the work to be performed and the most logical and cost-effective sequence of performing it, there remains further analysis necessary to produce a workable and efficient construction schedule. Contractors often find that labor, equipment or materials are in short supply. Shortages of these essential resources can significantly affect the commencement, performance and completion of activities scheduled and can cause the project to be extended beyond the scheduled duration (Callahan et al, 1992).

The contractor's ability to complete and hand over the construction project within the planned time frame is rooted in his capabilities, which include managerial competence and available resources. These resources include manpower, money, materials and equipment. A contractor has two sources of manpower: direct hire and sub-contracting. In most types of contracts, if a sub-contractor causes a delay, the owner shall refer to the contractor for resolution. Therefore, it is necessary for the contractor to continuously oversee his sub-contractors' performance. Contractors have a two-sided problem, which is balancing their interests between owners and sub-contractors. Many factors related to contractors may lead to project delay; such factors are subdivided into five major categories as follows:

- Materials
- Equipment
- Manpower
- Project management performance
- Project finance

A. Materials

Materials are the main factor in any construction project, representing a major expense. Managing materials is not just a concern during on-site construction, but decisions taken in regard to material procurement may also be required during the initial planning and scheduling stages. In some cases, more costly suppliers may be employed to save time.

Materials may be delivered late, damaged during storage or stolen unless special care and precautions are taken. In addition, delays and extra expenses may be incurred if materials required for particular activities are not available on time. Accordingly, ensuring a timely delivery of materials is an important concern for the contractor.

A rise in material prices may sometimes inspire the client to wait, hoping the price will decline, especially for large projects that require a large amount of materials and where a rise in price makes a significant difference. Waiting for price changes results in delays to some activities that might be critical, leading to delays in project completion.

In some cases, changes of project specifications take place due to mistakes in design or to improve quality. These changes often do not require a change in material types; however, the materials required might take time to be delivered because of the price negotiation process for owner approval.

In summary, delays related to materials issues can be ascribed to four factors: shortage, delay in delivery, changes in material specifications, and changes in material.

B. Equipment

Typically, construction equipment is used to perform essentially repetitive operations and can be broadly classified according to two basic functions: operators, such as cranes and graders, which stay within the construction site, and haulers such as dump trucks and precast concrete trucks, which transport materials to and from the site.

Contractors may purchase, hire equipment or both. However, most contractors own their standard equipment as an economical solution as they use it regularly. In either case, “hiring or ownership is subject to a rate for its hire” (Kwakye, 1997). Additionally, selecting the appropriate type and size of construction equipment often affects the required amount of time and efforts and, thus, the job-site productivity of a project; therefore, it is important for a contractor to be familiar with the characteristics and features of the major types of equipment most commonly used in construction projects.

Selecting the appropriate type of equipment, delivering it to the site on time and ensuring it is well maintained or subject to break down are major tasks assigned to the contractor. Any failure to do one of these may lead to slowing down the work progress and, consequently, lead to a delay in project completion. As shortage or unavailability of required equipment has an impact on the project time, the contractor, therefore, should select appropriate equipment procurement and follow an effective, applicable plan to avoid additional costs and time extension.

C. Manpower

In the construction industry, many operations and processes are labour based. Efficient management of labour or human resources can be the key to a successful construction project.

"Productivity in the construction industry is often broadly defined as the output per labour hour" (Hendrickson, 1998). Manpower consists of three types with respect to skill levels: skilled, semi-skilled, and unskilled. These include foremen, technicians, site engineers, civil, mechanical, electrical engineers and inspectors. Contractors should establish a manpower plan, which involves identifying and assigning project roles, responsibilities and relationships. Roles and responsibilities may be assigned to individuals or groups. "Failure in selecting the correct number and category of the labour force will severely affect the quality, cost and the progress of works and may result in complete failure of the project" (Drewin, 1982). Planning should, therefore, take place at an early stage of a project. Additionally, control processes must be conducted to ensure that labourers are working as planned and to take any necessary action during the project's progress.

In the KSA construction sector, 80% to 90% of the manpower are foreigners. Generally, contracting companies are owned by Saudis, but most of the employees, from the top level to the general labour level, are recruited from outside the kingdom. In terms of time, this may cause problems in construction projects as recruiting labour requires several complicated steps (interviewing, testing, visas, travel, accommodation, health insurance, etc.) that are beyond the control of the contractor and, therefore, are time-consuming. Other problems may arise from culture gaps (different languages and different methods and systems of work) as many nationalities may be involved in the project. These gaps can slow down the project's progress as communication and coordination between the workers are slower than with a monolingual workforce. Conversely, the vast majority of people at all levels of manpower in the Far East or Western contracting companies speak the country’s main languages. This enables them to operate with efficient communication and coordination, which in turn has a positive impact on the overall duration of these projects as compared to those in KSA and gulf countries (Al-Sabah et al., 2012).

D. Project Management Performance

There is more than one environment for project management. It has never been simple, and, as with any evolutionary process, it has become even more complex (Kimmons & Loweree, 1989). Before examining project management performance, it is necessary to understand what project management means. The Project Management Institute (1996) identified project management as “the application of knowledge, skills, tools, and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project". Successful project management requires team leadership and coordination, diligent project planning and effective oversight of the delivery process. There are obstacles, however, preventing contractors from performing successfully. The National Audit Office (2001) identified five major barriers to improving construction performance by contractors:

- Limited project management skills with a strong emphasis on crisis management
- Limited identification and management of risk
- Reliance on contracts to resolve problems with adversarial relationships
- Delaying payments entitled to subcontractors and suppliers
- Limited understanding of the actual cost of construction components and processes

Contractor responsibilities involve many tasks that contribute to project management performance: Planning and scheduling the project, communication, coordination with project parties and controlling suppliers/sub-contractors are the main issues impacting project duration.

"As in many other walks of life, if we start off by doing things wrong, one bad practice leads to another, and we end up in a vicious downward spiral" (Horner & Duff, 2001). Planning is a vital issue in any project, and success or failure of construction projects can be primarily ascribed to planning. For a contractor, planning begins with selecting the most appropriate procurement methods for the project; the final detailed plan demonstrates what, when and how, thereby comprising all major necessary decisions. "The plan becomes a vehicle for communication with all project participants and is a prerequisite for detailed scheduling of the work and for the preparation of a definitive cost estimate" (Kimmosons & Loweree, 1989). Scheduling is a vital part of planning; it develops a timetable for the implementation of dates for the plan. The lack of an appropriate project plan usually results in poor implementation of the project. Project planning, therefore, must obviously take place at an early stage of the project; however, there should be planning revisions and amendments at any appropriate time during the project to cope with the changes common in construction.

In order to manage the project and ensure all is under control, contractors should build coordination and communication routes with all parties involved: subcontractors, suppliers, owners, the administration team, the local authorities, etc. Regular meetings between the involved parties can positively create an effective atmosphere for resolving issues of the various parties in a project.

Project quality control can also affect the duration of a project. Completing work without achieving the desired quality standards may lead to having to perform it again. To avoid such costly mistakes and to ensure the project will fulfill the needs for which it was undertaken, involves three stages, and quality control is required. Once the client has identified the desired quality standard, the contractor needs to determine how to achieve it. Secondly, the contractor must carry on the process of quality assurance, which involves evaluating overall project performance on a regular basis to provide confidence the project will comply with the desired quality. Finally, the contractor must monitor specific project results to determine if they comply with the desired quality and to eliminate causes of unsatisfactory performance (PMI., 1996).

According to PMI. (1996) the contractors should note each project has its own requirements; they should select an appropriate labour force in terms of qualifications and numbers that can fulfill the needs of a specific project. Motivating and training the labour force also increases their productivity. Conversely, inadequate selection, motivation, and training may lead to poor productivity, which in turn contributes to delays. Managerial issues within the contracting company play a significant role in handling the project process. Kungari (1988) stated that “weakness in the company may disturb the flow of project operations. Among the many bad practices of the company that affects the smooth performance of the job, we can list changing key personnel, management incompetence, and the shortage of professional and administrative staff [and] lack of technical and/or managerial experience." Incompetent human resources can lead to an inaccurate study of the project at the tender stage, selecting inefficient procurement methods, ineffectual planning, imprecise estimations for project duration and the loss of control of parties ranking below the contractor in the hierarchy of the project organization, such as suppliers and sub-contractors.

E. Project finance

The methods used to finance construction projects is one of the most dynamic and complex areas in modem industry. While clients previously paid for work done, it is increasingly common today for the construction contractor to arrange the finance necessary for their projects. These methods, first adopted in infrastructure projects in the transport and energy industries, are now being applied to building work (Best & de Valence, 2002). Thus, not only owners but also contractors may face problems in financing a project. Difficulties that may be faced are represented in the delay or inability to pay the direct and indirect costs. Direct costs include materials, labour and subcontract expenditures, while indirect costs are the expenditures that support the direct activities, such as supervision and warehousing. Furthermore, the complexity of construction cash flow, disputes with suppliers in regard to payment and other common problems in construction projects may all contribute to delays in completion. The contractor should make sure there is sufficient capital to undertake a specific project and put all financing processes under control by adopting an effective project financing method.

3.6.2 Consultant related factors

The owner may employ an external consultant to assist in managing a project. The consultant may be responsible for carrying out the design of the project, including architectural, structural, mechanical and electrical designs. The consultant may also be responsible for preparing the project documents, such as drawings, specifications, bills of quantities and tender documents. In some cases, consultants undertake the responsibility for project planning, scheduling, cost estimation and quality control. However, the authors focus will be on the tasks required during the construction phase, starting with reviewing and approving the design drawings, then monitoring the performance of the contractors, followed by supervising the work execution.

Delays occurring in construction projects due to consultant performance include delaying the preparation of drawings or the approval of contractor submissions, accepting inadequate design drawings and delays in performing inspections or testing procedures. Such delays and more may arise as a result of insufficient qualifications or experience of the consultant engineer staff or poor communication and coordination with other parties involved in the project. From time to time during the project, contractors may have many inquiries; slow response by the consultant engineer may lead to slowing down of the work progress. In a case where a response is slow, the contractors may extemporize and execute a solution for the problem they face. This solution may not satisfy the consultant, which in turn results in executing the work again. Therefore, consultants should attend pre-construction meetings with assigned contractors and respond promptly to them during the project (PMI., 1996).

Supervision of productivity on site is an important factor contributing to project success. The consultant should constantly inspect work, keep the client updated on the project progress and issue instructions as required. The consultant also must establish a communication protocol with related parties, as well as review and approve design drawings and the contractors' work. In addition, the consultant is required to help resolve all discrepancies in the contract documents and visit the job site as required to handle construction problems. Any delay in performing these tasks will have a negative impact on the project duration.

3.6.3 Client related factors

The client (or owner) is the key to the entire construction process from inspection to completion, and at times, to post-occupancy maintenance (Kwakye, 1998). The owner's duties are onerous as the nature of construction projects is complex and requires a knowledgeable person or organization to manage the project. Many owners that sponsor a number of projects have their in-house project management teams fulfill their responsibilities. Nevertheless, many construction clients, if not most, do not have the organizational capabilities to manage their own construction projects. Therefore, they employ an external project manager to run the project and act as their representatives. One of the critical issues at the early stage of the project is determining the contract duration. Many owners require expedited completion, but a thorough study must be made to estimate the contract duration. When an unrealistic contract duration is imposed, it will obviously force the contractor either to accelerate the progress of works and neglect the desired quality or to perform work as required but not on time. Another significant matter is handing over the site. Failure of the owner to hand over the site to the contractor on time will cause a delay in commencing work (PMI., 1996).

The involvement of the owner in the project may accelerate the project's progress. The owner should be able to make quick and immediate decisions on various matters, such as changing orders, approving work or responding to the contractor during construction. Such prompt action will avoid hold-ups and maintain the momentum of productivity. However, the owner's decisions or actions should not cause any disruption to the flow of work. "The working relationship between an owner and a contractor is one of the most crucial determinants of project success" (Kimmons & Loweree, 1989). The owner's involvement in the project should be smooth and without disruption to the contractor's project plan. Financial aspects should also be considered; the owner must ensure adequate funds are available to meet required progress and to fulfill professional service payments. Shortage of money or delay of payments may result in a slow-moving project and, therefore, late completion.

3.6.4 Other Sub-categories

This delay category is further subdivided into three subcategories; early planning and design, government regulations and external factors.

A. Early planning and design

The quality of early planning and design affects the whole life cycle of a project. Accurate planning can secure the smooth progress of work and a successful completion on time; however, it requires a great deal of information about the project and related matters. "The purpose of the provision of information and the use of the various planning tools is to enable the parties to put their respective contract obligation into effect. It can be summed up in a single question: How are we going to deliver this project on time and within budget?" (Carnell, 2000). Completed and clear documents, specifications and design ease the contractor's obligations, create a proper atmosphere for work and do not give the contractor excuses for delays.

Determining the overall timing of the enterprise is crucial to calculating its risks and dynamics of its implementation, including how much time must be available for each of the basic stages of the project (National Economic Development Office, 1991). Determining contract duration needs a comprehensive, methodical and careful study of every stage of the project. Some projects are required to be completed in a short duration for economic reasons, but imposing a short duration must be planned on a realistic ground with concern for all barriers that may be faced during the project. Short duration contracts may lead parties involved to face difficulties and disputes. These disputes may be escalated to arbitration, then to litigation, and thus consume long periods of time while waiting for legal action and decisions (PMI., 1996).

At the early planning and design stage, it must be recognized that drawings are a means of communication rather than an end product, and, hence, should be carefully detailed and coordinated to provide good information. Adequate information on the planned shape, size, location and constituent parts of the building; as well as on materials, jointing and fixing methods and so on must be provided to adequately convey the designer's target. Ambiguities, mistakes, and inconsistencies in specifications and drawings will lead to many stoppages during construction, and, therefore, a longer project duration. Furthermore, unclear specifications and drawings may not give the owner a clear image of the project, so he will not be updated with the progress at the construction stage, which, in turn, will result in adversarial disputes and change orders. In fact, spending enough time at the early planning and design stage can speed the progress of productivity and avoid drifting into a ‘disputes and blame' culture. Basically, paying careful attention to the early stages of the project will result in completing the project on time or earlier than planned (PMI., 1996).

B. Government regulations

Almost every country in the world has a government division responsible for controlling and regulating the activity of building construction. It is the body that issues planning permission for construction projects in its area of jurisdiction. For this reason, application forms and drawings must be submitted to this division (the municipality in KSA), and approval must be obtained before commencing work. However, there are many other governmental authorities involved in construction activity, such as the statutory authorities and fire authorities. Owners, consultants, contractors and other parties involved in construction projects need to deal and comply with such authorities in order to obtain work permits, labour permits, safety measures, utilities and so on.

It is common for construction parties to face difficulties getting work permits issued from governmental authorities. In some cases, the delays or difficulties in obtaining work permits are due to the bureaucratic system adopted by the authority concerned or the poor qualifications and performance of its members. In order to avoid such delays, project teams should communicate and coordinate with governmental authorities as early as possible and regularly communicate with the relevant authorities during the project. Furthermore, the consultant should receive full information regarding construction laws and regulations to avoid the time-consuming redesign of and illegal aspects of the design. According to Eveld (1981) amendments to regulations and laws are important factors that may have a negative impact on project duration. Regulatory and legislative changes may be related to the construction specifications (solid to a liquid percentage, height of buildings, land use, etc.), labour law (e.g. barring access to some nationalities) or other factors. These changes can affect the project procedures and result in delayed project completion

Adopting the tendering system of selecting the lowest bidding contractor in public projects may lead to accepting a contractor with poor qualifications or resources, which consequently may lead to poor performance and delays in the project progress. Additionally, this strategy discourages contractors from mobilizing the best efforts and resources they have in order to win the bidding competition.

A final legal consideration is that ineffective delay penalties may contribute to spreading corruption in the construction industry. In other words, contractors may choose not to perform the work as stated in the contract, knowing that penalties stipulated are an inadequate deterrent. This gap in the law gives a chance to unscrupulous contractors to work improperly.

C. External factors

Some factors are beyond the control of contractors and owners and may cause construction delays. The occurrence of these factors, as stated in Section 3.3.2 gives the contractor the right to an extension of time.

Temperatures in KSA during the summer season range between 40°C and 52°C. In contrast, the weather in Europe becomes severe in winter; as temperature ranges between 12°C and -13°C. In this extreme weather, productivity is negatively affected, and the progress of work slows down. The contractor is expected to consider in his program that during the winter months, there will be probably days when the weather will delay or prevent outside works. However, the contractor may be in delay because of his own default, which results in a delay, for instance, when making the building weather-tight.

If there are exceptionally adverse weather conditions for the time of year, the contractor may be entitled to an extension of time. This can happen even though it is the contractor's own delay that has caused the work to be affected by the adverse weather conditions” (Birkby & Brough, 2002). Sometimes contractors face difficulties with the subsurface condition on site. These difficulties include very strong rocks below the site, many utility lines (electricity, gas, and so on) and/or a water table in the vicinity of the site that may not be marked on available maps. Unexpected subsurface conditions may not only delay the work but also require a redesign of the project master plan.

Throughout the year, there are many social and cultural celebrations and festivities. Normally, at that time, the traffic becomes congested and may affect the job site. Under such conditions, it would take longer for suppliers and labors to access the site. This negatively affects productivity and causes delays.

Another factor that affects contract duration and is beyond the control of the parties is the rise of material prices after the contract has been signed. This happened in 2003, when the price of steel more than doubled. Many projects were stopped in anticipation of a return to old price levels, causing direct delays. Although such price increases are beyond the control of the contracting parties, they may also create disputes between contractors and clients, which will further increase the project duration.

The interfaces between many parties in the project is a significant issue. Many disciplines, different backgrounds, different education levels, as well as different aims and objectives are often involved. It is no easy matter to bring all these people together and expect them to work for almost a year without drama, problems, and disputes.

For the purposes of the present research, potential delay factors were carefully identified from studies previously mentioned in Chapter 2, sections 2.3 and Chapter 3, sections 3.3 and 3.4. Similarly, the factors of delay categorized by the projects parties in this Chapter, section 3.6, were also obtained. Factors of delay concluded from project management related papers, articles and observed by project practitioners were included and added to the final list. The list included more than 300 factors of delay, which were collated and then alphabetically organized. This list can be found in Appendix A.

3.7 Summary

This chapter reviewed and presented research literature to address mainly the first two goals of the present study. To address Goal-1, the first section provided a background overview of the construction industry’s importance in general and in the KSA construction industry in particular. The section overviewed the construction classification and parties involved in the construction projects. The second section presented the construction status, development stages and–economic profile of the construction sector in Saudi Arabia. It was found that Saudi Arabia has a very strong economy, having the world's second largest oil reserves and is considered the largest and fastest growing market in Gulf and Middle East Regions. In the last ten years, Saudi Arabia has experienced a construction boom, with approximately 30,000 public projects and a total capital spending exceeded $400 billion. However, during this period, the kingdom reported only 14% of the current projects have been finished on time, and 66% were stumbled or underperformed.

This chapter presented in the third part the general types of construction delays and how they are categorized according to the main researchers in the field of project management. The construction delays were categorized according to the liability of the construction parties based on the four main groups of construction delays (1-Critical versus non-critical; 2- Excusable versus non-excusable; 3- compensable versus non-compensable; 4-concurrent versus non-concurrent).

The chapter also discussed in the last part the classification of the project delay factors in the construction industry. The classification highlighted how the factors of delays referred to the parties involved in the project delays. Many factors of delay in construction projects have been examined and categorized. With the same categories previously described, construction delay factors can be summarized as: (1-Contractor related factors; 2- Consultant related factors; 3- Client related factors; 4- Others). More than 300 factors of delay were identified in the earlier part of the chapter, with many factors interpreted in different forms from the previous literature, project management related papers, articles and project practitioners; therefore, a sorting process was required to avoid duplication. The factors of delay list was developed to assure no factor was repeated or partially included with other factors so that each factor would be independent and reflect its full meaning.

The next chapter presents a detailed discussion of the research methodology applied in this study, based on the findings from the literature review in Chapters 2 and 3. The sorting, categorizing and grouping processes will be covered in Chapter 4 to provide the opportunity to select the factors most suited to the research survey, with a high probability of covering all significant sources of delay.

CHAPTER 4: MATERIAL AND METHODOLOGY

4.1 Chapter 4 (Material & Methodology) layout.

Figure 4.1 outlines the structure of this chapter.

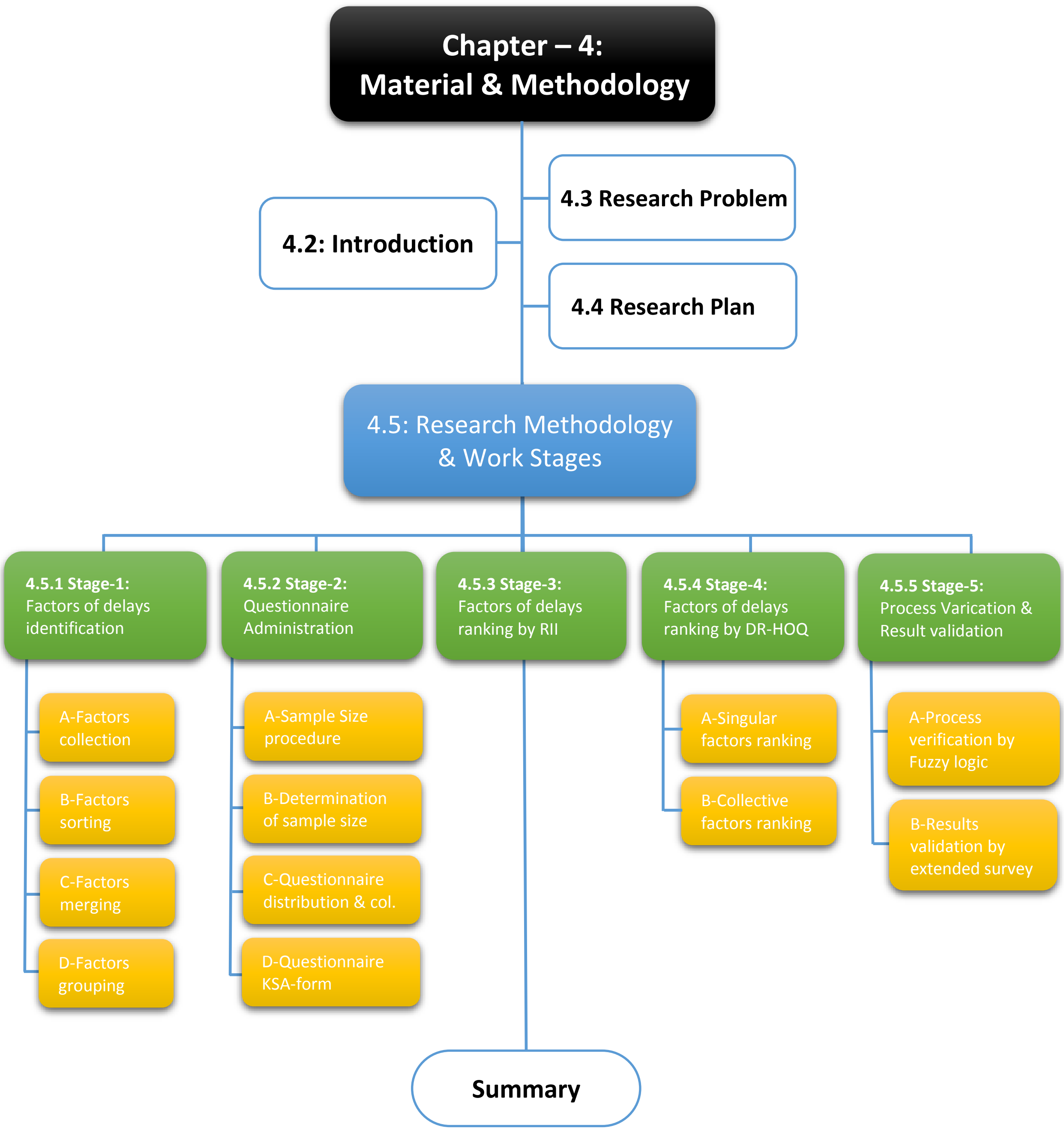


Figure 4.1: Chapter-4 General Layout

4.2 Introduction

Following the explanations regarding the aims and objectives of this research in Chapter 1, setting out a picture of the construction industry in KSA with relevant delays issues in both (public and private) sectors as well as those observed in other countries in Chapter 2 and presenting the classification and grouping background of delay factors in Chapters 3, it is time to present the methodology used to carry out this research and address its aims. This chapter explains how the project delay problem was investigated and describes the tools used. It also lists the characteristics of the research sample and the method of analysis. This chapter discusses the research methodology applied in the present study.

The research methodology refers to the set of processes that are used to collect and analyze data Leedy & Ormrod (2001). Mingers (2001) defined the research methodology as a "structured set of guidelines or activities to assist in generating valid and reliable research results". This chapter explains and justifies the methodology adopted in this research as well as the link between the research goals and outcomes.

4.3 Research Problem

As discussed in Chapter 3, Section 3.4 the construction sector in Saudi Arabia has faced many challenges during the recent construction boom (2004-2014). The issue of projects delay still persists as the official results of the statistical authority of Saudi Arabia reported 66% of the projects underperform due to major delays in the period (2016-2018). The report indicated that only 14% of the current projects are finished on time, and 44% of them exceeded 6% of their budgets (Ministry of Economy and Planning, 2018).

These challenges are critical and more involved in the developing countries based on current practices that result in a lack of project management, weak government influence and supervision, relatively unskilled labour forces, low levels of productivity, poor infrastructure, fraudulent practices, interest rates changes, inflation, business risks related to political factors and the economic and cultural environment in the host country (Mankiw, 2010; Lee et al., 2011; Dakhil, 2013; Luu et al., 2015). Some of them are unique to the kingdom, while others are inherent in any construction industry. However, owners share three primary concerns: spiraling costs, quality and time of completion. These challenges are compounded by the traditional ‘sequential’ approach to construction. The design, bidding, and construction process are based on the assumption that the solution to a design problem can be embodied in a set of nearly faultless contract documents-capable of transmitting all the owner’s needs to the general contractor (Bubshait & Al-Musaid, 1992; Althynian, 2010; Alsalim, 2013). These factors of risks, if not properly identified, evaluated and managed, can result in poor project performance in terms of budget, schedule, quality, and safety, and can significantly affect the company’s overall performance (Ahsan et al., 2010; Andi, 2006).

Making the right decision is typically not a simple matter as most decisions in construction projects are highly complex in nature. This complexity is due to a wide variety of factors involved in the delay, either in the construction process or in management that affect project success or failure. Identifying these critical factors can be helpful for analyzing the potential reasons for a favorable or unfavorable outcome (Low & Chuan, 2006).

The literature listed in tables 2.1 and 2.2 (1991-2017) has neither presented any attempt at evaluating the factors of delay according to the five main Project Performance Measures (PPMs), nor to any interrelationships between the factors of delays that could impact the evaluation and ranking of the delay factors. In other words, interrelationships could contribute to radical changes in the importance of factors of delay. These interrelationships could be embedded between the factors of delay on one side and attributing to the projects performance measures on the other side (AbuKwaik et al., 2017). The behavior of the delay factors don’t stand alone; indeed, they are affected and influenced by these interrelationships that are very important to identify and analyse. Another observation was that various previous studies in the list were lacking any mechanisms employed to evaluate or assess the impact of the group delay factors on the PPMs.

Therefore, the present study investigates and analysed the critical projects delay factors in public and private sectors by focusing on those most critical factors in Saudi Arabia and GCC regions. The analysis includes 5 steps: (1) Identifying, sorting, merging and grouping the factors most relevant to projects’ delay in Saudi Arabia and other developing countries that face considerable construction booms and have similar geographical and cultural characteristics, (2) Measuring the frequency and severity of the factors corresponded by all parties, (3) Investigating and analysing the relationships between the factors and performance measures, (4) Ranking the delay factors effectively, (6) Evaluating the impact of the grouped delay factors and (7) Verifying the process and validating the results. Brandon & Lu (2008) pointed out it is important to identify the dominant factors that lead to the project's time overrun so efforts can be concentrated on reducing them and improving the project management practices. This study aimed to improve the project main performance measures such as time, cost, safety, quality and environment; therefore, goals 2, 3, 4, 5, 6 and 7 have been identified and addressed in this Chapter:

Goal-2: To identify the main factors of delay in construction projects in KSA and other developing countries facing considerable construction booms that have similar geographical and cultural characteristics so efforts can be made to rank these factors and to provide more control to the PPMs.

Goal-3: To identify the extent to which the contractor, consultant and owner agree on the ranking of the importance of delay factors.

Goal-4: To measure the frequency of occurrence, the severity of impact and importance of construction delay factors in KSA.

Goal-5: To evaluate and build membership functions between the most critical delay factors and PPMs (time, cost, quality, safety and environment).

Goal-6: To identify and evaluate, if any, the inter-relationships between the most critical factors of delay to achieve more rational ranking.

Goal-7: To evaluate the grouped factors of delay (Critical Chains) with PPMs.

4.4 Research Plan

The research plan is a "structured set of guidelines or activities to assist in generating valid and reliable research results" (Mingers, 2001). The research plan sets out the procedures for the research, including decisions, assumptions and detailed methods for collecting and analysing data. Research also determines relationships amongst variables to expand existing knowledge for a specified purpose. Research is also a means to explore, describe, understand, explain, predict, change and evaluate the findings (Zikmund, Babin, Carr & Griffin, 2010). Creswell (2009) described the research design as a plan or proposal based on three elements: the philosophy paradigms, strategies or approaches of the research inquiry and the specific research methods.

Creswell (2009) and Denzin & Lincoln (2011) presented four different paradigms: (1) positivism, (2) constructivism, (3) participatory, and (4) pragmatism. The paradigm used in traditional research is the positivist paradigm, also called positivist research (Denzin & Lincoln, 2011). This method uses a systematic, scientific research approach (Hughes, 2001). Burrell & Morgan (2005) defined positivist research as research "which seeks to explain and predict what happens in the social world by searching for regularities and causal relationships between its constituent elements". Positivist researchers also is considered to be a deterministic philosophy as causes are believed to determine effects or outcomes (Creswell, 2009). One of the major goals of using positivism in the present research was to obtain valid and reliable knowledge as a set of universal principles that can explain, predict and control human behavior across the target sample. Thus, the positivist researcher takes a controlled and structural approach to conducting research by initially identifying a research topic, constructing appropriate research questions, adopting a suitable research approach, collecting data and analysing and interpreting the relationships between the variables.

While any research study aims to identify factors that influence an outcome, the positivist research approach is sufficient (Creswell, 2009). As the aim of the present research was to investigate the critical factors of delay that strongly impact the construction project processes that have effects on the outputs, and based on the research questions presented, this study adopted the positivist research approach.

The second element in a research methodology is the strategies or approaches of the research inquiry. The strategy of the research inquiry is the type of method used that provides a specific direction for the research design procedures (Creswell, 2009). Previously, inquiry strategies associated with quantitative research were closely linked to positivist research (Robson, 2011). More recently, quantitative strategies have involved complex studies with many variables explored through surveys (Bryman & Cramer, 2009). As the present study investigated the critical factors of delays that impact the Saudi Arabian construction projects, the quantitative approach was used.

The last element is the research method that involves the forms of data collection, analysis and interpretation to create the output of the research. The research design process for the present study is presented in Figure 4.2. A research design represents the "master plan that specifies the methods and procedures for collecting and analyzing the needed information" (Zikmund et al., 2010). The research design was divided into five stages based on the purpose of the present study.

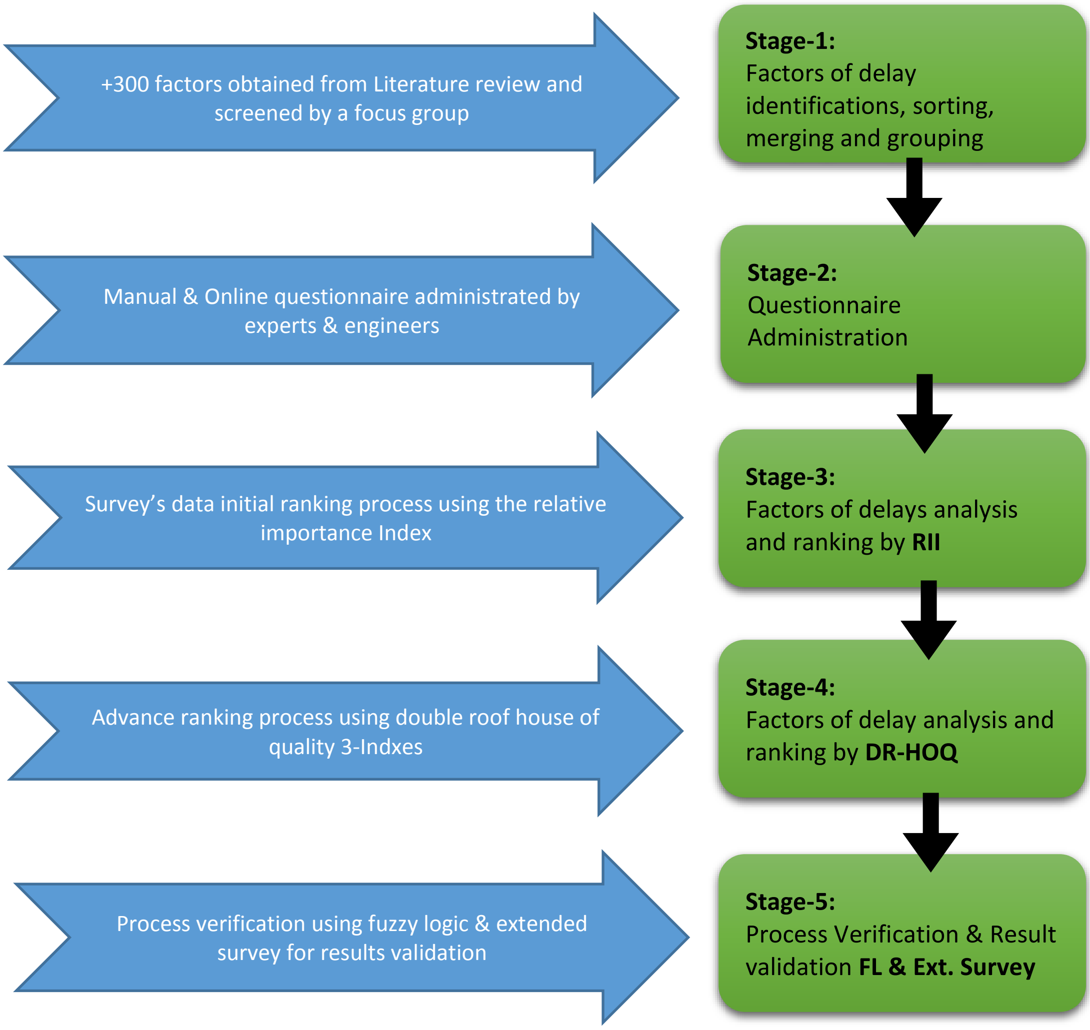


Figure 4.2: Master Plan of the Five Stages of the Research

In order to present clear ideas about delays in construction projects and to examine the hypotheses identified, it was decided to conduct the study in five stages.

The first stage was a comprehensive review of the relevant literature, starting with an overview of the countries concerned with the topic of this research. This stage shed light as well on all significant aspects of construction delays as covered by previous works and common concerns in the field of projects by picking hot-topics daily/weekly/monthly issues raised by newspapers, journal papers and international conferences. More than 300 factors of delay were identified from the literature, PM articles and projects practitioners, which were sorted, merged and grouped by a focus group. The long list of factors was reduced to 66 factors of delay through several sequential steps. These factors of delay were used in the questionnaire in stage-2.

The second stage was the administration of a questionnaire that would be used later to highlight and rank the main causes of construction delay in Saudi Arabia based on their severity of impact and frequency of occurrence.

The third stage was concerned with analysis of the data collected from the questionnaire. The analysis was performed using a reliable method that would determine the frequency and severity of each factor of delay representing all shared views in both online and manual surveys. After detailed reviews and after examining the adaptability of this tool to the inputs of the survey, it was determined that the Relative Important Index "RII" was the most suitable technique for this kind of analysis.

The 66-factors of delay required a further sensitivity analysis after it was realized that there are relationships between the inputs (Factors of Delay) and outputs (Project Performance Measures). Moreover, the inputs have interrelations between each other that would impact the ranking of the delay factors as well. Accordingly, the concept of double roof house of quality was created and developed by the author for communicating these relationships. This is what was covered in the fourth stage.

The fifth stage was concerned with verification and validation of the results. Due to the nature and behavior of the relationships between the inputs and outputs, it was necessary to adopt an effective tool or technique capable of dealing with the non-linearity of the relationships between the factors of delay. Fuzzy logic through MathLab software was chosen to be used in this stage for verifying the collective (group of factors) impact vs. the projects performance measures. An extended survey was used for validating singular impact of delay factors.

4.5 Research Methodology & Work Stages

The vast amount of delay factors that were obtained and analysed from selected previous studies, required sorting, merging and grouping them properly into five categories to avoid overlapping, repetition and randomness. To allow for a proper academic analysis, it was necessary to shorten the list from 300 factors to a quantifiable number that could be logically processed.

The research proceeded through the five stages outlined in the methodology section. Each stage had to be done in sequence in order to analyse the data in a progressive manner. Many focus group sessions were conducted during the first stage and the fourth stage of the research. The focus group included the author and six experts in the field of project management such as (project managers, contract directors, consultants, and clients) who have been working in either field projects or consultation services for more than 15 years. The following sections provide a short context for each stage that is going to be covered briefly in this chapter and with more comprehensive details in chapter five.

4.5.1 Stage-1: Identification of Delay Factors, Sorting, and Grouping

Three hundred and three factors of delays were identified from the literature review, project management related papers, articles and project practitioners. The factors were collected in a list and then organized. A copy of this list is included in Appendix A. The initial list had too many factors of delays that were interpreted in different forms; therefore, a sorting process was carried out by the author to avoid duplication. The updated list was developed to assure that no factor was repeated or partially included with other factors so each factor would be independent and reflect its relationship. After sorting, the list included 146 factors, and approximately 150 factors were eliminated. This analysis has addressed the remaining part of Goal-2.

Following the sorting process, the merging and categorization process was carried out by conducting the first two sessions of the focus group. The involvement of the focus group was necessary to avoid subjectivity and to insure the independence and the eligibility of the selection. The list was reduced after the merging process to 73 factors, which become easier for the categorization process.

The 73 factors were then categorized into 5 groups, in which each group is referred to individual party or authority. The groups were formed as follows:

- Contractor (Project Manager):
  - Material
  - Equipment
  - Manpower
  - Project management
- Engineer (Consultant)
  - Early planning and design
- Owner (Client)
  - Government regulations
  - External Factors

After the grouping process, the list of factors eventually was reduced to 66 critical factors of delay. Figure 4.3 shows how the factors of delays were reduced from more than 300 factors to 66 factors.

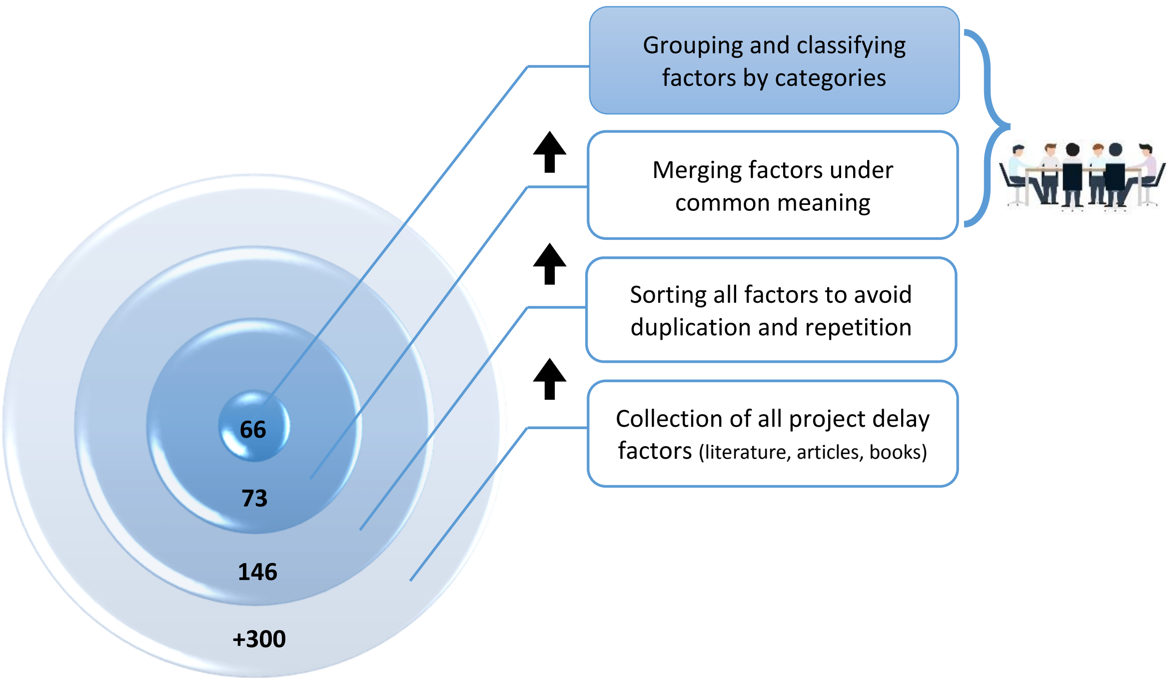


Figure 4.3: Identifying, Sorting, Merging, and Grouping Factors

Summary of construction delay factors

The factors of delay in construction projects concluded from the list have been examined and categorized. With the same categories used above, construction delay factors can be summarized as follows:

CONTRACTOR:

- **Materials**
  1. Shortage of required materials
  2. Delay in materials delivery
  3. Changes in materials prices
  4. Changes in materials specifications
- **Equipment**
  5. Shortage of required equipment
  6. Failure of equipment
  7. Inadequate equipment used for the works
- **Manpower**
  8. Shortage of manpower (skilled, semi-skilled, unskilled labor)
  9. Low skills of manpower
- **Project Management**
  10. Lack of motivation among contractor's members
  11. Shortage of contractor's administrative personnel
  12. Shortage of technical professionals in the contractor's organization
  13. Poor communications by the contractor with the parties involved in the project
  14. Contractor's poor coordination with the parties involved in the project
  15. Slow preparation of changed orders requested by the contractor
  16. Ineffective contractor head office involvement in the project
  17. Delays in mobilization
  18. Poor controlling of subcontractors by contractor
  19. Loose safety rules and regulations within the contractor's organization
  20. Poor qualifications of the contractor's technical staff assigned to the project
  21. Improper technical studies by the contractor during the bidding stage
  22. Ineffective planning and scheduling of the project by the contractor
  23. Delays to field survey by the contractor
  24. Ineffective control of project progress by the contractor

25. Inefficient quality control by the contractor
26. Delay in the preparation of contractor submissions
27. Improper construction methods implemented by the contractor

- **Project Finance**

28. Difficulties in financing the project by the contractor
29. Cash flow problems faced by the contractor
30. Problems between the contractor and his subcontractors with regard to payments

CUNSULTANT

31. Poor qualification of consultant engineer's staff assigned to the project
32. Delay in the preparation of drawings
33. Delay in the approval of contractor submissions by the consultant
34. Poor communication between the consultant engineer and other parties involved
35. Poor coordination by the consultant engineer with other parties involved
36. Delays in performing inspection and testing by the consultant engineer
37. Slow response from the consultant engineer to contractor inquiries
38. Inadequate design specifications
39. Poor contract management

OWNER

40. Client delay in furnishing and delivering the site to the contractor
41. Unrealistic contract duration
42. Delay in the settlement of contractor claims by the client
43. Suspension of work by the client's organization
44. Delay in issuing of change orders by the client
45. Slow decision making by the client's organization
46. Interference by the client in the construction operations
47. Uncooperative client complicating contract administration for the contractor
48. Delay in progress payments by the client
49. Client's poor communication with the construction parties and government authorities
50. Client's failure to coordinate with government authorities during planning
51. Poor coordination by the client with the various parties during construction
52. Excessive bureaucracy in the client's administration

Early Planning and Design

53. Changes in the scope of the project
54. Ambiguities, mistakes and inconsistencies in specifications and drawings
55. Subsurface site conditions differing materially from contract documents
56. Original contract duration too short

Government Regulations

57. Ineffective delay penalty
58. Difficulties in obtaining work permits
59. Government tendering system requirement for selecting the lowest bidding contractor
60. Changes in government regulations and laws

External Factors

61. Severe weather conditions on the job site
62. Effects of subsurface conditions (type of soil, utility lines, water table)
63. Traffic control and restrictions on the job site
64. Effects of social and cultural conditions
65. Rise in the prices of materials
66. Work interference between various contractors

4.5.2 Stage-2: Online/Manual Questionnaire

The survey method is a common tool used to collect primary data from a representative sample of individuals (Creswell, 2008). A questionnaire is a set of carefully designed questions given to a group of people in exactly the same form in order to collect the required data about a topic (Jupp, 2006). The questionnaire is an appropriate and accurate way to determine the responses of the participants (Fraenkel & Wallen, 2000).

4.5.2.1 Questionnaire Development

The questionnaire was designed to meet research goals 3, 4 and to test the first research hypothesis. According to this objective the survey was developed including four sections to confirm if the research problem exists, contractual arrangements and their impact to the delay, the performance of the project parties to the main PPMs (time, cost and quality). That last section was developed to measure the severity of impact & frequency of occurrence for the shortlisted 66 delay factors that needed to be analysed by RII for the initial ranking stage. A copy of this questionnaire is listed in Appendix B and C. Through its development, an effective questionnaire should address the objective of the question and the nature of the answer (De Vaus, 2002b). The development of the questionnaire in this study followed Leedy's (1997) four practical guidelines, which are using clear language, meeting research aims, planning development including distribution /collection and creating a solid cover letter. Thus, in order to have clear language as well as clear understanding of the questionnaire, the survey was written in two languages (English and Arabic), which is appropriate for the participants.

The information presented in the previous chapters helped to widen the author's knowledge and create an awareness of other issues that might not have been taken into account such as the repetition of some delay factors, grouping methods and the tools for analysis used for the ranking process. A provisional version of the questionnaire was then developed to cover all aspects needed to accomplish the purpose of the research. However, it was also necessary to ensure the questionnaire was reliable.

For this reason, a quality control process was undertaken to ensure that research Hypothesis 1, Goal 3 and Goal 4 are met within the context of the questionnaire. This was accomplished through a practical test in which project managers, engineers, consultants and clients were asked to fill in the questionnaire in order to examine the level of clarity. The quality control process ended with an approval procedure by the research supervisor. The aim of the questionnaire was to identify the most important factors of construction delay in KSA. It was also valuable for examining the grounds that may affect the factors of delay, including procurement methods and tendering arrangements. In addition, it was expected the respondents' knowledge and experiences would differ from one to another and that this might have an impact on their answers; therefore, attention was paid to addressing this point. A list of such ideas was considered when preparing the questionnaire. In order to present the questionnaire in a systematic way, it was decided to divide the questions into four sections:

1. Questions concerning the respondent's experience. This section contains general questions about the profession, period of experience, sector, type of work, specialty and the size of projects in which the respondent has participated.

2. Questions dealing with contractual arrangements, including procurement methods and tendering.
3. Questions concerning the performance of the projects in which the respondent has been involved, the number of projects in which the respondent has participated, including inquires of which ones were delayed and the average delay times. This section also contained questions about the average delay forgiven by clients, the party responsible for the delay and the five most important causes of delay. This section addressed the Research Goal 3.
4. Questions regarding the list of 66 factors of delay in construction projects. Four levels were used to calculate the frequency of occurrence and the degree of severity of each factor of delay. This section addressed the Research Goal 4.

4.5.2.2 Questionnaire Scale

There are many types of questions that could be used during the questionnaire development. A Likert scale is a psychometric scale commonly involved in research that employs questionnaires. It is the most widely used approach to scaling responses in a survey. Five ordered response levels are generally used (Dawes, 2008), although many researchers use seven or nine levels. In the present study, the questionnaire, in Part 1, 2 and 3, consisted of mixed types of questions, such as close-ended questions, multiple choices questions and comment box open-ended questions where a Likert scale question was mainly used in Part 4 . In Part 4 of the questionnaire as presented in Figure 4.4, a 4-point Likert scale were used. For example “Never=1”, “Occasionally=2”, “Frequently=3”, “Constantly =4” was used to measure the frequency of occurrence and “No Effect=1”, “Fairly severe=2”, “Severe=3”, “Very Severe=4” to measure the severity of impact. The advantages of using a Likert scale are that it is simple to construct, likely to produce a highly reliable scale and is easy for participants to read and complete.

4.5.2.3 Pilot Testing the Questionnaire

Zikmund (2010) defined pilot testing as the administration of a questionnaire to a small group of respondents to allow researchers to detect ambiguity or bias in the questions. It is essential the questionnaire components are tested in realistic situations to ensure the data collection will work. In the present study, the questionnaire was formulated to be clear and not long because a long questionnaire may prevent participants from responding. Length has been identified as a factor for an increased non-response rate (De Vaus, 2002b).

A pilot testing sample should be a group of respondents selected from the same target sample population as the study (Creswell, 2008; Zikmund et al., 2010). This way the pilot testing respondents should not be too different than the actual respondents.

In order to evaluate the clarity of the questionnaire as well as the feasibility of the survey as a whole, a pilot-test survey was conducted in order to identify any further need of revision. A sample of five respondents was selected to complete the survey in order to test the content validity of the questionnaire items. The questionnaires were distributed in the English language, based on the preference of the participants. The participants were given material informing them of the purpose of the research, the likely time it would take to complete the questionnaire, assurance the information provided would be confidential and a statement that the participation was voluntary, with their consent being assumed by their completion and submission of the survey instrument.

From the feedback provided by respondents, the average time taken to complete the questionnaire was approximately 16 minutes. It was therefore considered unnecessary to reduce the overall number of questions in the questionnaire to make it shorter.

A few changes were made on the questionnaire based on the pilot study results. These changes were related to the clarity of some statements and the possibility of choosing more than one answer for some questions. These five respondents, after participating in the pre-test, also participated in the final survey sampling. The final questionnaires for both online and manual approaches are presented in Appendix B.

4.5.2.4 Ideal Samples Size and Questionnaire Development Protocol

It is essential to determine the correct sample size and how many responses the research really needs. This simple point is a never-ending quandary for researchers. A larger sample can yield more accurate results, but excessive responses can be expensive. Sampling design and procedure are an important issue for the research design. De Vaus

(2002a) indicated good sampling and questionnaire design should produce an 80% response distribution. In selecting a valid and efficient sample for the present study, the sampling procedure, as outlined in seven stages developed by Zikmund (2003), was followed using slight modifications.

Consequential research requires comprehending the statistics that drive sample size decisions. A simple equation will help to confidently determine the sample size.

Before calculating the sample size, a number of characteristics about the target population and the sample required must be taken into consideration. Figure 4.4 illustrates the seven undertaken aspects related to the questionnaire development protocol.

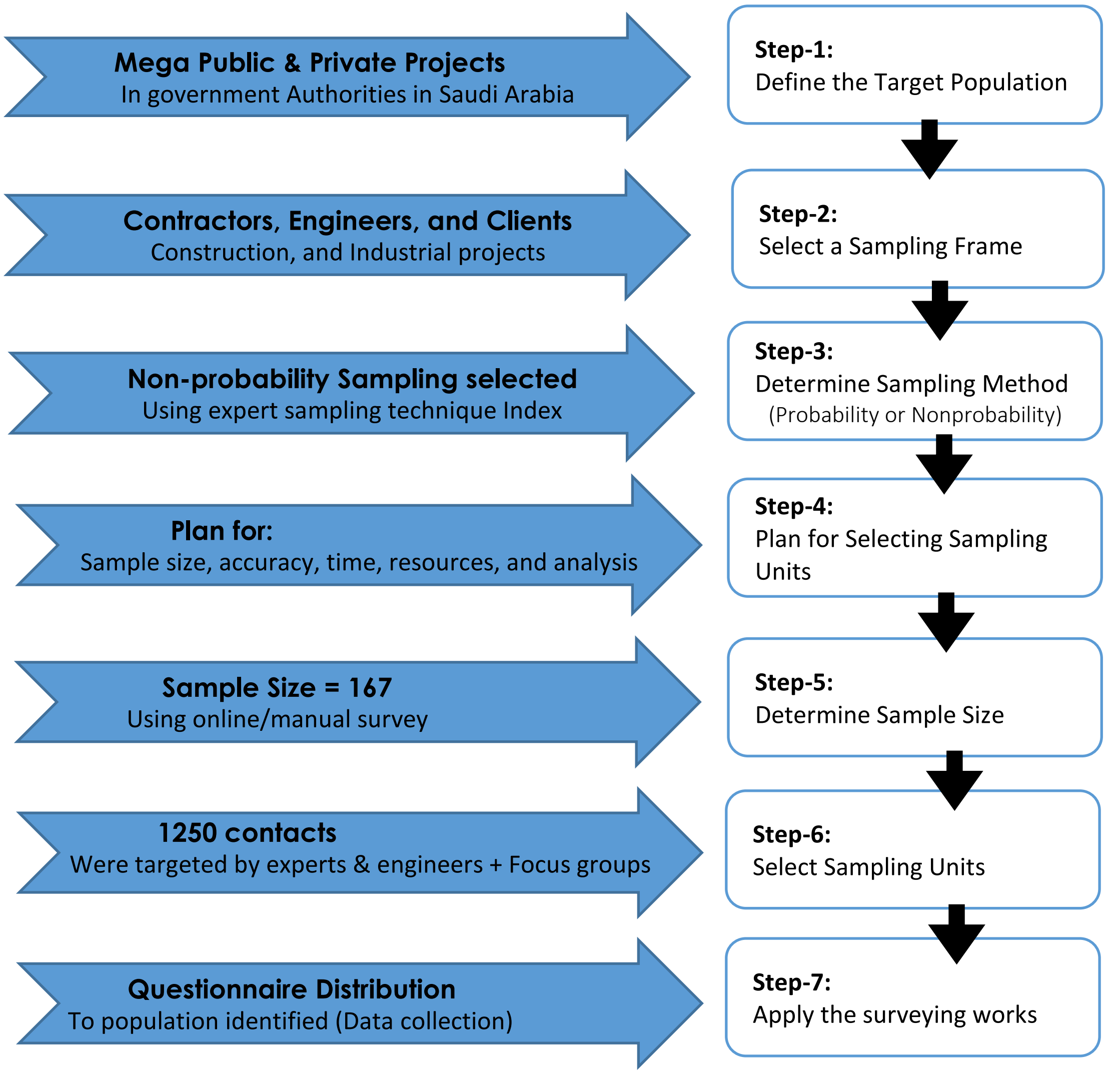


Figure 4.4: Seven Aspects of the Questionnaire Development Protocol

Step-1: Define the Target Population

Population Size — As shown in figure 4.4, the process starts with the identification of the population that the researcher wishes to investigate (Sekaran, 2003). The target population is the specific complete group relevant to the research project. As the present study targets public as well as large private construction and industrial projects in Saudi Arabia, the target population for this research was defined as the government authorities involved in public construction projects as well as the mega industrial projects owners in Saudi Arabia.

The questionnaires were distributed in the headquarters of government organizations and ministries as well as municipalities, consultants' offices and industrial zones authorities involved in the most public construction projects in Saudi Arabia. All the government organizations are located in the main cities of Saudi Arabia, which are Riyadh, Jeddah, and Dammam.

In the present research, the approximate number of senior projects managers, projects directors, projects consultants, owners, and managers of big contracting companies was estimated to be approximately 4000 persons. This figure was provided by the Jeddah Chamber of Commerce and represents the total number of professional engineers enrolled in 2016.

Step-2: Select a Sampling Frame

After the target population was identified, the next step involved creating the sample frame. According to Sekaran (2003), a sample frame, also called the working population, is the list of elements in the population from which a sample of study may be drawn. In this research, the sample frame was mostly engineers such as senior projects managers, projects directors, projects consultants, owners and managers of big contracting companies.

Step-3: Determine Sampling Method

It is very important to determine the sampling method after creating the sample frame. There are two methods of approach, which are the probability and non-probability approaches.

Non-probability sampling is a sampling technique where the odds of any member being selected for a sample cannot be calculated. It is the opposite of probability sampling, in which the odds can be calculated. In addition, probability sampling involves random selection, while non-probability sampling doesn't as it relies on the subjective judgement of the researcher. The samples in non-probability sampling are also gathered in a process that does not give all the individuals in the population equal chances of being selected.

Due to the time and cost constraints, the present study was conducted based on a sample representation of the target population. The study used a non-probability sampling technique as it included participants who were available and willing to participate in the study. Experts sampling is a non-probability sampling technique where subjects are selected because of their convenient accessibility and proximity to the researcher. Researchers generally use specified samples to obtain a reasonable number of completed questionnaires quickly and economically (Zikmund et al., 2010). In the present study, government agencies, project managers, project consultants and owners are the participants of the targeted sample drawn from the projects field in Saudi Arabia.

Step-4: Plan for Selecting Sampling Units

A sampling plan is outlined to determine the procedures in selecting sample size, and the methods in collecting data from the samples are studied in terms of timing and accuracy. The present study used a survey method in the form of administrating a questionnaire to collect data as well as conducting six organisational surveying within a 16 week collection period. The survey was conducted on-line and manually to ensure spreading the questionnaires to the widest range within the projects field. The data was checked and adjusted to provide for analysis at a later stage. The purpose of checking and adjusting data is to ensure the completeness, accuracy and reliability of the data before analysis takes place.

Step-5: Determine Sample Size

The sample size is the selected number of people to be chosen to represent the population. The sample should be large enough to answer the research questions

(Zikmund et al., 2010). The population of this research was composed of three categories: owners or their project representatives, consultant engineers or project supervisors and contractors or project managers who work in the construction sector within KSA.

The survey covered the main cities of Riyadh, Jeddah and Makkah as well as the Eastern Province. Samples were sent manually to approximately 50 employees and officials, and the rest were sent via the online questionnaire to reach a wider range of respondents.

Almost 1000 direct contacts were reached by e-mail addresses that were provided by the head office of the industrial authority in KSA. Moreover, the list included the author's professional contacts of approximately 250 persons. The questionnaire was also posted via the author's web-page on LinkedIn through the below link:
https://docs.google.com/forms/d/1KogOVS1ewYCbR2K4pmP5mIMF7VbyzDrekmfRpr596us/edit#responses

The total numbers of contacts made was more than 1250; however, the actual percentage of response was initially approximately 5-6%, despite the fact that participants were selected very carefully by taking into consideration their work fields and expertise. After frequent reminders, the response rate increased to 10%.

Generally, the excuses of contractors and consultants were mostly due to lack of time, while some others didn't bother to even read it. While all organization owners and supervisors selected for the survey were indeed involved in construction projects, the culture of contributing to a customer or an academic survey in Saudi Arabia apparently did not exist.

Before calculating the sample size, certain information about the target population and the sample was required:

- **The margin of Error** (Confidence Interval) — No sample will be flawless, so it is essential to decide how much error to allow. The confidence interval determines how much higher or lower than the population mean the research aims to let the sample mean fall. In the present research, by considering the population to be at 4,000, a margin of error of +/- 5% was used.

- **Confidence Level** — it must be determined how confident the researcher want to be so the actual mean falls within our confidence interval. The most common confidence intervals are 90% confident, 95% confident, and 99% confident. Here, it was assumed a 90% confidence level is acceptable and falls within the normal range.

- **Standard Deviation** — The standard of deviations refers to how much variance the researcher expects from the total responses. As the survey had not actually been administered in full yet, the safe decision is to use 0.5. This is the most forgiving number and ensures the samples will be large enough. Accordingly, most of the required values are defined for calculating the sample size.

- **Response Distribution --** Response distribution is the probability distribution of all answers by the target variable. If the sample is highly skewed one way or the other, it means the distribution will be higher or lower than 50%. As indicated by De Vaus (2002a), good sampling and questionnaire design should produce an 80% response distribution. In the present research, the targeted samples (respondents) were selected carefully to give a higher data accuracy. The selected samples were mostly experts with long experience in the field of the research which is highly expected to reach to the proposed response distribution at 80% unlike random sampling where the sample distribution is usually set at 50%.

- **Sample Size and Calculations** — The confidence level corresponds to a Z-score. This is a constant value needed for the equation. These are the z-scores for the most common confidence levels:
  - <u>90% – Z Score = 1.645</u> … This is confidence level used in the calculation.
  - 95% – Z score = 1.96
  - 99% – Z score = 2.576

  Next, the Z-score, standard of deviation and confidence interval were plugged into the following equation:

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

  The calculations follow, assuming that the research chooses a **90%** confidence level, **0.5** standard deviation, and a margin of error (confidence interval) of (**+/-5%)**, **80%** the response of the distribution and **4,000** is the targeted population.

Sample size of an infinite population (SS):

$$SS = \frac{(Z\text{-}score)^{2}\ x\ \text{St. Deviation}\ x\ (1\text{-St. Deviation})}{(\text{Margin of error})^{2}}$$

$$SS = \frac{(1.645)^{2}\ x\ (0.5\ x\ 0.5)}{(0.05)^{2}} = \frac{2.7\ x\ 0.25}{0.0025} = 270$$

Thus, 270 respondents are needed for the infinite population. The Correction of Sample Size (CSS) is to correct the number of the infinite sample size with respect to the targeted population. The sample size was corrected by representing the targeted population of 4,000 engineers with a standard response distribution equal to 50%.

$$CSS = \frac{(\text{SS})}{1 + \frac{\text{SS} - 1}{\text{Targeted Population}}} = \frac{270}{1 + \frac{270 - 1}{4000}} = \frac{270}{1 + 0.067} = \frac{270}{1.067} = 253$$

- CSS at 50% response distribution = **253** samples.
- CSS at 80% response distribution = **167** samples by using the online calculator.

The correct sample size was calculated using the sample size calculator at a response distribution equal to 80% as shown in Figure 4.5. The online sample size calculation can be found in the following link: http://www.raosoft.com/samplesize.html.

During the data collection, it was found that the ability to get more valuable responses was very complicated and time consuming. However, it was decided, after having the consent of the research supervisors, to conduct additional surveys that would cover the missing sample size (167) responses. Accordingly, six additional organisations were targeted which includes at last a six engineers in each one, who contributed individually to the manual survey. This attempt has added 36 more respondents to the total number of the sample size required to cover the gap of achieving 167 responses. Table 4.1 clarifies the total respondent's contribution.

TABLE 4.1: THE TOTAL RESPONDENT'S CONTRIBUTION

	Industrial list	**Personal list**	**Friends contacts**	**LinkedIn**	**Organisational surveying**	**Total**
Distributed	860	49	88	253	6	1250
Respondents	79	28	11	13	36	**167**
Sample Size	**167**					

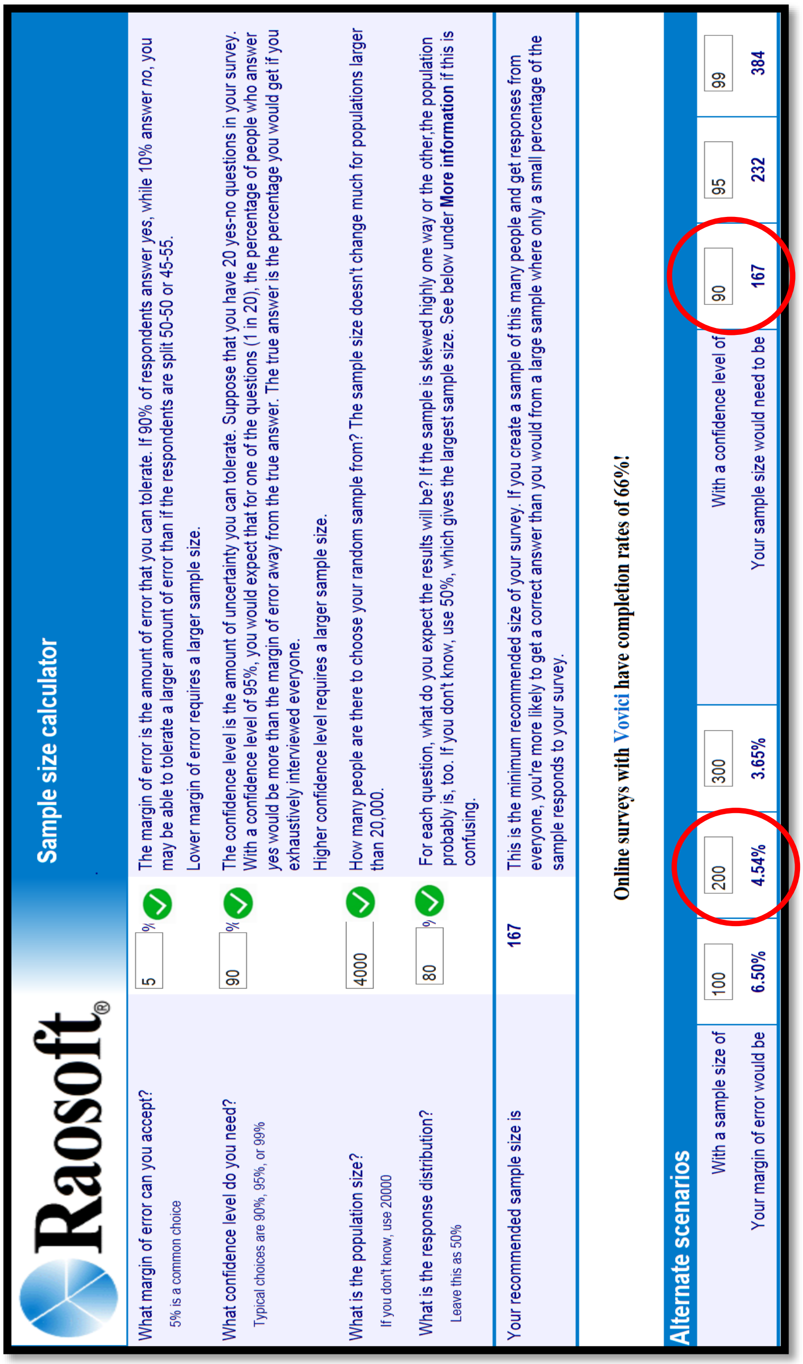


Figure 4.5: Screenshot of the Sample Size Calculator

Step-6: Selecting Sampling Units

The researcher should select the sampling unit to study before proceeding with the data collection (Zikmund et al., 2010). The sampling unit is a single element or group of elements subject to selection in the sample (Zikmund et al., 2010). As the present study targeted the clients who represented government agencies in public construction projects, the survey of the 167 clients represented the sample units for the present study.

Step-7: Apply the surveying works

In this final step, the researcher was ready to proceed with the final questionnaire writing as well as distribution and collection of the survey from the population identified.

The questionnaire was written in English and was distributed in KSA, which covered the regions of Jeddah, Makkah, Riyadh, and Eastern Province. The following points were addressed in order to obtain a high-level response:

- Forward a cover letter.
- Identify the type of research, sponsoring organization and the researcher's name.
- Explain the purpose and the benefits of the study.
- Encourage the participants to fill in the questionnaire in tactful language.
- Inform the participants that their name, department, or company name will not appear in the research.
- Structure the questionnaire in a smart and attractive form.
- Present the questionnaire in a multi-options format, limiting open questions to only one question.
- Keep the questionnaire as short as possible, but comprehensive enough so that it could be completed within 15 to 20 minutes.
- Because of the cultural differences between the regions, it was decided to use an appropriate distribution method for all regions.

Questionnaire Form to be distributed in Saudi Arabia

Project Completion: A Comparative Study of Construction Delay, Quality and Over Budget Factors in Saudi Arabia.

A part of the dissertation research for Ph.D. Industrial Engineering- Project Management; by Abdulwahab Abukwaik

Please respond to the following questions either by ticking the appropriate box or by writing your answer in the space provided.

The full copy of this questionnaire is available in Appendix **B** and **C**.

4.5.3 Stage-3: Factors of Delay Ranking by Applying RII

4.5.3.1 Introduction to RII (Relative Importance Index)

Data collected from the survey was analyzed using descriptive statistical techniques. An advanced and accurate analysis method was required to arrange the large amount of data in a systematic, fast and reliable way to address Goal 4. For this purpose, the Google online survey Statistical computing and Excel-Office were chosen as the best options available.

Many tools could be used for ranking the delay factors such as importance index, severity index, frequency index, multiple regression analysis, rank correlation coefficient, mean square and others. However, the relative importance index (RII) was found to be an effective tool to prioritize the data according to their severity and frequency. The RII method was commonly used in previous research work when the authors attempted to implement a statistical ranking process. For example, Kometa et al. (1994) and Assaf et al. (1995) were the first who used the RII method to determine the relative importance of the various causes and effects of delays. As indicated in Chapter 2, tables 2.4 and 2.5, the RII was perceived an effective tool for ranking the delay factors by most of the authors after conducting the research's survey (Chan & Kumaraswamy, 1997; Odeh & Battaineh, 2002; Sambasivan & Soon, 2007; Assaf & Hejji, 2006; Fugar & Agyakwah, 2010; Mahamid et al., 2012; Al-Sabah et al., 2012; Arentes et al., 2015).

4.5.3.2 RII (Relative Importance Index)

RII combined both effects of frequency of occurrence and severity of impact for each factor of delay. Table 4.2 below illustrates how the applicant rates the level of frequency & severity based on previous experience. This section has addressed Goal 4.

TABLE 4.2: FREQUENCY AND SEVERITY WEIGHTING

Scale	Frequency (F)	Weight	Severity (S)	Weight
1	Never	1	No effect	1
2	Occasionally	2	Fairly severe	2
3	Frequently	3	Severe	3
4	Constantly	4	Very severe	4

In part-four of the survey, the respondents were asked to determine the factors regarding their frequency and severity weights. The scales provided ranges from 1 to 4, as shown in Table 4.2. However, in order to launch a quantitative measure of the frequency and the severity, it was decided to weight both "Frequency & Severity" equally during the analysis of RII. The average score or the Frequency Index (FI) and Severity Index (SI) for each delay factor were calculated as per the following formulae:

A. RII Technique: This technique allows for the calculation of the RII according the (Wi) which represents the average value of frequency and severity for each factor from the survey. The four-point scale ranging from 1 (very little degree affect) to 4 (very high degree affect) was adopted and transformed to RII for each factor as follows:

RII = $\sum_{i}^{N}\left(\frac{\mathrm{W}i}{\mathrm{A}\;x\;\mathrm{N}}\right)$ --- (1)

Where, Wi is the weighting given to each factor by the respondents (ranging from 1 to 4), A is the highest weight (i.e. 4 in this case), and N is the total number of respondents. The higher the value of RII, more important is the factors of delay.

A second technique which uses frequency index and severity index was adopted in this study using the data collected from the survey, which was parented and analysed as illustrated in Table 4.3. The formulae are shown below.

B. Importance Index Technique: In this technique, for each cause/factor, two questions were asked: What is the frequency of occurrence for this factor? And what is the degree of severity of this factor on project delay? Both frequency of occurrence and severity of impact were categorized on a four-point scale. Frequency of occurrence was categorized as follows: always, often, sometimes and rarely (on a 4 to 1 point scale). Similarly, degree of severity was categorized as follows: extreme, great, moderate and little (on a 4 to 1 point scale).

1- Frequency index: A formula was used to rank factors of delay based on frequency of occurrence as identified by the participants.

Frequency Index (F.I.) (%) = $\sum_{1}^{\mathrm{N}} a\;x\;\left(\frac{(\mathrm{n})}{\mathrm{N}}\right) x\;100$ ----------------- (2)

Where a is the constant expressing weighting given to each response (ranges From 1 for rarely up to 4 for always), n is the frequency of the responses and N is total number of responses.

2- Severity index: A formula was used to rank factors of delay based on severity as indicated by the participants.

Severity Index (S.I.) (%) = $\sum_{1}^{N} a \; x \; \left(\frac{(n)}{N}\right) x \; 100$ -------------------- (3)

Where a is the constant expressing weighting given to each response (ranges from 1 for little up to 4 for severe), n is the frequency of the responses and N is total number of responses.

3- Importance index: The importance index of each cause was calculated as a function of both frequency and severity indices, as follows:

Importance Index (IMPI) (%) = $\left(\frac{(\text{F.I.} \; x \; \text{S.I.})}{100}\right)$-------------------------- (4)

A total of 66 well-recognized factors of delay were identified and provided in the survey form. Defining the importance degree of each factor was considered as it leads to the main objectives of this survey. The respondents were asked to calculate the level of frequency and severity of each factor using the range of weights provided.

The following parts present and analyze the data collected regarding the frequency and severity of the factors. Different types of ranking analysis are presented and analyzed in Chapter 5. The importance-based ranks include the total answers of each professional group (contractors, consultants, owners).

The analysis of ranking focused directly on the importance of factors rather than ranking them according to frequency and severity. However, because of the significant value of presenting the rank of factors based on the frequency and severity separately, tables showing the ranked factors based on frequency and severity in details and it is presented in Appendix **F**.

The importance of each factor was the consequence of integration between frequency and severity of that factor. The method of gathering the weight of frequency and severity of each factor is explained in Table 4.3, and several abbreviations are introduced by the sides of the table.

TABLE 4.3: FULL LIST-FACTORS OF DELAY WITH RII ANALYSIS

Party involved in factor of delay

Factors of delays

Frequency Index %

Severity Index %

RII – Relative Index %

Ranking of factors

Factors involved by party

No.	Factor Category	Factors of Delay	Frquency				F.I.		Severity				S.I.		RII	Risk	Points
			1	2	3	4	Rate	%	1	2	3	4	Rate	%	Overall %	Order	
13	Contractor - PM	13. Shortage of technical professionals in the contractor's org.	4	11	16	**10**	2.9231	73.08%	2	11	16	10	2.8718	71.79%	52.47%	1	65
	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	1	16	17	5	2.6667	66.67%	0	10	19	10	3	75.00%	50.00%	2	
	Contractor - PM	22. Ineffective planning & scheduling of the project by the contractor	3	10	**24**	2	2.641	66.03%	1	7	21	10	3.0256	75.64%	49.94%	3	
	Contractor - PM	19. Loose safety rules & regulations within the contractor's org.	2	12	19	6	2.7436	68.59%	2	13	11	13	2.8974	72.44%	49.68%	4	
	Contractor - PM	21. Improper technical studies by the contractor during bidding stage	3	14	17	5	2.6154	65.38%	1	13	9	**16**	3.0256	75.64%	49.46%	5	
	Early plan & Design	53. Changes in the scope of the project	3	19	8	9	2.5897	64.74%	2	12	11	14	2.9487	73.72%	47.73%	6	
	Contractor - PM	20. Poor qualifications of contractor's tech. staff assigned to the project	4	13	16	6	2.6154	65.38%	1	13	14	11	2.8974	72.44%	47.36%	7	
	Contractor - PM	14. Contractor's poor coordination with parties' invol. in project	5	14	15	5	2.5128	62.82%	3	6	19	11	2.9744	74.36%	46.71%	8	
	Client	45. Slow decision making by the client's organization	4	18	11	6	2.4872	62.18%	2	12	11	14	2.9487	73.72%	45.84%	9	
	Early plan & Design	54. Ambiguities, mistakes, and inconsistencies in specs & drawings	3	19	13	4	2.4615	61.54%	2	11	12	14	2.9744	74.36%	45.76%	**10**	
	Contractor - PM	15. Slow preparation of changed orders requested by contractor	3	13	18	5	2.641	66.03%	2	12	18	7	2.7692	69.23%	45.71%	11	
	Contractor - MP	10. Low skill of manpower	3	14	19	3	2.5641	64.10%	0	13	19	7	2.8462	71.15%	45.61%	12	
	Contractor - PM	24. Ineffective control of project progress by the contractor	2	18	15	4	2.5385	63.46%	0	14	16	9	2.8718	71.79%	45.56%	13	
59	Gov. Regulation	59. Gov. tendering system of selecting the lowest bidding contractor	7	10	13	9	2.6154	65.38%	5	9	15	10	2.7692	69.23%	45.27%	14	52
38	Consultant	38. Inadequate design specifications	3	21	11	4	2.4103	60.26%	1	14	8	16	3	75.00%	45.19%	15	
	Consultant	[illegible]. Poor contract management	1	23	10	5	2.4872	62.18%	2	12	14	11	2.8718	71.79%	44.64%	16	
	Client	42. Delay in the settlement of contractor claims by the client	2	20	11	6	2.5385	63.46%	2	13	15	9	2.7949	69.87%	44.34%	17	
	Contractor - PF	29. Cash flow problems faced by the contractor	3	24	6	6	2.3846	59.62%	1	12	13	13	2.9744	74.36%	44.33%	18	
	Contractor - PM	25. Inefficient quality control by the contractor	2	20	12	5	2.5128	62.82%	1	13	17	8	2.8205	70.51%	44.30%	19	
	Client	41. Unrealistic contract duration	4	18	12	5	2.4615	61.54%	3	13	9	14	2.8718	71.79%	44.18%	20	
	Client	44. Delay in issuing of change orders by the client	2	20	12	5	2.5128	62.82%	1	14	16	8	2.7949	69.87%	43.89%	21	
	Client	48. Delay in progress payments by the client	3	20	11	5	2.4615	61.54%	2	14	11	12	2.8462	71.15%	43.79%	22	
	Contractor - PM	11. Lack of motivation among contractor's members	2	21	13	3	2.4359	60.90%	0	14	16	9	2.8718	71.79%	43.72%	23	
	Consultant	33. Delay in the approval of contractor submissions by the consultant	3	21	11	4	2.4103	60.26%	1	15	11	12	2.8718	71.79%	43.26%	24	
	Contractor - PF	28. Difficulties in financing the project by the contractor	5	20	12	2	2.2821	57.05%	3	8	13	15	3.0256	75.64%	43.15%	25	
	Contractor - PM	18. Poor controlling of subcontractors by contractor	5	17	12	5	2.4359	60.90%	2	15	10	12	2.8205	70.51%	42.94%	26	
2	contractor - M	2. Delay in materials delivery	1	20	16	2	2.4872	62.18%	2	14	15	8	2.7436	68.59%	42.65%	27	39
30	Contractor - PF	30. Problems between the contractor and his subcontractors with regard	4	20	10	5	2.4103	60.26%	1	16	12	10	2.7949	69.87%	42.10%	28	38
56	Early plan & Design	56. Original contract duration is too short	4	17	16	2	2.4103	60.26%	2	13	16	8	2.7692	69.23%	41.72%	29	
12	Contractor - PM	12. Shortage of contractor's administrative personnel	3	21	12	3	2.3846	59.62%	2	14	13	10	2.7949	69.87%	41.65%	30	
4	contractor - M	4. Changes in materials specifications	2	22	11	4	2.4359	60.90%	0	19	12	8	2.7179	67.95%	41.38%	31	
31	Consultant	31. Poor qualification of cons. engineer's staff assigned to the project	2	23	10	4	2.4103	60.26%	1	15	16	7	2.7436	68.59%	41.33%	32	
34	Consultant	34 Poor com. between the consultant engineer and other parties involved	5	21	8	5	2.3333	58.33%	1	15	14	9	2.7949	69.87%	40.76%	33	
35	Consultant	35. Poor coordination by the cons. engineer with other parties involved	3	23	9	4	2.359	58.97%	1	16	14	8	2.7436	68.59%	40.45%	34	
51	Client	51. Poor coordination by the client with the various parties during const.	3	24	9	3	2.3077	57.69%	1	14	18	6	2.7436	68.59%	39.57%	35	
43	Client	43. Suspension of work by the client's organization	5	22	8	4	2.2821	57.05%	2	15	12	10	2.7692	69.23%	39.50%	36	
52	Client	52. Excessive bureaucracy in the client's administration	6	18	11	4	2.3333	58.33%	3	13	16	7	2.6923	67.31%	39.26%	37	
60	Gov. Regulation	60. Changes in government regulations and laws	5	20	13	1	2.2564	56.41%	2	11	**20**	6	2.7692	69.23%	39.05%	39	
50	Client	50. Client's failure to coordinate with gov. authorities during planning	3	24	11	1	2.2564	56.41%	1	15	15	8	2.7692	69.23%	39.05%	38	
58	Gov. Regulation	58. Difficulties in obtaining work permits	6	21	8	4	2.2564	56.41%	2	13	17	7	2.7436	68.59%	38.69%	40	
16	Contractor - PM	16. Ineffective contractor head office involvement in the project	2	25	10	2	2.3077	57.69%	1	16	17	5	2.6667	66.67%	38.46%	41	25
46	Client	46. Interference by the client in the construction operations	4	21	10	4	2.359	58.97%	2	19	11	7	2.5897	64.74%	38.18%	42	
32	Consultant	32. Delay in the preparation of drawings	4	23	11	1	2.2308	55.77%	1	17	13	8	2.7179	67.95%	37.89%	43	
49	Client	49. Client's poor com. with the construction parties and gov. authorities	4	24	9	2	2.2308	55.77%	2	16	13	8	2.6923	67.31%	37.54%	44	
37	Consultant	37. Slow response from the cons. engineer to contractor inquiries	3	25	7	4	2.3077	57.69%	1	19	14	5	2.5897	64.74%	37.35%	46	
26	Contractor - PM	26. Delay in the preparation of contractor submissions	2	25	10	2	2.3077	57.69%	0	**21**	13	5	2.5897	64.74%	37.35%	45	
47	Client	47. Uncooperative client with the contractor complicating contract administra	4	24	9	2	2.2308	55.77%	2	17	13	7	2.641	66.03%	36.82%	47	
55	Early plan & Design	55. Subsurface site conditions materially differing from contract docum.	3	24	11	1	2.2564	56.41%	4	14	15	6	2.5897	64.74%	36.52%	48	
23	Contractor - PM	23. Delays to field survey by the contractor	4	20	13	2	2.3333	58.33%	3	18	14	4	2.4872	62.18%	36.27%	49	
40	Client	40. Delay in furnishing & delivering the site to the contractor by client	4	22	10	3	2.3077	57.69%	2	21	10	6	2.5128	62.82%	36.24%	50	
5	contractor - EQ	5. Shortage of required equipment	10	21	7	4	2.2821	57.05%	3	16	16	4	2.5385	63.46%	36.21%	51	
66	External factors	66. Work interference between various contractors	4	**26**	8	1	2.1538	53.85%	2	15	16	6	2.6667	66.67%	35.90%	52	
62	External factors	62. Effects of subsurface conditions (type of soil, utility lines, water table)	5	23	9	2	2.2051	55.13%	4	15	13	7	2.5897	64.74%	35.69%	53	
1	contractor - M	1. Shortage of required material	4	24	10	1	2.2051	55.13%	4	13	19	3	2.5385	63.46%	34.99%	54	12
57	Gov. Regulation	57. Ineffective delay penalty	5	23	10	1	2.1795	54.49%	4	15	14	6	2.5641	64.10%	34.93%	55	11
27	Contractor - PM	27. Improper construction methods implemented by contractor	5	26	7	1	2.1026	52.56%	1	20	11	7	2.6154	65.38%	34.37%	56	
65	External factors	65. Rise in the prices of materials	5	24	7	3	2.2051	55.13%	4	16	15	4	2.4872	62.18%	34.28%	57	
36	Consultant	36. Delays in performing inspection and testing by the cons. engineer	2	26	8	1	2.1026	52.56%	2	20	12	5	2.5128	62.82%	33.02%	58	
8	contractor - EQ	8. Inadequate equipment used for the works	9	20	9	1	2.0513	51.28%	2	18	14	5	2.5641	64.10%	32.87%	59	
3	contractor - M	3. Changes in materials prices	7	21	9	2	2.1538	53.85%	4	18	13	4	2.4359	60.90%	32.79%	60	
7	contractor - EQ	7. Shortage of supporting and shoring installations for excavations	8	23	6	2	2.0513	51.28%	5	18	10	6	2.4359	60.90%	31.23%	61	
6	contractor - EQ	6. Failure of equipment	11	20	4	4	2.0256	50.64%	**7**	12	13	6	2.4103	60.26%	30.51%	62	
63	External factors	63. Traffic control and restrictions on the job site	7	24	7	1	2.0513	51.28%	6	17	12	4	2.359	58.97%	30.24%	64	
17	Contractor - PM	17. Delays in mobilization	6	27	4	2	2.0513	51.28%	6	17	12	4	2.359	58.97%	30.24%	63	
61	External factors	61. Severe weather conditions on the job site	11	20	7	1	1.9487	48.72%	4	21	11	3	2.3333	58.33%	28.42%	65	
64	External factors	64. Effects of social and cultural conditions	**15**	18	5	1	1.7949	44.87%	**7**	23	8	1	2.0769	51.92%	23.30%	66	
							Range	44.9 -73.1%						51.9-75.6%	23.3% - 52.5%		

Party of Delay	RII Scores 66 Factors	RII%	TOP 10	TOP 15	TOP 20
Contractor weight:	1515	70.6%	7 factors	10 factors	12 factors
Consultant Weight:	279	13.0%	0	1 factor	2 factors
Client Direct Weight:	260	12.1%	1 factor	1 factor	3 factors
Client-A Early plan & Desi	46	2.1%	2 factors	2 factorr	2 factors
Client-B Gov. Regulation	30	1.4%	0	1 factor	1 factor
External factors	15	0.7%	0	0	0
Total	**2145**	100%			

4.5.3.3 Linear & Nonlinear Behaviors between the Delay Factors & PPMs

As a result of the process of ranking by using the RII, the factors of delays were ranked, and each factor has its own order in the list. Factors that were evaluated with high frequency and severity were given higher values in comparison to those appearing less frequently and with less severe impacts on the projects.

Goal 5 of the research was addressed to critically analyze the relationships of contractors, consultants, and owners with PPMs, i.e. time, cost, quality, safety and environment and then to apply sensitivity analysis for identifying the relationships between the most critical factors of delays and their degree of relevance to achieve a more practical ranking of these factors.

In this study and in the course of the focus group sessions for sorting, grouping and evaluating the factors of delays according to the PPMs, it was discovered many factors have nonlinear relationships with respect to the PPMs. Accordingly, the second hypothesis of this research has been tested as a number of delay factors presented non-linear relationships with the 5-PPMs. The values of these relationships are presented in the next section 4.5.4.3 under the title of Filling in the DR-HOQ. Most of the previous studies in the literature reviewed assumed the relationships are usually linear and generally expressed the relationships with constant values or grades. This present study has a novel concept for revealing the existence of nonlinear relationships between factors of delay and PPMs. Figures 4.6.A, 4.6.B and 4.6.C illustrate three examples of non-linearity relationships occurring between some factors of project delays and the PPMs.

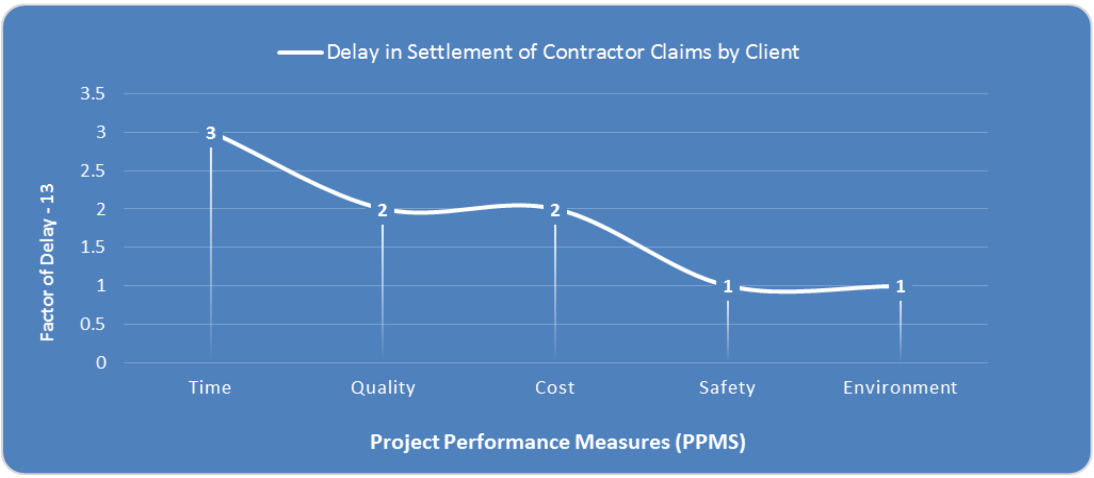


Figure 4.6.A: Non-linear Relationship between Delay Factor-13 and Performance Measures

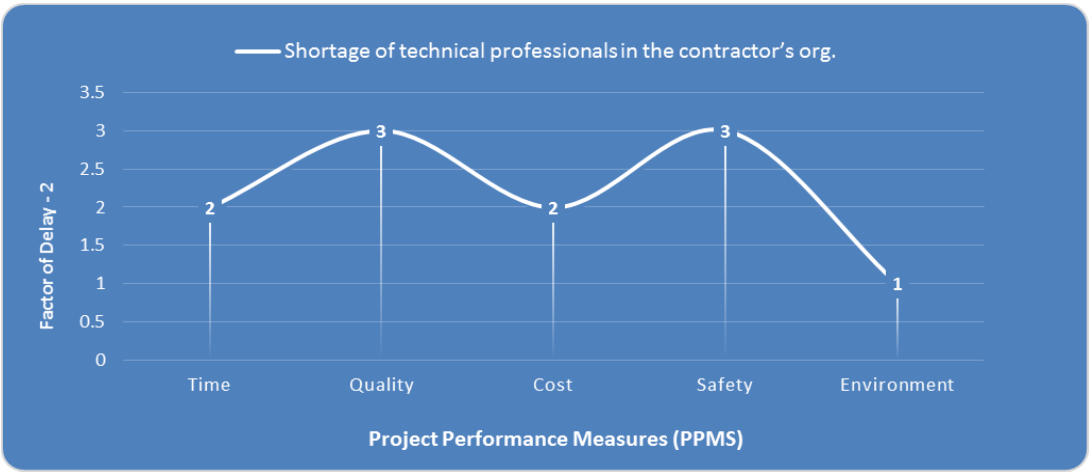


Figure 4.6.B: Non-linear Relationship between Delay Factor-2 and Performance Measures

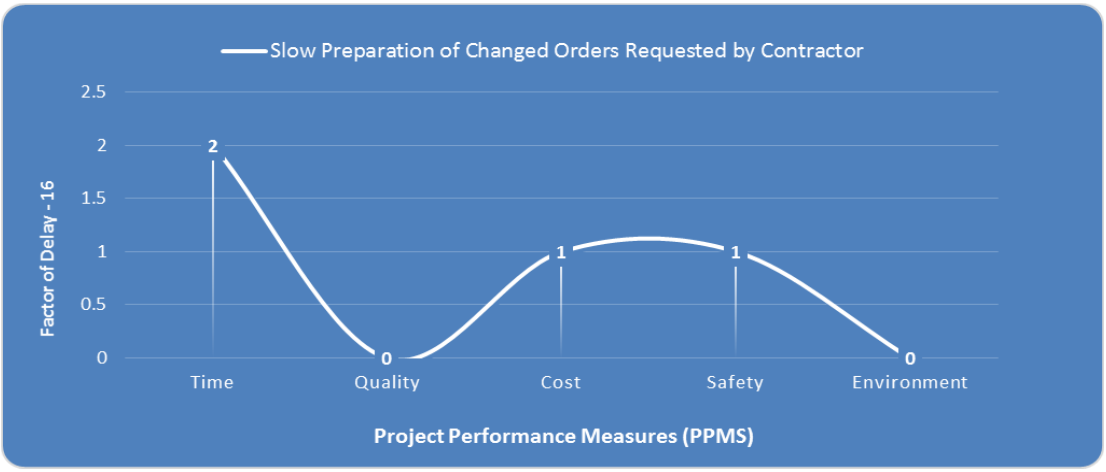


Figure 4.6.C: Non-linear Relationship between Delay Factor-16 and Performance Measures

In mathematics, nonlinear programming is the process of solving an optimization problem defined by a system of equalities and inequalities and collectively termed constraints over a set of unknown real variables and along with an objective function to be maximized or minimized, where some of the constraints or the objective function is nonlinear. It is the sub-field of mathematical optimization that deals with non-linear problems.

A typical non-convex problem is that of optimizing transportation costs by selecting from a set of transportation methods, one or more of which exhibit economies of scale, with various connectivity and capacity constraints. An example would be petroleum product transport given a selection or combination of pipeline, rail tanker, road tanker, river barge or coastal tank ship. Owing to economic batch size, the cost functions may have discontinuities in addition to smooth changes.

Modern engineering practice involves much numerical optimization. Except in certain narrow but important cases such as passive electronic circuits, engineering problems are non-linear, and they are usually very complicated.

In experimental science, some simple data analysis (such as fitting a spectrum with a sum of peaks of known location and shape but unknown magnitude) can be done with linear methods, but in general, these problems, also, are non-linear. Typically, one has a theoretical model of the system under study with variable parameters in it and a model of the experiment or experiments, which may also have unknown parameters. One tries to find the best fit numerically. In this case, one often wants a measure of the precision of the result, as well as the best fit itself.

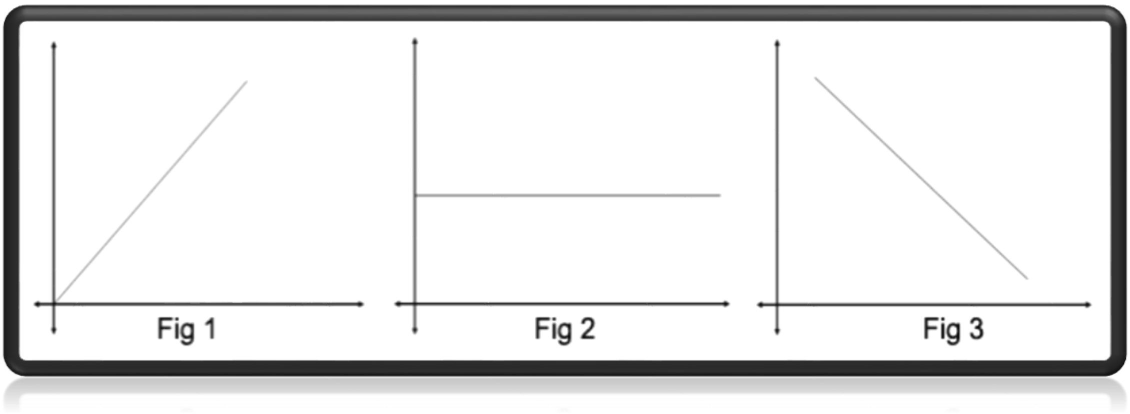


Figure 4.7: Linear Graphs

The linear relationship happens if two variables as shown in Figure 4.7: (1-3) result in a straight line as the relationship between two variables. This straight line relationship happens due to constant change without any additional factors.

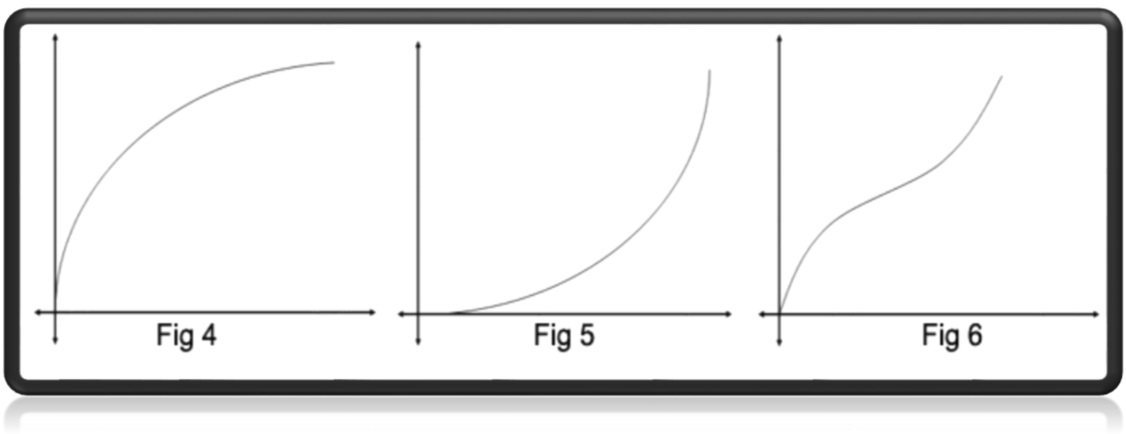


Figure 4.8: Non-Linear Graphs

A nonlinear relationship occurs if two variables, as shown in Figure 4.8: (4-6) result in a curve formation rather than a straight line then, two variables are said to have curvilinear or non-linear relationship. This happens when the rate of change in the dependent variable is not constant for a unit change in an independent variable(s). This can happen due to a number of factors. For example, business activity of any kind is not undertaken in a closed system or simply in isolation; hence, variables like engineering characteristics, government regulations and human decisions affect the relationship between delay factors and time, cost and quality and thus it will not be in a linear form.

The majority of behaviors in real life are of curvilinear nature; that is, they depict non-linear relationships in terms of environmental factors (for example inflation) and also when observed over a longer range of time. The linear relationships are used to understand the real behavior as it is much easier to describe. The present study requires a suitable analytical tool or simulation process to translate these relationships in terms of values. The House of Quality (HOQ) was found to be a useful tool for the study and also fits the purpose to achieve the objective of the research. In industrial engineering, the process is called the Quality Function Deployment (QFD).

4.5.4 Stage-4: Double Roof House of Quality DR-HOQ

4.5.4.1 Introduction to House of Quality

The HOQ Matrix is the most recognized and widely used tool for modelling non-linear behaviors between the engineering characteristics (ECs) and customer attributes (CAs) of a system or product. The process is QFD, which translates customer requirements based on marketing research and benchmarking data into an appropriate number of engineering targets to be met by a new product design. Basically, it is the nerve center and the engine that drives the entire QFD process (Zheng & Chin, 2005). According to Hauser and Clausing (1988), it is “a kind of conceptual map that provides the means for inter-functional relations and communication.” There are many different forms of the HOQ, but its ability to be adapted to the requirements of a particular problem make it a very strong and reliable system to use. Its general format is made up of six major components. These include customer requirements, technical requirements, a planning matrix, an interrelationship matrix, a technical correlation matrix and a technical priorities/benchmarks and targets section.

The HOQ is a diagram or structure similar to the one of a house that helps to determine how a product or service is living up to customer needs. Although quite intricate, the diagram is capable of storing a lot of information and comparing large amounts of data used for defining the non-linear relationship between customer desires and the system/product capabilities. It is a part of QFD and adopts a planning matrix or correlation matrix to relate what the customer wants to how a firm that delivers the products or service is going to meet those wants. It looks like a house with a correlation matrix as its roof, the customer wants versus product or technical features as the main structure, competitor evaluation as the porch, etc. It is based on the belief that products or services should be designed to reflect customers' desires and tastes. It is also reported to increase cross-functional integration within organizations using it, especially in marketing, engineering and manufacturing.

The basic structure is a table with "Whats" as the labels on the top and "Hows" on the left. The roof is a diagonal matrix of "Hows vs. Hows" or “Whats vs Whats”, and the body of the house is a matrix of "Whats vs. Hows". Both of these matrices are filled with indicators of whether the interaction of a specific item is a strong positive, a strong negative, or somewhere in between.

Additional annexes on the right side and bottom hold the "Whys" (market research, etc.) and the "How Much". Rankings based on the “Whys” and the correlations can be used to calculate priorities for the “Hows” (Carnevalli & Miguel, 2008). Figure 4.9 shows the first roof is fixed on the top of the structure to reflect the relationship between the customer's attributes or the PPMs in the present study.

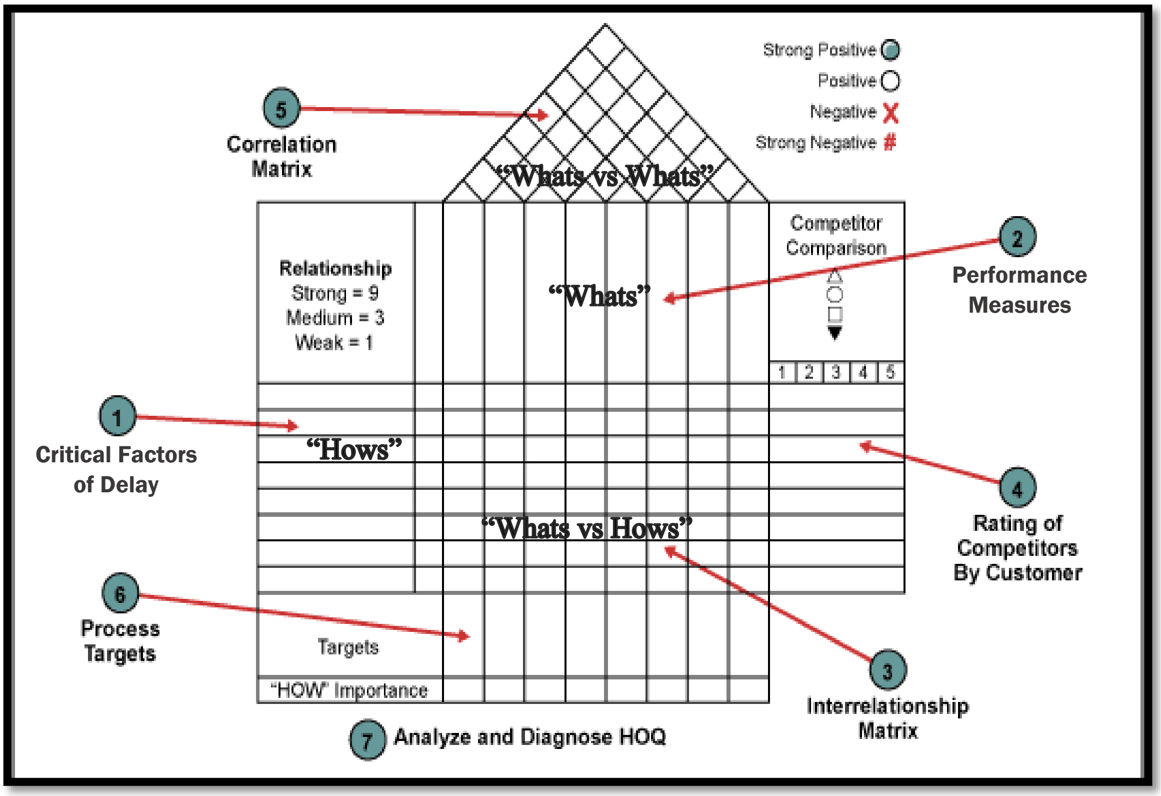


Figure 4.9: Single Roof House of Quality

(Source: http://aplg-planetariums.org/house-of-quality-template)

The single-roof house of quality described both relationships between "Hows" and "Whats" in the main structure, i.e. 0, l, 2 and 3, while the second relationships or the correlation matrix have been built on the top roof between the "Whats" vs. "Whats" (Performance Measures) i.e. nothing, low, medium and high.

4.5.4.2 HOQ Step of Development to DR-HOQ

HOQ analysis can also be cascaded, with "Hows" from one level becoming the "Whats" of a lower level; as this progresses, the decisions are more related to the engineering and manufacturing details. A modified approach was developed by the author and then published successfully in the 5th International Conference of Civil Structure, Rome – 2017 (Abukwaik, et al., 2017).

The newly developed approach is called Double Roof House of Quality (DR-HOQ). This concept has a unique principle for representing the dual impacts of inter-relationships at the same time. In other words, the embedded relationships between the factors of delays would be represented by one roof and the same thing for the PPMs in a second roof so that it can consider both “Hows” vs. “Hows” and “Whats” vs.” Whats”, especially if the relationships between them are strong and effective.

Similarly, this concept, which was applied in the present study, seems to be very new and innovative. During the literature review, which has covered more than 60 different publications with regard to projects delays, there was no any similar approaches or mechanisms applied. Accordingly, there were no investigated attempts to analyze the relationships between the technical delay factors.

After the initial ranking for the factors of delay by applying the RII method and during the deep analysis for the process of factors of delays’ ranking, it became very obvious that some factors have non-linear relationships with PPMs, i.e. time, cost, quality, safety and environment. A conceptual mechanism is required to be able to understand and predict the relationships (Zikmund et al., 2010). As anticipated earlier, those factors had relationships between each other, which pushes the author for further sensitivity analysis to test Hypothesis 2.

The DR-HOQ was intended to be applied after the RII analysis to create additional indices for re-ranking optimization to address Goals 5 and 6. The DR-HOQ method has mostly covered all relationships contributed toward prioritizing factors of delays in a detailed analysis by combining three indices. Each index has its own weight to use to interpret each effect separately for this prioritization. Figure 4.10 shows both roofs. The first roof is fixed on the top of the structure to represent the relationships between the customer's attributes and PPMs to address Goal 5. The second roof is fixed on the left side of the structure to represent the inter-relationships between the top 20 factors of delays to address Goal 6. This number of delay factors (TOP-20 factors) represents the most critical factors resulting from the RII ranking. Seventeen factors have covered the most critical identified delay factors from the previous studies. Three factors of delay were added to the final list due to their importance to projects delay as reported by respondents in the survey. These factors are loose safety roles and regulation by contractor, government tendering system of selecting the lowest bidding contractor and inefficient quality control by contractor.

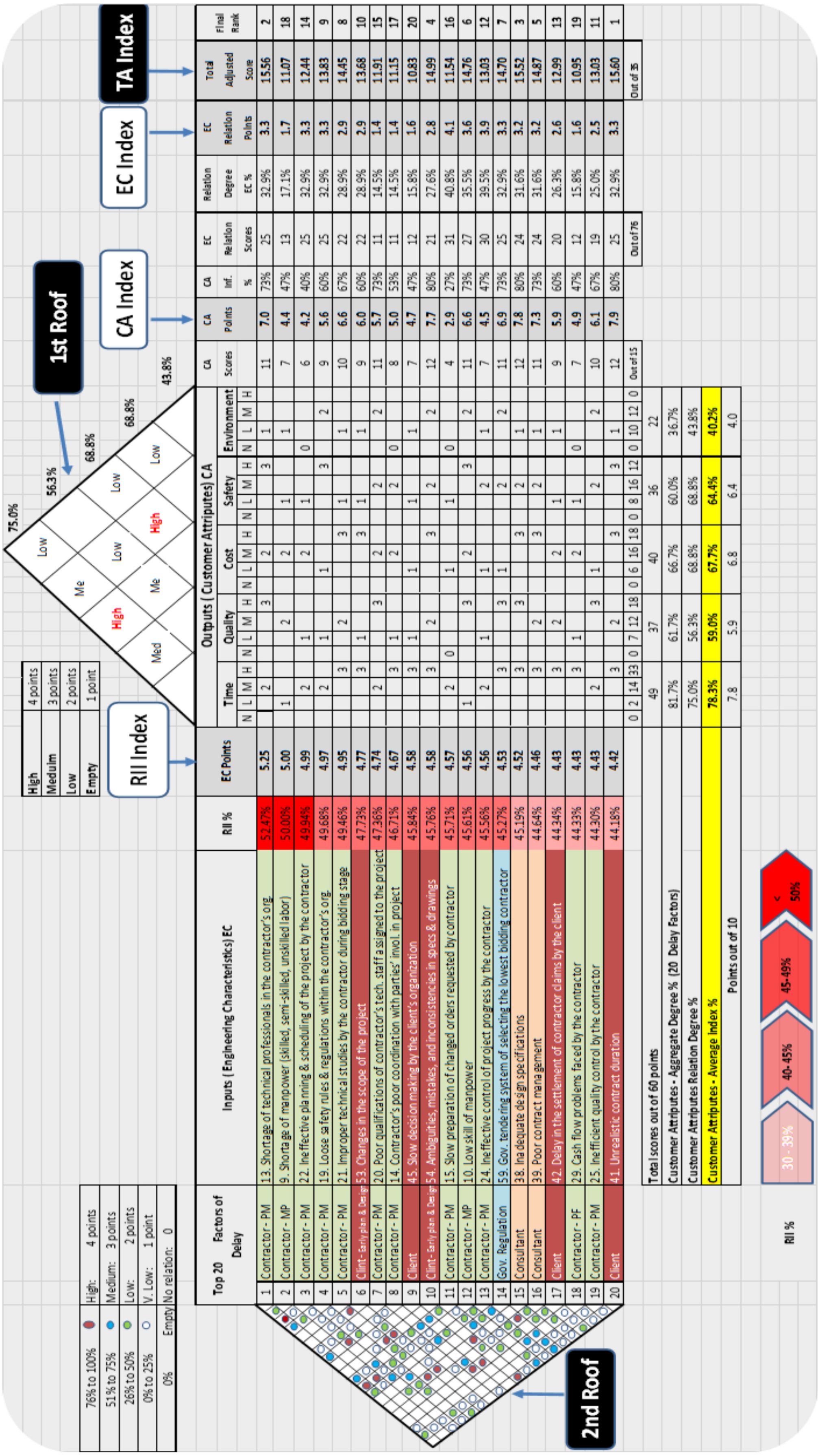


Figure 4.10: All Indices Including Total Adjusted Index Using DR-HOQ

4.5.4.3 Filling in the DR-HOQ

The first key element of any HOQ chart is the list of customer requirements or performance measures (“Whats”). The performance measures can be obtained from similar applications or through a conduced survey. The five performance measures are already mentioned in figure 4.10 as part of Roof-1 and prioritized by the relevant impacts to the delay factors or the engineering characteristics (ECs). It is important to know that this list can be refined into the next level of detail by elaborating primary requirements to produce secondary and tertiary requirements. The second key element is the list of technical requirements or the delay factors “Hows”. As previously stated, these are the critical projects factors of delay. The third key element of any HOQ chart is the relationships between “Whats” and “Hows”. However, attempting to trace the relationships of “Whats” and “Hows” becomes quite confusing. The present research needed a way of untangling this complex web of relationships. One way to reduce this confusion is to turn the “How” list perpendicular to the “What” list and define the relationships in a matrix enclosed by the rectangular region. A symbol or its equivalent number is placed at the intersections of the “Whats” and “Hows” that are related. This method allows very complex relationships to be depicted and easily interpreted.

It also permits the author and corresponding experts to cross check this thinking by examining Research Hypothesis 2. A blank row indicates a certain degree of relationship included between each critical factor of delay with the PPMs such as time, quality and cost. Furthermore, blank columns indicate a certain degree of relationship for each PPM with the factors of delays. The fourth key element of any HOQ chart is the “How Much” section. These are the measurements for the “Hows.” These target values should represent how strong or weak the delay factors are with the PPMs.

The interrelationship matrix “How Much” is important for two reasons:

- To provide an objective means of assuring requirements have been met.
- To provide targets for further detailed development in the structure of the first roof therefore providing specific objectives that guide the subsequent development/modification and afford a means of objectively assessing progress.

For this reason, the “How Muches” should be measurable as much as possible because measurable items provide more opportunity for analysis and optimization than do non-measurable items. This aspect provides another cross check of the thinking. If most of the “How Muches” are not measurable, then we have not been detailed or understood enough about the ideas behind the “Hows.” In summary, these (four key elements) form the foundation of QFD and can be found on any HOQ.

Correlation Matrix: There are several useful extensions to the basic QFD charts that greatly enhance their usefulness. These are used as required, according to the content and purpose of each particular project. The correlation matrix is a triangular table often attached to the “Whats,” establishing the correlation between each “What” item. The purpose of the first roof is to identify areas where trade-off decisions and research and development may be required. As in the Relationship Matrix, numbers are used to describe the strength and type of the relationships, Figure 4.11 illustrates the values of these relationships, which range from 0 to 3 according to an assessment carried out by the author and experts during the last two sessions of the focus group.

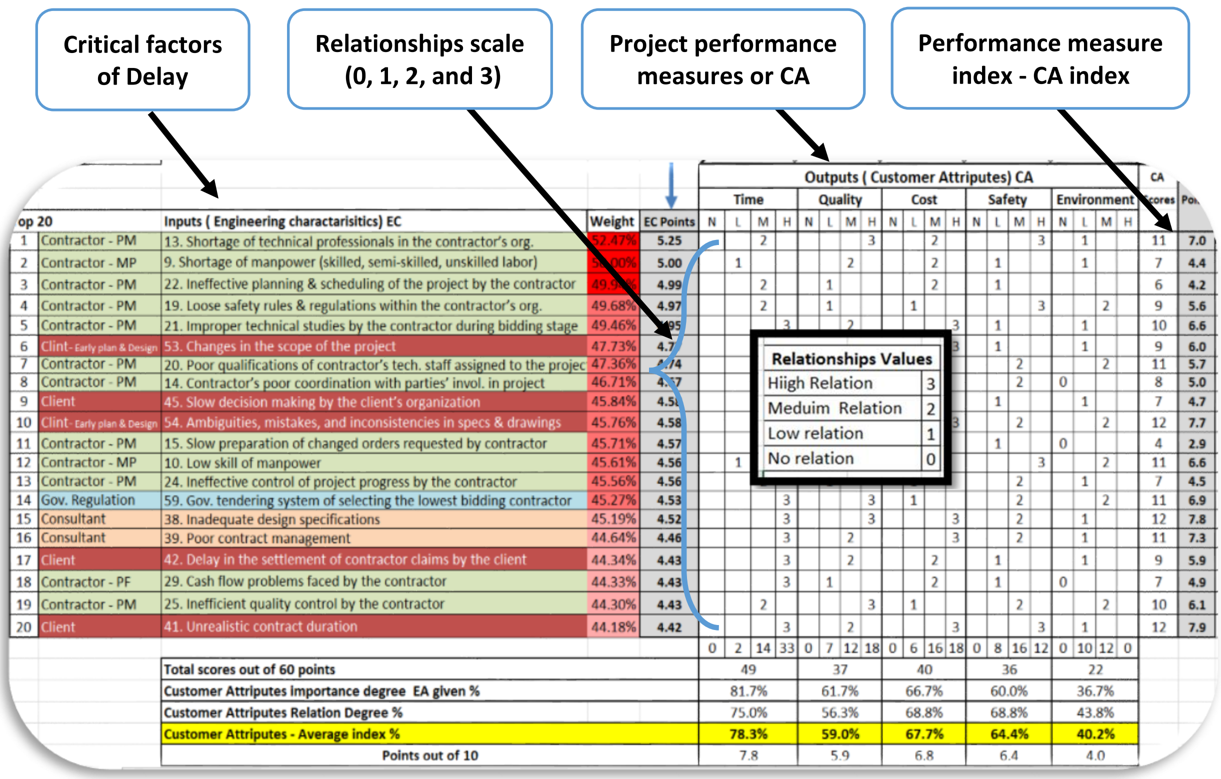
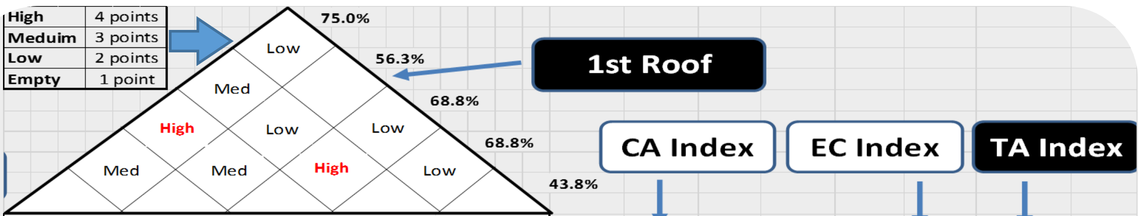


Figure 4.11: Interrelationship Matrix Box and Values Distribution

As shown in figure 4.11, critical factor of delay - 20 (Unrealistic contract duration had the highest scores out of 15. This factor has a strong relationship with respect to the PPMs, representing a high degree of involvement (12/15=7.9). The rest of the 19 delay factors were calculated the same way with an individual index ranging from 2.9 to 7.9. This part of the current analysis has determined all relationships between "Hows" vs. "Whats".

A- Customer Attributes Index (CAI %):

As previously explained, the first Roof of the HOQ was intended to be developed to represent the relationships between the "Whats" and "Hows" and the correlation degrees between "Whats" and "Whats." The values and the degrees of all relationship matrices were developed and assessed by the focus group that included the author and six experts in the field of project management. The main function of the first roof is to identify the correlation degrees between the PPMs with certain value ranges (1-4). Figure 4.12 shows the four correlation degrees: (Empty/Neutral: 1 point), (Low: 2 points), (Medium: 3 points), and (High: 4 points).



Outputs (Customer Attriputes) CA

Time				Quality				Cost				Safety				Environt				CA Scores	CA Points	CA%	EC Scores	EC%	EC Points	Total Adjusted Index	Final Rank
N	L	M	H	N	L	M	H	N	L	M	H	N	L	M	H	N	L	M	H								
		2					3			2					3		1			11	7.0	47%	25	32.9%	3.3	15.56	2
	1					2				2			1				1			7	4.4	29%	13	17.1%	1.7	11.07	18
		2			1					2			1							6	4.2	28%	25	32.9%	3.3	12.44	14
									1						3			2		9	5.6	37%	25	32.9%	3.3	13.83	9
											3		1				1			10	6.6	44%	22	28.9%	2.9	14.45	8
											3		1				1			9	6.0	40%	22	28.9%	2.9	13.68	10
										2				2				2		11	5.7	38%	11	14.5%	1.4	11.91	15
			3		1					2				2		0				8	5.0	34%	11	14.5%	1.4	11.15	17
			3		1				1				1				1			7	4.7	31%	12	15.8%	1.6	10.83	20
			3			2					3			2				2		12	7.7	51%	21	27.6%	2.8	14.99	4
		2		0					1				1			0				4	2.9	19%	31	40.8%	4.1	11.54	16
	1						3			2					3			2		11	6.6	44%	27	35.5%	3.6	14.76	6
		2			1				1					2			1			7	4.5	30%	30	39.5%	3.9	13.03	12
			3				3		1					2				2		11	6.9	46%	25	32.9%	3.3	14.70	7
			3				3				3			2			1			12	7.8	52%	24	31.6%	3.2	15.52	3
			3			2					3			2			1			11	7.3	48%	24	31.6%	3.2	14.87	5
			3			2				2			1				1			9	5.9	40%	20	26.3%	2.6	12.99	13
			3		1					2			1			0				7	4.9	33%	12	15.8%	1.6	10.95	19
		2					3		1					2				2		10	6.1	41%	19	25.0%	2.5	13.03	11
			3			2					3				3		1			12	7.9	53%	25	32.9%	3.3	15.60	1
0	2	14	33	0	7	12	18	0	6	16	18	0	8	16	12	0	10	12	0	Out of 15			Out of 76			Out of 35	
49				37				40				36				22				Total scores out of 60 points							
81.7%				61.7%				66.7%				60.0%				36.7%				Customer Attriputes importance degree EA given %							
75.0%				56.3%				68.8%				68.8%				43.8%				Customer Attriputes Relation Degree %							
78.3%				**59.0%**				**67.7%**				**64.4%**				**40.2%**				**Customer Attriputes - Average index %**							
7.8				5.9				6.8				6.4				4.0				Points out of 10							

Figure 4.12: Customer Attributes (Performance Measures) Correlation Degree %

As indicated in figure 4.12, the top roof interprets the correlation degrees between PPMs from low to high. The roof presents two high correlation degrees that exist between (Time & Cost) and (Cost & Safety). The more time consumed in a project over the time schedule, the higher the impact on the project budget. Similarly, with additional emphasis on safety within a project means spending more money on the project budget to maintain this standard.

Accordingly, some performance measures are more critical to factors of delay compared to others. Therefore, the influence of each performance measure is different and must be evaluated and represented with corresponding weights to avoid equal contributions among the five PPMs. Hence, two elements are evaluated for this purpose. The first is the correlation degrees' influence between the PPMs resulting from the top roof and the second is the aggregate values of relationships between the top 20 factors of delay and each performance measure.

The total values of each PPM were summed and divided by 60 (Maximum scores) to achieve the first element. For example, the Time measure has gained 49 scores and is divided by 60 to give 81.7%. Similarly, relationships values between PPMs in the first roof were calculated and divided by 16 (Maximum scores) to achieve the second element. For example, the Time measure has four relationships (1-High: 4 points, 2-Med: 3+3 points, and 1-Low: 2 points). Total gained points of 12 were divided by 16 (Maximum score) to give 75%. The experts within the focus group recommended combining both elements by averaging them to provide an effective contribution to the CA index %.

As a result, the most important PPM is found to be time measure, which has an average - CA impact % with regards to the top 20 factors of delay is equal to (81.7% + 75%) /2 = 78.3%, while the cost measure is found to be the second at (66.7% + 68.8%) /2 = 67.7%, followed by the safety measure at (61.7% + 56.3%) /2 = 64.4%. The least important performance measures are quality and environment, with an average - CA impact % of (61.7% + 56.3%) /2= 59% and (36.7% + 43.8%)/2= 40.2% respectively. Figure 4.13 shows the calculation and the main four steps that were taken to determine the CAI for each factor of delay.

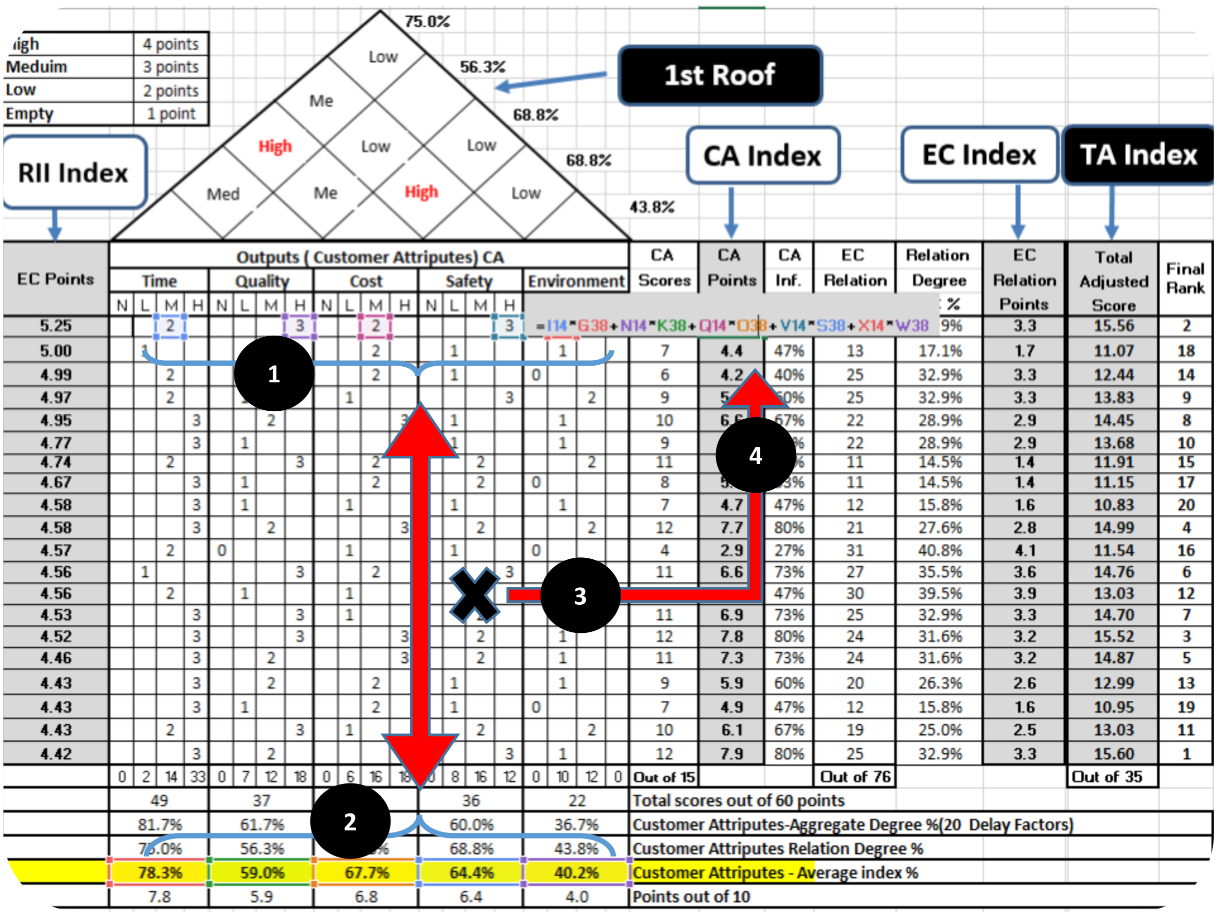


Figure 4.13: Customer Attributes Performance Measure Index %

The method used for calculating the CAI is shown in the following steps:

Factor of delay no. 1 “Shortage of technical staff”: (FD-1)

- Time relationship FD-1 x Time CA-average Index = 2 x 0.783 = 1.56
- Quality relationship FD-1 x Quality CA-average Index = 3 x 0.590 = 1.77
- Cost relationship FD-1 x Cost CA-average Index = 2 x 0.677 = 1.35
- Safety relationship FD-1 x Safety CA-average Index = 3 x 0.644 = 1.93
- Environ. relationship FD-1 x Environ CA-average Index = 1 x 0.402 = 0.40
- (CA Score FD-1) …..…………………………………………..……... = **7.024**
- (CA relation degree % FD-1) = (7.024/15) …………..………………… **= 47%**

Where, 15 is the max possible points (5 relations x 3 points = 15)

B- Engineering Characteristics Index (EC Index):

The main objective of initiating the second roof for the house of quality structure is to be able to create interrelationships between the factors of delays and their impacts on each other to address Goal 6. The following five criteria were applied during the focus group sessions to initiate, evaluate and finally assess these interrelationships. It is expected that some factors have different impacts compared to other factors, depending on following points:

- ✓ The severity of the factor
- ✓ Labor matters involvement in the factor
- ✓ Financial matters involvement in the factor
- ✓ Design matters involvement in the factor
- ✓ Project management practices involvement in the factor

The left fixed roof in figure 4.14 represents all interrelationships between the Engineering Characteristics (Top 20 factors). The degrees of interrelationships are described as follows:

- No-relation: No relationship or connection. 0% : 0
- Very-low: Proportional interrelationship with negligible effect. 0-25% : 1 point
- Low: Proportional interrelationship with minor effect. 26-50% : 2 points
- Medium: Proportional interrelationship with remarkable effect. 51-75% : 3 points
- High: Strong proportional interrelationship with dramatic effect. 76-100% : 4 points

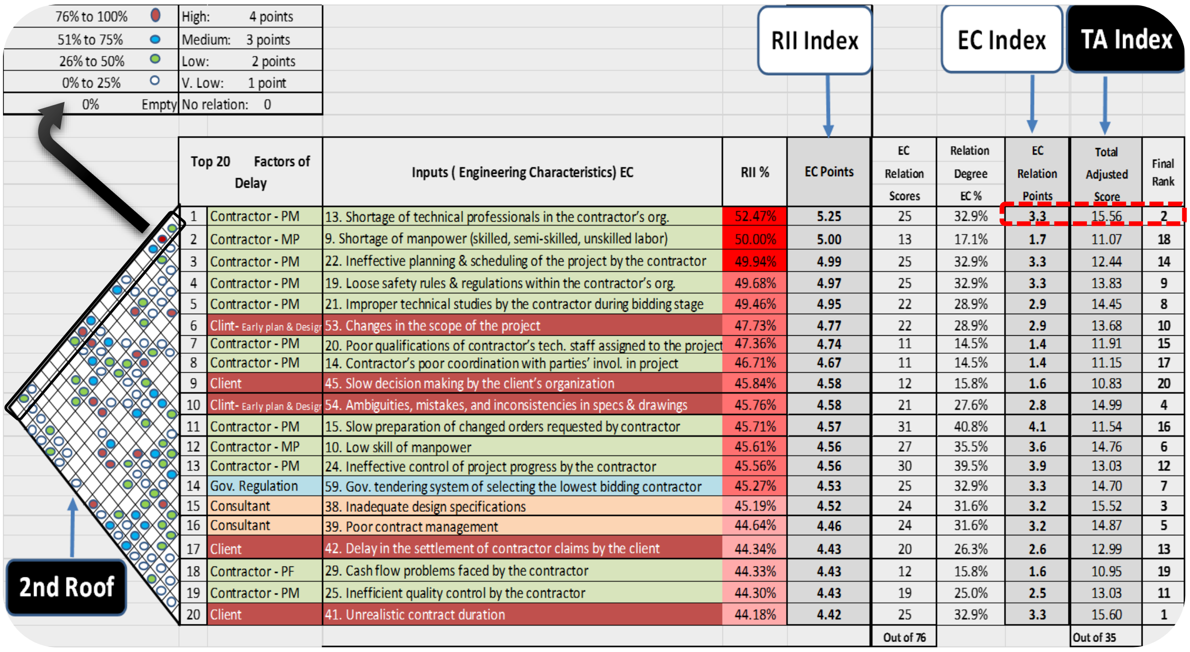
The total number of 341 interrelationships were interpreted into points that reflect how each factor of delay interacts or is influenced by others. The formula that was used is described as follow:

The total possible number of interrelationships in the second roof is (20 x 19 = 380) minus the total number of blank interrelationships (39) equals 341 interrelationships.

The total number of interrelationships and relationships for both roofs was 457 interrelationships i.e. 341+16+100 = 457.

- 341 out of 457 interrelationships (75%) were the interrelationships between factors of delay, which were created in the second roof.
- 100 out of 457 relationships (21%) were relationships between factors of delays and customer attributes, which were created in the rectangular correlation box.
- 16 out of 457 relationships (4%) were from the correlation degrees between the five performance measures, which were created in the first roof.

The EC Index was created by the author to represent interrelationships by giving an independent weight for each factor of delay. The range of degree was 16% to 41%. Figure 4.14-shows the degree of interrelationships between all factors of delay.



Top 20	Factors of Delay	Inputs (Engineering Characteristics) EC	RII %	EC Points	EC Relation Scores	Relation Degree EC %	EC Relation Points	Total Adjusted Score	Final Rank
1	Contractor - PM	13. Shortage of technical professionals in the contractor's org.	52.47%	5.25	25	32.9%	3.3	15.56	2
2	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	50.00%	5.00	13	17.1%	1.7	11.07	18
3	Contractor - PM	22. Ineffective planning & scheduling of the project by the contractor	49.94%	4.99	25	32.9%	3.3	12.44	14
4	Contractor - PM	19. Loose safety rules & regulations within the contractor's org.	49.68%	4.97	25	32.9%	3.3	13.83	9
5	Contractor - PM	21. Improper technical studies by the contractor during bidding stage	49.46%	4.95	22	28.9%	2.9	14.45	8
6	Clint- Early plan & Desigr	53. Changes in the scope of the project	47.73%	4.77	22	28.9%	2.9	13.68	10
7	Contractor - PM	20. Poor qualifications of contractor's tech. staff assigned to the project	47.36%	4.74	11	14.5%	1.4	11.91	15
8	Contractor - PM	14. Contractor's poor coordination with parties' invol. in project	46.71%	4.67	11	14.5%	1.4	11.15	17
9	Client	45. Slow decision making by the client's organization	45.84%	4.58	12	15.8%	1.6	10.83	20
10	Clint- Early plan & Desigr	54. Ambiguities, mistakes, and inconsistencies in specs & drawings	45.76%	4.58	21	27.6%	2.8	14.99	4
11	Contractor - PM	15. Slow preparation of changed orders requested by contractor	45.71%	4.57	31	40.8%	4.1	11.54	16
12	Contractor - MP	10. Low skill of manpower	45.61%	4.56	27	35.5%	3.6	14.76	6
13	Contractor - PM	24. Ineffective control of project progress by the contractor	45.56%	4.56	30	39.5%	3.9	13.03	12
14	Gov. Regulation	59. Gov. tendering system of selecting the lowest bidding contractor	45.27%	4.53	25	32.9%	3.3	14.70	7
15	Consultant	38. Inadequate design specifications	45.19%	4.52	24	31.6%	3.2	15.52	3
16	Consultant	39. Poor contract management	44.64%	4.46	24	31.6%	3.2	14.87	5
17	Client	42. Delay in the settlement of contractor claims by the client	44.34%	4.43	20	26.3%	2.6	12.99	13
18	Contractor - PF	29. Cash flow problems faced by the contractor	44.33%	4.43	12	15.8%	1.6	10.95	19
19	Contractor - PM	25. Inefficient quality control by the contractor	44.30%	4.43	19	25.0%	2.5	13.03	11
20	Client	41. Unrealistic contract duration	44.18%	4.42	25	32.9%	3.3	15.60	1
					Out of 76			Out of 35	

Figure 4.14: Second Roof of the House of Quality (Factors Interrelationships)

The method used for calculating the EC Index is shown in the following steps:

Factor of delay no. 1 "Shortage of technical staff": (FD-1)

- High interrelationship FD-1 x 2- Red bond (4 points) = 2 x 4 = 8 points
- Medium interrelationship FD-1 x 3- Blue bonds (3 points) = 3 x 3 = 9 points
- Low interrelationship FD-1 x 3- Green bonds (2 points) = 3 x 2 = 6 points
- V. low interrelationship FD-1 x 2- White bonds (1 points) = 2 x 1 = 2 points
- No interrelationship FD-1 x 9- No bond (0 point) = 9 x 0 = 0 point
- Total (points FD-1) ………………………………………………………. = **25 points**
- (EC Index FD-1) = (25/ 76) ………...……………...…………………... = **32.9%**
- (EC Scores FD-1) = (0.33 x 10)…………..……………………………… = **3.3 scores**

Where, 76 is the max possible points (19 relations x 4 points = 76)

EC Scores = EC Index x 10 (max score in the index)

C- Total Adjusted Index and Final Ranking:

The Total Adjusted Index (TA Index) represents the collective efforts of the DR-HOQ. The main three indices (RII Index, CA Index, and EC Index) were merged together to give a higher level of sensitivity for ranking the factors of delay. It was decided during the focus group sessions that the three indices would contribute equally to the final ranking so that each index would represent (1/3) of the TA Index for the following reasons:

- RII: represents the voice of the client, consultant, and contractor (**Main Parties**).
- CA Index: represents the voice of customer (**Performance Measures**) in higher details by analyzing the significance of the five PMs to each factor of delay.
- EC Index: represents the engineering characteristics with regard to the embedded interrelationships between the (**Factors of Delays)**.

Figure 4.15 illustrates the re-ranking process after calculating the TA Index. Many factors of delay lost their high ranking while others gained a higher level. This part of the analysis has examined the Research Hypothesis 4. The ranking orders have changed because of depending solely on the RII. For example, “shortage of technical professional in contractor’s organization” stepped one level down and “unrealistic time duration” jumped up 19 ranks.

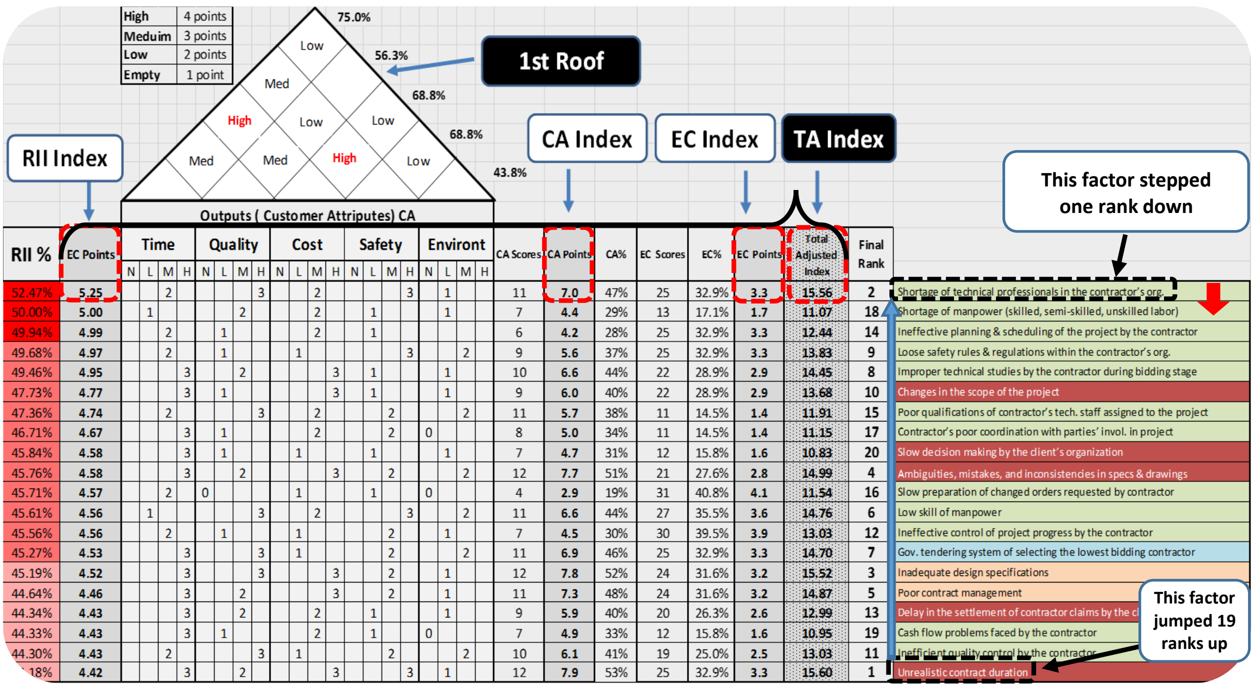


Figure 4.15: Total Adjusted Index (TA Index) Re-ranking Process

The method used for calculating the TA Index is shown in the following steps:

Factor of delay no. 1 “Shortage of technical staff”: (FD-1)

- RII Index FD-1 = 5.25 score
- CA Index FD-1 = 7.0 score
- EC Index FD-1 = 3.3 score
- **TA** Index FD-1 = (5.25 + 7.0 + 3.3**) = 15.56**
- **Ranking** FD-1 : **2**

4.5.4.4 Collective Ranking Method:

A- Group of Factors and Their Impacts on Projects Delay

After applying the sensitivity analysis using the DR-HOQ, it became clear that some factors have a high degree of interrelationships and some have lower degrees, while the remaining don’t have any degrees of interrelationships. At the very beginning of this research, it was claimed that many factors of delay are not independent as some of them have a strong degree of interrelation and so their impact cannot be ignored. Accordingly, the factors may change the importance level of some factors at the expense of others.

The DR-HOQ has helped to identify those groups and sort them in a way that would be easily interpreted and help in the final analysis. These groups are concluded from the second roof and are presented to address the Research Goal 7. The following section elaborates how the group of factors (chains) were formed and presented. The groups created have been categorized into four groups as follows:

1. Blank: No relationship or connection between the factors. 0%
2. White bond: Proportional relationship with negligible effect between the factors 0-25%
3. Green Bond: Proportional relationship with minor effect between the factors. 26-50%
4. Blue Bond: Proportional relationship with reasonable effect between the factors 51-75%
5. Red Bond: Strong prop. relationship with dramatic effect between the factors 76-100%

B- Collative Impact of Delay Factors' Formula Development

The groups of factors were formed based on the bond's strength between the factors of delay that were identified from the second roof's structure. The groups contained some factors with different weights based on the TA Index. The red group includes around 10 different chains and each one of them has a level of significance based on the number of delay factors and the weight of each factor.

The author has developed a novel concept by creating a new formula, which can be published in 2019, to calculate the collective impact of the delay factors (chain) when they are presented at the same time in any project. As a basic principle, the effect of an individual factor of delay would have less impact when a group of factors are accompanied in one project. The newly developed formula has taken in mind the logic of adding more than one factor for any project so that the final value would still be reasonable and considerable for any project delay's evaluation.

The presented formula below was developed in an iterative manner in order to simulate the collective risk's impact of more than one factor of delay at a time. The formula development criteria is presented as follows:

- Designed to evaluate the risk for more than one factor of delay.
- Bonds strength's value increases proportionally according to the factors number in the chain. For example, the Red bond value ranges between (0.75: ≤ 2-factors and 1.0: ≥ 4-factors).
- Risk weight of chain should not exceed 100% and should not be less than the highest TAI value of all factors in the chain.

$$\mathbf{RWC} = \frac{\mathrm{HVF} + \left[\mathrm{BD}\ x \sum_{1}^{\mathrm{N}} \left(\frac{(\mathrm{F1}+\mathrm{F2}+\mathrm{F3}\ldots\ldots)}{\mathrm{N}}\right)\right]}{\mathrm{FMV}}\ x\ 100 \ldots\ldots\ldots\ldots \quad (5)$$

Where,

RWC: Risk weight of chain

BD: Bond degree "0.25 to 1.0"

- ✓ **Red Group:** 0.75 - 1.0, 2 FACTORS:0.75, 3 FACTORS: 0.85, 4 FACTORS AND ABOVE: 1.00
- ✓ **Blue Group:** 0.5 - 0.75, 2 FACTORS:0.50, 3 FACTORS: 0.60, 4 FACTORS AND ABOVE: 0.75
- ✓ **Green Group:** 0.25 - 0.5, 2 FACTORS:0.25, 3 FACTORS: 0.35, 4 FACTORS AND ABOVE: 0.50
- ✓ **White Group:** 0.0 - 0.25, 2 FACTORS:0.05, 3 FACTORS: 0.15, 4 FACTORS AND ABOVE: 0.25

HVF: Highest value of factor in the chain

FMV: Factors maximum value = 35 points

N: The max number of factors involved in the chain

F: Factor's TAI value in the chain

The method used for calculating the Risk Weight Factor of the Chain (RWC) is shown in the following steps:

Red Chain-2 which contains **5** factors of delay as follows:

1. Ambiguity & mistakes in the project scope and specification by the Client
2. Changes in the scope of the project by the Client.
3. Improper technical study by the contractor during the bidding stage.
4. Inadequate design and specification by the consultant.
5. Unrealistic contract time duration by the Client.

The values of variables resulting from the DR-HOQ analysis are used in the formula are as follows:

- $F_{TAI\text{-}1}$ = 14.99 scores
- $F_{TAI\text{-}2}$ = 13.70 scores
- $F_{TAI\text{-}3}$ = 14.45 scores
- $F_{TAI\text{-}4}$ = 15.52 scores
- $F_{TAI\text{-}5}$ = 15.60 scores
- HVF = 15.60 scores
- FMV = 35
- BD = **1.0** : Red Chain Bond, the maximum value is selected ($\leq$ 4-factors)
- N = 5

$$\mathbf{RWC} = \frac{15.6 + \left[1.0\ x \sum_{1}^{5}\left(\frac{(14.99+13.7+14.45+15.52+15.6)}{5}\right)\right]}{35}\ x\ 100$$

RWC = 87%

The total risk weight of this chain is 87%. The RWC results for the remaining red chain factors are presented in chapter 5, table 5.20.

4.5.5 Stage-5: Process of Verification

After the determination of the project's critical delay factors effect/impact on the project performance measures "Time, cost, quality, safety and environment", the analysis was continued with further investigation on how the group of critical factors as a chain would impact PPMs in general, associated with a risk factor described as an accumulated weight for each chain. The approach of verification is required mainly to oversee whether the empirical formula which was developed by the author has a similar sense of the collective impact to the project's delay or not. Indeed, this process of verification has a wider dimension of assessing the other performance measures, such as cost and time, which is new concept of assessing more than one performance measure at once.

The developed verification process using Fuzzy Logic (FL) would help also to give a future anticipation for any undergoing project by setting the proposed values of the top 20 factors of delay. Fuzzy logic is a unique tool for connecting non-linear relationships with a number of fuzzification processes. The values of the inputs will be fuzzified based on the stored membership functions, which were created basically from the DR-HOQ and then modified by the author.

This process of verification could be used as well to verify the impact of each factor of delay individual (singular factor impact), provided the rest of the factors will be defaulted in moderate conditions.

4.5.5.1 Verification of the Collective Impact

It is obvious that when a group of delay factors exist together in any specific project, this would have a higher impact compared to a project which is surrounded by one or two factors of delay. The more factors of delay that exist in any project, the higher risk of impacting the projects PPMs. In section 5.11, the impacts of the selected group of factors were very clear with regard to a single factor of delay. Some of these chains have presented a very high degree of relationship even though they could be blue bonded or even green bonded connection. The strength of these connections ranged between 25% and 100%.

Accordingly, it is very important to evaluate the predictable impact of these chains in the same reality to determine their impacts throughout a process which could address the nature of the non-linear relationships between the factors of delay and the PPMs. During the literature review, it was observed that most of the researchers were dependent on verifying their initial assumptions by comparing what they collected and analysed with the results concluded in their surveys.

This research adopted a new technique of analysing the information based on the vast experience of the researcher in the field project management which extended to more than 15 years before start talking about projects delay issues.

The special belief in the present study for the non-linear relationships has been proven before starting on the methodology and as such is considered very important in carefully selecting the best available method that could initially create the relationships among all of them and evaluate these relationships by creating rules to simulate them into tangible results at the end. The DR-HOQ was a very useful tool to build these relationships, measure the correspondence degree, create indices and give a proper final weight to each critical factor of delay.

After a deep review of the literature and investigation of similar topics and concepts, the author recommended to consider Fuzzy Logic Modeling as the tool of the verification process. The advantages and limitations listed below were determined before proceeding with this process. This was an important step to be done in order to help the author tackle any foreseen problems before they appear at a later stage and to take the needed precautions if needed.

FL Advantages:

- The process deals with all types of non-linearity in all relationships.
- It gives a human thinking approach rather than using the crisp values concept.
- It allows for creating membership functions with ranges of values.
- It provides easy data reflection and factors behavior's impact in linguistic translation.
- Both manual and numerical editing are possible.
- The practicability of rules creation and editing exists, for example conditional, special weights, method and other features.

FL Limitations:

- It needs to create all linguistic variables carefully with a clear repetitive wording.
- It needs specialists/experts in the field of the study who can build the membership functions with their practical ranges and values.
- Rules creations are very time-consuming efforts.
- The educational copy can't handle the high number of membership functions.

4.5.5.2 Verification by Using Fuzzy Logic (Top-10 Chain of Delay Factors)

Introduction to Fuzzy Logic

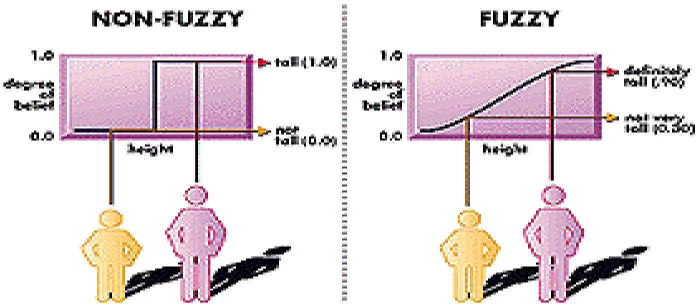


Figure 4.16: Fuzzy & Non-Fuzzy Data Behavior

FL starts with and builds on a set of user-supplied human language rules. The fuzzy systems convert these rules into their mathematical equivalents. This simplifies the job of the system designer and the computer and results in much more accurate representations of how systems behave in the real world (Zadeh, 2008). FL is much more than a logical system. It has many facets. The principal facets are: logical, fuzzy-set-theoretic, epistemic and relational. Most of the practical applications of fuzzy logic are associated with its relational facet. Figure 4.16 shows the difference of the data behavior between the fuzzy logic and crisp values concept of the non-fuzzy principle.

Additional benefits of FL include simplicity and flexibility. FL can handle problems with imprecise and incomplete data, and it can model (nonlinear functions) of arbitrary complexity. "If you don't have a good plant model, or if the system is changing, or a process of verification is required then fuzzy will produce a better solution than conventional control techniques," says Bob Varley, a Senior Systems Engineer at Harris Corp., an aerospace company in Palm Bay, Florida.

It is usually possible to create a fuzzy system to match any set of input-output data. The FL Toolbox makes this particularly easy by supplying adaptive techniques such as adaptive neuro-fuzzy inference systems (ANFIS) and fuzzy subtractive clustering.

FL models, known as fuzzy inference systems, consist of a number of conditional "if-then" rules. For the designer who understands the system, these rules are easy to write, and as many rules as necessary can be supplied to describe the system adequately, although typically only a moderate number of rules are needed.

In FL, unlike standard conditional logic, the truth of any statement is a matter of degree. (How cold is it? How high should we set the heat?) We are familiar with inference rules of the form p -> q (p implies q). With fuzzy logic, it's possible to say (.5* p) -> (.5 * q). For example, the rule if (weather is cold) then (heat is on), both variables; cold and on, ranges of values. Fuzzy inference systems rely on membership functions to input to the computer how to calculate the correct value between 0 and 1. The degree to which any fuzzy statement is true is denoted by a value between 0 and 1.
The rule-based approach and flexible membership function scheme don't only make fuzzy systems straightforward to create, but they also simplify the design of systems and ensure that you can easily update and maintain the system over time.

Why Use FL as Process of Verification

FL offers several unique features that make it a particularly good choice for many non-linear problems.

1. It is inherently robust since it does not require precise, noise-free inputs and can be programmed to stop safely if a feedback sensor quits or is destroyed. The output control is a smooth control function despite a wide range of input.
2. Since the FL controller processes user-defined rules governing the target control system, it can be modified and tweaked easily to improve or drastically alter system performance. New sensors can easily be incorporated into the system simply by generating appropriate governing rules.
3. FL is not limited to a few feedback inputs and one or two outputs, nor is it necessary to measure or compute rate-of-change parameters in order to be implemented. Any data that provides some indication of a system's actions and

reactions is sufficient. This gives the advantage of the system to be inexpensive and imprecise, thus keeping the overall system cost and complexity low.

4. Because of the rule-based operation, any reasonable number of inputs can be processed (1-8 or more) and numerous outputs (1-4 or more) generated, although defining the rule base quickly becomes complex if too many inputs and outputs are chosen for a single implementation; since rules defining their interrelations must also be defined. It would be better to break the control system into smaller chunks and use several smaller FL controllers distributed on the system, each with more limited responsibilities. FL can control (nonlinear systems) that would be difficult or impossible to be modeled mathematically. This opens doors for verifying the group of factors (inputs) and their collective impact the project performance measures (outputs).

Main Steps of Fuzzy Logic (FL)

There are a six main steps for starting any process of verification by applying fuzzy logic into any system or problem to be solved (Kalargros & Gao, 1998; Abukwaik, 2007).

1. Define the system objectives and criteria: What am I trying to improve?, What kind of response do I need?, and What are the possible (probable) system failure modes?.
2. Determine the input and output relationships and choose a minimum number of variables for input to the FL engine (typically error and rate-of-change-of-error).
3. Using the rule-based structure of FL, break the system problem down into a series of IF X AND Y THEN Z rules that define the desired system output response for a given system’s input conditions. The number and complexity of rules depending on the number of input parameters that are to be processed and the number of fuzzy variables associated with each parameter. If possible, use at least variable and its time derivative. Although it is possible to use a single and instantaneous error parameter without knowing its rate of change, this cripples the system's ability to minimize overshoot for a step inputs.

4. Create FL membership functions that define the meaning (values) of Input/ Output terms used in the rules.
5. Create the necessary pre /post-processing FL routines if implementing in S/W, otherwise, program the rules into the FL H/W engine.
6. Test the system, evaluate the results, tune the rules and membership functions, and retest until satisfactory results are obtained.

A- Fuzzy Sets

The Fuzzy Set Theory was formalized by Professor Lofti Zadeh of the University of California in 1965. What Zadeh proposed is very much a paradigm shift that first gained acceptance in the Far East, and its successful application has ensured its adoption around the world.

A paradigm is a set of rules and regulations which define boundaries and tell us what to do to be successful in solving problems within these boundaries. For example, the use of transistors instead of vacuum tubes is a paradigm shift - likewise, the development of Fuzzy Set Theory from the conventional Bivalent Set Theory is a paradigm shift.

The Bivalent Set Theory can be somewhat limiting if we wish to describe a humanistic problem mathematically. For example, Figure 4.17 illustrates bivalent sets to characterize the temperature of a room.

The picture is withheld for a copy write.

Figure 4.17: Bivalent Sets to Characterize the Temperature of a Room

The most obvious limiting feature of bivalent sets that can be seen clearly from the diagram is they are mutually exclusive - it is not possible to have membership of more than one set. Opinion would widely vary as to whether 50 degrees Fahrenheit is 'cold' or 'cool'; hence, the expert knowledge needed to define the current system is mathematically at odds with the humanistic world. Clearly, it is not accurate to define a transition from a quantity such as 'warm' to 'hot' by the application of one-degree Celsius of heat. In the real world, a smooth, unnoticeable drift from warm to hot would occur. This natural phenomenon can be described more accurately by Fuzzy Set Theory. Figure 4.18 shows how fuzzy sets quantifying the same information can describe this natural drift.

The picture is withheld for a copy write.

Figure 4.18: Fuzzy Sets to Characterize Temperature of a Room

B- Fuzzy logic Definitions:

- Universe of Discourse: The Universe of Discourse is the range of all possible values for an input to a fuzzy system.
- Fuzzy Set: A Fuzzy Set is any set that allows its members to have different grades of membership (membership function) in the interval [0, 1].
- Support: The Support of a fuzzy set (F) is the crisp set of all points in the Universe of Discourse (U) such that the membership function of F is non-zero.
- Crossover point: The Crossover point of a fuzzy set is the element in U at which its membership function is 0.5.
- Fuzzy Singleton: A Fuzzy singleton is a fuzzy set whose support is a single point in U with a membership function of one.

C- Linguistic Variables

In 1973, Professor Lotfi Zadeh proposed the concept of linguistic or "fuzzy" variables. Think of them as linguistic objects or words, rather than numbers. The sensor input is a noun, e.g. "temperature", "displacement", "velocity", "flow", "pressure", etc. Since the error is just the difference, it can be thought of the same way. Fuzzy variables themselves are adjectives that modify the variable (e.g. "large positive" error, "small positive" error, "zero" error, "small negative" error, and "large negative" error). As a minimum, one could simply have "positive", "zero", and "negative" variables for each of the parameters. Additional ranges such as "very large" and "very small" could also be added to extend the responsiveness to exceptional or very nonlinear conditions, but aren't necessary for a basic system.

FL does not require precise inputs, is inherently robust and can process any reasonable number of inputs, but system complexity increases rapidly as more inputs and outputs are given. Distributed processors would probably be easier to implement. Simple, plain-language rules are used to describe the desired system response in terms of linguistic variables rather than mathematical formulas.

D- Membership Functions

In the present study, the rule matrix was introduced and used by the help of DR-HOQ. The next logical question was how to apply these rules. This led to the next concept, which is the membership function.

The membership function is a graphical representation of the magnitude of each input participation. It associates a weighting for each of the inputs that are processed, defines the functional overlap between inputs and ultimately determines an output response. The rules employ the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion. Once functions are inferred, scaled and combined, they are defuzzied into a crisp output that drives the system.

There are different membership functions associated with each input and output response. Some features to note are:

- SHAPE - triangular is common, but bell, trapezoidal, Haversian and exponential have been used. More complex functions are possible but require greater computing overhead to implement.
- HEIGHT or magnitude (usually normalized to 1)
- WIDTH (of the base of function)
- SHOULDERING (locks height at maximum if an outer function or Shouldered functions evaluate as 1.0 past their center)
- CENTER points (center of the member function shape)

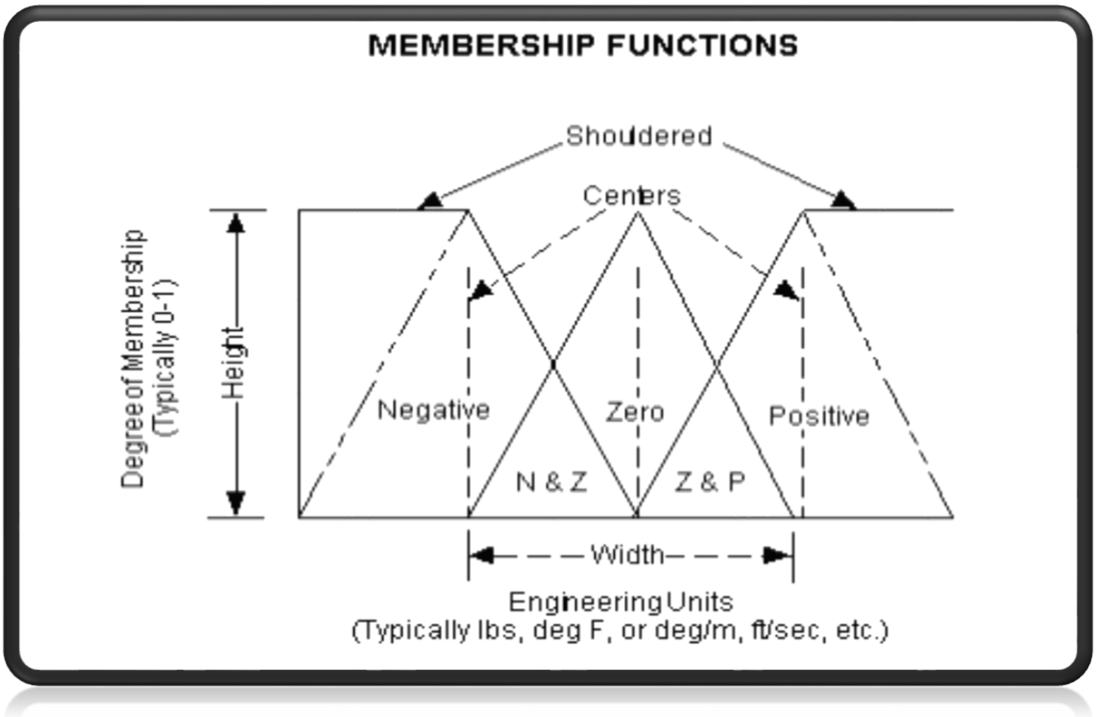


Figure 4.19: The Features of a Membership Function

Figure 4.19 illustrates the features of the triangular membership function, which is used in the present study due to its mathematical simplicity. Other shapes can be used too, but the triangular shape lends itself to this illustration.

The degree of membership (DOM) is determined by plugging the selected input parameter (error or error-dot) into the horizontal axis and projecting vertically to the upper boundary of the membership function(s).

4.5.5.3 Fuzzy Logic Modeling and Processing by MathLab

The FL system is based on inputs and outputs, along with rules connecting them to each other. In Figure 4.20 the left side shows the top twenty factors of delay that were created as a group of membership functions in yellow and, he five PPMs created with a five membership functions in blue. The white box, which is located in the middle, is the brain of the FL system. It is the area where the rules are created to perform the fuzzification process.

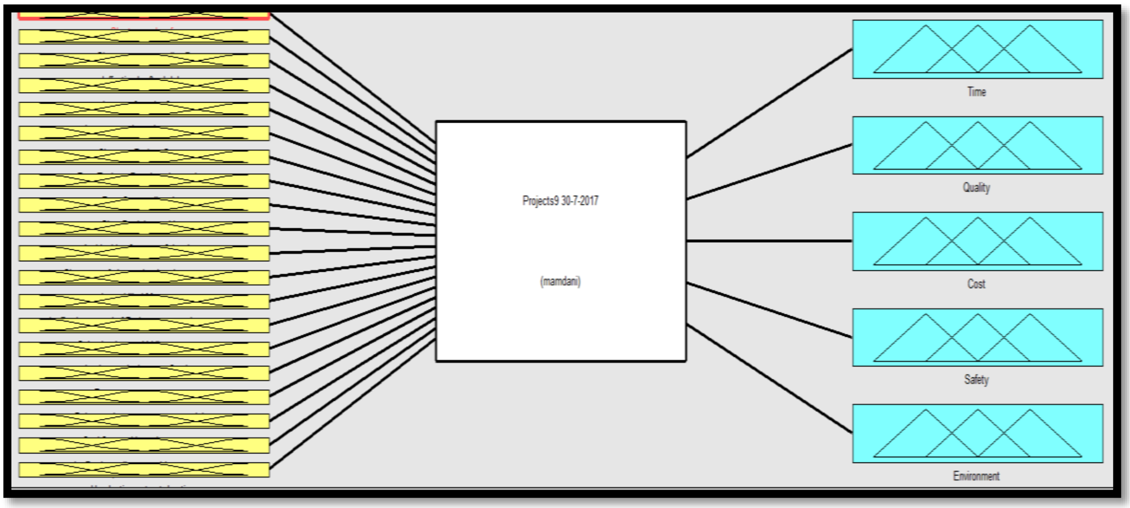


Figure 4.20 Top-20 Factors vs. 5 Performance Measures

The middle white box contains approximately 202 rules, or Functional Relationships, as follows:

- 68 rules were created form the Red Chain Factors of Delays.
- 62 rules were created from the Blue Chain Factors of Delays.
- 72 rules were created from the Green Chain Factors of Delays.

Additional rules could be created from the White Chain Factors of Delays, but due to their lower risk factors and to avoid system complexity, the author decided to not include them in this stage. Indeed, most of these rules are repeated and covered by the chains of factors. The 202 rules are covered in detail and presented in tables later in this chapter.

Introduction to MATLAB

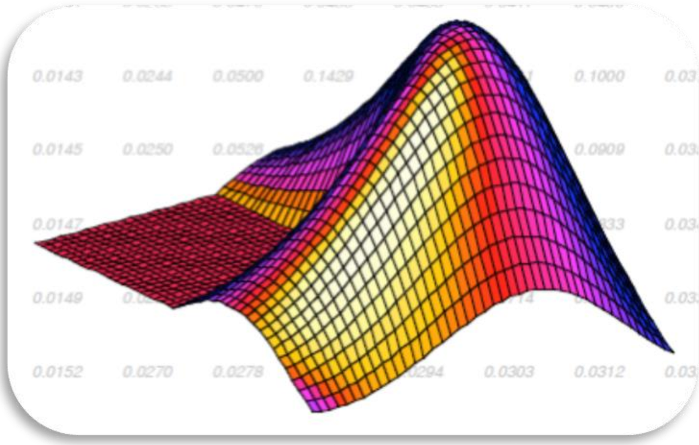


Figure 4.21 MATLAB Software's Logo

MATLAB is widely used in all areas of applied mathematics, education and research at universities and in the industry. MATLAB stands for MATrix LABoratory, and the software is built up around vectors and matrices. This makes the software particularly useful for linear algebra, but MATLAB is also a great tool for solving algebraic and differential equations as well as numerical integration. MATLAB has powerful graphics tools and can produce excellent images in both 2D and 3D. It is also one of the easiest programming languages for writing mathematical programs. MATLAB also has tool boxes useful for functions such as signal processing, image processing and optimization. Figure 4.21 presents the logo of the MATLAB which illustrates the 3D effect of the data behavior.

In addition, it has a variety of graphical capabilities that can be extended through other programs written in its own programming language. Many such programs come with the system; a number of these extend MATLAB's capabilities to nonlinear problems, such as the solution of initial value problems for ordinary differential equations.

MATLAB is designed to solve problems numerically; that is, in finite-precision arithmetic. Therefore, it produces approximate rather than precise solutions and should not be confused with a symbolic computation system (SCS) such as Mathematica or Maple. It should be understood that this does not make MATLAB better or worse than SCS; it is a tool designed for different tasks and is, therefore, not directly comparable.

A- Membership Functions for All Inputs & Outputs

Based on the results obtained from previous sessions of focus group and the author's effort that was extended for a period of almost two months; the results collected created 125 linguistic variables representing both the factors of delay as well as the project performance measures.

The full list of the top 20 factors of delay is illustrated in Table 4.4, with each factor having four or five linguistic variables.

TABLE 4.4: LINGUISTIC VARIABLES – FACTORS OF DELAY

EC- Factors of Delay	Level-4	Level-3	Level-2	Level-1	Level-0
Shortage of tech. prof	No shortage	Low shortage	Med shortage	High shortage	N/A
Shortage of labor (all skills)	No shortage	Low shortage	Med shortsge	High shortsge	N/A
Ineffective plan & sched.	Advanced	Moderate	Occational	Poor	N/A
Loose safety rules & regulations	Fully adheared	Average	Poor	Not Adheared	N/A
Improper tech. studies by during bidding	Super-Detailed	Standard	Weak	Cursory	N/A
Changes in the scope of the project	Negligible	Simple	Moderate	Major	Severe
Poor tech. staff assigned to the project	Professional	Qualified	Poor	Not qualified	N/A
Contractor's poor coordination with parties	Progressive	Communicative	Weak	Disconnected	N/A
Slow decision making by the client's organization	Proactive	Fast ontime	Normal	Slow	N/A
Ambiguities and mistakes in specs & drawings	Comperhesive	Clear	Prospective	Vague	N/A
Slow preparation changed orders by contractor	Proactive	Responsive	late	languid	N/A
Low skill of manpower	nonexistent	rarely	occasional	chronic	N/A
Ineffective control of project prog.by contractor	Advanced	effective	inactive	Messy	N/A
Gov. tendering system -selecting lowest bidding	Selective	Fair	considerable	cheaply	N/A
Inadequate design specifications	Professional	Adecuate	Prospetive	Messy	N/A
Poor contract management	Professional	controller	weak	ignorant	N/A
Delay settlement of contractor claims by client	proactive	responsive	Delayed	ignorant	N/A
Cash flow problems faced by the contractor	Secured	Funded	insufficient	Overdraft	N/A
Inefficient quality control by the contractor	Efficient	controller	corrective	Messy	N/A
Unrealistic contract duration	Conservative	Realistic	Reasonable	Risky	N/A

The PPMs consist of five main measures that were carefully zoned to reveal whether a project is going to be finished early, on time, delayed or a failure with regard to time. They also reveal the cost performance and how a project moves according to budgeted plan. Some projects may fall under the same planned budget, some will save money and others may face slight or significant budget overrun slightly, which would lead to a project's crisis. Table 4.5 below shows the four levels of variables from the best to the worst.

TABLE 4.5: LINGUISTIC VARIABLES – PERFORMANCE MEASURES

Project Performance Measures - CA	Level-4	Level-3	Level-2	Level-1
Time	Earlier	Ontime	Delayed	Failure
Quality	Perfect	Meets scope	Corrective	Bad
Cost	Thrift	As planned	Over-run	Crises
Safety	Secured	Adhered	Concerned	Risky
Environment	Circumspect	Adhered	Concerned	incurious
Success Factor	Outstanding	Sucsseded	Concerned	Faliure

Each membership function has its own analysis that represents a group of linguistic variables. Each linguistic variable has a specific range of values that reflect the existence/performance of this variable within a specific zone.

B- Linguistic variables for Factors of delays

One of the main steps in building the perfect model in MATLAB is to represent a clear value description of inputs and outputs. This is called linguistic variables, in which each indicates the status of a specific factor in a specific range or zone. For example, the shortage of technical staff was interpreted into four linguistic variables: "no shortage, low shortage, medium shortage and high shortage".

Figure 4.22 shows the four linguistic variables for factor of delay-1 (shortage of technical staff by the contractor). This range of variables created a full membership function so the lowest variable is called no shortage, which represents a trapezoid curve between 0 to 10%. The highest variable is called high shortage, which represents the trapezoid curve between 30 to 60% of the total technical staff shortage of the same project.

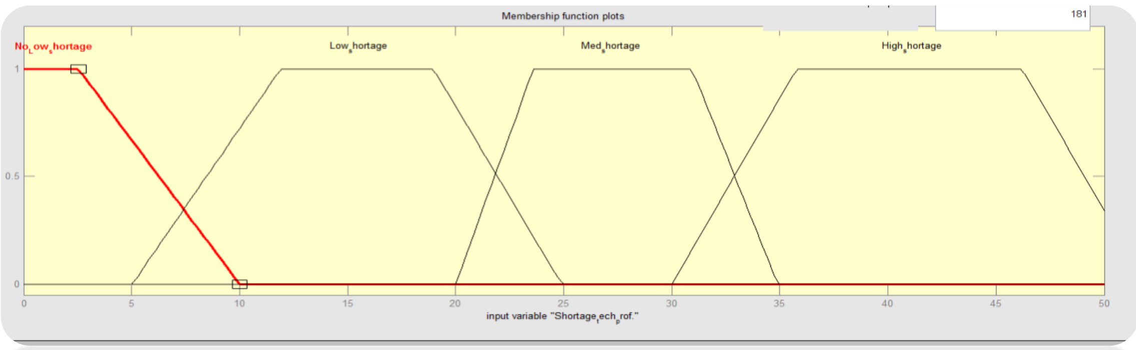


Figure 4.22: Factor-1 Shortage of Technical Staff Membership Function

Figures (4.23-A to 4.23-D) illustrates the top 20 factors of delay interpreted as a group of membership functions. The membership functions have different types i.e. “rectangular, trapezoid, etc.,” all based on the author’s preference as well as the nature of the data.

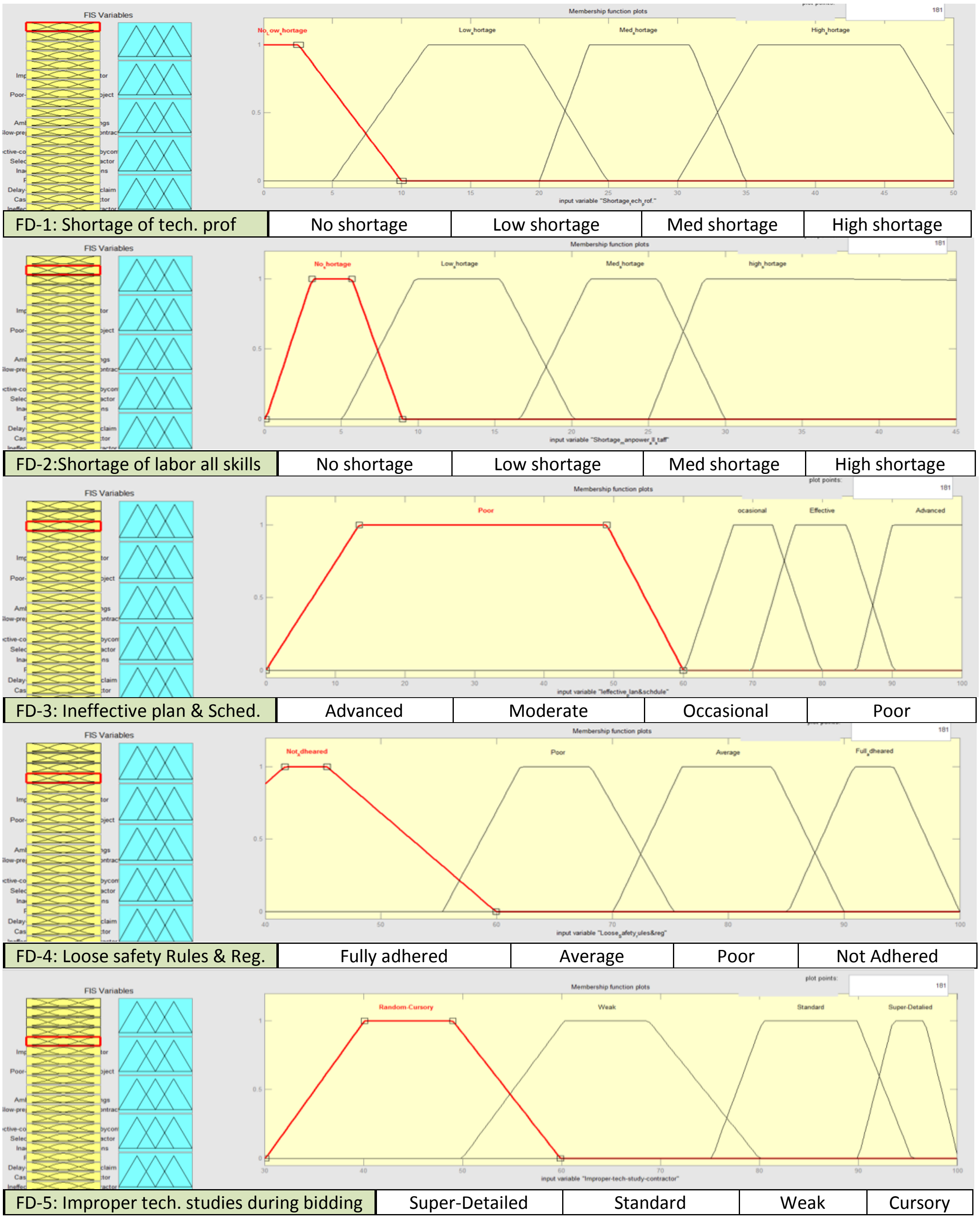


Figure 4.23-A: Top-1-5 Factors of Delay & Their Membership Functions

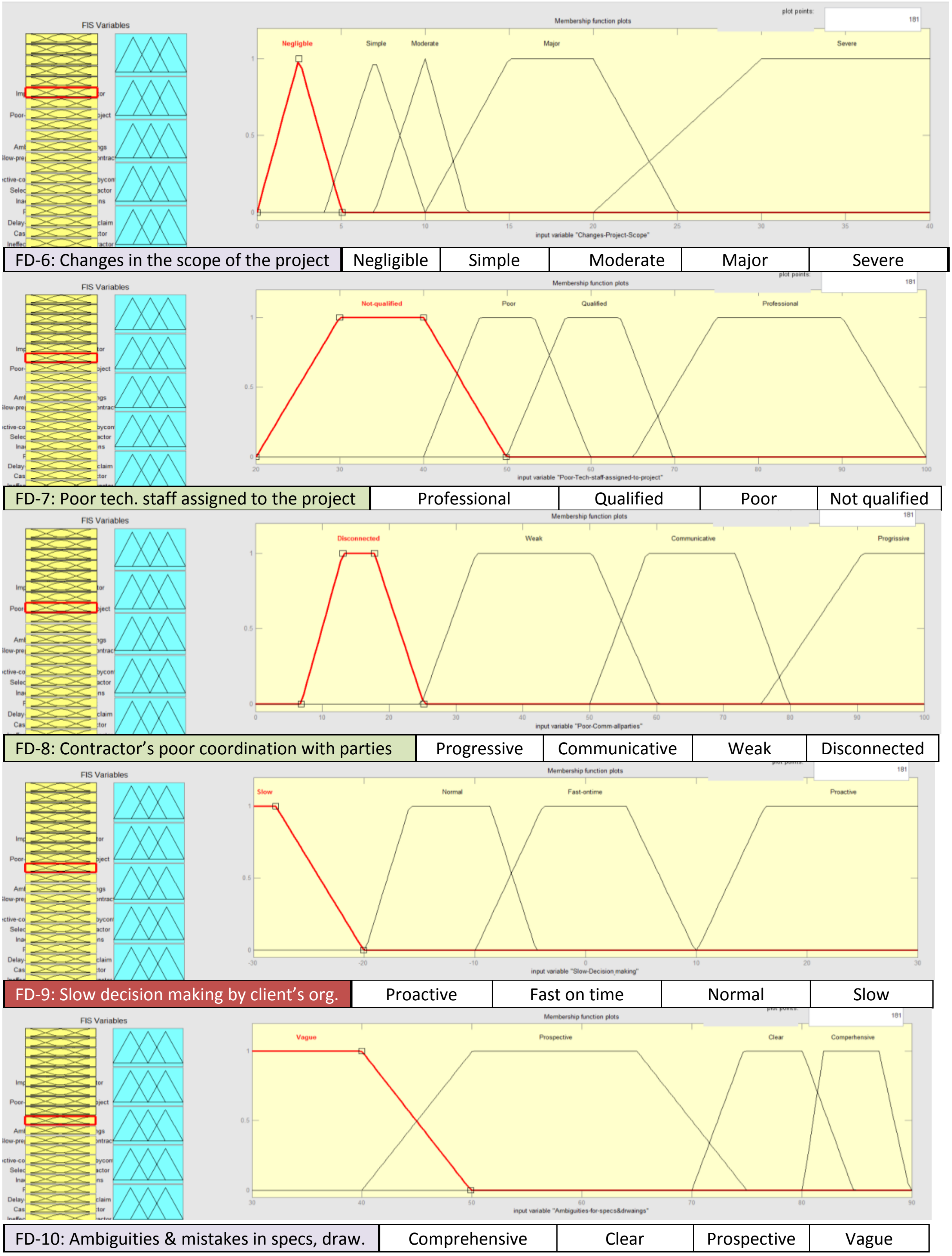


Figure 4.23-B: Top 6-10 Factors of Delay & Their Membership Functions

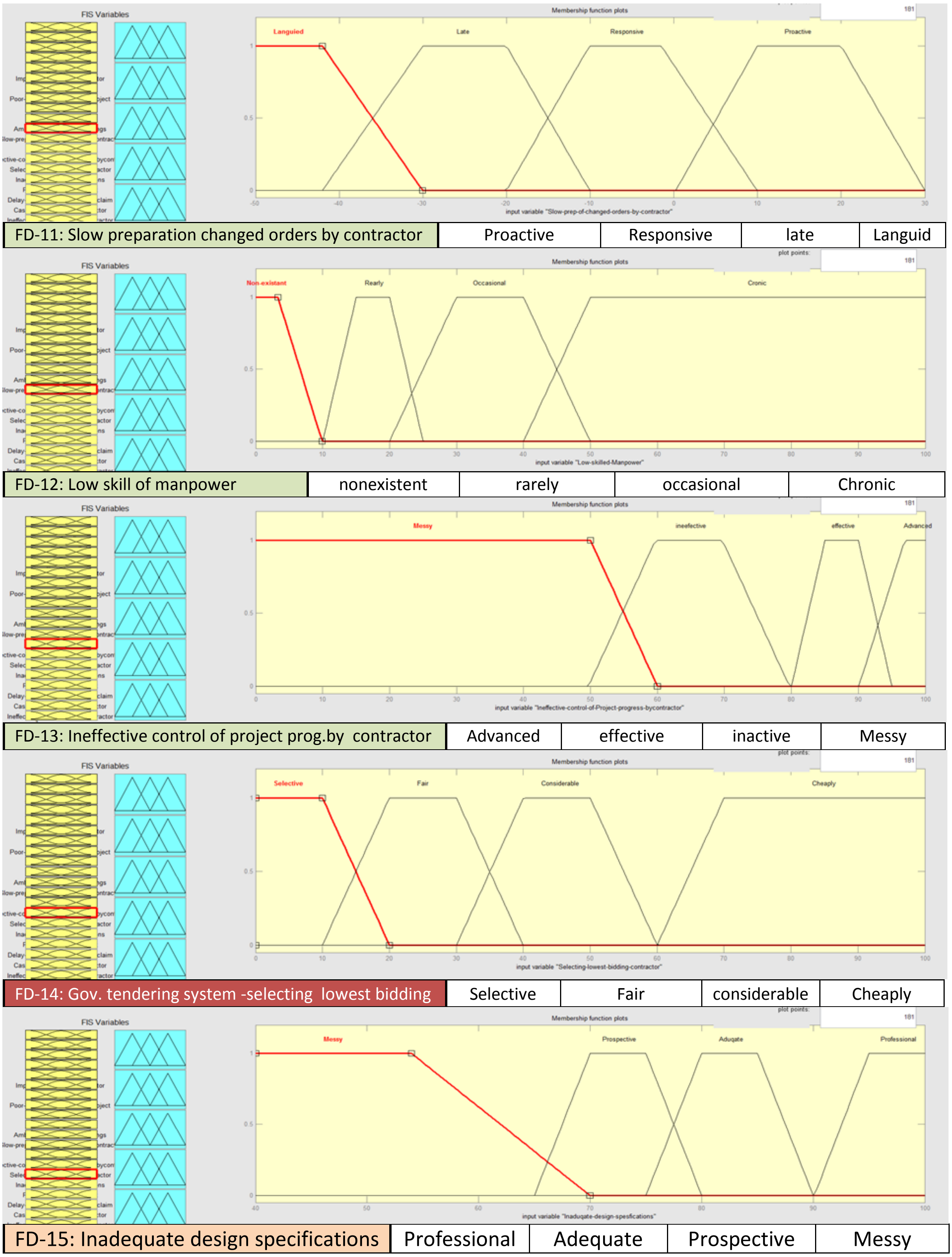
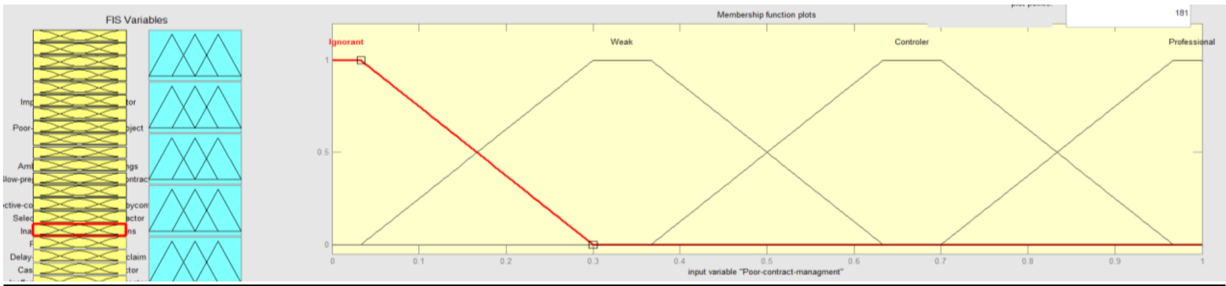
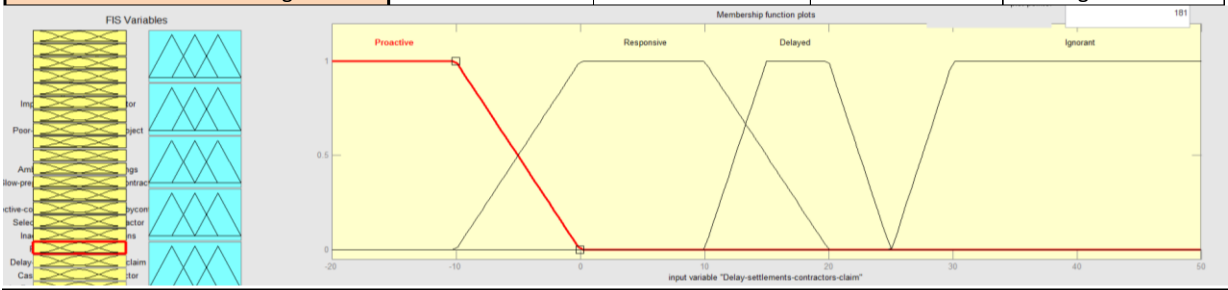


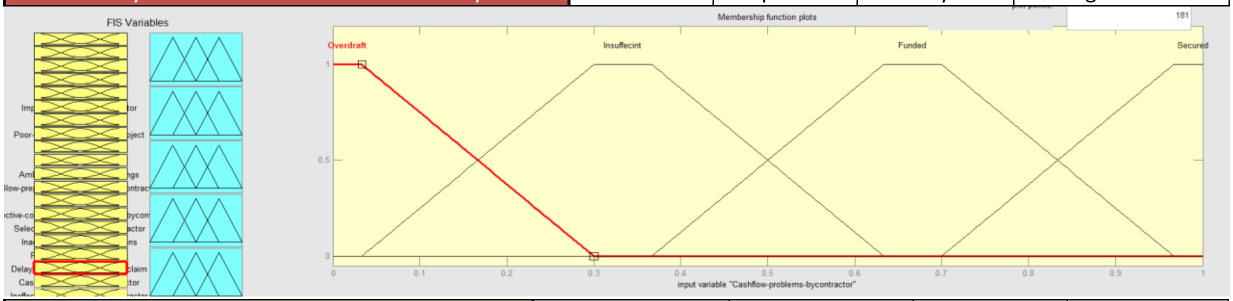
Figure 4.23-C: Top 11-15 Factors of Delay & Their Membership Functions



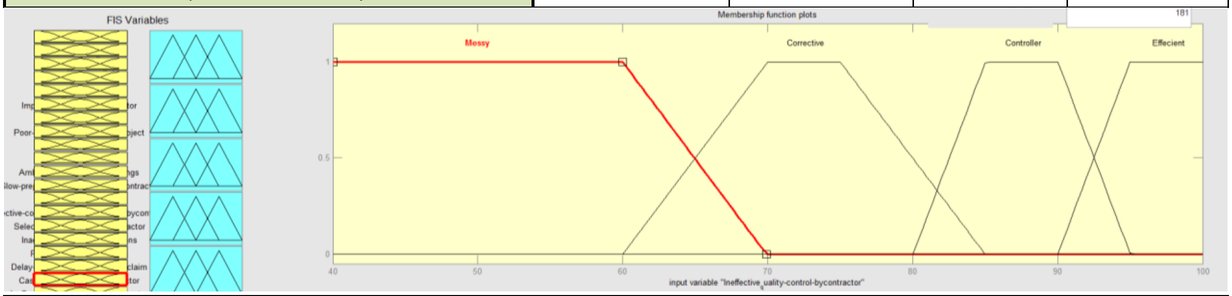
FD-16: Poor contract management	Professional	controller	weak	Ignorant



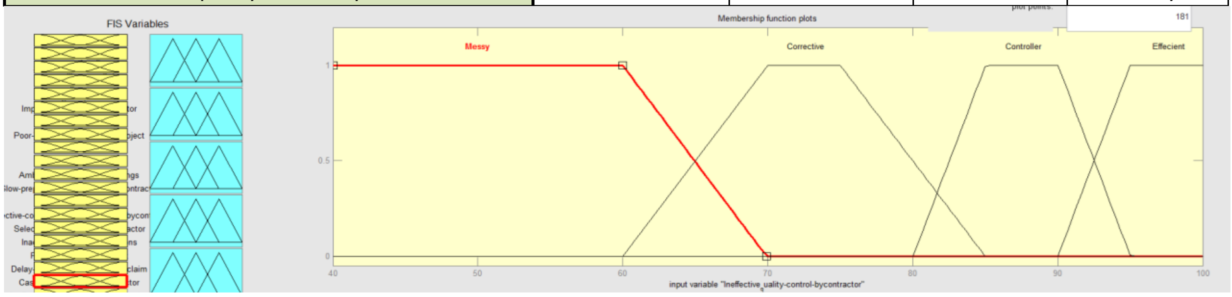
FD-17: Delay settlement of contractor claims by client	Proactive	responsive	Delayed	ignorant



FD-18: Cash flow problems faced by the contractor	Secured	Funded	insufficient	Overdraft



FD-19: Inefficient quality control by the contractor	Efficient	controller	corrective	Messy



FD-20: Unrealistic contract duration	Conservative	Realistic	Reasonable	Risky

Figure 4.23-D: Top 15-20 Factors of Delay & Their Membership Functions

C- Linguistic Variables for Project Performance Measures

According to the creation of membership function for the factors of delay, the same concept was applied to all performance measures, i.e. time, cost, quality, safety and environment. PPM-1 (time) was interpreted into five linguistic variables (Earlier, On-time, Delayed, Major delay and Failure).

Figure 4.24 shows the four linguistic variables of the PPM-1 (Time: scheduled time). This range of variables created a completed membership function so that the lowest variable-1, called "Earlier," represents a trapezoid curve between 80% and 105% of commitment to the agreed time schedule for a specific project. The project is described as "failure," as indicated in variable-4 by representing the trapezoid curve between 50% and above from the agreed time schedule of the project.

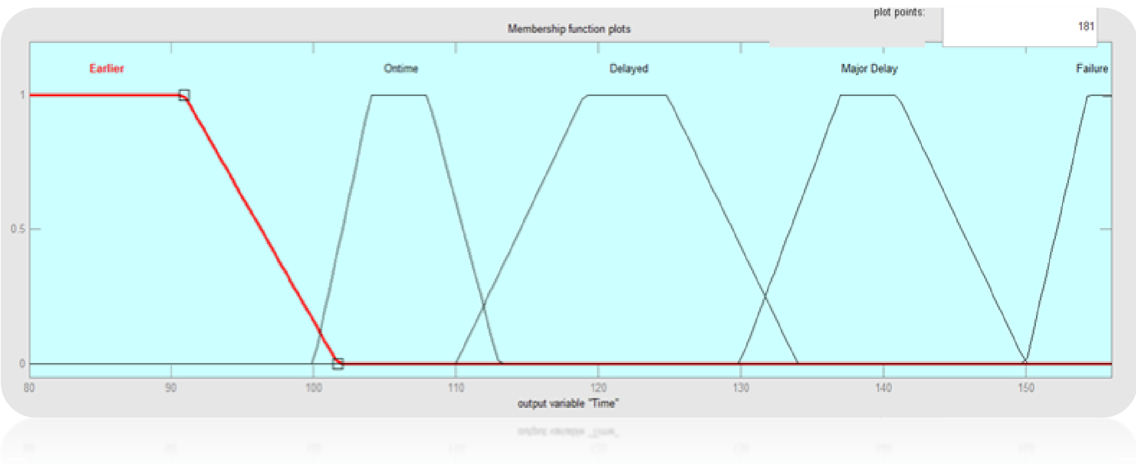


Figure 4.24: Performance Measure-1-Time Membership Function

The five membership functions were clearly set up with respect to the PPMs. This is considered the final step of the modeling process in FL. The owners or the project managers would be able to get a predictable, proactive figures before the initiation stage or during the execution stage of the projects. Figure 5.25 illustrates how the 5-membership functions were created for the PPMs in MATLAB using fuzzy's sets modeling.

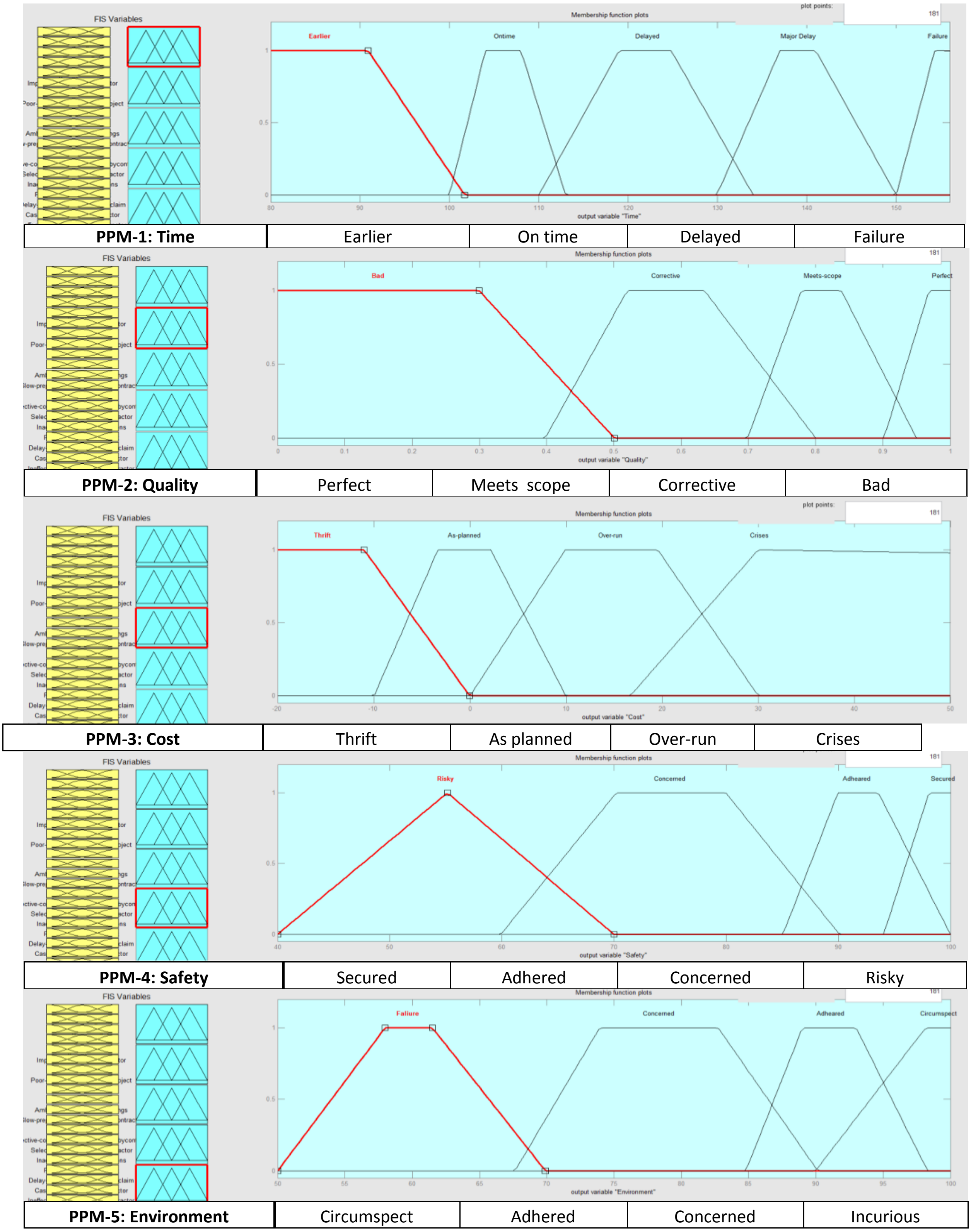


Figure 4.25: Five Performance Measures & Their Membership Functions

D-Rules Creation for Fuzzification Process

There were 202 rules created for the fuzzification process for the Red, Blue and Green Chains of the delay factors. Of these, 68 rules were created for the Red Chain factors of delays, while 62 rules were created for the Blue Chain. The highest number of rules were related to the Green Chain due to higher involvement of delay factors. Tables 4.6-A to 4.8-D present all rules involved in the fuzzification process.

TABLE 4.6-A: RED CHAIN – MEMBERSHIP FUNCTIONS

RED-Chains RULES									
	Chain-1	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Improper tech. studies by during bidding	Super-Detailed	Standard	Weak	Cursory	Standard	Weak	Standard	Cursory
	Changes in the scope of the project	Negligable	Simple	Moderate	Major	Moderate	Simple	Simple	Simple
	Ambiguities and mistakes in specs & drawings	Comperhesive	Clear	Prospective	Vague	Vague	Clear	Prospective	Clear
	Inadequate design specifications	Professinal	Adecuate	Prospetive	Messy	Messy	Adecuate	Prospetive	Professinal
Customer Attributes	Time	Earlier	Ontime	Delayed	Failure	Delayed	Delayed	Delayed	Delayed
	Quality	Perfect	Meets scope	Corrective	Bad	Bad	Meets scope	Bad	Meets scope
	Cost	Thrift	As planned	Over-run	Crises	Over-run	Over-run	Over-run	As planned
	Safety	Secured	Adheared	Concerned	Risky	Concerned	Adheared	Concerned	Adheared
	Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Adheared	Concerned	Adheared
	Chain-2	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Amb. & mistakes in specs	Comperhesive	Clear	Prospective	Vague	Comperhesive	Prospective	Clear	Comperhesive
	Dealy in settlement	proactive	responsive	Delayed	ignorant	responsive	Delayed	responsive	Delayed
	Short. Of tech staff	No shortage	Low shortage	Med shortsge	H. shortsge	Med shortsge	No shortage	Med shortsge	No shortage
	short. Of manpoer all skills	No shortage	Low shortage	Med shortsge	H. shortsge	Med shortsge	No shortage	Med shortsge	No shortage
	Low skills of manpower	nonexistent	raerly	occoasional	cronic	occoasional	nonexistent	raerly	occoasional
Customer Attributes	Time	Earlier	Ontime	Delayed	Failure	Delayed	Delayed	Ontime	Ontime
	Quality	Perfect	Meets scope	Corrective	Bad	Bad	Meets scope	Corrective	Corrective
	Cost	Thrift	As planned	Over-run	Crises	As planned	As planned	Over-run	As planned
	Safety	Secured	Adheared	Concerned	Risky	Concerned	Adheared	Concerned	Adheared
	Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Adheared	Concerned	Adheared
	Chain-3	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Dealy in settlement	proactive	responsive	Delayed	ignorant	responsive	Delayed	Delayed	responsive
	Short. Of tech staff	No shortage	Low shortage	Med shortsge	H. shortsge	Med shortsge	Low shortage	No shortage	H. shortsge
	short. Of manpoer all skills	No shortage	Low shortage	Med shortsge	H. shortsge	Med shortsge	Low shortage	No shortage	H. shortsge
Customer Attributes	Time	Earlier	Ontime	Delayed	Failure	Delayed	Delayed	Delayed	Delayed
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Meets scope	Meets scope	Bad
	Cost	Thrift	As planned	Over-run	Crises	Over-run	As planned	Thrift	Over-run
	Safety	Secured	Adheared	Concerned	Risky	Concerned	Adheared	Adheared	Concerned
	Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Adheared	Adheared	Concerned
	Chain-4	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Short. Of tech staff	No shortage	Low shortage	Med shortsge	H. shortsge	Low shortage	H. shortsge		
	Low skills of manpower	nonexistent	raerly	occoasional	cronic	cronic	raerly		
Customer Attributes	Time	Earlier	Ontime	Delayed	Failure	Ontime	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Corrective		
	Cost	Thrift	As planned	Over-run	Crises	As planned	As planned		
	Safety	Secured	Adheared	Concerned	Risky	Concerned	Concerned		
	Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Concerned		

TABLE 4.6-B: RED CHAIN – MEMBERSHIP FUNCTIONS

	Chain-5	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	short. Of manpoer all skills	No shortage	Low shortage	Med shortsge	High shortsge	High shortsge	Low shortage		
	Low skills of manpower	nonexistent	raerly	occoasional	cronic	raerly	cronic		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Bad		
	Cost	Thrift	As planned	Over-run	Crises	As planned	As planned		
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Concerned		
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Concerned		

	Chain-6	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Low skills of manpower	nonexistent	raerly	occoasional	cronic	raerly	cronic	raerly	occoasional
	poor cntract management	Professional	Qualified	Poor	Not qualified	Poor	Qualified	Qualified	Poor
	unrealistic cont. duration	Conservative	Realistic	Resanable	Risky	Risky	Realistic	Risky	Conservative
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Faliure	Delayed	Delayed	Ontime
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Corrective	Meets scope	Corrective
	Cost	Thrift	As planned	Over-run	Crises	Over-run	As planned	As planned	As planned
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Concerned	Adheared	Adheared
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Concerned	Adheared	Adheared

	Chain-7	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	poor cntract management	Professional	Qualified	Poor	Not qualified	Qualified	Not qualified		
	unrealistic cont. duration	Conservative	Realistic	Resanable	Risky	Risky	Realistic		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Meets scope	Corrective		
	Cost	Thrift	As planned	Over-run	Crises	As planned	Over-run		
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Adheared		
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared		

	Chain-8	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	unrealistic cont. duration	Conservative	Realistic	Resanable	Risky	Risky	Realistic		
	ineff. Planning & sched.	Advanced	Moderate	Occational	Poor	Moderate	Poor		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Meets scope		
	Cost	Thrift	As planned	Over-run	Crises	As planned	Over-run		
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Concerned		
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared		

	Chain-9	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	ineff. Planning & sched.	Advanced	Moderate	Occational	Poor	Moderate	Occational		
	cont. poor coordination	prigrissive	commuicative	weak	disconnected	weak	commuicative		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Meets scope		
	Cost	Thrift	As planned	Over-run	Crises	As planned	As planned		
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Adheared		
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared		

	Chain-10	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	slow decision making-CL	Proactive	Fast ontime	Normal	Slow	Fast ontime	Slow		
	Delay in settlement	proactive	responsive	Delayed	ignorant	Delayed	responsive		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Meets scope	Corrective		
	Cost	Thrift	As planned	Over-run	Crises	Over-run	As planned		
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Concerned		
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Concerned		

TABLE 4.7-A: BLUE CHAIN – MEMBERSHIP FUNCTIONS

	Chain-1	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Short. Of tech Prof.	No shortage	Low shortage	Med shortsge	High shortsge	Low shortage	Med shortsge	High shortsge	No shortage
	Loose safety rules & reg	Fully adheared	Average	Poor	Not Adheared	Average	Poor	Average	Poor
	Improper tech study cont	Super-Detailed	Standard	Weak	Cursory	Weak	Standard	Weak	Standard
	slow prep changed order	Proactive	Responsive	late	languid	late	Responsive	Responsive	languid
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed	Delayed	Delayed
	Quality	Perfect	Meets scope	Corrective	Bad	Meets scope	Corrective	Bad	Meets scope
	Cost	Thrift	As planned	Over-run	Crises	Over-run	Over-run	Over-run	As planned
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Adheared	Concerned	Concerned
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared	Concerned	Concerned

	Chain-2	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	ineff. Planning & sched.	Advanced	Moderate	Occational	Poor	Moderate	Poor	Moderate	Moderate
	slow prep changed order	Proactive	Responsive	late	languid	late	Responsive	late	Responsive
	ineff. Control of project	Advanced	effective	inactive	Messy	inactive	effective	Advanced	Messy
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed	Delayed	Delayed
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Meets scope	Meets scope	Corrective
	Cost	Thrift	As planned	Over-run	Crises	As planned	As planned	As planned	As planned
	Safety	Secured	Adheared	Concerned	Risky	Concerned	Concerned	Adheared	Adheared
	Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Concerned	Adheared	Adheared

	Chain-3	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	loose safett rules & reg	Fully adheared	Average	Poor	Not Adheared	Average	Poor		
	gov. tendering sys.	Selective	Fair	considerable	cheaply	considerable	Fair		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Corrective		
	Cost	Thrift	As planned	Over-run	Crises	As planned	As planned		
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Concerned		
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Concerned		

	Chain-4	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Cont poor coordination	Progrissive	ommunicativ	Weak	Disconnected	Communicative	Weak	Weak	Communicative
	slow prep changed order	Proactive	Responsive	late	languid	Responsive	late	Responsive	late
	ineff. Control of project	Advanced	effective	inactive	Messy	inactive	effective	inactive	effective
	por contract management	Professinal	controler	weak	ignorant	weak	controler	controler	weak
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Corrective	Corrective	Corrective
	Cost	Thrift	As planned	Over-run	Crises	As planned	As planned	As planned	As planned
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Adheared	Adheared	Adheared
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared	Adheared	Adheared

	Chain-5	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	slow decision making-CL	Proactive	Fast ontime	Normal	Slow	Fast ontime	Slow		
	slow prep changed order	Proactive	Responsive	late	languid	late	Responsive		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Meets scope	Meets scope		
	Cost	Thrift	As planned	Over-run	Crises	As planned	As planned		
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Adheared		
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared		

TABLE 4.7-B: BLUE CHAIN – MEMBERSHIP FUNCTIONS

	Chain-6	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	slow prep changed order	Proactive	Responsive	late	languid	Responsive	languid		
	gov. tendering sys.	Selective	Fair	considerable	cheaply	cheaply	Fair		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Meets scope		
	Cost	Thrift	As planned	Over-run	Crises	As planned	As planned		
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Adheared		
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared		
	Chain-7	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Low skills of manpower	No shortage	Low shortage	Med shortsge	High shortsge	Low shortage	High shortsge		
	unrealistic cont duration	Conservative	Realistic	Resanable	Risky	Risky	Realistic		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Faliure	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Meets scope	Corrective		
	Cost	Thrift	As planned	Over-run	Crises	Over-run	As planned		
	Safety	Secured	Adheared	Concerned	Risky	Concerned	Concerned		
	Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Concerned		
	Chain-8	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	ineff. Cotrol of project	Advanced	effective	inactive	Messy	effective	Messy		
	gov. tendering sys.	Selective	Fair	considerable	cheaply	cheaply	Fair		
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed		
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Bad		
	Cost	Thrift	As planned	Over-run	Crises	As planned	Over-run		
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Concerned		
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Concerned		
	Chain-9	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	gov. tendering sys.	Selective	Fair	considerable	cheaply	Fair	cheaply	Fair	cheaply
	cash flow problem	Secured	Funded	insuffecint	Overdraft	insuffecint	Funded	insuffecint	Secured
	unrealstic cont duration	Conservative	Realistic	Resanable	Risky	Resanable	Realistic	Realistic	Conservative
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Faliure	Ontime	Delayed	Ontime
	Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Corrective	Meets scope	Bad
	Cost	Thrift	As planned	Over-run	Crises	Over-run	As planned	As planned	Thrift
	Safety	Secured	Adheared	Concerned	Risky	Concerned	Adheared	Adheared	Adheared
	Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Adheared	Adheared	Adheared

TABLE 4.8-A: GREEN CHAIN – MEMBERSHIP FUNCTIONS

Green-Chains RULES									
	Chain-1	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Short. Of tech Prof.	No shortage	low shortage	Mid shortage	high shortage	No shortage	low shortage	Mid shortage	high shortage
	short. Of MP all skils	No shortage	low shortage	Mid shortage	high shortage	low shortage	Mid shortage	high shortage	No shortage
	ineff. Planning & sched.	advanced	Modorate	occasional	Poor	occasional	Poor	advanced	Poor
	ineff. Control of project	advanced	effective	ineffective	Messy	ineffective	ineffective	effective	advanced
	ineff. Quality Control	effective	controller	corrective	messy	messy	corrective	controller	corrective
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

TABLE 4.8-B: GREEN CHAIN – MEMBERSHIP FUNCTIONS

	Chain-2	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	short. Of MP all skils	No shortage	low shortage	Mid shortage	high shortage	No shortage	low shortage	Mid shortage	high shortage
	loose safety rules & reg	full adheared	average	poor	not adheared	average	poor	not adheared	full adheared
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

	Chain-3	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	ineff. Planning & sched.	advanced	Modorate	occasional	Poor	advanced	Poor	Modorate	occasional
	poor contract management	Professional	controller	weak	ignorant	controller	weak	ignorant	Professional
	Inad. design specs.	Professional	accurate	Prospective	messy	Prospective	accurate	Professional	messy
	ineff. Control of project	advanced	effective	ineffective	Messy	Messy	advanced	ineffective	effective
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

	Chain-4	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	loose saftett rules & reg	full adheared	average	poor	not adheared	full adheared	not adheared	average	poor
	Low skills of manpower	non-exist	rearly	occuasional	cronic	rearly	occuasional	occuasional	cronic
	cont. poor coordination	progressive	communicative	weak	disconnected	weak	communicative	disconnected	weak
	Inad. design specs.	Professional	accurate	Prospective	messy	messy	Professional	Prospective	accurate
	short. Of MP all skils	No shortage	low shortage	Mid shortage	high shortage	Mid shortage	low shortage	low shortage	No shortage
	poor contract management	Professional	controller	weak	ignorant	controller	weak	Professional	controller
	ineff. Quality Control	effective	controller	corrective	messy	effective	messy	controller	corrective
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

	Chain-5	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Imp. tech. studies by during bidd.	super-detailed	standard	weak	cursory	super-detailed	cursory	standard	weak
	slow prep changed order	proactive	responsive	late	languid	responsive	late	proactive	languid
	Low skills of manpower	non-exist	rearly	occuasional	cronic	occuasional	rearly	rearly	non-exist
	unrealistic cont duration	conservative	realistic	reasnable	Risky	Risky	conservative	reasnable	realistic
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

	Chain-6	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	change In the scope of pro.	Negligible	simple	Moderate	Major				
	gov. tendering sys.	Selective	Fair	considerable	cheaply				
	slow decision making-CI	proactive	fast-ontime	normal	slow				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

TABLE 4.8-C: GREEN CHAIN – MEMBERSHIP FUNCTIONS

	Chain-7	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Poor qualif. Of tech. staff	professional	qualified	poor	not qualified				
	ineff. Planning & sched.	advanced	Modorate	occasional	Poor				
	slow prep changed order	proactive	responsive	late	languid				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				
	Chain-8	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Amb. and mistakes in specs	comperhensive	clear	prospective	vague				
	slow prep changed order	proactive	responsive	late	languid				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				
	Chain-9	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	slow prep changed order	proactive	responsive	late	languid				
	ineff. Quality Control	effective	controller	corrective	messy				
	Delay in settlmemt	proactive	responsive	delayed	ignorant				
	Amb. & mistakes in specs	comperhensive	clear	prospective	vague				
	Poor qualif. Of tech. staff	professional	qualified	poor	not qualified				
	change In the scope of pro.	Negligible	simple	Moderate	Major				
Customer Attributes	Time	Earlier	Ontime	Delayed	Failure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				
	Chain-10	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Amb. & mistakes in specs	comperhensive	clear	prospective	vague				
	slow prep changed order	proactive	responsive	late	languid				
	poor contract management	Professional	controller	weak	ignorant				
Customer Attributes	Time	Earlier	Ontime	Delayed	Failure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				
	Chain-11	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	slow decision making-CI	proactive	fast-ontime	normal	slow				
	change In the scope of pro.	Negligible	simple	Moderate	Major				
	ineff. Quality Control	effective	controller	corrective	messy				
Customer Attributes	Time	Earlier	Ontime	Delayed	Failure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

TABLE 4.8-D: GREEN CHAIN – MEMBERSHIP FUNCTIONS

	Chain-12	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	cont. poor coordination	progressive	communicative	weak	disconnected				
	loose safety rules & reg	full adheared	average	poor	not adheared				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

	Chain-13	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Poor qualif. Of tech. staff	professional	qualified	poor	not qualified				
	ineff. Planning & sched.	advanced	Modorate	occasional	Poor				
	slow prep changed order	proactive	responsive	late	languid				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

	Chain-14	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	change In the scope of pro.	Negligible	simple	Moderate	Major				
	slow decision making-CI	proactive	fast-ontime	normal	slow				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

	Chain-15	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Imp. tech. studies by during bidd.	super-detailed	starndard	weak	cursory				
	slow prep changed order	proactive	responsive	late	languid				
	Low skills of manpower	non-exist	rearly	occuasional	cronic				
	Unrealsitc cont. duration	conservative	realistic	reasnable	Risky				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

TABLE 4.8-E: GREEN CHAIN – MEMBERSHIP FUNCTIONS

	Chain-16	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	loose safety rules & reg	full adheared	average	poor	not adheared				
	cont. poor coordination	progressive	communicative	weak	disconnected				
	Low skills of manpower	non-exist	rearly	occasional	cronic				
	Inad. design specs.	Professional	accurate	Prospective	messy				
	poor contract management	Professional	controller	weak	ignorant				
	change In the scope of pro.	Negligible	simple	Moderate	Major				
	ineff. Quality Control	effective	controller	corrective	messy				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				
	Chain-17	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	ineff. Planning & sched.	advanced	Modorate	occasional	Poor				
	Poor qualif. Of tech. staff	professional	qualified	poor	not qualified				
	Inad. design specs.	Professional	accurate	Prospective	messy				
	Short. Of tech Prof.	No shortage	low shortage	Mid shortage	high shortage				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				
	Chain-18	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	short. Of MP all skills	No shortage	low shortage	Mid shortage	high shortage				
	loose safety rules & reg	full adheared	average	poor	not adheared				
	Short. Of tech Prof.	No shortage	low shortage	Mid shortage	high shortage				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				
	Chain-19	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
Factors	Short. Of tech Prof.	No shortage	low shortage	Mid shortage	high shortage				
	short. Of MP all skills	No shortage	low shortage	Mid shortage	high shortage				
	ineff. Planning & sched.	advanced	Modorate	occasional	Poor				
	ineff. Quality Control	effective	controller	corrective	messy				
Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure				
	Quality	Perfect	Meets scope	Corrective	Bad				
	Cost	Thrift	As planned	Over-run	Crises				
	Safety	Secured	Adheared	Concerned	Risky				
	Environment	Circumspect	Adheared	Concerned	incurious				

4.5.6 Validation of Ranking by Using Extended Survey (Top-20 Factors)

After applying the (DR-HOQ) analysis for ranking the projects delay factors, including all processes of sensitivity analysis by the representation of all indices, the re-ranking mechanism became robust enough for the logical ranking. However, the results of ranking is recommended to be validated by an additional technique that would verify the introduced final ranking is reliable.

The decision was made to administrate an extended survey to cover the scope and limitation of the research as stated in points 1, 2, 3 and 4 for one major project related to the field of construction and industrial project. The project selected went through a list of criteria as per the points below:

- Relevance of the field (construction or industrial)
- Location of the project (KSA)
- Size of the project (Mega Project)
- Complexity level (complicated with multiple activities)
- Recently finished (2014-2018)
- Accessibility of data
- Approachability to the projects engineers
- Inclusion of all projects phases (initiation, planning, execution, control and closing)
- Involvement of project management office or consultant services.

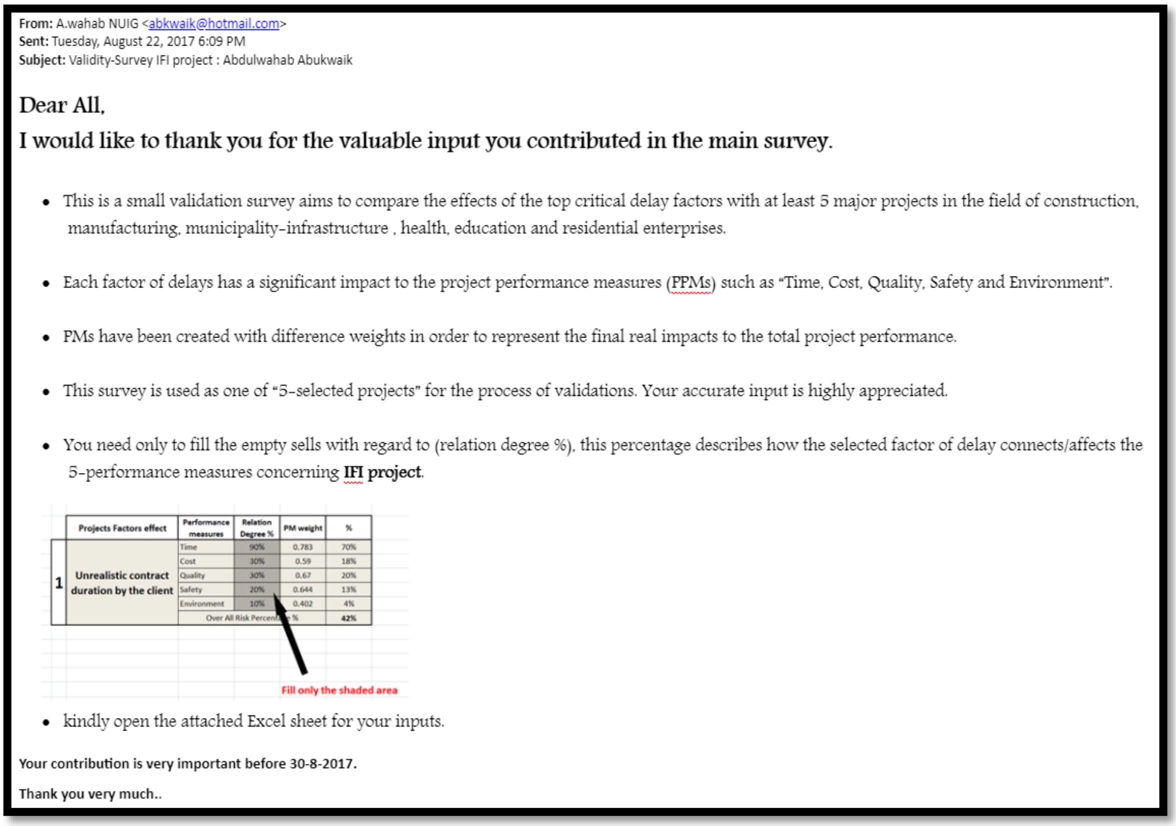
The project that eventually met all the above criteria was the International Food Industry project (IFI). This project was executed in KSA, Jeddah City, industrial area, phase-3. The project value was more than SR 300 million, with a proposed delivery time of 17 months. The project consisted of many components, including plant construction, admiration building, workshops, utilities, waste treatment system, irrigation, huge electro-mechanical works, piping, excavations, underground infrastructure, drainage facilities, storage tanks, equipment's, machines installations, staff recruitment /training, logistic operation and material handling. This project was managed by a third party, White Stone consultants, and a project management office with a local affiliate, Dr. Al-Sherbini.

The survey was developed to cover the real impacts of the top 20 delay factors with respect to the PPMs such as time, cost, quality, safety and environment. The survey was sent to 12 participants who were fully involved with the whole project cycles. The participants were project director, four project engineers, two consultant engineers, a quality inspector, a contract manager, an administrative project manager and the two heads of engineering. Figure 4.26 presents the general project prospective located in Saudi Arabia, Jeddah City, Industrial Area-2.

- Cost: $ 95 Million
- Time: 17 Month
- Types: Industrial & Construction
- Project category: Food Industry
- Project difficulty: High
- Project structure: project construction management

Figure 4.26: Areal View of IFI Project in KSA-Jeddah

Figure 4.27 is a copy of the formal communication used by the engineers involved in the project during the initiation, planning, execution and handover stages. The data from the extended survey was collected, and the results represent the average values of all respondents.


From: A.wahab NUIG <abkwaik@hotmail.com>
Sent: Tuesday, August 22, 2017 6:09 PM
Subject: Validity-Survey IFI project : Abdulwahab Abukwaik

Dear All,
I would like to thank you for the valuable input you contributed in the main survey.

- This is a small validation survey aims to compare the effects of the top critical delay factors with at least 5 major projects in the field of construction, manufacturing, municipality-infrastructure , health, education and residential enterprises.
- Each factor of delays has a significant impact to the project performance measures (FPMs) such as "Time, Cost, Quality, Safety and Environment".
- PMs have been created with difference weights in order to represent the final real impacts to the total project performance.
- This survey is used as one of "5-selected projects" for the process of validations. Your accurate input is highly appreciated.
- You need only to fill the empty sells with regard to (relation degree %), this percentage describes how the selected factor of delay connects/affects the 5-performance measures concerning **IFI project**.

	Projects Factors effect	Performance measures	Relation Degree %	PM weight	%
1	Unrealistic contract duration by the client	Time	90%	0.783	70%
		Cost	30%	0.59	18%
		Quality	30%	0.67	20%
		Safety	20%	0.644	13%
		Environment	10%	0.402	4%
		Over All Risk Percent… %			**42%**

- kindly open the attached Excel sheet for your inputs.

Your contribution is very important before 30-8-2017.

Thank you very much..

Figure 4.27: Extended Survey Communication for IFI Project in KSA-Jeddah

The following points are the main guidelines for the extended survey:

- This is a small validation survey that aims to compare the effects of the top critical delay factors for a major project in the field of construction, manufacturing, municipality-infrastructure, health, education and residential enterprises.
- Each factor of delay has a significant impact on the project performance measures (PPMs) including Time, Cost, Quality, Safety and Environment.
- PPMs have been created with different weights in order to represent the final real impacts on the total project performance.
- This survey is used as one out of five alternative projects for the process of validation. Your accurate input is highly appreciated.
- You need only to fill the empty cells with regard to relation degree %; this percentage describes how the selected factor of delay connects/affects the five performance measures concerning the IFI project.
- The relation degree represents the average values of all respondents and the overall risk % $= \sum_{1}^{5} \left(\frac{(\text{Relation Degree}-1\ x\ \text{PM weight}-1) + \text{Relation Degree}-2\ \text{x PM weight}-2) + \cdots)}{\text{Total PM weight } (0.78+0.67+0.59+0.64+0.4)=3{,}09} \right)$ ------------ (6)

Table 4.9 shows the sample the factor of delay (Unrealistic contact duration by the client). The engineers were asked to fill the relation degree% cells to get the overall risk percentage.

TABLE 4.9: EXTENDED SURVEY – SAMPLE

Factors of Delays: IFI Project								
Projects Factors effect	**Performance measures**	**Relation Degree %**	**PM weight**	**%**	**Evaluation Scale**		**Relation Degree**	**%**
Unrealistic contract duration by the client	Time		0.783	0%		1	**Very high**	> 70%
	Cost		0.67	0%		2	**High**	51% - 70%
	Quality		0.59	0%		3	**Average**	31% - 50%
	Safety		0.644	0%		4	**Low**	16% - 30%
	Environment		0.402	0%		5	**Very low**	5% - 15%
	Over All Risk Percentage %			**0%**		6	**No relation**	< 5%

4.6 Summary

The purpose of the chapter was to introduce the stages of methodology used to identify the critical factors of delays contributing to the projects delay in Saudi Arabia. The first stage demonstrated the steps undertaken to collect, sort, merge and group the factors of the delay from the previous studies and PM articles. The focus group in this stage included 66 factors of delay, which were categorized into 5 groups to be used for the main research questionnaire. This part of analysis has addressed Goal 2.

The second stage used the quantitative method to achieve Research Goal 3 by administrating a survey in the form of a questionnaire. The survey aimed to measure the frequency of occurrence and the severity of the 66 factors of delay to the project's time overrun. The participants' inputs for evaluating the severity and frequency of each factor of delay were used for the initial ranking process by applying the RII analysis in stage three to achieve the Research Goal 4.

The top 20 factors of delay resulting from the initial ranking in stage three represented the majority of the risk involved in the project delay. In stage four, the DR-HOQ was applied after the RII analysis to create additional indices for re-ranking optimization. The DR-HOQ method mainly covered all relationships contributing to prioritizing factors of delays in a detailed analysis by combining 3- indices; this analysis has addressed the Research Goals 5 and 6. Each index has its own weight to interpret each effect separately for the final ranking. The group of delay factors were formed and then evaluated by a formula, which was developed by the author to address Goal 7.

In stage five, FL Modeling was used to verify the collective impact of the group of factors, or chains, collected from stage four. The process of verification determined whether or not the collective impacts resulting from the empirical formula developed by the author were representative and had similar impacts to performance measures.

An extended survey corresponding to the top 20 critical factors determined by applying DR-HOQ with PPM was conducted on a real mega-project. The survey was administrated to the 12 experts directly involved in this project from the beginning until the handover. The results of survey were used to validate ranking of delay factors and to determine the gaps identified.

CHAPTER 5: RESEARCH ANALYSIS & FINDINGS

5.1 Chapter 5: (Research Analysis & Findings) layout.

Figure 5.1 outlines the structure of Research Analysis & Findings.

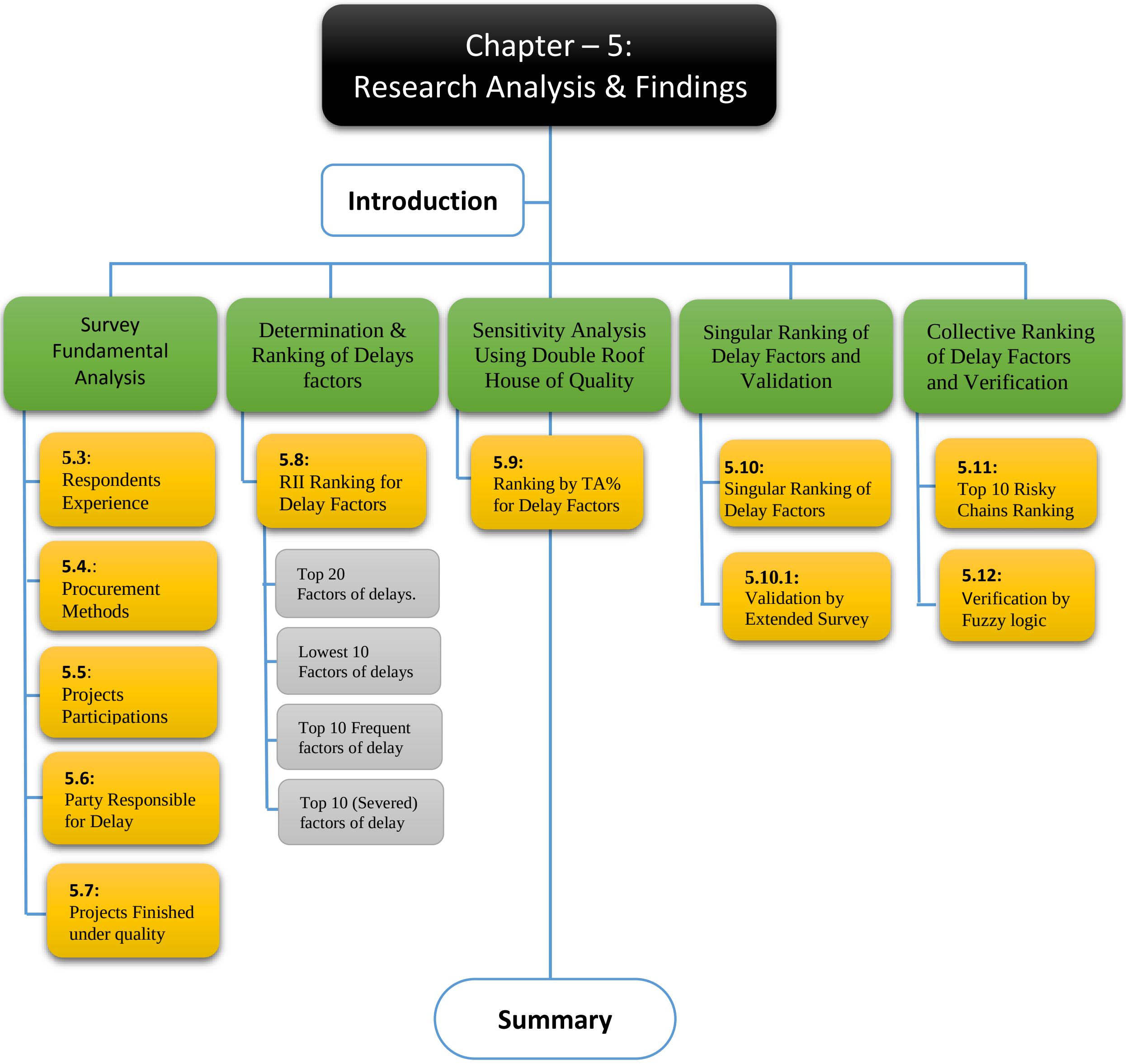


Figure 5.1: Chapter-5 General Layout

5.2 Introduction

Chapter 5 presents the data collected from the survey and an analysis of the inputs from respondents who were involved in construction and industrial projects in Saudi Arabia. Included are the respondents' demographic profiles based on characteristics such as the type of organization they represented (public, semi-public, and private), their age, education and years of experience. The survey analysis indicated no common agreement between the project parties with regard to the ranking of delay factors, which addressed the Research Goal 3. Moreover, the research analysed the severity and frequency of delay factors in the five phases of a construction project cycle, which addressed Research Goal 4.

The relationships between the factors of delays and performance measures were created by focus group. Similarly, the embedded interrelationships between the factors of delay were also identified to improve ranking. A total of 457 relationships were identified, which addressed the Research Goal 5 and 6.

An empirical formula was developed for evaluating the collective impact of delay factors (chains) against the PPMs. To test the reliability of the calculated risk factors, this formula was later verified by FL, which addressed Research Goal 7. This chapter also includes an extended survey for the validations of results concerning the singular/collective impacts of the delay factors.

Finally, the analysis focused on the collective impact of delay factors by previewing approximately 30 different scenarios via FL Modeling, which provided a deeper view of these risk factors and led to a universal mechanism proposal that would enable both public and private sectors to control projects in all stages.

Chapter 5 covers all work involved from the survey analysis until the conclusion. The sections included in this chapter are as follows:

- Survey fundamental analysis
- Determination and ranking of the delay factors
- Findings from the analysis using DR-HOQ
- Results of validation using extended survey
- Grouping of factors and their impact on projects delay
- Results of Verification using FL (Top-10 chains' ranking)

5.3 Survey Analysis

The survey analysis presented in this section corresponded to the total number of respondents (167 responses); however, in some sections, detailed comparisons were applied, if required. Therefore, figures, charts and tables are provided, as needed, to illustrate the research findings. Accordingly, the computability of the data or conflicts, if any, are discussed as it seems useful and relevant to the research goals and hypotheses.

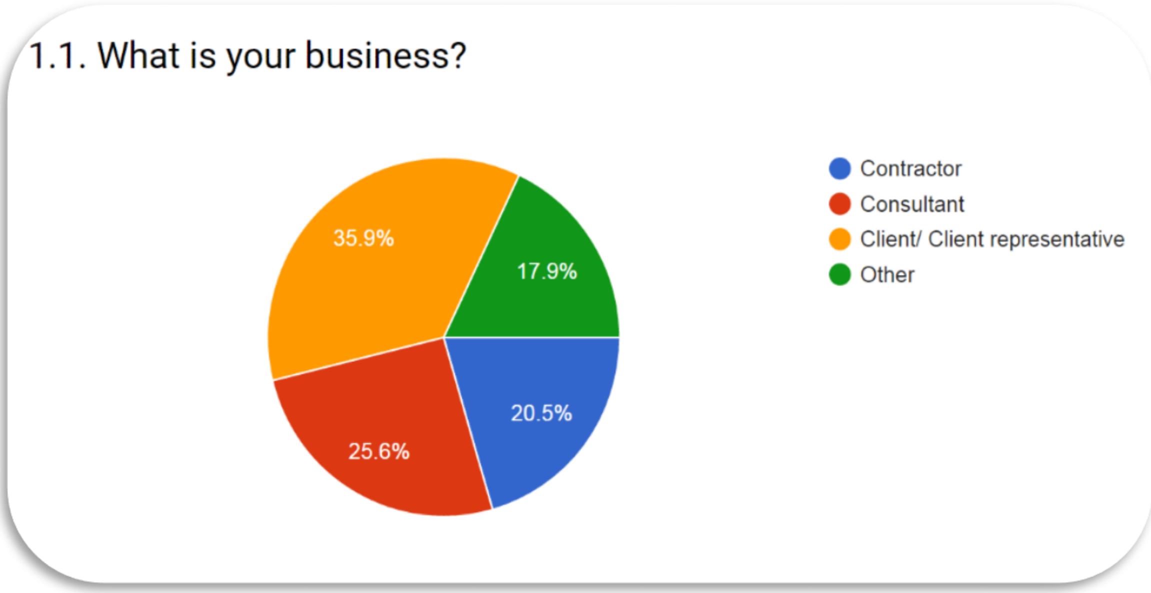


Figure 5.2: Types of Participation in Projects by Survey Respondents

5.3.1 Respondent Experience

This section presents general information about project participation by survey respondents. The aim of this section is to portray involvement with regard to the respondents, indicating, therefore, the degree of reliability of their data. Figure 5.2 shows that most of the responding stakeholders (approximately 36%) were clients or their representatives, with the consultants coming in second (approximately 26%). The contractors represented a little less (approximately 21%); however, the figures are a good indicator of the research reliability as these three populations are almost equally represented. Others, (consultant's affiliates, field practitioners, and economists) collectively were the smallest group responding (approximately 18%).

5.3.2 Sector Type:

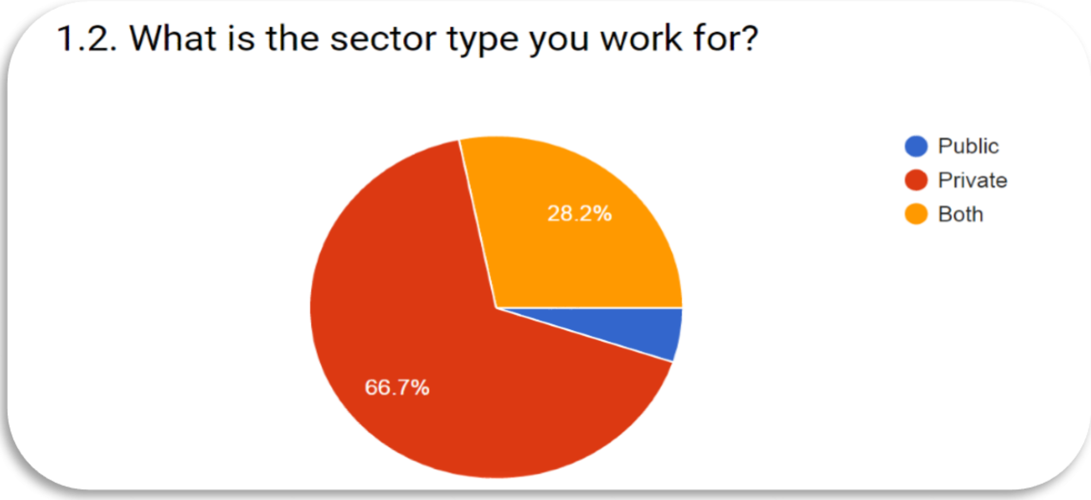


Figure 5.3: Sector Types of Respondents

Respondents were asked to determine the sector type they worked for. Figure 5.3 shows the vast majority of respondents work for the private sector (approximately 67%), and the least work exclusively for the public sector (approximately 5%). Several respondents (approximately 28%) work in both the public and private sectors of the KSA construction industry.

5.3.3 Years of Experience

Approximately 23% reported having experience of 11 to 15 years, while a similar percentage reported having of 5 to 10 years, which raises the reliability of the data collected. Almost 18% reported having experience of less than 5 years.

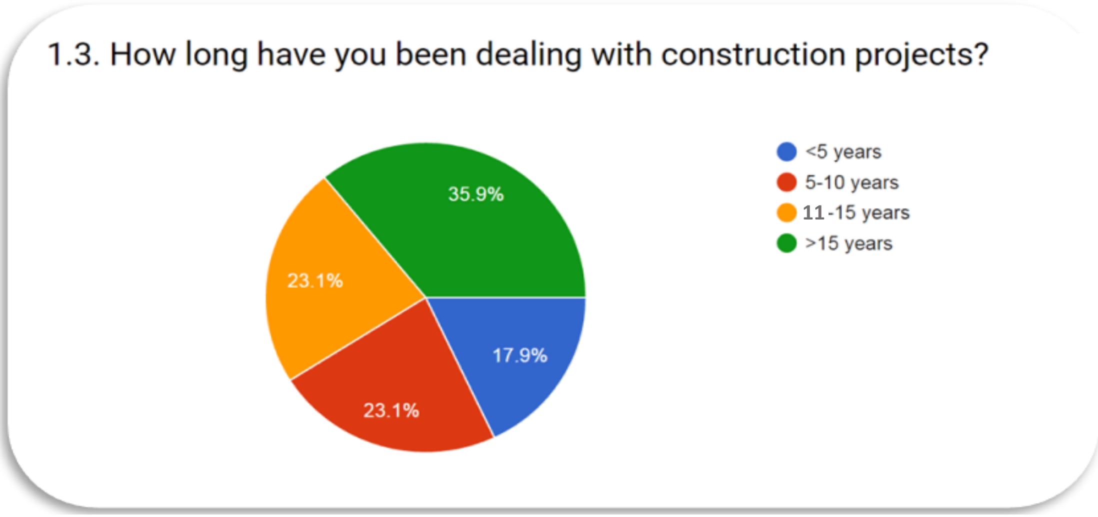


Figure 5.4: Respondent Years of Construction Experience

Figure 5.4 shows the years of experience for the respondents. Approximately 36% of them have experience exceeding 15 years, while those with 5 to 10 years and those with 11 to 15 years each comprised approximately 23% of the total responding. The lowest percentage (approximately 18%) was from participants with less than 5 years of experience.

5.3.4 Specialties of Respondents

The different types of construction projects were grouped into four major categories: Commercial, Industrial, Government, and Residential. However, as many respondents specialized in more than one type of construction project, the analysis was more helpful due to the wider experience and knowledge obtained from the respondents. The author was able to take a wider overview due the respondents' long experience in addition to their multiple skills in the four categories.

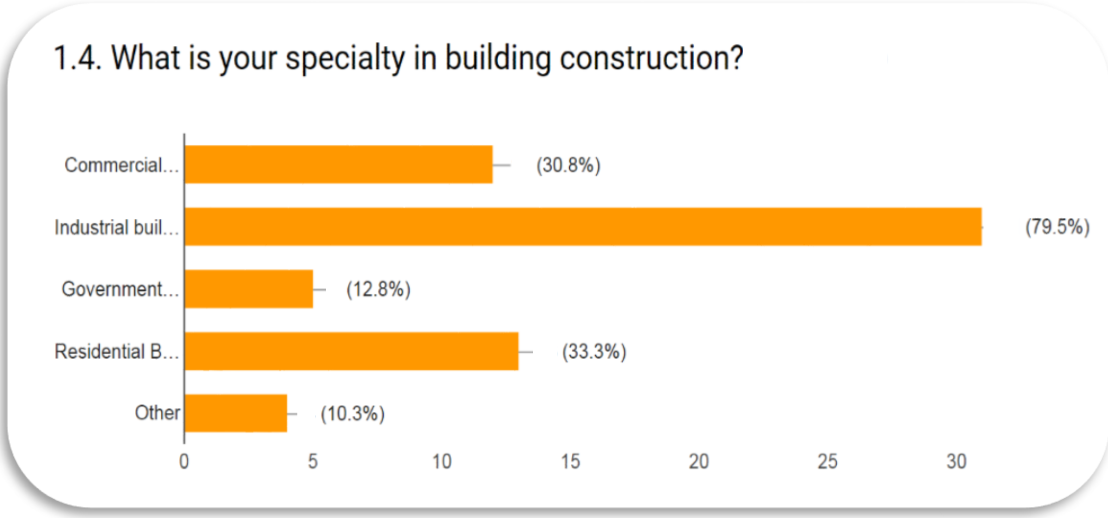


Figure 5.5: Respondent Construction Specialties

Figure 5.5 indicates most respondents (approximately 80%) had industrial building related experience followed by residential buildings (approximately 33%), then commercial buildings (approximately 31 %) and finally government projects and others (approximately 23%). A significant number of respondents reported having experience in more than one sector.

5.3.5 Project Size

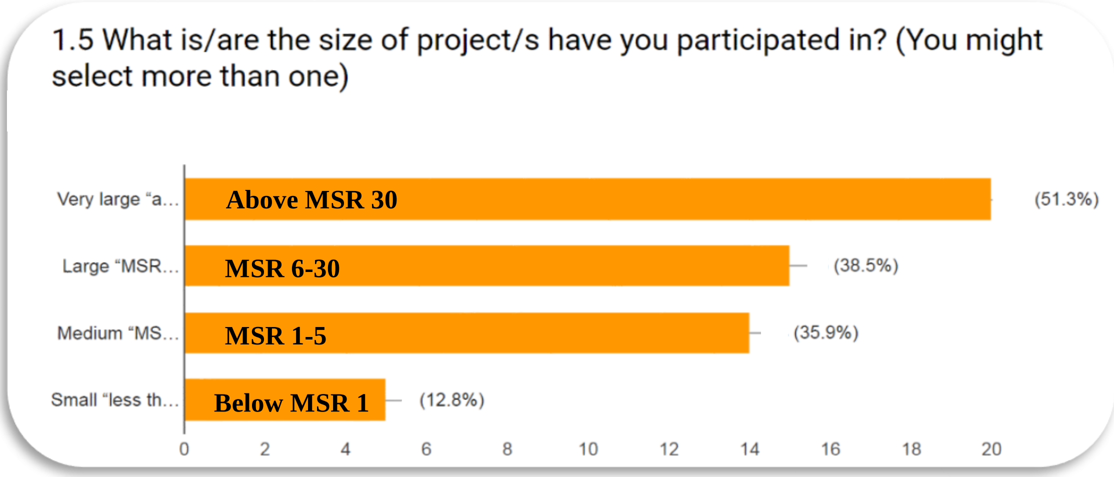


Figure 5.6: Respondents Projects Values in Millions of Saudi Riyal

Figure 5.6 illustrates a number of respondents reported involvement in projects of various sizes. Approximately 51% of respondents reported experience with very large projects, while approximately 39% reported having experience with large projects. Among the participants, approximately 36% reported having experience medium-size projects and approximately 13% reported have been involved in small projects.

Respondents who participated in very large or large projects represented almost 90% of the total. These projects are the most important categories as they generate the most concern about project delays in Saudi Arabia. Small and medium-size projects are also important but don't have the same privilege of details in comparison to the bigger ones regarding delay factors.

5.4.1 Procurement Methods

Various types of procurement methods are commonly used in construction projects. These methods are grouped into four major categories. The respondents were asked to select the method/s in which they have experience. Figure 5.7 below indicates the majority of respondents (approximately 59%) had experience in construction management, followed by design and build (approximately 54%). Approximately 49% reported they had experience with both traditional and management procurement methods.

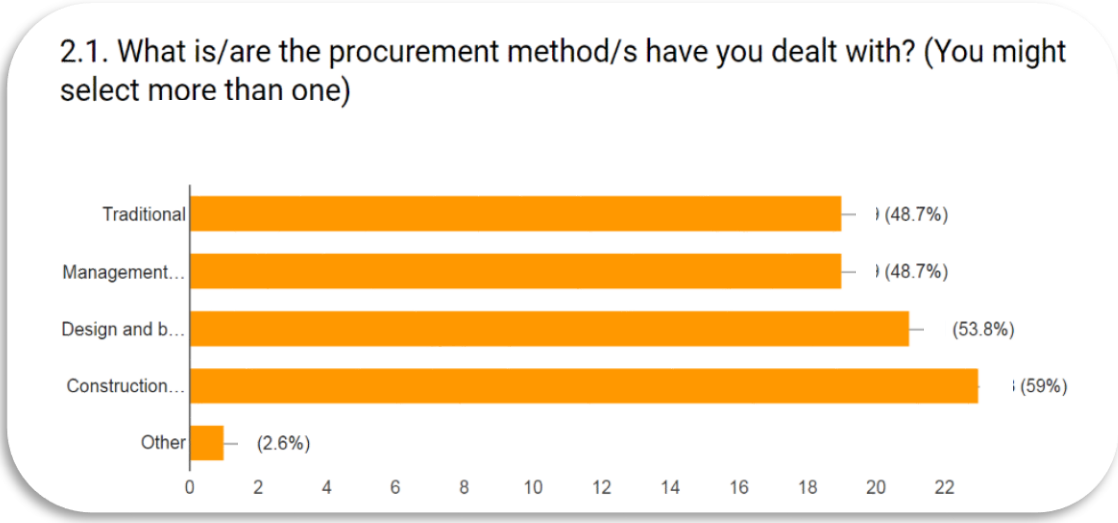


Figure 5.7: Respondents Experience with Procurement Methods

5.4.2 Tendering Arrangements

Five main categories of tendering arrangements were identified in the questionnaire, and respondents were asked to select the arrangement they had experienced. Figure 5.8 shows open-tendering had been experienced by the greatest numbers of respondents (approximately 69%), followed by negotiation tendering (59 %) and then selective tendering (approximately 56%). The two-stage selective tendering and serial tendering were experienced by approximately 47% and 8%, respectively.

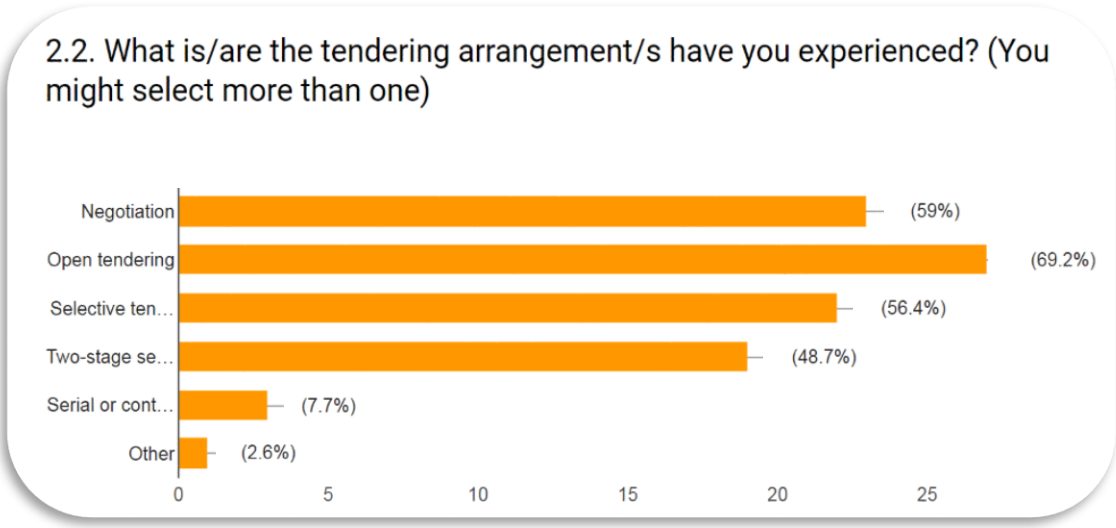


Figure 5.8: Respondent Experience with Tendering Arrangement

5.4.3 Tenders Which Contribute the Most to Delay

As indicated in Figure 5.9, the tendering arrangement making the greatest contribution to project delay was design and build (approximately 46%), followed by traditional tendering (approximately 39%) and management contracting (approximately 28%). The tendering arrangement with the least contribution to project delay was construction project management. Involving the consultant for managing the contact partially or in full is expected to reduce project delay.

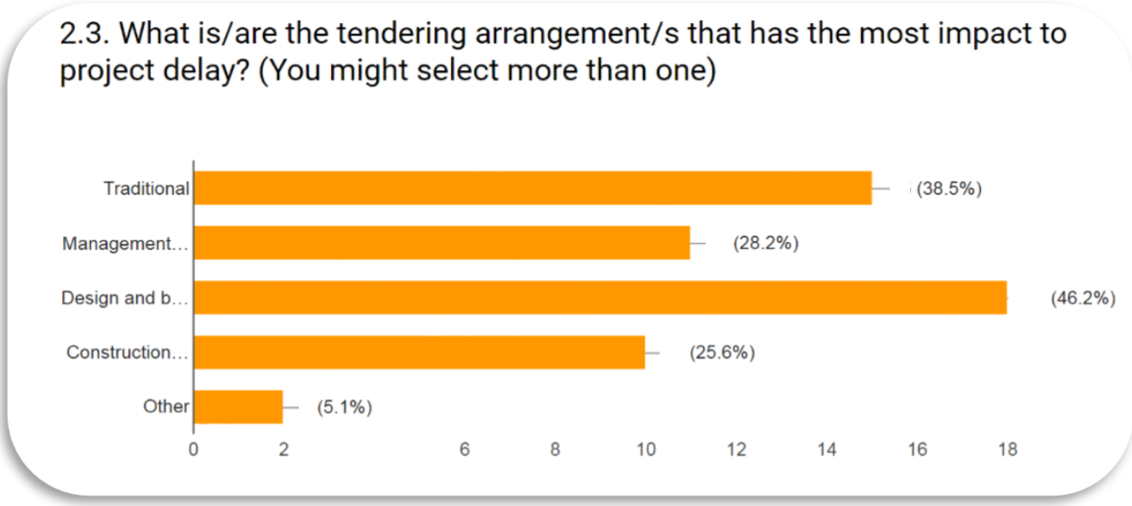


Figure 5.9: Tendering Agreements Impact to Project Delay

5.4.4 Tenders that contribute to project budget overrun

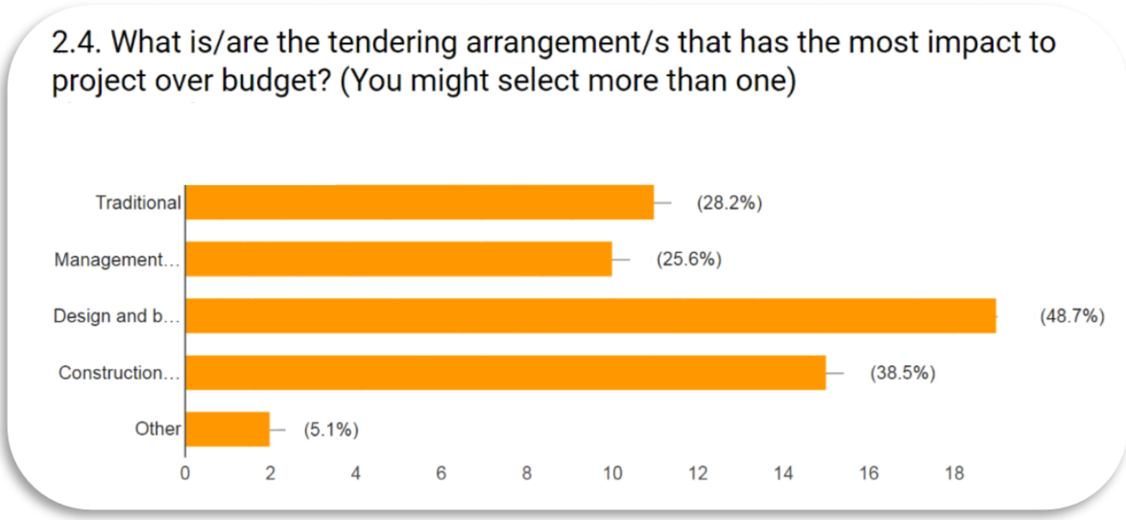


Figure 5.10: Tendering Agreements Impact to Project's Budget

Figure 5.10 indicates approximately 49% of the respondents agreed that design and build tender arrangements had the biggest impact on the project cost overrun compared to other types of tenders. Almost 28% of the respondents claimed the construction tendering process was critical. The project management tender appears was reported to affect the cost overrun by approximately 25% of the respondents. Involving the consultant for managing the contact partially or in-full is expected to improve control of project expenses.

5.5 Respondent Participation in Projects

This section presents an analysis of the construction project performance the participants experienced. It discusses and analyses the number of projects, how many of them were delayed, the average time of delay, authorized time and the first responsible party for the delay.

5.5.1 Number of construction projects respondents have experienced

Figure 5.11 indicates the respondent participation was extensive, providing knowledge obtained from more than 2,060 projects executed in the Saudi Arabia. Moreover, the average number for each participant was 15 projects, which indicates a rich contribution from every respondents and value added to the survey.

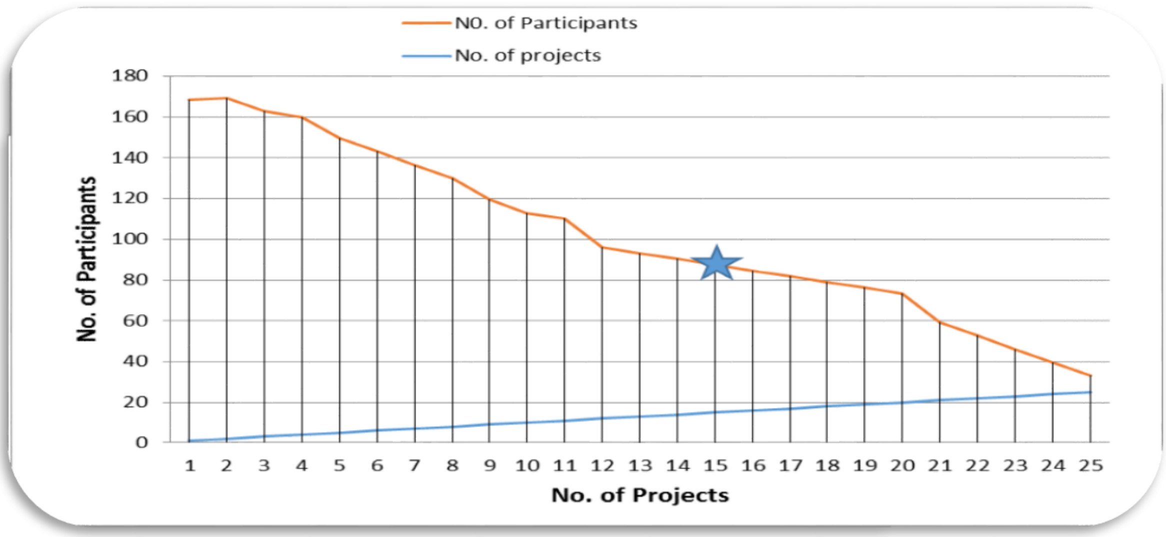


Figure 5.11: Participants Projects Involvement

The total number of projects survey respondents reported was 2063. On average, each respondent had been involved in 15 projects up to the time of the survey. This is relatively reasonable for the survey's output.

As shown in Figure 5.11, the survey results covered a wide range of experiences. Junior project managers observed different difficulties compared to those who had been in the project field for a long period. The junior project managers with limited years of experience are expected to be involved in tight challenges that some professionals don't face in their working level. Some critical issues are usually solved or even remained at their low layers. The survey covered many ranges of experience, starting from junior engineers who have less than 5 years up to those who have been in the project field for more than three decades.

5.5.2 Respondent Delay Experiences

Figure 5.12 indicates the vast majority of respondents have already experienced delays in construction projects. Approximately 92% of all participants reported one or more delays in their projects, whereas just 8% of the participants hadn't yet experienced a project delay of the reported delays, the projects were not completed as planned or as stated in the contracts. This could be due to the fact that 18% of the participants were junior engineers who did not have sufficient project involvement. The proportion of respondents who were involved in delayed projects compared to those who weren't involved in delayed projects was 92% to 8%.

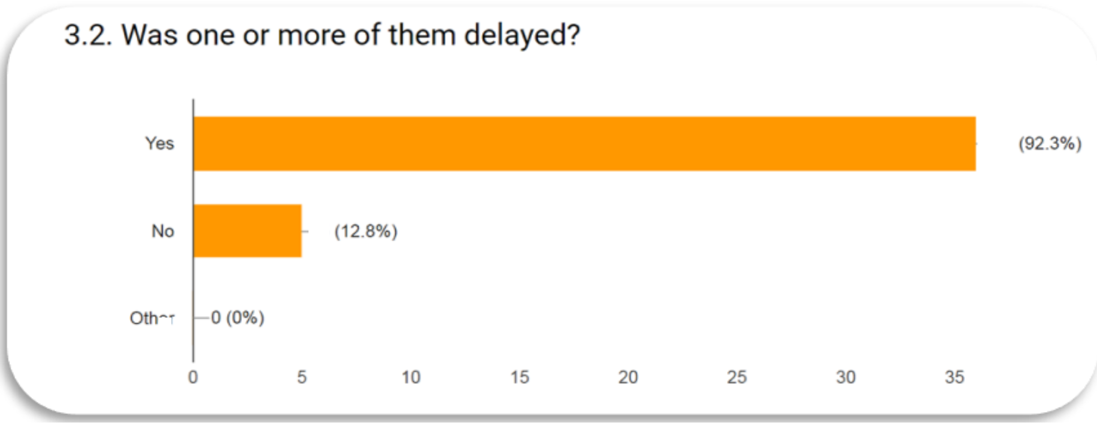


Figure 5.12: Respondent Project Delay Experiences

5.5.3 Delays Percentages and Average Delay Time

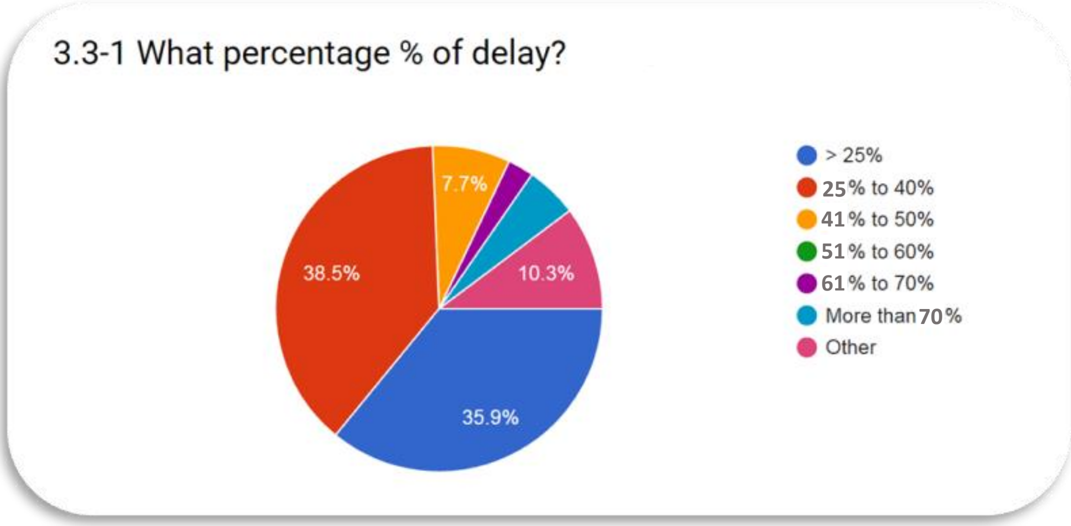


Figure 5.13: Respondent Project Delay % Distribution

Figure 5.13 illustrates the percentage of the participant's delayed projects compared to those that were not delayed. Almost 40% of the respondents admitted that 25 to 40% of their listed projects were delayed, while approximately 36% of the respondents acknowledged that 25% of all projects they handle were delayed. The remaining 24% of the respondents had different stumbled project percentages based on many reasons, which will be clarified in Chapter 6.

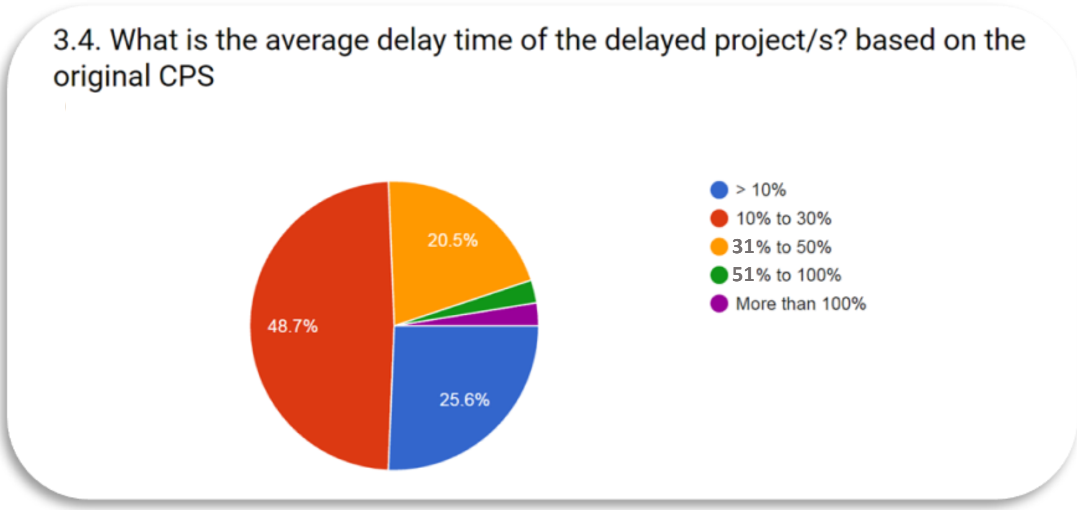


Figure 5.14: Respondents Average Project Delay % Distribution

Average delayed time was classified into five categories, and respondents were asked to select one of these categories to indicate the average delay time of all delayed projects they had experienced. Figure 5.14 demonstrates approximately 49% of the respondents experienced projects delay between 10% to 30% more than the project's agreed plan. Respondents that experienced very limited or almost no delay were approximately 26% from the project agreed plan. Delays category (31% to 50%) from the project plan comes as the third frequency representing 21% of respondents. 3% of the respondents reported delays from the project plan with respect to the delay category (51% to 100%). The lowest percentage was reported to delays above (>100%) which was around 2%.

As mentioned in the previous paragraph which addressed generally the delays categories practiced by respondents delay during the execution stage of their projects. The survey's finding has helped a lot to categorize the average delays parentage and to be in position to compare it with the analyzed data in section 5.6 .

5.5.4 Average Delayed Time Authorized by Client

The delayed time for a project may or may not have been authorized by the client, usually depending on the type of delay, contract specification and characteristics of the owner. The duration of authorized time was divided into five categories to include all probabilities that may occur in a delayed project.

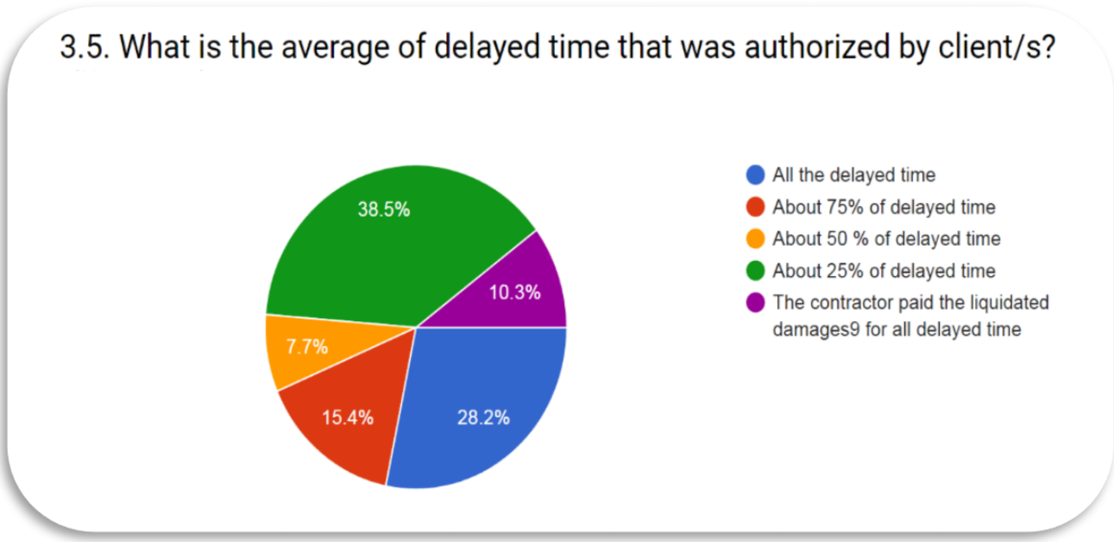


Figure 5.15: Average Project Delay Time Authorized by Client

Figure 5.15 shows that approximately 39% of the participants reported the client authorized delays up to 25% of delay time, while approximately 28% of respondents reported that client contributed to all delay time in their projects. Only about 10% of participants indicated the client made no contribution to the project delays. Contractors are obliged to compensate liquidated damages if the delay was not caused by the client. This particular analysis could help to identify the client's average usual contribution to a delayed project from the prospective of the respondents. This will be explained in further detail in section 5.6.

5.6 Party Most Responsible for Delays

Most of the respondents represented by contractors, consultants and clients in Saudi Arabia have reported that the contractor is the most responsible party for project delays. Figure 5.16 highlights this general consensus as approximately 54% of the respondents expressed this view. Clients came second with little difference as compared to the contractors. In this case, approximately 44% of the respondents believed the project delays were associated with the client. The consultant emerged as being the least responsible party, causing delays only about 3% of the time. However, these figures were based on the results from all respondents in the research survey. More emphasis would be applied in detail as it shows the results according to further analysis carried out by the DR-HOQ.

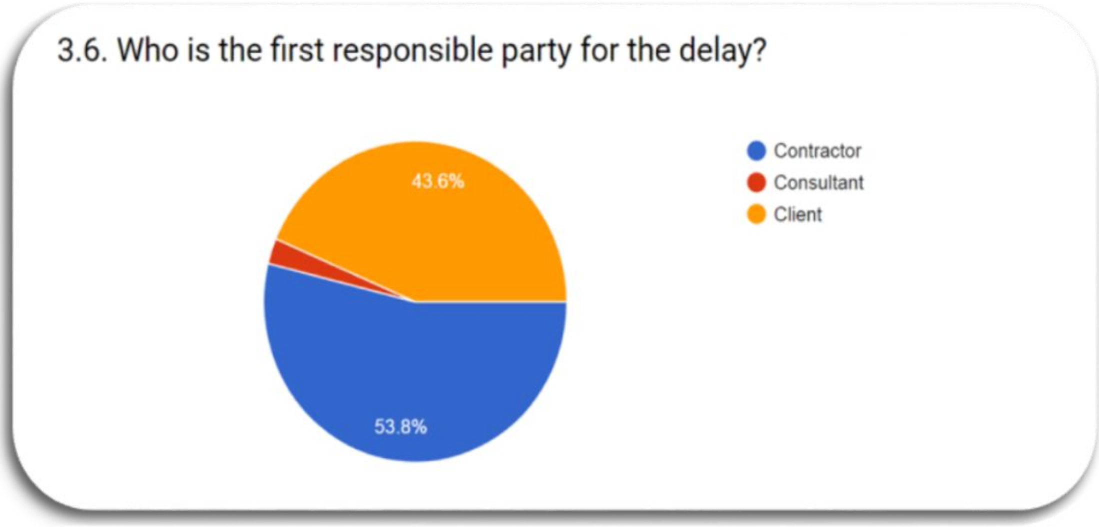


Figure 5.16: First Responsible Party of Delay

Results obtained from section 3.6 in the survey demonstrate the attitudes of the parties towards the party most responsible for delays. The level of the agreement does not appear high as each group has different attitudes than the others. However, the positions of the contractor and client groups are most contrasted. Moreover, the agreement between contractors and consultants is low; however, the judgment of consultants and owners seem to be higher. This conclusion makes sense due to the fact that the consultants are paid by clients and usually refer most slowness and flexibility to the execution, which mainly falls under the contractor's domain.

Research goal 3 is concerned with determining which party is most responsible for delays. To answer this important question, the present study aimed to explore and analyse the reality behind this debate witnessed in the literature review. In order to validate the survey findings, the results in Figure 5.16 show the direct answer of the respondents compared to the RII analysis in Table 5.1. The contractor appears to be the most responsible party of delay in both cases at 54% and 51%, respectively. The client came the second party in the both cases as well at 44% and 34%. The consultant remained the last party responsible for delays at 3% and 14%, respectively.

5.7 Projects Finished Under-Quality

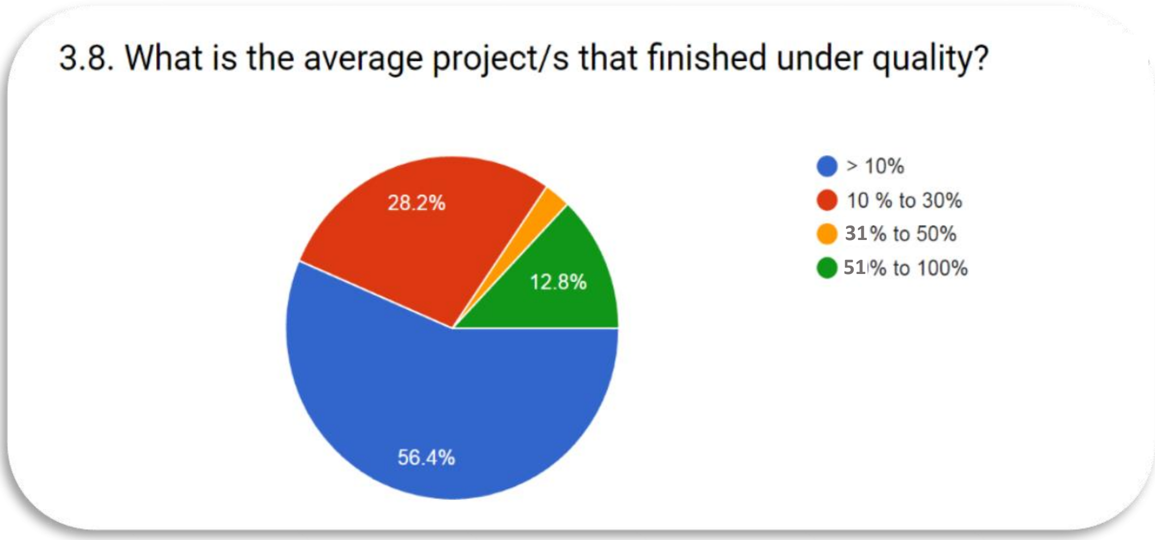


Figure 5.17: Average Projects Finished Under-Quality

In the survey, participants were asked to indicate the average percentage of projects which finished below the agreed quality, taking into consideration that the range is from 0% to 100%. Figure 5.17 indicates that approximately 56% of respondents reported that up to 10% of their projects were under-quality and around 28% faced quality issues in up to 30% of their total projects. Only about 13% of the total participants were suffering severe quality issues that reached above 50%.

These results indicate the projects in Saudi Arabia suffer time delay and quality deficiencies as well. The experience of delay appeared more chronic compared to lack of quality and cost overrun. The most important point in this finding is that 13% of the respondents face severe quality issues during the execution stage and reported that more than 50% of the projects were either corrected or modified. This finding could result from the cheap selection practices of the contractors, as well as the lack of supervision for the appointed consultant.

5.8 RII Ranking for Factors of Delay

In part four of the survey, the respondents were asked to determine the factors of delay regarding their frequency and severity weights. The scales provided ranges from 1 to 4 as explained in Chapter 4, section 4.5.3.2. Frequency of occurrence was categorized as follows: always, often, sometimes and rarely (on a 4 to 1 point scale). Similarly, degree of severity was categorized as follows: extreme, great, moderate and little (on a 4 to 1 point scale). However, in order to launch a quantitative measure of the frequency and the severity, it was decided to consider the importance of both "Frequency & Severity" to the factors of delay as equal.

The importance of each cause was consequential to integration between frequency and severity of that cause. The method of gathering the weight of frequency and severity of each cause was explained in Chapter 4. Table 5.1 shows the ranking of delay factors by applying the RII.

TABLE 5.1: FULL LIST-FACTORS OF DELAY USING RII

No.	Factor Category	Factors of Delay	Frquency 1	2	3	4	F.I. Rate	F.I. %	Severity 1	2	3	4	S.I. Rate	S.I. %	RII Overall %	Risk Order	Points
13	Contractor - PM	13. Shortage of technical professionals in the contractor's org.	4	11	16	**10**	2.9231	73.08%	2	11	16	10	2.8718	71.79%	52.47%	1	65
9	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	1	16	17	5	2.6667	66.67%	0	10	19	10	3	75.00%	50.00%	2	64
22	Contractor - PM	22. Ineffective planning & scheduling of the project by the contractor	3	10	**24**	2	2.641	66.03%	1	7	21	10	3.0256	75.64%	49.94%	3	63
19	Contractor - PM	19. Loose safety rules & regulations within the contractor's org.	2	12	19	6	2.7436	68.59%	2	13	11	13	2.8974	72.44%	49.68%	4	62
21	Contractor - PM	21. Improper technical studies by the contractor during bidding stage	3	14	17	5	2.6154	65.38%	1	13	9	**16**	3.0256	75.64%	49.46%	5	61
53	Early plan & Design	53. Changes in the scope of the project	3	19	8	9	2.5897	64.74%	2	12	11	14	2.9487	73.72%	47.73%	6	60
20	Contractor - PM	20. Poor qualifications of contractor's tech. staff assigned to the project	4	13	16	6	2.6154	65.38%	1	13	14	11	2.8974	72.44%	47.36%	7	59
14	Contractor - PM	14. Contractor's poor coordination with parties' invol. in project	5	14	15	5	2.5128	62.82%	3	6	19	11	2.9744	74.36%	46.71%	8	58
45	Client	45. Slow decision making by the client's organization	4	18	11	6	2.4872	62.18%	2	12	11	14	2.9487	73.72%	45.84%	9	57
54	Early plan & Design	54. Ambiguities, mistakes, and inconsistencies in specs & drawings	3	19	13	4	2.4615	61.54%	2	11	12	14	2.9744	74.36%	45.76%	10	56
15	Contractor - PM	15. Slow preparation of changed orders requested by contractor	3	13	18	5	2.641	66.03%	2	12	18	7	2.7692	69.23%	45.71%	11	55
10	Contractor - MP	10. Low skill of manpower	3	14	19	3	2.5641	64.10%	0	13	19	7	2.8462	71.15%	45.61%	12	54
24	Contractor - PM	24. Ineffective control of project progress by the contractor	2	18	15	4	2.5385	63.46%	0	14	16	9	2.8718	71.79%	45.56%	13	53
59	Gov. Regulation	59. Gov. tendering system of selecting the lowest bidding contractor	7	10	13	9	2.6154	65.38%	5	9	15	10	2.7692	69.23%	45.27%	14	52
38	Consultant	38. Inadequate design specifications	3	21	11	4	2.4103	60.26%	1	14	8	16	3	75.00%	45.19%	15	51
39	Consultant	39. Poor contract management	1	23	10	5	2.4872	62.18%	2	12	14	11	2.8718	71.79%	44.64%	16	50
42	Client	42. Delay in the settlement of contractor claims by the client	2	20	11	6	2.5385	63.46%	2	13	15	9	2.7949	69.87%	44.34%	17	49
29	Contractor - PF	29. Cash flow problems faced by the contractor	3	24	6	6	2.3846	59.62%	1	12	13	13	2.9744	74.36%	44.33%	18	48
25	Contractor - PM	25. Inefficient quality control by the contractor	2	20	12	5	2.5128	62.82%	1	13	17	8	2.8205	70.51%	44.30%	19	47
41	Client	41. Unrealistic contract duration	4	18	12	5	2.4615	61.54%	3	13	9	14	2.8718	71.79%	44.18%	20	46
44	Client	44. Delay in issuing of change orders by the client	2	20	12	5	2.5128	62.82%	1	14	16	8	2.7949	69.87%	43.89%	21	45
48	Client	48. Delay in progress payments by the client	3	20	11	5	2.4615	61.54%	2	14	11	12	2.8462	71.15%	43.79%	22	44
11	Contractor - PM	11. Lack of motivation among contractor's members	2	21	13	3	2.4359	60.90%	0	14	16	9	2.8718	71.79%	43.72%	23	43
33	Consultant	33. Delay in the approval of contractor submissions by the consultant	3	21	11	4	2.4103	60.26%	1	15	11	12	2.8718	71.79%	43.26%	24	42
28	Contractor - PF	28. Difficulties in financing the project by the contractor	5	20	12	2	2.2821	57.05%	3	8	13	15	3.0256	75.64%	43.15%	25	41
18	Contractor - PM	18. Poor controlling of subcontractors by contractor	5	17	12	5	2.4359	60.90%	2	15	10	12	2.8205	70.51%	42.94%	26	40
2	contractor - M	2. Delay in materials delivery	1	20	16	2	2.4872	62.18%	2	14	15	8	2.7436	68.59%	42.65%	27	39
30	Contractor - PF	30. Problems between the contractor and his subcontractors with regard	4	20	10	5	2.4103	60.26%	1	16	12	10	2.7949	69.87%	42.10%	28	38
56	Early plan & Design	56. Original contract duration is too short	4	17	16	2	2.4103	60.26%	2	13	16	8	2.7692	69.23%	41.72%	29	37
12	Contractor - PM	12. Shortage of contractor's administrative personnel	3	21	12	3	2.3846	59.62%	2	14	13	10	2.7949	69.87%	41.65%	30	36
4	contractor - M	4. Changes in materials specifications	2	22	11	4	2.4359	60.90%	0	19	12	8	2.7179	67.95%	41.38%	31	35
31	Consultant	31. Poor qualification of cons. engineer's staff assigned to the project	2	23	10	4	2.4103	60.26%	1	15	16	7	2.7436	68.59%	41.33%	32	34
34	Consultant	34 Poor com. between the consultant engineer and other parties involved	5	21	8	5	2.3333	58.33%	1	15	14	9	2.7949	69.87%	40.76%	33	33
35	Consultant	35. Poor coordination by the cons. engineer with other parties involved	3	23	9	4	2.359	58.97%	1	16	14	8	2.7436	68.59%	40.45%	34	32
51	Client	51. Poor coordination by the client with the various parties during const.	3	24	9	3	2.3077	57.69%	1	14	18	6	2.7436	68.59%	39.57%	35	31
43	Client	43. Suspension of work by the client's organization	5	22	8	4	2.2821	57.05%	2	15	12	10	2.7692	69.23%	39.50%	36	30
52	Client	52. Excessive bureaucracy in the client's administration	6	18	11	4	2.3333	58.33%	3	13	16	7	2.6923	67.31%	39.26%	37	29
60	Gov. Regulation	60. Changes in government regulations and laws	5	20	13	1	2.2564	56.41%	2	11	**20**	6	2.7692	69.23%	39.05%	39	27
50	Client	50. Client's failure to coordinate with gov. authorities during planning	3	24	11	1	2.2564	56.41%	1	15	15	8	2.7692	69.23%	39.05%	38	28
58	Gov. Regulation	58. Difficulties in obtaining work permits	6	21	8	4	2.2564	56.41%	2	13	17	7	2.7436	68.59%	38.69%	40	26
16	Contractor - PM	16. Ineffective contractor head office involvement in the project	2	25	10	2	2.3077	57.69%	1	16	17	5	2.6667	66.67%	38.46%	41	25
46	Client	46. Interference by the client in the construction operations	4	21	10	4	2.359	58.97%	2	19	11	7	2.5897	64.74%	38.18%	42	24
32	Consultant	32. Delay in the preparation of drawings	4	23	11	1	2.2308	55.77%	1	17	13	8	2.7179	67.95%	37.89%	43	23
49	Client	49. Client's poor com. with the construction parties and gov. authorities	4	24	9	2	2.2308	55.77%	2	16	13	8	2.6923	67.31%	37.54%	44	22
37	Consultant	37. Slow response from the cons. engineer to contractor inquiries	3	25	7	4	2.3077	57.69%	1	19	14	5	2.5897	64.74%	37.35%	46	20
26	Contractor - PM	26. Delay in the preparation of contractor submissions	2	25	10	2	2.3077	57.69%	0	**21**	13	5	2.5897	64.74%	37.35%	45	21
47	Client	47. Uncooperative client with the contractor complicating contract administra	4	24	9	2	2.2308	55.77%	2	17	13	7	2.641	66.03%	36.82%	47	19
55	Early plan & Design	55. Subsurface site conditions materially differing from contract docum.	3	24	11	1	2.2564	56.41%	4	14	15	6	2.5897	64.74%	36.52%	48	18
23	Contractor - PM	23. Delays to field survey by the contractor	4	20	13	2	2.3333	58.33%	3	18	14	4	2.4872	62.18%	36.27%	49	17
40	Client	40. Delay in furnishing & delivering the site to the contractor by client	4	22	10	3	2.3077	57.69%	2	21	10	6	2.5128	62.82%	36.24%	50	16
5	contractor - EQ	5. Shortage of required equipment	10	21	7	4	2.2821	57.05%	3	16	16	4	2.5385	63.46%	36.21%	51	15
66	External factors	66. Work interference between various contractors	4	**26**	8	1	2.1538	53.85%	2	15	16	6	2.6667	66.67%	35.90%	52	14
62	External factors	62. Effects of subsurface conditions (type of soil, utility lines, water table)	5	23	9	2	2.2051	55.13%	4	15	13	7	2.5897	64.74%	35.69%	53	13
1	contractor - M	1. Shortage of required material	4	24	10	1	2.2051	55.13%	4	13	19	3	2.5385	63.46%	34.99%	54	12
57	Gov. Regulation	57. Ineffective delay penalty	5	23	10	1	2.1795	54.49%	4	15	14	6	2.5641	64.10%	34.93%	55	11
27	Contractor - PM	27. Improper construction methods implemented by contractor	5	26	7	1	2.1026	52.56%	1	20	11	7	2.6154	65.38%	34.37%	56	10
65	External factors	65. Rise in the prices of materials	5	24	7	3	2.2051	55.13%	4	16	15	4	2.4872	62.18%	34.28%	57	9
36	Consultant	36. Delays in performing inspection and testing by the cons. engineer	2	26	8	1	2.1026	52.56%	2	20	12	5	2.5128	62.82%	33.02%	58	8
8	contractor - EQ	8. Inadequate equipment used for the works	9	20	9	1	2.0513	51.28%	2	18	14	5	2.5641	64.10%	32.87%	59	7
3	contractor - M	3. Changes in materials prices	7	21	9	2	2.1538	53.85%	4	18	13	4	2.4359	60.90%	32.79%	60	6
7	contractor - EQ	7. Shortage of supporting and shoring installations for excavations	8	23	6	2	2.0513	51.28%	5	18	10	6	2.4359	60.90%	31.23%	61	5
6	contractor - EQ	6. Failure of equipment	11	20	4	4	2.0256	50.64%	**7**	12	13	6	2.4103	60.26%	30.51%	62	4
63	External factors	63. Traffic control and restrictions on the job site	7	24	7	1	2.0513	51.28%	6	17	12	4	2.359	58.97%	30.24%	64	2
17	Contractor - PM	17. Delays in mobilization	6	27	4	2	2.0513	51.28%	6	17	12	4	2.359	58.97%	30.24%	63	3
61	External factors	61. Severe weather conditions on the job site	11	20	7	1	1.9487	48.72%	4	21	11	3	2.3333	58.33%	28.42%	65	1
64	External factors	64. Effects of social and cultural conditions	**15**	18	5	1	1.7949	44.87%	**7**	23	8	1	2.0769	51.92%	23.30%	66	0
							Range	**44.9 -73.1%**						**51.9-75.6%**	**23.3% - 52.5%**		**2145**

Party of Delay	RII Scores 66 Factors	RII%	TOP 10	TOP 15	TOP 20
Contractor weight:	1515	70.6%	7 factors	10 factors	12 factors
Consultant Weight:	279	13.0%	0	1 factor	2 factors
Client Direct Weight:	260	12.1%	1 factor	1 factor	3 factors
Client-A Early plan & Desi	46	2.1%	2 factors	2 factorr	2 factors
Client-B Gov. Regulation	30	1.4%	0	1 factor	1 factor
External factors	15	0.7%	0	0	0
Total	**2145**	100%			

5.8.1 Top 20 Factors of Delay by Using RII

After ranking the factors using RII, it was found that 12 out of the top 20 factors were related to the contractors. The most important factor found was shortage of technical professionals in the contractor organization, with a RII equal to 53%. Table 5.2 indicates the top 20 factors of delay as ranked before the additional analysis that was applied at later stages.

The general conclusion from these factors is that the availability of qualified technical staff and allocating them in the right positions. Improper technical studies, weak planning and scheduling, lack of safety rules, frequent changes in the scope and poor communication between all parties are mostly the critical reasons behind projects delay.

TABLE 5.2: TOP 20 FACTORS OF DELAY USING RII

No.	Factor Category	Discription	F.I. Rate	F.I. %	S.I. Rate	S.I. %	IWI Overall %	Risk Order	Points
13	Contractor - PM	13. Shortage of technical professionals in the contractor's org.	2.923	73.08%	2.87	71.79%	52.47%	1	65
9	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	2.667	66.67%	3	75.00%	50.00%	2	64
22	Contractor - PM	22. Ineffective planning & scheduling of the project by the contra	2.641	66.03%	3.03	75.64%	49.94%	3	63
19	Contractor - PM	19. Loose safety rules & regulations within the contractor's org.	2.744	68.59%	2.9	72.44%	49.68%	4	62
21	Contractor - PM	21. Improper technical studies by the contractor during bidding	2.615	65.38%	3.03	75.64%	49.46%	5	61
53	Early plan & Design	53. Changes in the scope of the project	2.59	64.74%	2.95	73.72%	47.73%	6	60
20	Contractor - PM	20. Poor qualifications of contractor's tech. staff assigned to the	2.615	65.38%	2.9	72.44%	47.36%	7	59
14	Contractor - PM	14. Contractor's poor coordination with parties' invol. in project	2.513	62.82%	2.97	74.36%	46.71%	8	58
45	Client	45. Slow decision making by the client's organization	2.487	62.18%	2.95	73.72%	45.84%	9	57
54	Early plan & Design	54. Ambiguities, mistakes, and inconsistencies in specs & drawin	2.462	61.54%	2.97	74.36%	45.76%	10	56
15	Contractor - PM	15. Slow preparation of changed orders requested by contractor	2.641	66.03%	2.77	69.23%	45.71%	11	55
10	Contractor - MP	10. Low skill of manpower	2.564	64.10%	2.85	71.15%	45.61%	12	54
24	Contractor - PM	24. Ineffective control of project progress by the contractor	2.538	63.46%	2.87	71.79%	45.56%	13	53
59	Gov. Regulation	59. Gov. tendering system of selecting the lowest bidding contra	2.615	65.38%	2.77	69.23%	45.27%	14	52
38	Consultant	38. Inadequate design specifications	2.41	60.26%	3	75.00%	45.19%	15	51
39	Consultant	39. Poor contract management	2.487	62.18%	2.87	71.79%	44.64%	16	50
42	Client	42. Delay in the settlement of contractor claims by the client	2.538	63.46%	2.79	69.87%	44.34%	17	49
29	Contractor - PF	29. Cash flow problems faced by the contractor	2.385	59.62%	2.97	74.36%	44.33%	18	48
25	Contractor - PM	25. Inefficient quality control by the contractor	2.513	62.82%	2.82	70.51%	44.30%	19	47
41	Client	41. Unrealistic contract duration	2.462	61.54%	2.87	71.79%	44.18%	20	46

5.8.2 Lowest Ranking 10 Factors of Delay by Using RII

Four factors of delays out of 10 were related to the group of external factors that have the lowest category impact in general to project delays in Saudi Arabia. Social and cultural conditions were ranked the lowest, followed by severe weather conditions. The lowest ranking factors belonged to the contractor and included the delays in mobilization, failure of equipment and changes in material prices. Table 5.3 clarifies that the RII % ranges from 23% to 34% and most of them referred to the external factors and the contractor.

TABLE 5.3: LOWEST 10 FACTORS OF DELAY USING RII

No.	Factor Category	Discription	F.I.		S.I.		RII	Risk Order	Points
			Rate	%	Rate	%	Overall %		
64	External factors	64. Effects of social and cultural conditions	1.795	44.87%	2.08	51.92%	23.30%	66	0
61	External factors	61. Severe weather conditions on the job site	1.949	48.72%	2.33	58.33%	28.42%	65	1
17	Contractor - PM	17. Delays in mobilization	2.051	51.28%	2.36	58.97%	30.24%	63	3
63	External factors	63. Traffic control and restrictions on the job site	2.051	51.28%	2.36	58.97%	30.24%	64	2
6	contractor - EQ	6. Failure of equipment	2.026	50.64%	2.41	60.26%	30.51%	62	4
7	contractor - EQ	7. Shortage of supporting and shoring installations for excavatio	2.051	51.28%	2.44	60.90%	31.23%	61	5
3	contractor - M	3. Changes in materials prices	2.154	53.85%	2.44	60.90%	32.79%	60	6
8	contractor - EQ	8. Inadequate equipment used for the works	2.051	51.28%	2.56	64.10%	32.87%	59	7
36	Consultant	36. Delays in performing inspection and testing by the cons. eng	2.103	52.56%	2.51	62.82%	33.02%	58	8
65	External factors	65. Rise in the prices of materials	2.205	55.13%	2.49	62.18%	34.28%	57	9

5.8.3 Top 10 Most Severe Factors of Delay

One of the important things to know after identifying the top 20 factors of delays is to analyse the factors of delay that have a high severity index. An early awareness of their impact would slash their effects in the early stages of the project's cycle.

As shown in Table 5.4, the highest severity index (S.I. %) is 76%. Most of the participants admitted the difficulty of the contractor to finance the project is considered the biggest concern and has an enormous influence on project delay. The second most severe factor is the improper technical studies conducted by the contractor during the bidding stage. Ineffective planning and scheduling by the contractor is considered the third most severe factor. The most severe factors appeared to be referred to the contractor, which indeed requires high attention during the tendering process.

TABLE 5.4: TOP 10 FACTORS OF DELAY RANKING – BY (SEVERITY INDEX)

No.	Factor Category	Discription	F.I.		S.I.		RII	Risk Order	Points
			Rate	%	Rate	%	Overall %		
28	Contractor - PF	28. Difficulties in financing the project by the contractor	2.282	57.05%	3.03	75.64%	43.15%	25	41
21	Contractor - PM	21. Improper technical studies by the contractor during bidding	2.615	65.38%	3.03	75.64%	49.46%	**5**	61
22	Contractor - PM	22. Ineffective planning & scheduling of the project by the contra	2.641	66.03%	3.03	75.64%	49.94%	**3**	63
38	Consultant	38. Inadequate design specifications	2.41	60.26%	3	75.00%	45.19%	15	51
9	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	2.667	66.67%	3	75.00%	50.00%	**2**	64
29	Contractor - PF	29. Cash flow problems faced by the contractor	2.385	59.62%	2.97	74.36%	44.33%	18	48
54	Early plan & Design	54. Ambiguities, mistakes, and inconsistencies in specs & drawin	2.462	61.54%	2.97	74.36%	45.76%	**10**	56
14	Contractor - PM	14. Contractor's poor coordination with parties' invol. in project	2.513	62.82%	2.97	74.36%	46.71%	**8**	58
45	Client	45. Slow decision making by the client's organization	2.487	62.18%	2.95	73.72%	45.84%	**9**	57
53	Early plan & Design	53. Changes in the scope of the project	2.59	64.74%	2.95	73.72%	47.73%	**6**	60

Inadequate design specification by the consultant has been ranked as the fourth one. This factor is very critical and has a major impact technically and financially to any project as it could lead to a big project's failure and suspend all activities on the site. The projects that involve high technical requirements and are surrounded with so many ambiguities and issues have to be handed to a very qualified engineering offices (consultants) that would guarantee meeting all technical requirements. Furthermore, the consultant has to give a very detailed time schedule and full cost analysis in the initiation stage to avoid causing project overruns.

Ambiguities, mistakes and inconsistencies in specifications and drawings at the early stage of the project could lead to a major delay in the project planning and execution as well. The difference between the highest severity and lowest severity in the list is only 2%. This means that most of the factors in the list are very critical and strongly affect the PPMs.

5.8.4 Top 10 Frequent Factors of Delay

The critical factors of delay produced impacts based on both severity and frequency. In this section, the factors will be addressed based on how frequently and commonly they are repeated in general projects. This consensus by respondents representing all parties have confirmed this recurrence. Eight factors out of ten (80 %) are related to the contractor. This percentage is considered very high in comparison to those of other parties. The project managers suffer due to the recurrence of the factors, particularly in the execution stage.

TABLE 5.5: TOP 10 FACTORS F DELAY RANKING – BY FREQUENCY INDEX

No.	Factor Category	Discription	F.I.		S.I.		RII	Risk Order	Points
			Rate	%	Rate	%	Overall %		
13	Contractor - PM	13. Shortage of technical professionals in the contractor's org.	2.923	73.08%	2.87	71.79%	52.47%	1	65
19	Contractor - PM	19. Loose safety rules & regulations within the contractor's org.	2.744	68.59%	2.9	72.44%	49.68%	4	62
9	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	2.667	66.67%	3	75.00%	50.00%	2	64
22	Contractor - PM	22. Ineffective planning & scheduling of the project by the contra	2.641	66.03%	3.03	75.64%	49.94%	3	63
15	Contractor - PM	15. Slow preparation of changed orders requested by contractor	2.641	66.03%	2.77	69.23%	45.71%	11	55
21	Contractor - PM	21. Improper technical studies by the contractor during bidding	2.615	65.38%	3.03	75.64%	49.46%	5	61
20	Contractor - PM	20. Poor qualifications of contractor's tech. staff assigned to the	2.615	65.38%	2.9	72.44%	47.36%	7	59
59	Gov. Regulation	59. Gov. tendering system of selecting the lowest bidding contra	2.615	65.38%	2.77	69.23%	45.27%	14	52
53	Early plan & Design	53. Changes in the scope of the project	2.59	64.74%	2.95	73.72%	47.73%	6	60
10	Contractor - MP	10. Low skill of manpower	2.564	64.10%	2.85	71.15%	45.61%	12	54

Table 5.5 shows the top 10 factors that frequently appear in most of the projects. The most frequent factor is shortage of technical professionals in the contractor's organization. Lax safety rules and regulations ranked second in the contractor's organization followed by shortage of the general skills of staff. Ineffective planning and scheduling, slow preparation of change orders during bidding time, improper technical studies, and poor qualification of staff assigned to the project by contractor are ranked fourth, fifth, sixth, and seventh, respectively.

Tendering system of selecting the cheapest contractor by the government authorities seem to be an issue and still exists in most of the governmental projects, which contributes heavily to projects delay in Saudi Arabia. Changes in the projects scope is ranked number nine, and it mostly referred to both client and consultant.

5.9 Sensitivity Analysis by Using Double Roof House of Quality (DR-HOQ)

The newly developed approach, DR-HOQ, has a unique principle for representing the dual impacts of inter-relationships simultaneously. In other words; the embedded relationships between the factors of delays would be represented by one roof and the PPMs in a second roof. This concept is new and innovative-- none of the previous studies have investigated the relationships between the technical delay factors. Figure 5.18 shows both roofs. The first roof is fixed on the top of the structure to reflect the relationships between the PPMs. The second roof is fixed on the left side of the structure to reflect the inter-relationships between the top 20 factors of delay.

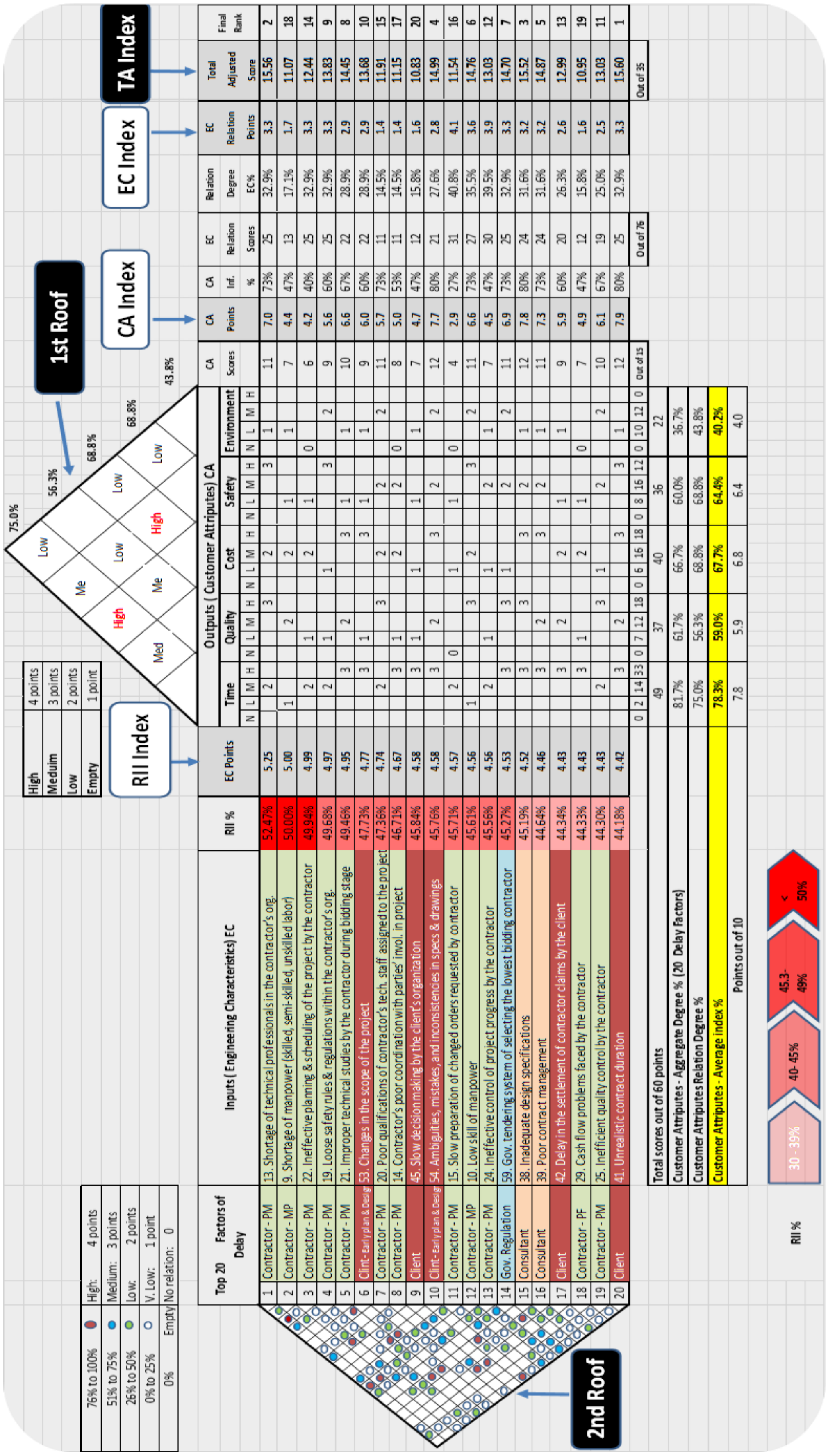


Figure 5.18: Double Roof House of Quality

5.9.1 Ranking of Delay Factors Using Total Adjusted Index

One of the main benefits of the DR-HOQ is the creation of additional indices. A judgment based on one index may not give real credibility for ranking the factors of delay. Hence, the additional two indices would make the ranking more reliable and rational. The RII was determined by multiplying the frequency and severity indices, as was previously demonstrated in full detail in Chapter 4, section 4.5.3.2.

The RII as a single index standing alone for ranking the factors of delay appears to be very lean and ineffective. This index evaluates the factors of delay based on severity and frequency in isolation from the effects of the relationships between the delay factors. Combining the three indexes in a major index called Total Adjusted Index (TAI) has empowered the process of ranking and makes it more reliable as shown in Figure 5.19.

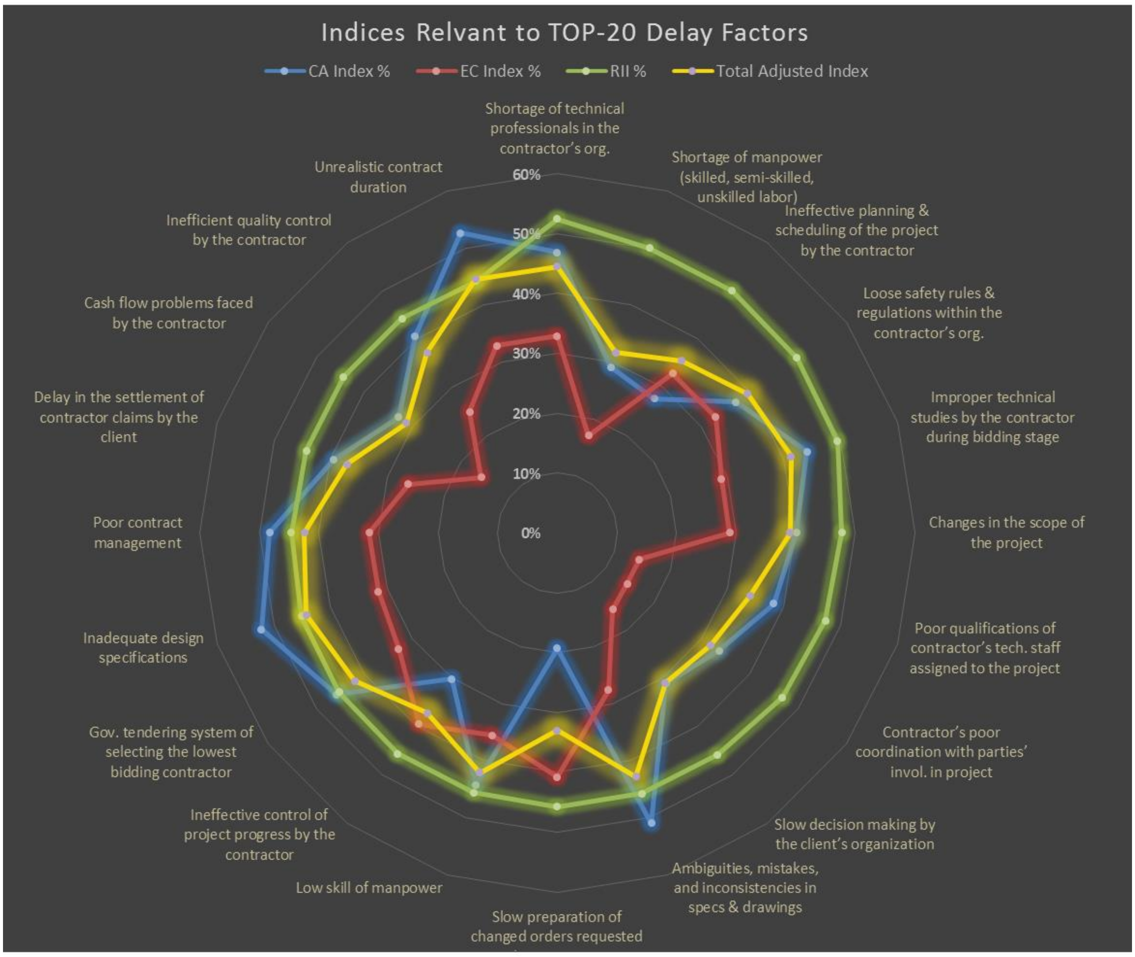


Figure 5.19: Indices Relevant to Critical Factors of Delays

The sixth research question of the present study is to apply sensitivity analysis for identifying the relationships between the top 20 factors of delay and their relevance degree, if any, to achieve more rational ranking of these factors.

The ranking of the top 20 critical delay factors was completely reordered after the realization of these relationships as discussed before in Chapter 4, section 4.5.4. The contribution of all indices represented by the RII, Engineering Characteristics Index (EC Index) and Customer Attributes Index (CA Index). The indices have been combined into one index called the Total Adjusted Index (TAI). The scores of three indices were added together to present the total value of the TAI.

Table 5.6 shows the three different indices influences on each critical factor of delay. For example, factor 1 (shortage of technical staff) was downgraded from Rank1 to Rank 2 and Factor15 (Inadequate design specification) upgraded from Rank15 to Rank 3.

TABLE 5.6: FACTORS OF DELAY ADJUSTED RANKING

Top-20 RII Ranking		Factos of Delay (Engineering Charactarisitics) EC	RII Weight	EC Points	CA Points	EC Relations points	Total Adjusted Score	Final Rank
1	Contractor - PM	13. Shortage of technical professionals in the contractor's org.	52.47%	5.25	7.0	3.3	15.56	2
2	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	50.00%	5.00	4.4	1.7	11.07	18
3	Contractor - PM	22. Ineffective planning & scheduling of the project by the contractor	49.94%	4.99	4.2	3.3	12.44	14
4	Contractor - PM	19. Loose safety rules & regulations within the contractor's org.	49.68%	4.97	5.6	3.3	13.83	9
5	Contractor - PM	21. Improper technical studies by the contractor during bidding stage	49.46%	4.95	6.6	2.9	14.45	8
6	Clint- Early plan & Des	53. Changes in the scope of the project	47.73%	4.77	6.0	2.9	13.68	10
7	Contractor - PM	20. Poor qualifications of contractor's tech. staff assigned to the projec	47.36%	4.74	5.7	1.4	11.91	15
8	Contractor - PM	14. Contractor's poor coordination with parties' invol. in project	46.71%	4.67	5.0	1.4	11.15	17
9	Client	45. Slow decision making by the client's organization	45.84%	4.58	4.7	1.6	10.83	20
10	Clint- Early plan & Des	54. Ambiguities, mistakes, and inconsistencies in specs & drawings	45.76%	4.58	7.7	2.8	14.99	4
11	Contractor - PM	15. Slow preparation of changed orders requested by contractor	45.71%	4.57	2.9	4.1	11.54	16
12	Contractor - MP	10. Low skill of manpower	45.61%	4.56	6.6	3.6	14.76	6
13	Contractor - PM	24. Ineffective control of project progress by the contractor	45.56%	4.56	4.5	3.9	13.03	12
14	Gov. Regulation	59. Gov. tendering system of selecting the lowest bidding contractor	45.27%	4.53	6.9	3.3	14.70	7
15	Consultant	38. Inadequate design specifications	45.19%	4.52	7.8	3.2	15.52	3
16	Consultant	39. Poor contract management	44.64%	4.46	7.3	3.2	14.87	5
17	Client	42. Delay in the settlement of contractor claims by the client	44.34%	4.43	5.9	2.6	12.99	13
18	Contractor - PF	29. Cash flow problems faced by the contractor	44.33%	4.43	4.9	1.6	10.95	19
19	Contractor - PM	25. Inefficient quality control by the contractor	44.30%	4.43	6.1	2.5	13.03	11
20	Client	41. Unrealistic contract duration	44.18%	4.42	7.9	3.3	15.60	1

The final adjusted ranking using the TAI produced a radical change for some factors, such as unrealistic time duration. That factor moved up 19 levels due its high involvement in all delay factors as it is usually planned at the very early stage of the project cycle. Shortage of technical professionals in the contractor organization was ranked as the second critical factor, followed by inadequate design and specification by consultant. These findings confirm the author's anticipation at the early stage of this research. The EC Index presented a high degree of involvement between the factors of delay, as clearly explained in Chapter 4.

5.9.2 The Final Singular Ranking of the Project Delay Factors

Top 20 critical factors of delay are presented as follows:

1) Unrealistic contract duration
2) Shortage of technical professionals in the contractor's organization
3) Inadequate design specifications
4) Ambiguities, mistakes, and inconsistencies in specs & drawings
5) Poor contract management
6) Low skill of manpower
7) Governmental tendering system of selecting the lowest bidding contractor
8) Improper technical studies by the contractor during bidding stage
9) Loose safety rules & regulations within the contractor's organization.
10) Changes in the scope of the project
11) Inefficient quality control by the contractor
12) Ineffective control of project progress by the contractor
13) Delay in the settlement of contractor claims by the client
14) Ineffective planning & scheduling of the project by the contractor
15) Poor qualifications of contractor's technical staff assigned to the project
16) Slow preparation of changed orders requested by contractor
17) Contractor's poor coordination with parties' involved in project
18) Shortage of manpower (skilled, semi-skilled, unskilled labor)
19) Cash flow problems faced by the contractor
20) Slow decision making by the client's organization

5.10 Validation of Ranking by Using Extended Survey (Top-20 Factors)

After applying the DR-HOQ analysis for ranking the projects delay factors, including all processes of sensitivity analysis by the representation of all indices, the re-ranking mechanism became robust enough for the logical ranking. However, the results of ranking was recommended to be validated by an additional technique that would verify whether the introduced final ranking is reliable. The PPMs represented by time, cost, quality, safety and environment were given different weights based on the findings from the DR-HOQ analysis. The time measure was given the highest weight (78%), followed by cost (67%) and safety (64%). The quality and environment measures were given least weights at 57% and 40%, respectively.

Table 5.7 illustrates the (Accumulative Risk Factor) for the top 20 factors of delay, which is comparable to the value of the TAI in the sensitivity analysis concluded by DR-HOQ. The results show the highest risk factor (Government tendering system of selecting the lowest bidding) at 48% and the lowest factor (slow decision by the Clint's organization) at 26%. Six factors out of 20 recorded a risk degree of 40% and above, while the remaining factors recorded risk degrees from 26% to 39%.

TABLE 5.7: EXTENDED SURVEY'S VALIDATION RESULTS

Factors of Delays: IFI Project

	Projects Factors effect	Performance Measures	Relation Degree %	PM's weight	Risk Factor by Responses
1	**Unrealistic contract duration by the client**	Time	78%	0.783	61%
		Cost	34%	0.67	23%
		Quality	29%	0.59	17%
		Safety	18%	0.644	12%
		Environment	13%	0.402	5%
		Overall Risk Percentage %			**40%**
2	**Shortage of technical professionals in the contractor's org.**	Time	48%	0.783	38%
		Cost	41%	0.67	27%
		Quality	30%	0.59	18%
		Safety	16%	0.644	10%
		Environment	15%	0.402	6%
		Overall Risk Percentage %			**33%**

3	Inadequate design specifications by the consultant	Time	78%	0.783	61%
		Cost	48%	0.67	32%
		Quality	30%	0.59	18%
		Safety	21%	0.644	14%
		Environment	16%	0.402	6%
		Overall Risk Percentage %			**43%**
4	Ambiguities, mistakes, and inconsistencies in specs & drawings by Client	Time	39%	0.783	31%
		Cost	30%	0.67	20%
		Quality	23%	0.59	14%
		Safety	18%	0.644	12%
		Environment	15%	0.402	6%
		Overall Risk Percentage %			**27%**
5	Poor contract management by consultant	Time	80%	0.783	63%
		Cost	33%	0.67	22%
		Quality	24%	0.59	14%
		Safety	20%	0.644	13%
		Environment	13%	0.402	5%
		Overall Risk Percentage %			**39%**
6	Low skills of manpower - contractor	Time	58%	0.783	45%
		Cost	33%	0.67	22%
		Quality	29%	0.59	17%
		Safety	30%	0.644	19%
		Environment	18%	0.402	7%
		Overall Risk Percentage %			**37%**
7	Governmental tendering system of selecting the lowest bidding contractor	Time	73%	0.783	57%
		Cost	45%	0.67	30%
		Quality	58%	0.59	34%
		Safety	25%	0.644	16%
		Environment	19%	0.402	8%
		Overall Risk Percentage %			**48%**
8	Improper technical studies by the contractor during bidding stage	Time	73%	0.783	57%
		Cost	45%	0.67	30%
		Quality	30%	0.59	18%
		Safety	20%	0.644	13%
		Environment	13%	0.402	5%
		Overall Risk Percentage %			**40%**

9	**Loose safety rules & regulations within the contractor's org.**	Time	40%	0.783	31%
		Cost	30%	0.67	20%
		Quality	30%	0.59	18%
		Safety	58%	0.644	37%
		Environment	20%	0.402	8%
		Overall Risk Percentage %			**38%**

10	**Changes in the scope of the project by the client**	Time	68%	0.783	53%
		Cost	43%	0.67	29%
		Quality	23%	0.59	14%
		Safety	18%	0.644	12%
		Environment	13%	0.402	5%
		Overall Risk Percentage %			**36%**

11	**Inefficient quality control by the contractor**	Time	45%	0.783	35%
		Cost	28%	0.67	19%
		Quality	45%	0.59	27%
		Safety	28%	0.644	18%
		Environment	15%	0.402	6%
		Overall Risk Percentage %			**35%**

12	**Ineffective control of project progress by the contractor**	Time	55%	0.783	43%
		Cost	33%	0.67	22%
		Quality	23%	0.59	14%
		Safety	15%	0.644	10%
		Environment	10%	0.402	4%
		Overall Risk Percentage %			**30%**

13	**Delay in the settlement of contractor claims by the client**	Time	53%	0.783	41%
		Cost	25%	0.67	17%
		Quality	18%	0.59	11%
		Safety	13%	0.644	8%
		Environment	10%	0.402	4%
		Overall Risk Percentage %			**27%**

14	**Ineffective planning & scheduling of the project by the contractor**	Time	50%	0.783	39%
		Cost	25%	0.67	17%
		Quality	18%	0.59	11%
		Safety	14%	0.644	9%
		Environment	13%	0.402	5%
		Overall Risk Percentage %			**27%**

15	Poor qualifications of contractor's tech. staff assigned to the project	Time	38%	0.783	30%
		Cost	13%	0.67	9%
		Quality	23%	0.59	14%
		Safety	24%	0.644	15%
		Environment	5%	0.402	2%
		Overall Risk Percentage %			**23%**
16	Slow preparation of changed orders requested by contractor	Time	85%	0.783	67%
		Cost	43%	0.67	29%
		Quality	33%	0.59	19%
		Safety	14%	0.644	9%
		Environment	10%	0.402	4%
		Overall Risk Percentage %			**44%**
17	Contractor's poor coordination with parties involved in project	Time	60%	0.783	47%
		Cost	33%	0.67	22%
		Quality	43%	0.59	19%
		Safety	14%	0.644	9%
		Environment	10%	0.402	4%
		Overall Risk Percentage %			**36%**
18	Shortage of manpower (skilled, semi-skilled, unskilled labor)	Time	63%	0.783	49%
		Cost	40%	0.67	27%
		Quality	40%	0.59	24%
		Safety	40%	0.644	26%
		Environment	13%	0.402	5%
		Overall Risk Percentage %			**43%**
19	Cash flow problems faced by the contractor	Time	70%	0.783	55%
		Cost	35%	0.67	23%
		Quality	18%	0.59	12%
		Safety	15%	0.644	10%
		Environment	10%	0.402	4%
		Overall Risk Percentage %			**34%**
20	Slow decision making by the client's organization	Time	73%	0.783	57%
		Cost	11%	0.67	7%
		Quality	12%	0.59	7%
		Safety	8%	0.644	5%
		Environment	4%	0.402	2%
		Overall Risk Percentage %			**26%**

The average risk factor for the top 10 delay factors was 38.1% while the average risk factor of the lowest 10 delays factor was 29.1%. Accordingly, the result of survey confirms that the top 10 delays factors are riskier than the lowest 10 delay factors. The difference of approximately 10% is considerably high and significant. This indicates the reliability of ranking to projects applied in the construction field in Saudi Arabia.

The analysis of validation was used to authenticate the ranking process and to present the importance of the top 20 factors of delay and the reliability of ranking. Nevertheless, some factors appeared important; however, they are positioned at a relatively low ranking. This discrepancy was mainly observed for Factor 7 and Factor 16 due the nature of the project and the weak preparation by all parties during the early stages of the projects. Table 5.8 illustrates the comparison between the final ranking using the DR-HOQ and the ranking results as per the extended survey. The table includes all indices used for the analysis to measure the reliability of ranking through the identified gap between TAI % and the Survey Index.

TABLE 5.8: VALIDATION RANKING BY EXTENDED SURVEY

Top 20 Factors of Delay	Party	RII %	CA %	EC %	TA Score	TAI %	Rank-1	Survey %	Rank-2	GAP
Unrealistic contract duration	URCD-O	44.18%	60%	32.9%	15.60	52.0%	1	40%	5	12%
Shortage of technical professionals in the contractor's org.	STP-C	52.47%	55%	32.9%	15.56	51.9%	2	33%	14	19%
Inadequate design specifications	IDS-E	45.19%	60%	31.6%	15.52	51.7%	3	43%	3	9%
Ambiguities, mistakes, and inconsistencies in specs & drawings	AMSD-O	45.76%	60%	27.6%	14.99	50.0%	4	27%	16	23%
Poor contract management	PCM-E	44.64%	55%	31.6%	14.87	49.6%	5	39%	7	11%
Low skill of manpower	LSMP-C	45.61%	55%	35.5%	14.76	49.2%	6	37%	9	12%
Gov. tendering system of selecting the lowest bidding contractor	GTLB-O	45.27%	55%	32.9%	14.70	49.0%	7	48%	1	1%
Improper technical studies by the contractor during bidding stage	IMTS-C	49.46%	50%	28.9%	14.45	48.2%	8	40%	6	8%
Loose safety rules & regulations within the contractor's org.	LSRR-C	49.68%	45%	32.9%	13.83	46.1%	9	38%	8	8%
Changes in the scope of the project	CSP-O	47.73%	45%	28.9%	13.68	45.6%	10	36%	10	10%
Inefficient quality control by the contractor	IEQC-C	44.30%	50%	25.0%	13.03	43.4%	11	35%	12	8%
Ineffective control of project progress by the contractor	IECPP-C	45.56%	35%	39.5%	13.03	43.4%	12	30%	15	13%
Delay in the settlement of contractor claims by the client	DSC-O	44.34%	45%	26.3%	12.99	43.3%	13	27%	17	16%
Ineffective planning & scheduling of the project by the contractor	IEPS-C	49.94%	30%	32.9%	12.44	41.5%	14	27%	18	14%
Poor qualifications of contractor's tech. staff assigned to project	PQS-C	47.36%	55%	14.5%	11.91	39.7%	15	23%	20	17%
Slow preparation of changed orders requested by contractor	SPCO-C	45.71%	20%	40.8%	11.54	38.5%	16	44%	2	-6%
Contractor's poor coordination with parties' invol. in project	PCAP-C	46.71%	40%	14.5%	11.15	37.2%	17	36%	11	1%
Shortage of manpower (skilled, semi-skilled, unskilled labor)	SMPALL-C	50.00%	35%	17.1%	11.07	36.9%	18	43%	4	-6%
Cash flow problems faced by the contractor	CFP-C	44.33%	35%	15.8%	10.95	36.5%	19	34%	13	2%
Slow decision making by the client's organization	SDM-O	45.84%	35%	15.8%	10.83	36.1%	20	26%	19	10%
Average %						44.5%		35.3%		9.2%

Validation of Findings:

- The extended survey was used as a validation for the final ranking of the delay factors, which may differ from one project to another based on many variables and site conditions.
- The top 10 factors in Table 5.10 shows higher risk compared to the lowest 10 factors. The gap deference between them was significant at +9%.
- Eight factors of delay in the top 10 list remained unchanged after validation.
- Four factors of delays had 16 to 19% gaps and 16 factors of delays were close to the ranking of the present study.
- The biggest gap was found at +23% for the fourth (Ambiguities, mistakes and inconsistence in specs/drawings), followed by the second factor (shortage of tech. professional) at +19%.
- The lowest gap was +1% for both the 7th factor (Selecting lowest bidding contract) and 17th factor (contractor poor coordination between parties), followed by the 19th factor (cash flow problem faced by contractor) at 2%.
- Selecting lowest bidding contract, slow preparation of changed orders, and inadequate design/specification were the most critical factors according to the validation process.
- Unrealistic time duration, shortage of technical professionals, and inadequate design/specification were the most critical factors according to research analysis.

Finally, the validation exercise revealed a high level of similarity in the ranking's orders in general. Four factors were ranked differently exceeding the limit of 15%. The ranking of the remaining 16 factors of delay seemed to be reliable and consistent after validation.

5.11 Collective Ranking of Delay Factors & Their Effects:

In Chapter 4, the mathematical approach for evaluating the collective impact of delay factors with the PPMs were explained in extensive detail. The approach used an empirical formula for identifying the collective impact of two or more factors that may arise in one project. The results of the formula were verified at a second stage using the FL concept.

5.11.1 Collective Impact of Red Chain Delay Factors

As shown in Figure 5.20, there are 10 red chains of factors representing different groups. The riskiest is chain two, which contains the factors: “Ambiguity & mistakes in the drawings, changes in the scope of the project, improper technical study, inadequate design specifications and unrealistic contact’s time duration”. The total weight of risk reached 87%, which means a project that contains this group of factors would face a severe failure or project delay. The lowest risk in this group is chain nine, which includes only two factors: “ineffective planning & scheduling and poor contract management” with a total risk weight estimated at 60.8%.

RED - Relations 75%- 100%

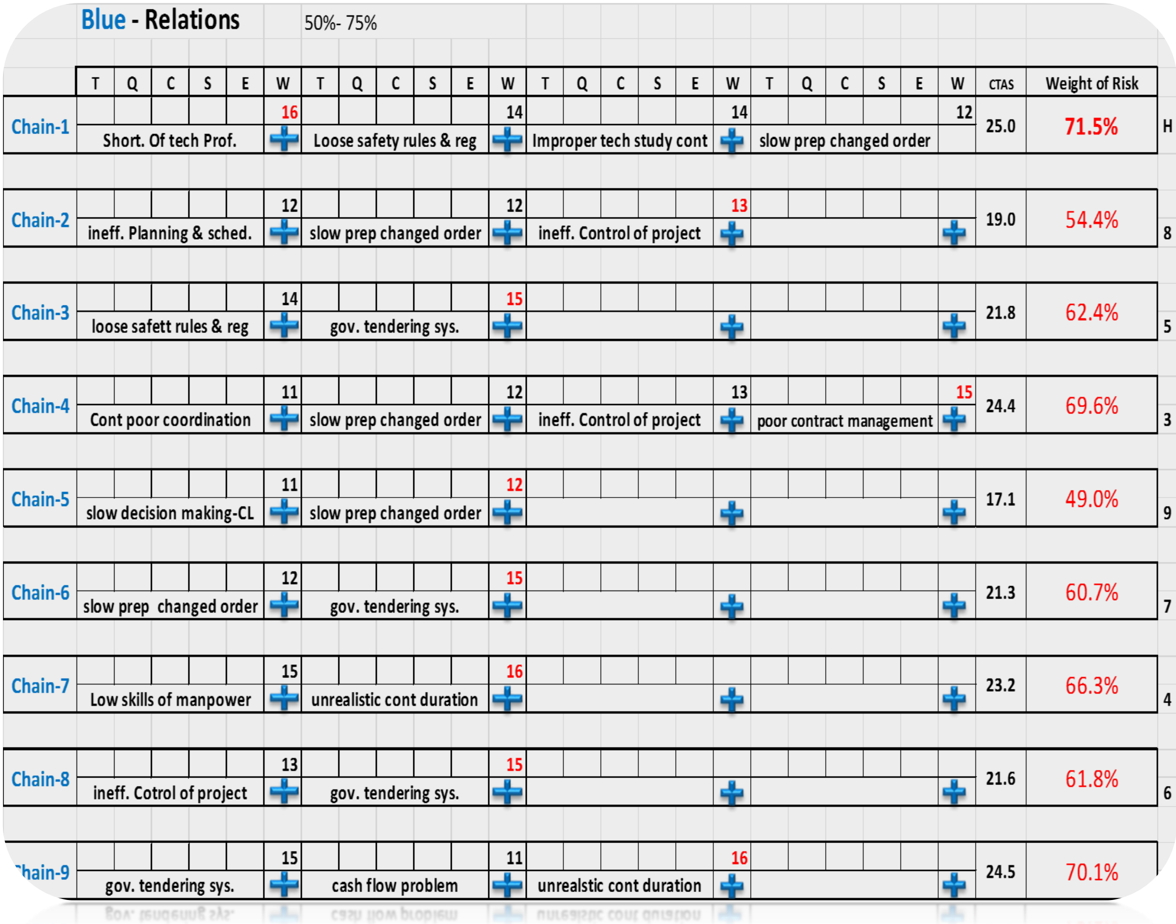
	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	W	GTAS	Weight of Risk	
Chain-1	3	2	3	1	1	14	3	2	3	2	2	15	3	3	3	2	1	16	3	1	3	1	1	14							30.2	86.2%	2
	Imp. Tech study						Amb. , mistakes in specs						Inadq. Design & specs						chages in scope of proj.														
Chain-2	3	2	3	2	2	15	3	1	3	1	1	14	3	2	3	1	1	14	3	3	3	2	1	16	3	2	3	3	1	16	30.45	87.0%	H
	Amb. & mistakes in specs						changes in scope of proj.						imp. Tech. study						inade. Design & specs						Unrealstic cont. duration								
Chain-3						13						11						11													24.06	68.8%	8
	Dealy in settlement						slow decision making - Cl						cont. poor coordination																				
Chain-4						16						15																			26.93	76.9%	5
	Short. Of tech staff						Low skills of Manpower																										
Chain-5						11						15																			24.45	69.8%	7
	short. Of manpoer all skills						Low skills of Manpower																										
Chain-6						15						16						11													27.29	78.0%	3
	Low skills of manpower						short. Of tech. staff						short. mapoer all skills																				
Chain-7						15						15																			25.96	74.2%	6
	por cntract management						gov. tendering sys.																										
Chain-8						16						15																			27.07	77.3%	4
	unrealistic cont. duration						Amb. , mistakes in specs																										
Chain-9						12						11																			21.29	60.8%	10
	ineff. Planning & sched.						cont. poor coordination																										
Chain-10						11						13																			21.92	62.6%	
	slow decision making-CL						Delay in settlement																										

Figure 5.20: Red Chains of Factors (75-100%)

Figure 5.21 shows there are nine blue chains of factors representing different weights of risks. The riskiest chain is chain one, which contains the factors: “shortage of technical staff, loose safety rules & regulations, slow preparation of change order by contractor”.

The total weight of risk reached 71.5%, taking into consideration the maximum bond strength is 75%, unlike the bond strength in the red chains with an assumed full effectiveness of 100%. The lowest risk chain in this group is chain three, which includes only two factors: “loose safety rules & regulations and governmental tendering system”, with a total weighted risk of 49%.

5.11.2 Collective Impact of Blue Chain Delay Factors



Blue - Relations 50%- 75%

	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	CTAS	Weight of Risk	
Chain-1	Short. Of tech Prof.	16	Loose safety rules & reg	14	Improper tech study cont	14	slow prep changed order	12	25.0	71.5%	H
Chain-2	ineff. Planning & sched.	12	slow prep changed order	12	ineff. Control of project	13			19.0	54.4%	8
Chain-3	loose safett rules & reg	14	gov. tendering sys.	15					21.8	62.4%	5
Chain-4	Cont poor coordination	11	slow prep changed order	12	ineff. Control of project	13	poor contract management	15	24.4	69.6%	3
Chain-5	slow decision making-CL	11	slow prep changed order	12					17.1	49.0%	9
Chain-6	slow prep changed order	12	gov. tendering sys.	15					21.3	60.7%	7
Chain-7	Low skills of manpower	15	unrealistic cont duration	16					23.2	66.3%	4
Chain-8	ineff. Cotrol of project	13	gov. tendering sys.	15					21.6	61.8%	6
Chain-9	gov. tendering sys.	15	cash flow problem	11	unrealstic cont duration	16			24.5	70.1%	

Figure 5.21: Blue Chains of Factors (50-75%)

5.11.3 Collective Impact of Green Chain Delay Factors

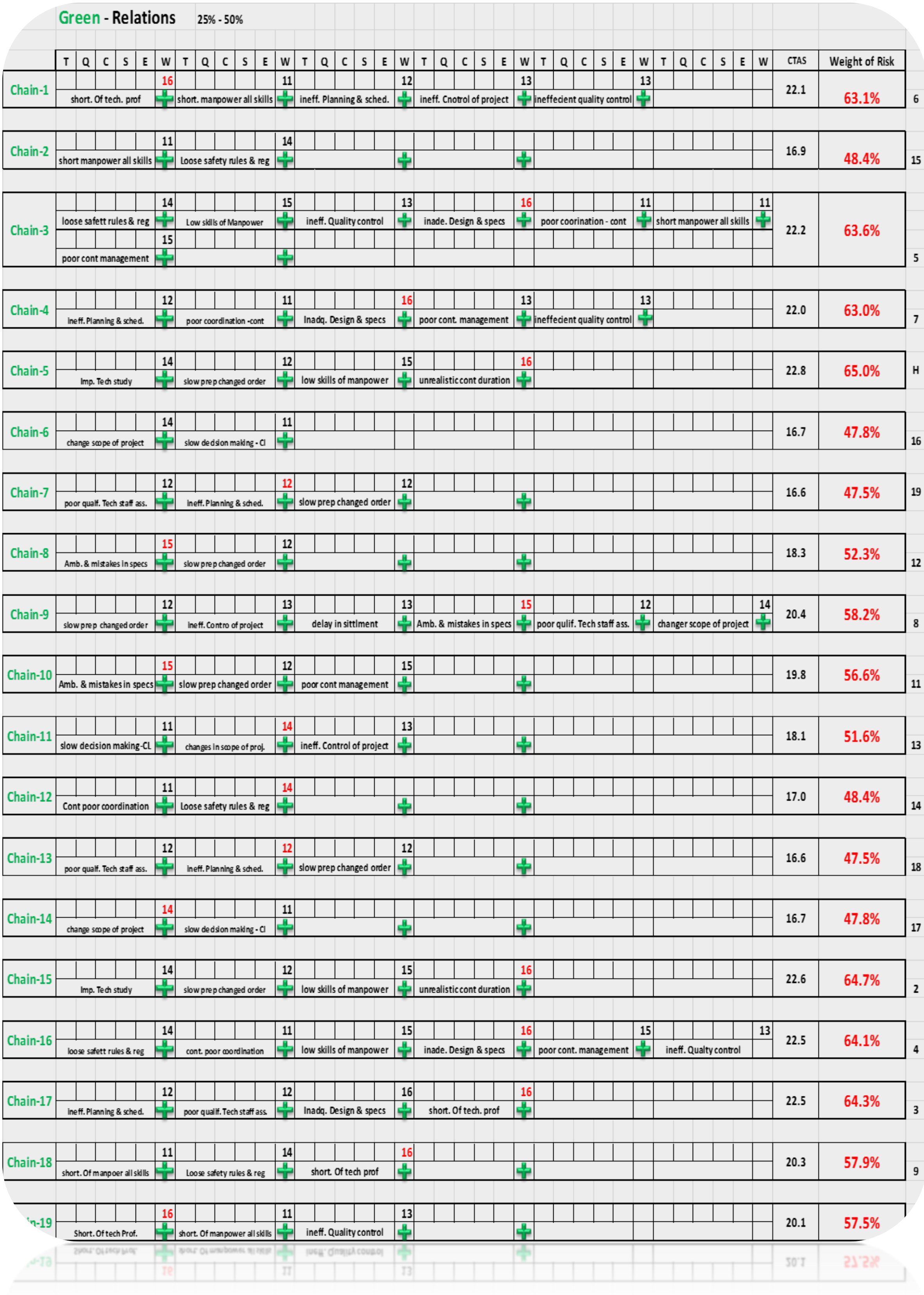


Figure 5.22 Green Chains of Factors (25-50%)

Figure 5.22 shows 19 green chains representing different groups of factors. The riskiest chains in this group are chains 3 and 16. Chain 3 contains seven factors, including: “loose safety rules & regulation, low skills of manpower provided by the contractor, ineffective quality control by the contractor, poor coordination & communication by contractor, inadequate design & specification by the consultant, short manpower skills in all levels by contractor and poor contract management”.

The second riskiest chain is 16, including:” loose safety rules & regulations, poor coordination & communication by the contractor, low skills of manpower, inadequate design & specifications by the consultant, poor contract management and ineffective quality control by the contractor”. The total weight of risk for both chains is 65%, taking into consideration the bond’s strength is 50%.

The lowest risk chain in this group is chain seven, which includes three factors: “poor qualification of technical staff by contractor, ineffective planning & scheduling by contractor and slow preparation of changed orders by contractor”. The total weighted risk is 47.5%.

5.11.4 Collective Impact of White Chain Delay Factors

Figure 5.23 shows 20 white chains that represent different groups of factors. The riskiest chain is chain ten, which contains seven factors: “slow preparation of changed order by contractor, low skills of manpower by contractor, inadequate design and specification by the consultant, poor contract management, unrealistic time duration, change scope of project, shortage of skilled manpower provided by contractor”. The total weight of risk is 55.7%, taking into consideration the bond strength is 25%.

The lowest risk in this group is chain four, which includes three factors: “chase flow problem by contractor, delay in the settlement of contractor claims by the client, regulations and ineffective quality control by the contractor” with a total weighted risk of 42.5%.

White - Relations 0% - 25%

	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	CTAS	Weight of Risk	
Chain-1	unrealistic cont duration	16	ineff. Quality control	13	cash flow problem	11	poor cont management	15	inade. Design & specs	16	ineff. Control of project	13	18.9	54.0%	
	slow prep changed order	12	cont. poor coordination	11											
Chain-2	neff. Quality control of pro	13	cash flow problem	11	delay in sittlment	13	poor cont management	15	ineff. Planning & sched.	12	short. Manpower all skills	11	18.8	53.8%	
	inade. Design & specs	16	ineff. Control of project	13	change scope of project	14	Improper tech study cont	14							
Chain-3	cash flow problem	11	delay in sittlment	13	ineff. Quality control	13	unrealistic cont duration	16					18.9	54.0%	
Chain-4	delay in sittlment	13	cash flow problem	11	ineff. Quality control	13							14.9	42.5%	L
Chain-5	poor cont management	15	unrealistic cont duration	16	ineff. Quality control	13	low skills of nanpower	15	slow prep changed order	12			19.1	54.5%	
Chain-6	inade. Design & specs	16	unrealistic cont duration	16	ineff. Quality control	13	ineff. Control of project	12	slow prep changed order	12			19.0	54.2%	
Chain-7	gov. tendering sys.	15	change scope of project	14									16.1	46.1%	
Chain-8	ineff. Control of project	13	inade. Design & specs	16	ineff. Quality control	13	unrealistic cont duration	16	poor qualf. Tech staff ass.	12	loose safett rules & reg	14	18.6	53.0%	
	short. Manpoewr all skills	11													
Chain-9	low skills of manpower	15	delay in sittlment	13	slow prep changed order	12	cont. poor coordination	11	poor qualf. Tech staff ass.	12	change scope of project	14	17.9	51.2%	
	ineff. Planning & sched	12													
Chain-10	slow prep changed order	12	low skills of manpower	15	Inadq. Design & specs	16	poor cont management	15	unrealistic cont duration	16	change scope of project	14	19.5	**55.7%**	H
	short. Manpoewr all skills	11													
Chain-11	Amb. & mistakes in specs	15	Loose safety rules & reg	14									16.4	46.9%	
Chain-12	slow decision making - clint	11	Improper tech study cont	14									16.3	46.4%	
Chain-13	cont. poor coordination	11	poor qualf. Tech staff ass.	12	low skills of manpower	15	unrealistic cont duration	16					18.3	52.2%	
Chain-14	poor qualf. Tech staff ass.	12	loose safett rules & reg	14	short. manpower all skills	11	short. Of tech. prof	16					18.2	51.9%	
Chain-15	change scope of project	14	loose safett rules & reg	14	ineff. Planning & sched.	12	slow prep changed order	12	low skills manpower	15	gov. tendering sys.	15	19.0	54.4%	
	ineff. Quality control	13	unrealistic cont duration	16											
Chain-16	Improper tech study cont	14	Loose safety rules & reg	14	ineff. Planning & sched.	12	slow decision making - cl	11	ineff. Quality control	13			17.7	50.5%	
Chain-17	Loose safety rules & reg	14	ineff. Planning & sched.	12	Improper tech study cont	14	change scope of project	14	poor qualf. Tech staff ass.	12	Amb. & mistakes in specs		18.0	51.5%	
	unrealistic cont duration	16													
Chain-18	ineff. Planning & sched.	12	short. Manpower all skills	11	unrealistic cont duration	16	loose safett rules & reg	14	Improper tech study cont	14	change scope of project	14	19.0	54.3%	
	low skills of manpower	15	ineff. Quality control	13											
Chain-19	short. Manpower all skills	11	ineff. Planning & sched.	12	poor qualf. Tech staff ass.	12	slow prep changed order	12	ineff. Control of project	13	ineff. Quality control	13	16.1	45.9%	
Chain-20	short. Of tech. prof	16	poor qualf. Tech staff ass.	12	cash flow problem	11							17.5	49.9%	

Figure 5.23: White Chains of Factors (0-25%)

5.11.5 Top Ten Risky Chains of Delay Factors

In the present study, the Red Chain factors had the highest impact on PPMs as compared to the other chains of factors. Figure 5.24 illustrates the risk weight of each chain from highest to lowest according to the collective impact of their factors that may appear in any project.

TOP 10 - Risky Chains

	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	W	GTAS	Risk Weight	Rank
Chain-2	3	2	3	2	2	15	3	1	3	1	1	14	3	2	3	1	1	14	3	3	3	2	1	16	3	2	3	3	1	16	30.45	87.0%	1
	Amb. & mistakes in specs						changes in scope of proj.						improperTech. study						inade. Design & specs						Unrealstic cont. duration								
Chain-1	3	2	3	1	1	14	3	2	3	2	2	15	3	3	3	2	1	16	3	1	3	1	1	14							30.18	86.2%	2
	ImproperTech. study						Amb., mistakes in specs						Inadq. Design & specs						chages in scope of proj.														
Chain-6						15						16						16													28.68	82.0%	3
	poor contract management						Shortage of tech. staff						unrealistic cont duration																				
Chain-8						16						15																			27.07	77.3%	4
	unrealistic cont. duration						ective plan & schedul pro																										
Chain-4						16						15																			26.93	76.9%	5
	Short. Of tech staff						Low skills of Manpower																										
Chain-7						15						15																			25.96	74.2%	6
	por cntract management						unrealistic cont duration																										
Chain-1						16						14						14						12							25.04	71.5%	7
	Short. Of tech Prof.						Loose safety rules & reg						Improper tech study cont						slow prep changed order														
Chain-9						15						11						16													24.54	70.1%	8
	Gov. tendering system						cash flow problem						unrealstic cont duration																				
Chain-4						11						12						13						15							24.36	69.6%	9
	Cont poor coordination						slow prep changed order						ineff. Control of project						poor contract management														
Chain-7						15						16																			23.19	66.3%	10
	Low skills of manpower						unrealistic cont duration																										

Figure 5.24: Top Ten Ranking of Risky Chains

As shown in Figure 5.24, the present research shed light on the top ten risky chains that were selected from the full list. This list contained ten chains from two different groups: red and blue. The list included six red chains and four blue chains.

The first risky chain in the list:

Red Chain 2, which contains five factors as follows:

1. Ambiguity & mistakes in the project scope and specification by the Client “owner” at early stage of the project initiation.
2. Changes in the scope of the project by the Client.
3. Improper technical study by the contractor during the bidding stage.
4. Inadequate design and specification by the consultant.
5. Unrealistic contract time duration by the Client.

Four delay factors are related to the scope design and specifications and one factor is related to the contract time schedule. The total risk weight of this chain is very high at 87%. If this chain appears, it is expected to be very critical to all PPMs and to significantly contribute to project delay. The chance to finish on time is less than 13%.

The second risky chain in the list:

Red Chain 1, which contains four factors as follows:

1. Ambiguity & mistakes in the project scope and specification by the Client "owner" at early stage of the project initiation.
2. Changes in the scope of the project by the Client.
3. Improper technical study by the contractor during the bidding stage.
4. Inadequate design and specification by the consultant.

Four delay factors are related to the scope design and specifications. The total risk weight of this chain is very high at 86.2%. Once this chain appears, it is expected to be very critical to all PPMs in general and to the quality performance measure in particular. Project chances to finish on time are less than 14%.

The third risky chain in the list:

Red Chain 6, which contains three factors as follows:

1. Poor contract management by the consultant or the client's assigned party.
2. Shortage of technical professionals in the contractor's organization.
3. Unrealistic contract time duration by the Client.

Two delay factors are related to the poor performance of the client and one factor is found related to the contractor's qualified personnel. The total risk weight of this chain is very high at 82%. Once this chain appears, it is expected to be very critical to all PPMs and contribute significantly to project delay. Project chances to finish on time are less than 18%.

The fourth risky chain in the list:

Red Chain 8, which contains only two factors as follows:

1. Unrealistic contract time duration by the client.
2. Ineffective planning and scheduling of the project by the contractor.

One delay factor is related to setting unrealistic contract time duration by the client and one factor is related to the contractor's ineffective planning and scheduling. The total risk weight of this chain is very high at 78.8%. Once this chain appears, it is expected to be very critical impact to all PPMs and to contribute significantly to project delay. Project chances to finish on time are less than 13%.

The fifth risky chain in the list:

Red Chain 4, which contains two factors as follows:

1. Shortage of technical professionalism in the contractor's organization.
2. Low skills of manpower provided by the contractor.

Two delay factors are related to the severe shortage of skilled and professional staff by the contractor. The total risk weight of this chain is very high at 76.9%. Once this chain appears, it is expected to have a very critical impact on project quality and to contribute significantly to project delay. Project chances of adherence to the agreed quality and to deliver the project on time are less than 14%.

The sixth risky chain in the list:

Red Chain7, which contains only two factors as follows:

1. Poor contract management by the consultant or the client's assigned party.
2. Unrealistic contract time duration by the client.

One delay factor is related to setting unrealistic contract time duration by the client and one factor is found related to the poor contract management by the consultant. The total risk weight of this chain is high at 74.2%. Once this chain appears, it is expected to have a very critical impact on the project time schedule and contributes significantly to project delay. Project chances to finish on time are less than 16%.

The seventh risky chain in the list:

Blue Chain1, which contains four factors as follow:

1. Shortage of technical professionalism in the contractor's organization.
2. Loose safety rules & regulations within the contractor's organization.
3. Improper technical study by the contractor during the bidding stage.
4. Slow preparation of changed order by the contractor.

Four delay factors are related to the contractor. The total risk weight of this chain is high at 71.5%. Once this chain appears, it is expected to be very critical to all PPMs in general and to the quality and safety performance measures in particular. Project chances to finish on time is less than 19%.

The eighth risky chain in the list:

Blue Chain 9, which contains three factors as follows:

1. Unrealistic contract time duration by the client.
2. Cash flow problems faced by the contractor.
3. Government tendering system of selecting the lowest bidding contractor by the client.

Two delay factors are related to the poor performance of the client by assigning the project to a low qualified contractor and, consequently, an unrealistic contract time duration is appointed. One factor is related to the contractor's cash flow problem. The total risk weight of this chain is reasonably high at 70.1%. Once this chain appears, it is expected to be a critical impact to the project cost and quality, which contributes significantly to project delay. Project chances to finish on time are less than 30%.

The ninth risky chain in the list:

Blue Chain 4, which contains four factors as follows:

1. Contractor's poor coordination with parties involved in the project.
2. Slow preparation of changed order by the contractor.
3. Ineffective control of project progress by the contractor.
4. Poor contract management by the consultant or the client's assigned party.

Three delay factors are found related to the contractor and one factor is related to the consultant's poor contract management. The total risk weight of this chain is 69.6%. Once this chain appears, it is expected to be critical to meet the project duration time and contributes significantly to project delay. Project chances to finish on time are less than 31%.

The tenth risky chain in the list:

Blue Chain 7, which contains two factors as follows:

1. Low skills of manpower provided by the contractor.
2. Unrealistic contract time duration by the Client.

One delay factor is related to setting unrealistic contract time duration by the client and one factor is related to the low skilled laborers supplied to the project by the consultant. The total risk weight of this chain is 66.3%. Once this chain appears, it is expected to be a critical impact on the project quality and time schedule and contributes significantly to project delay. Project chances to finish on time are less than 34%.

5.12 Results of Verification by Using FL (Top 10 Chains Ranking)

5.12.1 Top 10 factor chains

In this section, sets of rules were created with respect to the top ten risky chains that were initiated with the help of the DR-HOQ. These rules were carefully created with contributions of the author, projects consultants and project engineers who have been working and involved in the projects field.

More than 464 rules were created from 48 different chains (Group Factors). In this section, ten scenarios were demonstrated to simulate the effects/impacts of the delay factors when they exist together in a project. Each scenario included three different conditions (Ideal Condition, Normal Condition, and Poor Condition). The overall simulated weight indicates whether the collective impact of each chain responded logically or not.

This process of verification can be used as simulation program for any project that has a clear status for any factor of delay. The inputs of the selected factors will be processed assuming that the remaining delay factors are in their best conditions. The fuzzification process converts the inputs into tangible outputs (Performance Measures) based on the edited rules. The result of the performance measures are translated to ratios (±100%). This simulation process was conducted using a student version of MATLAB, which has a limited capacity of rules creation compared to the full version. Results could be further improved by using the full version and may become more sensitive if additional features are applied. For example, commands like "and, or none" can improve factors of delay conditions while creating the rules and accordingly improve the final results.

5.12.2 Verification Result for the 3- Scenarios:

The main objectives of the verification process are as follows:

- ✓ Evaluate the critical chain risk factors for result authentication based on three different conditions (Perfect, Normal, and Poor) for each group of factors.
- ✓ Identify the expected impacts for the remaining PPMs (Cost, quality, safety, and environment).
- ✓ Provide a general guideline for the decision making team before project commencement.
- ✓ Used as a prototype for PM to diagnose the solo or collective impacts of delay factors.
- ✓ All figures and tables for pages (200 – 232) present the results and conclusion made by each scenario, i.e. Tables 5.9 to 5.28 and Figures 5.25 to 5.63.

- **Scenario-1: Red Chain-2: Five factors and eight rules**

I. Critical delay factors:

1. Ambiguity & mistakes in the project scope and specification by the Client
2. Changes in the scope of the project by the Client.
3. Improper technical study by the contractor during the bidding stage.
4. Inadequate design and specification by the consultant.
5. Unrealistic contract time duration by the Client.

II. Rule building- Red chain-2:

TABLE 5.9: SCENARIO-1 RED CHAIN-2 OF 5 FACTORS AND 8 RULES

		Chain-2	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
1	Factors	Amb. & mistakes in specs	Comperhesive	Clear	Prospective	Vague	Comperhesive	Prospective	Clear	Comperhesive
2		Dealy in settlement	proactive	responsive	Delayed	ignorant	responsive	Delayed	responsive	Delayed
3		Short. Of tech staff	No shortage	Low shortage	Med shortsge	H. shortsge	Med shortsge	No shortage	Med shortsge	No shortage
4		short. Of manpoer all skills	No shortage	Low shortage	Med shortsge	H. shortsge	Med shortsge	No shortage	Med shortsge	No shortage
5		Low skills of manpower	nonexistent	raerly	occoasional	cronic	occoasional	nonexistent	raerly	occoasional
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed	Ontime	Ontime
2		Quality	Perfect	Meets scope	Corrective	Bad	Bad	Meets scope	Corrective	Corrective
3		Cost	Thrift	As planned	Over-run	Crises	As planned	As planned	Over-run	As planned
4		Safety	Secured	Adheared	Concerned	Risky	Concerned	Adheared	Concerned	Adheared
5		Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Adheared	Concerned	Adheared

III. Fuzzy sets modeling:

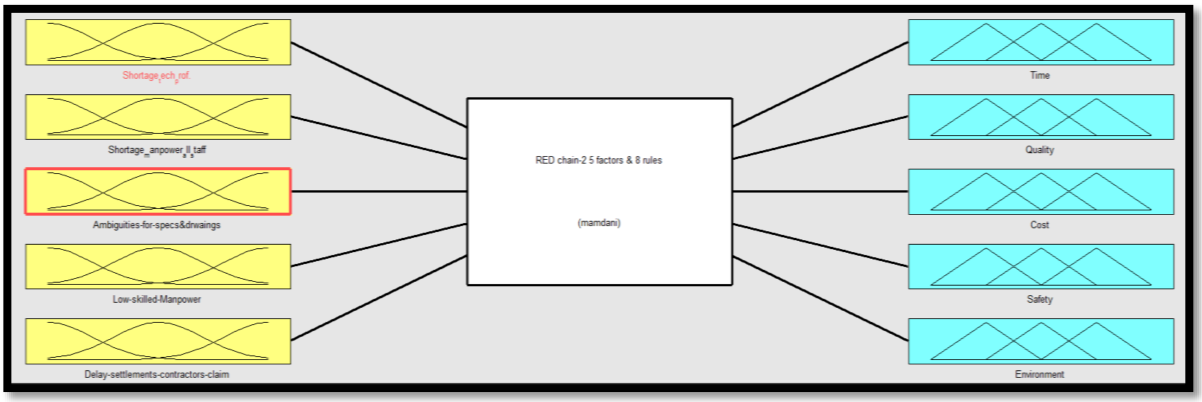


Figure 5.25: Red Chain-2

IV. Rules viewer 1:

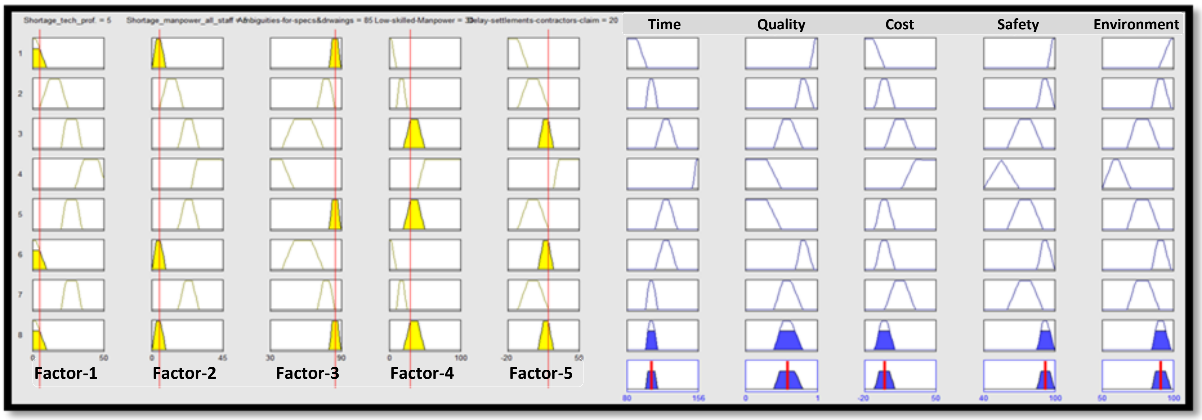


Figure 5.26: Red Chain-2 Fuzzy Logic Viewer 1

Iutput-1:

1. Ambiguity & mistakes in the project scope and specification by the Client 10%
2. Changes in the scope of the project by the Client 5%
3. Improper technical study by the contractor during the bidding stage (Suitability) 90%
4. Inadequate design and specification by the consultant (Adequacy) 75%
5. Unrealistic contract time duration by the Client. 95%

Output-1:

1- Time: 6% delayed from the agreed schedule
2- Quality: 82.2% adherence
3- Cost: -0.09% as planned
4- Safety: 92.4% adherence
5- Environment: 91.5% adherence

V. Rules viewer 2:

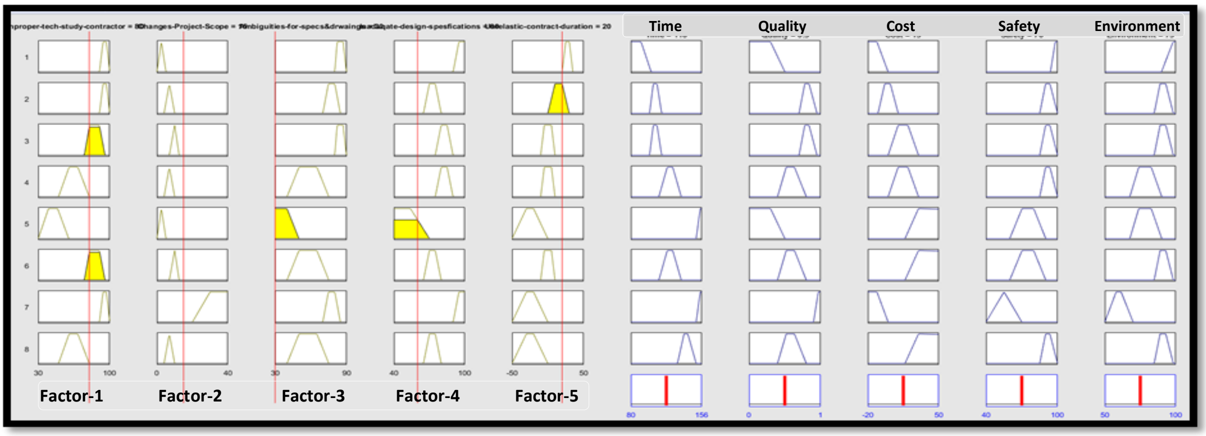


Figure 5.27: Red Chain-2 Fuzzy Logic Viewer 2

Iutput-2:

1. Ambiguity & mistakes in the project scope and specification by the Client (20%)
2. Changes in the scope of the project by the Client (15%)
3. Improper technical study by the contractor during the bidding stage (80%)
4. Inadequate design and specification by the consultant. (60%)
5. Unrealistic contract time duration by the Client. (80%)

Output-2:

1. Time: 22% delayed from the agreed schedule
2. Quality: 82% adherence
3. Cost: 15% overruns.
4. Safety: 87.4% adherence
5. Environment: 85.5% adherence

VI. Rules viewer-3:

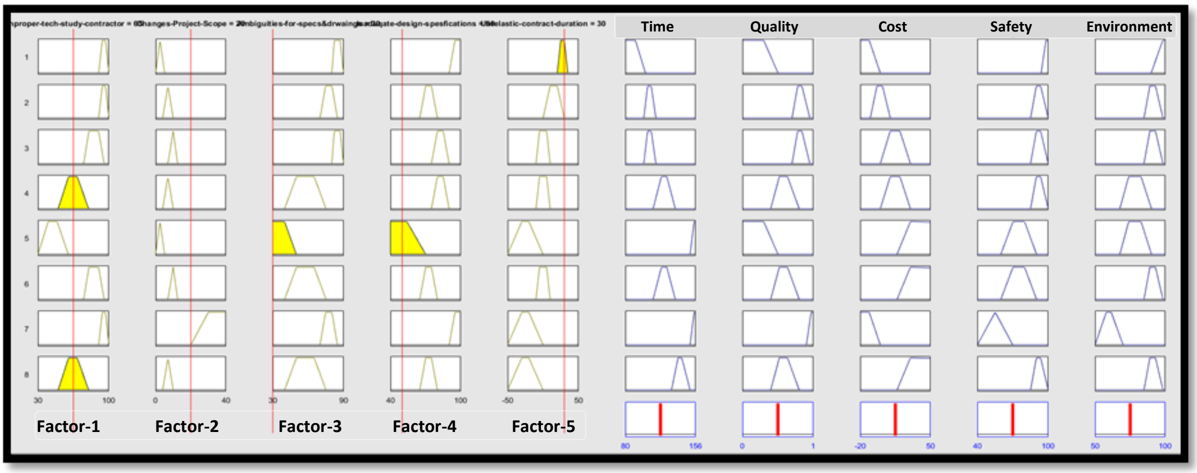


Figure 5.28: Red Chain-2 Fuzzy Logic Viewer 3

Iutput-3:

1. Ambiguity & mistakes in the project scope and specification by the Client (30%)
2. Changes in the scope of the project by the Client (20%)
3. Improper technical study by the contractor during the bidding stage (65%)
4. Inadequate design and specification by the consultant (50%)
5. Unrealistic contract time duration by the Client (70%)

Output-3:

1. Time: 35% delayed from the agreed schedule
2. Quality: 59.9% adherence
3. Cost: 15% overruns.
4. Safety: 75% adherence
5. Environment: 78.8% adherence

TABLE 5.10: RED CHAIN-2 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1. Ambiguity & mistakes in the project scope and specification 2. Changes in the scope of the project by the Client. 3. Improper technical study by the contractor in the bidding stage. 4. Inadequate design and specification by the consultant. 5. Unrealistic contract time duration by the Client.	6% delay from schedule	82.2% Adherence	(-0.8 %) Overrun	92.4% Adherence	91.5% Adherence	95.60%	Scenario-1	87.00%
Scenario-2 (Moderate Condition)	1. Ambiguity & mistakes in the project scope and specification 2. Changes in the scope of the project by the Client. 3. Improper technical study by the contractor in the bidding stage. 4. Inadequate design and specification by the consultant. 5. Unrealistic contract time duration by the Client.	29% delay from schedule	35.2% Adherence	14.9% Overrun	75% Adherence	87.7% Adherence	89.40%		
Scenario-3 (Extreme Condition)	1. Ambiguity & mistakes in the project scope and specification 2. Changes in the scope of the project by the Client. 3. Improper technical study by the contractor in the bidding stage. 4. Inadequate design and specification by the consultant. 5. Unrealistic contract time duration by the Client.	35% delay from schedule	59.9% Adherence	15% Overrun	75% Adherence	78.8% Adherence	71.20%		

Verification for Scenario-1:

Table 5.10 shows a positive result. The performance measures responded proportionally with inputs. The overall rating matched the conditions of delay factors.

- **Scenario-2: Red-Chain-2: Four factors and eight rules**

I. Critical delay factors:

1- Improper technical studies during bidding stage

2- Changes in the scope of the project

3- Ambiguities and mistakes in specs & drawings

4- Inadequate design specifications

II. Rule building- Red chain-1:

TABLE 5.11: SCENARIO-2 RED CHAIN-1 OF 4 FACTORS AND 8 RULES

		Chain-1	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
1	Factors	Improper tech. studies by during bidding	Super-Detailed	Standard	Weak	Cursory	Standard	Weak	Standard	Cursory
2		Changes in the scope of the project	Negligable	Simple	Moderate	Major	Moderate	Simple	Simple	Simple
3		Ambiguities and mistakes in specs & drawing	Comperhesive	Clear	Prospective	Vague	Vague	Clear	Prospective	Clear
4		Inadequate design specifications	Professinal	Adecuate	Prospetive	Messy	Messy	Adecuate	Prospetive	Professinal
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed	Delayed	Delayed
2		Quality	Perfect	Meets scope	Corrective	Bad	Bad	Meets scope	Bad	Meets scope
3		Cost	Thrift	As planned	Over-run	Crises	Over-run	Over-run	Over-run	As planned
4		Safety	Secured	Adheared	Concerned	Risky	Concerned	Adheared	Concerned	Adheared
5		Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Adheared	Concerned	Adheared

III. Fuzzy sets modeling:

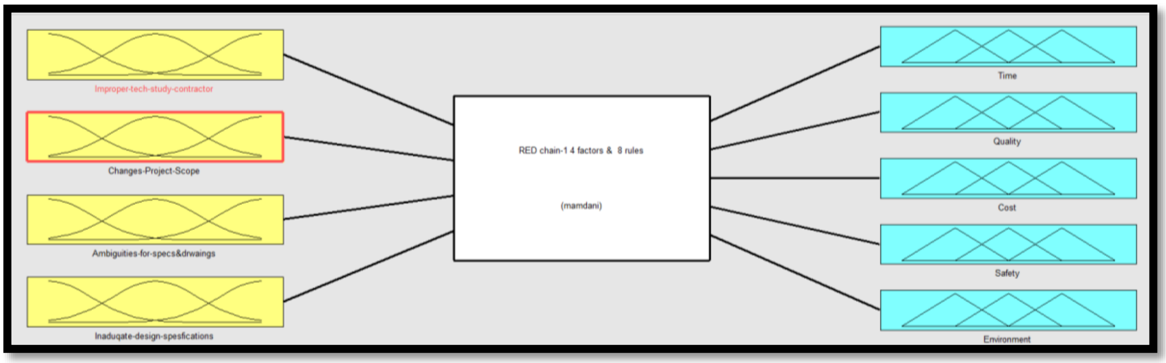


Figure 5.29: Red Chain-1

IV. Rules viewer 1:

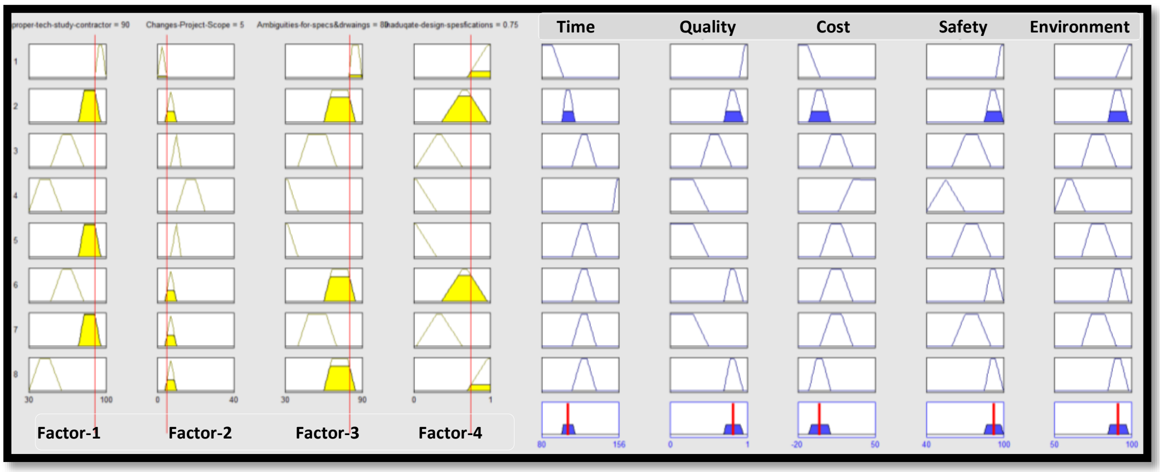


Figure 5.30: Red Chain-1 Fuzzy Logic Viewer 1

Iutput-1 (Perfect Condition):

1- Improper technical. studies during bidding stage: Property: 90%
2- Changes in the scope of the project: 5%
3- Ambiguities and mistakes in specs & drawings: Clearness 80%
4- Inadequate design specifications: Adequacy 75%

Output-1:

1- Time: 6% delayed from the agreed schedule
2- Quality: 82.2% adherence
3- Cost: -0.09% as planned
4- Safety: 92.4% adherence
5- Environment: 91.5% adherence

I. **Rules viewer 2:**

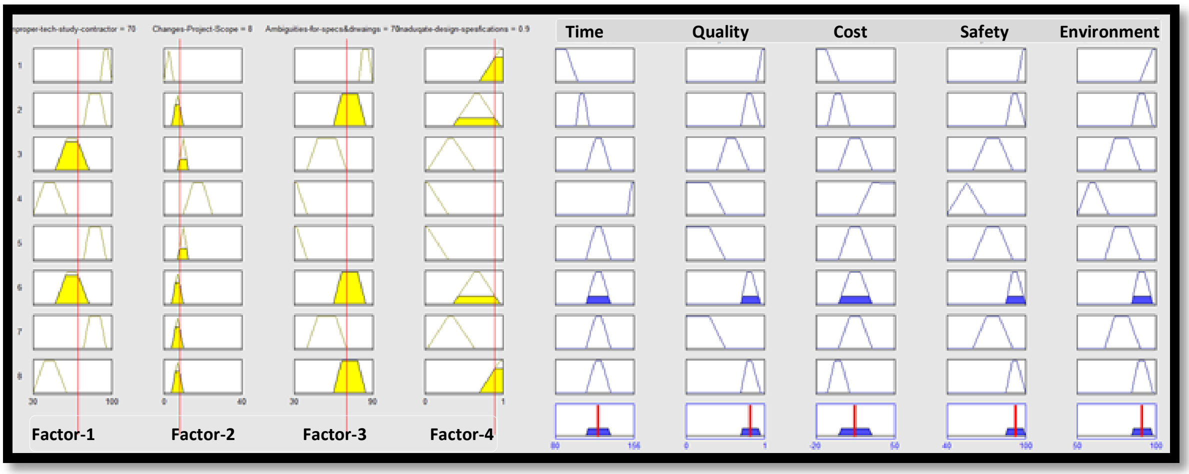


Figure 5.31: Red Chain-1 Fuzzy Logic Viewer 2

Iutput-2 (Moderate Condition):

1- Improper technical studies during bidding stage: Property: 70%
2- Changes in the scope of the project: 8%
3- Ambiguities and mistakes in specs & drawings: Clearness 70%
4- Inadequate design specifications: Adequacy 90%

Output-2:

1- Time: 22% delayed from the agreed schedule
2- Quality: 82% adherence
3- Cost: 15% overruns.
4- Safety: 92.4% adherence
5- Environment: 91.5% adherence

II. **Rules Viewer-3:**

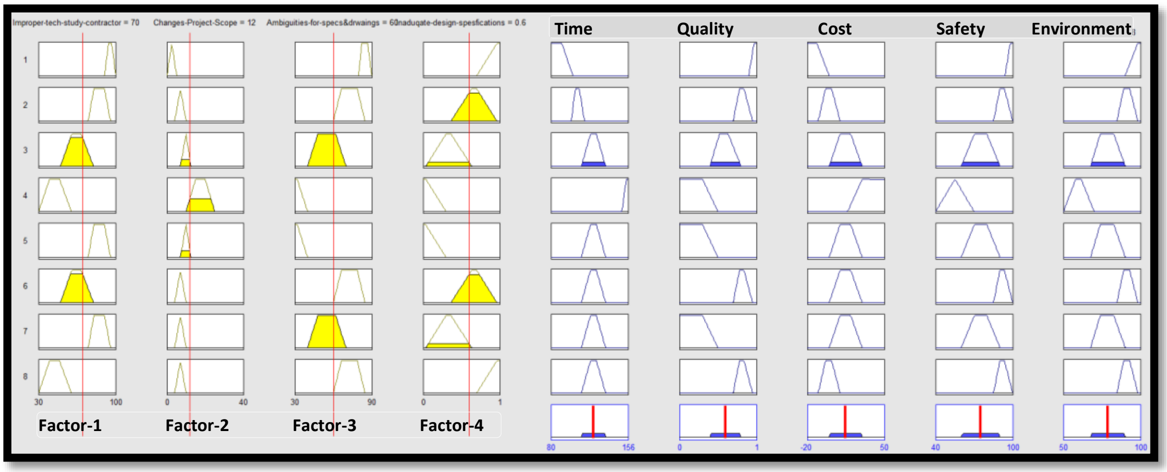


Figure 5.32: Red Chain-1 Fuzzy Logic Viewer 3

Iutput-3 (Extreme Condition):

1- Improper technical studies during bidding stage: Property: 70%
2- Changes in the scope of the project: 12%
3- Ambiguities and mistakes in specs & drawings: Clearness 60%
4- Inadequate design specifications: Adequacy 68%

Output-3:

1- Time: 22% delayed from the agreed schedule
2- Quality: 59.9% adherence
3- Cost: 15% overruns.
4- Safety: 75% adherence
5- Environment: 78.8% adherence

TABLE 5.12: RED CHAIN-1 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1- Shortage of technical staff: 5% 2- Loose safety rules & regulations: 80% 3- Improper technical study by the contractor: 80% 4- Slow preparation of changed order by the contractor: 0% on time	6% delay from schedule	82.2% Adherence	(-0.8 %) Overrun	92.4% Adherence	91.5% Adherence	92.22%	Scenario-2	86.20%
Scenario-2 (Moderate Condition)	1- Shortage of technical staff: 30% 2- Loose safety rules & regulations: 60% 3- Improper technical study by the contractor: 60% 4- Slow preparation of changed order by the contractor: 20% on time	29% delay from schedule	35.2% Adherence	14.9% Overrun	75% Adherence	87.7% Adherence	85.78%		
Scenario-3 (Extreme Condition)	1- Shortage of technical staff: 10% 2- Loose safety rules & regulations: 80% 3- Improper technical study by the contractor: 95% 4- Slow preparation of changed order by the contractor: 10% on time	(-10.8%) delay from schedule	93.9% Adherence	(-11%) Overrun	96.9% Adherence	96.2% Adherence	75.36%		

Verification for Scenario-2:

Table 5.12 shows a positive result. The performance measures responded proportionally with inputs. The overall rating matched the conditions of delay factors.

- **Scenario-3: Red-chain-6: Three factors and eight rules**

I. Critical delay factors:

1- Low skills of manpower
2- Poor contract management
3- Unrealistic contract time duration.

II. Rule building- Red chain-6:

TABLE 5.13: SCENARIO-3 RED CHAIN-6 OF 3 FACTORS AND 8 RULES

		Chain-6	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
1	Factors	Low skills of manpower	nonexistent	raerly	occoasional	cronic	raerly	cronic	raerly	occoasional
2		poor cntract management	Professional	Qualified	Poor	Not qualified	Poor	Qualified	Qualified	Poor
3		unrealistic cont. duration	Conservative	Realistic	Resanable	Risky	Risky	Realistic	Risky	Conservative
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Failure	Failure	Delayed	Delayed	Ontime
2		Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Corrective	Meets scope	Corrective
3		Cost	Thrift	As planned	Over-run	Crises	Over-run	As planned	As planned	As planned
4		Safety	Secured	Adheared	Concerned	Risky	Adheared	Concerned	Adheared	Adheared
5		Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Concerned	Adheared	Adheared

III. Fuzzy sets modeling:

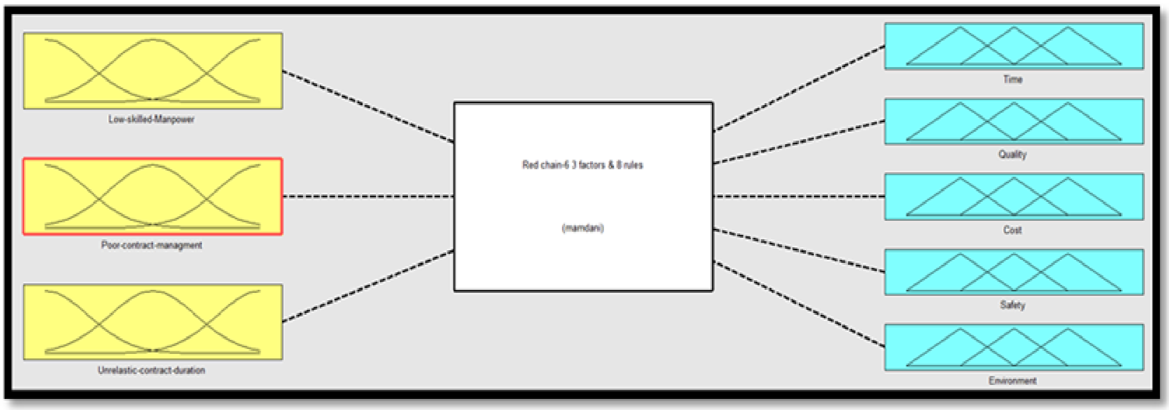


Figure 5.33: Red Chain-6

IV. Rules viewer-1:

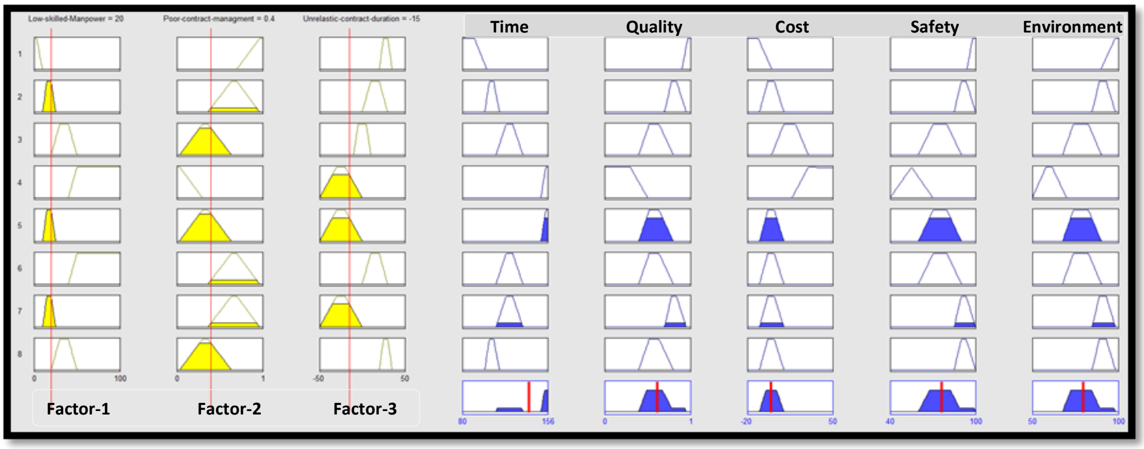


Figure 5.34: Red Chain-6 Fuzzy Logic Viewer 1

Iutput-1:

1- Low skills of manpower: 20%
2- Poor contract management: 40%
3- Unrealistic contract time duration: -15%

Output-1:

1- Time: 40% delayed from the agreed schedule
2- Quality: 61.4% adherence
3- Cost: -0.02% as planned.
4- Safety: 76.4% adherence
5- Environment: 79.8% adherence

V. Rules viewer-2:

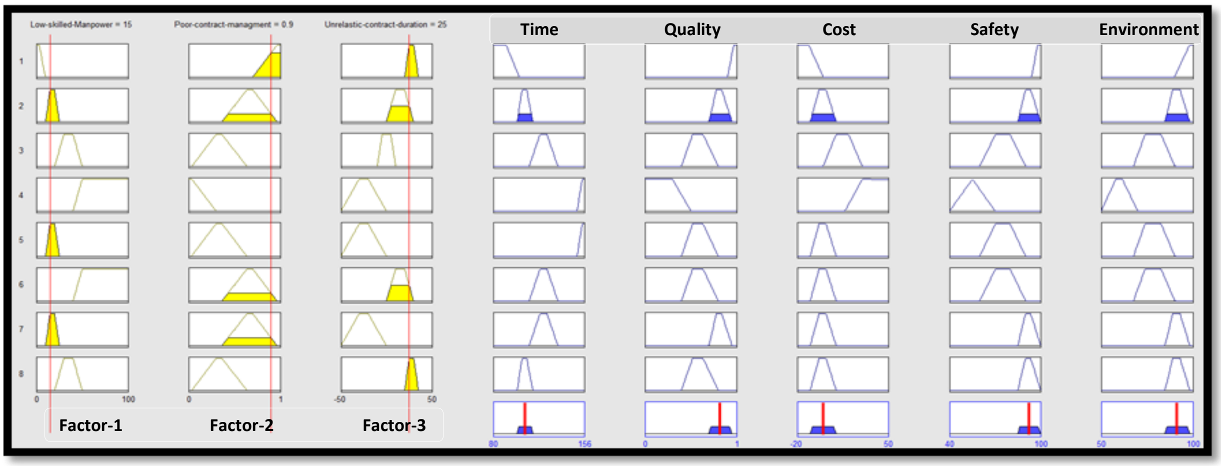


Figure 5.35: Red Chain-6 Fuzzy Logic Viewer 2

Iutput-2:

1- Low skills of manpower: 15%
2- Poor contract management: 90%
3- Unrealistic contract time duration: 25%

Output-2:

1- Time: 6% delayed from the agreed schedule
2- Quality: 82.2% adherence
3- Cost: -0.6% as planned
4- Safety: 92.4% adherence
5- Environment: 91.5% adherence

VI. Rules viewer-III:

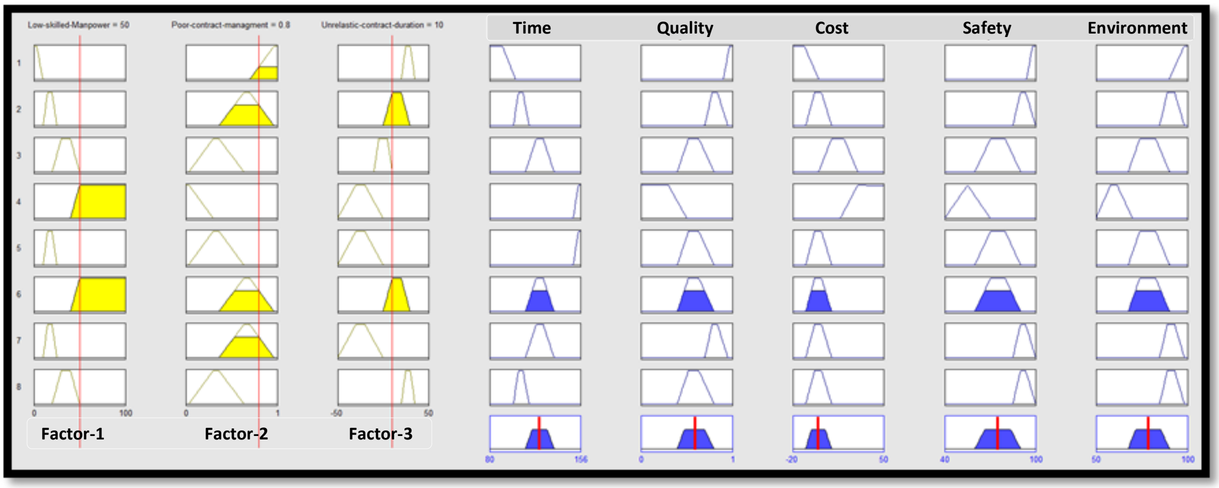


Figure 5.36: Red Chain-6 Fuzzy Logic Viewer 3

Iutput-3:

1- Low skills of manpower: 50%
2- Poor contract management: 80%
3- Unrealistic contract time duration: 10%

Output-3:

1- Time: 22% delayed from the agreed schedule
2- Quality: 59.3% adherence
3- Cost: -1.61% as planned.
4- Safety: 75% adherence
5- Environment: 78.7% adherence

TABLE 5.14: RED CHAIN-6 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1. Shortage of technical staff 15% 2. Poor contract management 90% 3. Unrealistic contract time duration 25%	6% delay from schedule	82.2% Adherence	(-0.6%) Overrun	92.4% Adherence	91.5% Adherence	**91.90%**	Scenario-3	**82.00%**
Scenario-2 (Moderate Condition)	1. Shortage of technical staff 50% 2. Poor contract management 80% 3. Unrealistic contract time duration 10%	22% delay from schedule	59.9% Adherence	(-1.61)% Overrun	75% Adherence	78.8% Adherence	**80.00%**		
Scenario-3 (Extreme Condition)	1. Shortage of technical staff 20% 2. Poor contract management 40% 3. Unrealistic contract time duration -15%	40% delay from schedule	61.4% Adherence	(-0.02 %) Overrun	76.4% Adherence	79.8% Adherence	**75.14%**		

Verification of Scenario-3:

Table 5.14 shows a positive result. The performance measures responded proportionally with inputs. The overall rating matched the conditions of delay factors.

- **Scenario-4:Red chain 8: Two factors and six Rules**

I. Critical delay factors:

1- Ineffective planning & scheduling by the contractor
2- Unrealistic time duration

II. Rules building- Red chain-8:

TABLE 5.15: SCENARIO-4 RED CHAIN-8 OF 2 FACTORS AND 6 RULES

		Chain-8	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6
1	Factors	unrealistic cont. duration	Conservative	Realistic	Resanable	Risky	Risky	Realistic
2		ineff. Planning & sched.	Advanced	Moderate	Occational	Poor	Moderate	Poor
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed
2		Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Meets scope
3		Cost	Thrift	As planned	Over-run	Crises	As planned	Over-run
4		Safety	Secured	Adheared	Concerned	Risky	Adheared	Concerned
5		Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared

III. Fuzzy sets modeling:

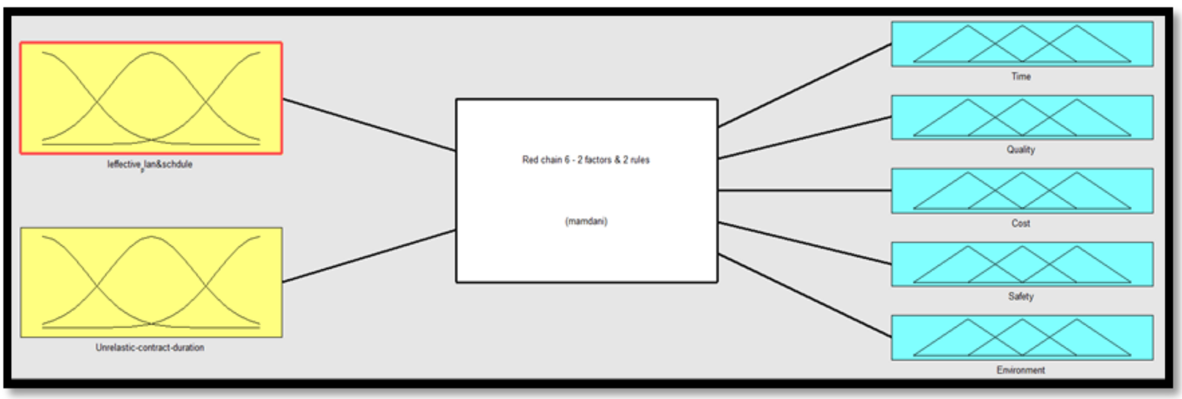


Figure 5.37: Red Chain-8

IV. Rules viewer-1:

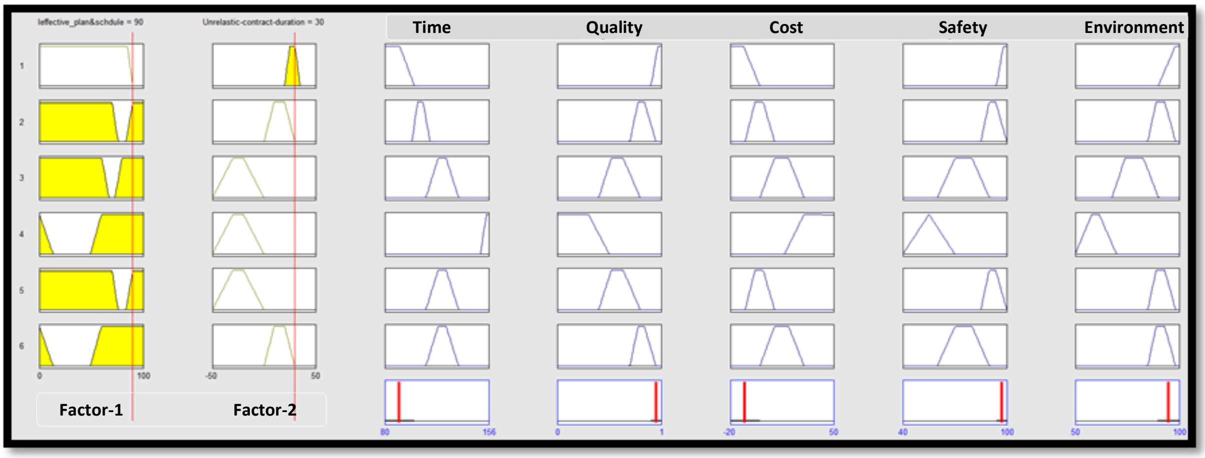


Figure 5.38: Red Chain-8 Fuzzy Logic Viewer 1

Iutput-1:

1- Ineffective planning & scheduling by the contractor: 90%
2- Unrealistic time duration: 30/%

Output-1:

1- Time: -9.4 % Earlier to the agreed schedule
2- Quality: 95.5% adherence
3- Cost: -10.2%, thrift.
4- Safety: 97.3% adherence
5- Environment: 95% adherence

V. Rules viewer-2:

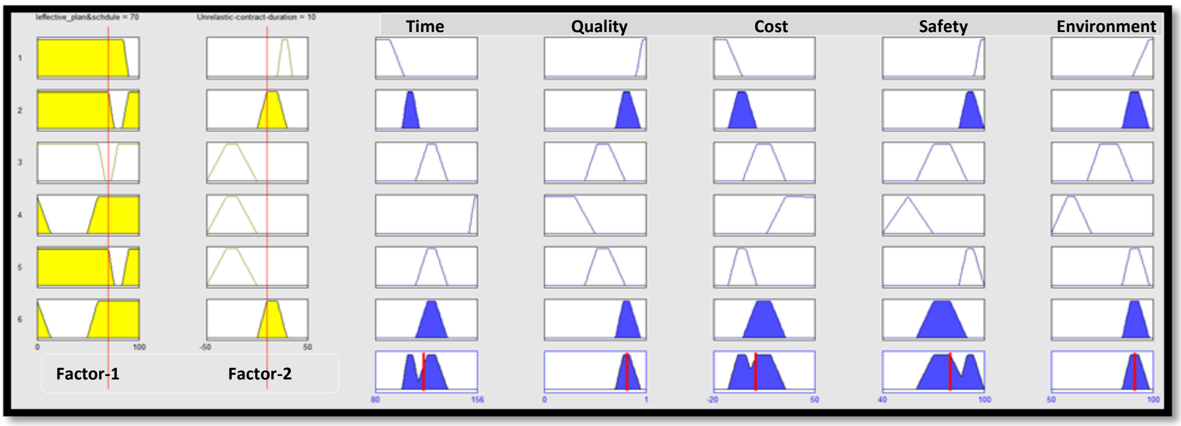


Figure 5.39: Red Chain-8 Fuzzy Logic Viewer 2

Iutput-2:

1- Ineffective planning & scheduling by the contractor: 70%
2- Unrealistic time duration: 10%

Output-2:

1- Time:16% delayed from the agreed schedule
2- Quality: 81.8% adherence
3- Cost: 9.37% as planned.
4- Safety: 80.3% adherence
5- Environment: 91.3% adherence

VI. Rules viewer-III:

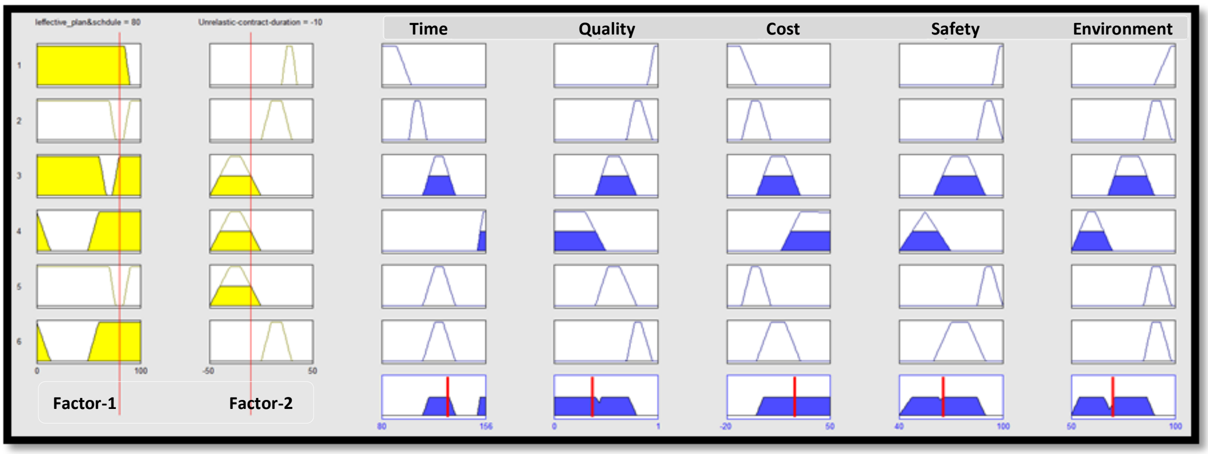


Figure 5.40: Red Chain-8 Fuzzy Logic Viewer 3

Iutput-3:

1- Ineffective planning & scheduling by the contractor: 80%
2- Unrealistic time duration: -10%

Output-3:

1- Time: 29% delayed from the agreed schedule
2- Quality: 67.7% adherence
3- Cost: 26.4% as planned.
4- Safety: 65.7% adherence
5- Environment: 70.2% adherence

TABLE 5.16 RED CHAIN-8 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1- Ineffective planning & scheduling by the contractor 90% 2- Unrealistic time duration (+30%) from the plan	(-9.4%) delay from schedule	95.5% Adherence	(-10.2%) Overrun	97.3% Adherence	95% Adherence	107.00%	Scenario-4	77%
Scenario-2 (Moderate Condition)	1- Ineffective planning & scheduling by the contractor 70% 2- Unrealistic time duration (+10%) from the plan	16% delay from schedule	81.8% Adherence	9.37% Overrun	80.3% Adherence	91.3% Adherence	85.60%		
Scenario-3 (Extreme Condition)	1- Ineffective planning & scheduling by the contractor 80% 2- Unrealistic time duration (-10%) from the plan	29% delay from schedule	67.7% Adherence	(26.4 %) Overrun	65.7% Adherence	70.2% Adherence	69.66%		

Verification of Scenario-4:

Table 5.16 shows a positive result. The performance measures responded proportionally with inputs. The overall rating matched the conditions of delay factors.

- **Scenario-5: Red-chain-4: Two factors and six rules**

I. Critical delay factors:

1- Shortage of technical staff
2- Low skills of manpower

II. Rule building- Red chain-4

TABLE 5.17: SCENARIO-5 RED CHAIN-4 OF 2 FACTORS AND 6 RULES

		Chain-4	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6
1	Factors	Short. Of tech staff	No shortage	Low shortage	Med shortsge	H. shortsge	Low shortage	H. shortsge
2		Low skills of manpower	nonexistent	raerly	occoasional	cronic	cronic	raerly
			⇩	⇩	⇩	⇩	⇩	⇩
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Ontime	Delayed
2		Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Corrective
3		Cost	Thrift	As planned	Over-run	Crises	As planned	As planned
4		Safety	Secured	Adheared	Concerned	Risky	Concerned	Concerned
5		Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Concerned

III. Fuzzy sets modeling:

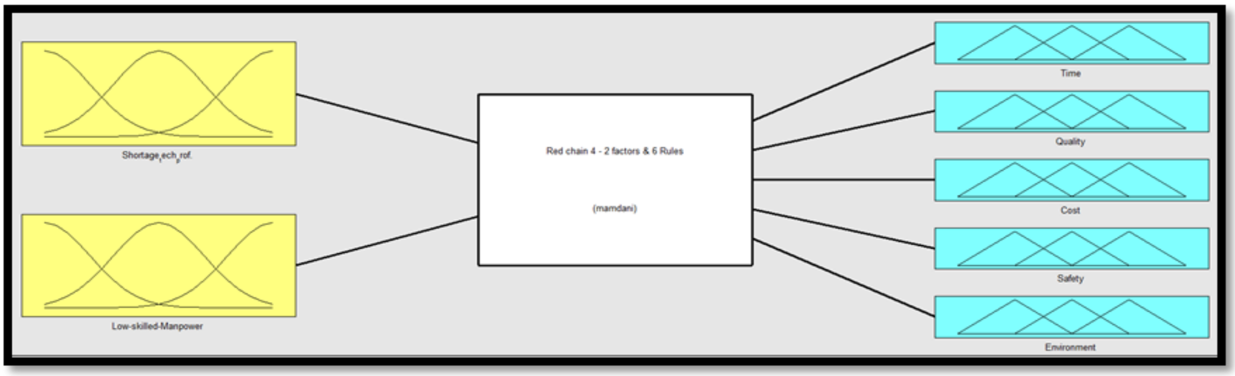


Figure 5.41: Red Chain-4

IV. Rules viewer-1

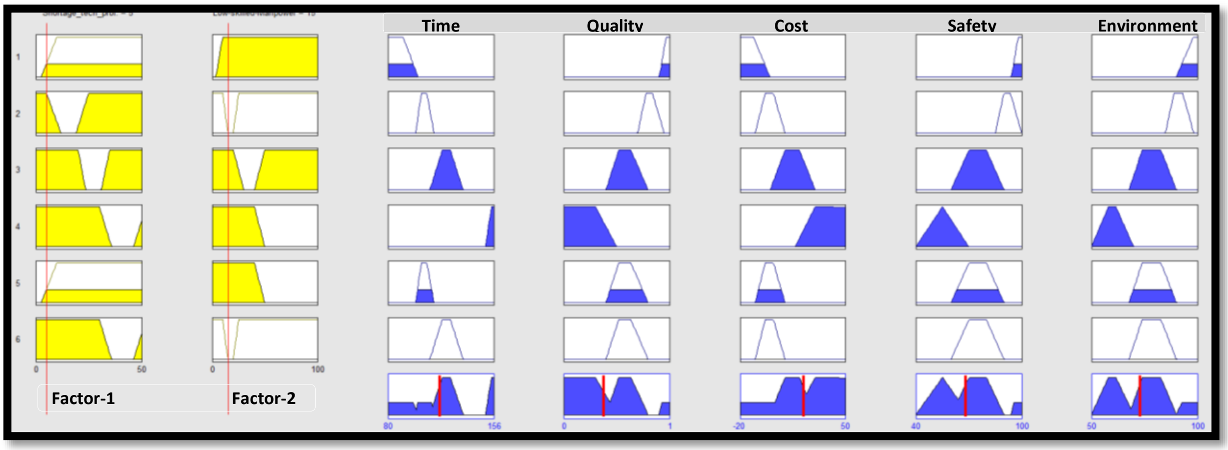


Figure 5.42: Red Chain-4 Fuzzy Logic Viewer 1

Iutput-1:

1. Shortage of technical staff 10%
2. Low skills of manpower 15%

Output-1:

1- Time: 17% delayed from the agreed schedule
2- Quality: 37.8% adherence
3- Cost: 22.3% overrun.
4- Safety: 68.2% adherence
5- Environment: 73.1% adherence

V. Rules viewer-2:

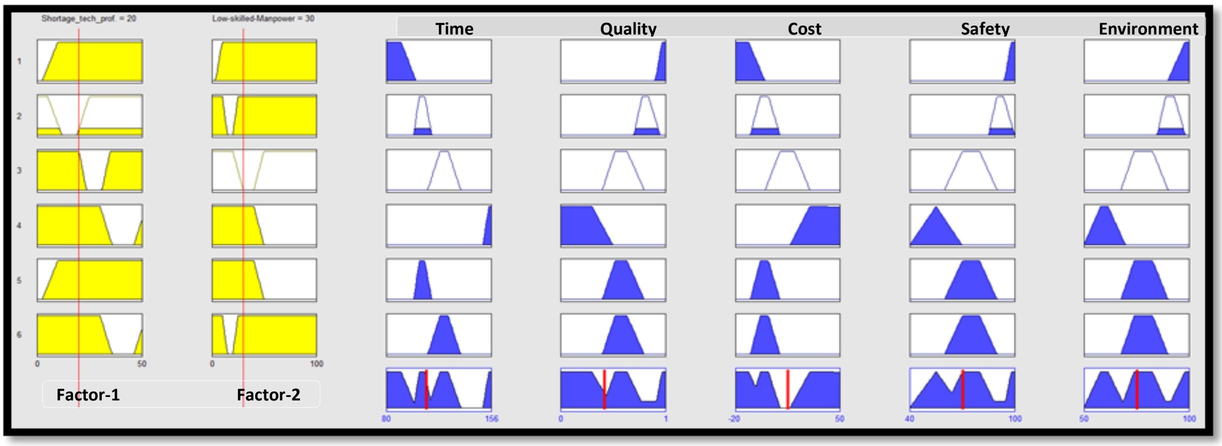


Figure 5.43: Red Chain-4 Fuzzy Logic Viewer 2

Iutput-2:

1- Shortage of technical staff 20%
2- Low skills of manpower 30%

Output-2:

1- Time: 9% delayed from the agreed schedule
2- Quality: 42.3% adherence
3- Cost: 15.6% as planned.
4- Safety: 70.7% adherence
5- Environment: 75.6% adherence

VI. Rules viewer-3:

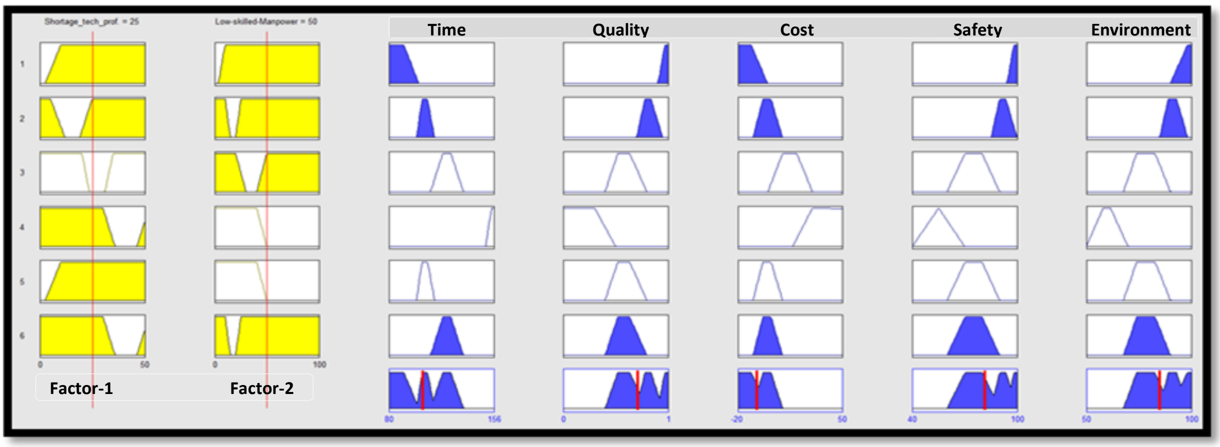


Figure 5.44: Red Chain-4 Fuzzy Logic Viewer 3

Output-3:

1- Shortage of technical staff 25%
2- Low skills of manpower 50%

Output-3:

1- Time: 6% delayed from the agreed schedule
2- Quality: 71.1% adherence
3- Cost: -7.61% as planned.
4- Safety: 81.8% adherence
5- Environment: 85.1% adherence

TABLE 5.18 RED CHAIN-4 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1. Shortage of technical staff 10% 2. Low skills of manpower 15%	17% delay from schedule	37.8% Adherence	22.3% Overrun	68.2% Adherence	37.1% Adherence	**62.80%**	Scenario-5	**76.90%**
Scenario-2 (Moderate Condition)	1- Poor contract management: 20% 2- Unrealistic contract time duration: 30%	9% delay from schedule	42.3% Adherence	15.6% Overrun	70.7% Adherence	75.6% Adherence	**72.80%**		
Scenario-3 (Extreme Condition)	1- Poor contract management: 25% 2- Unrealistic contract time duration: 50%	6% delay from schedule	71.1% Adherence	(-7.61%) Overrun	81.8% Adherence	85.1% Adherence	**87.90%**		

Verification of Scenario-5:

Table 5.18 shows a negative result. The performance measures responded negatively with inputs. The overall rating did not match the conditions of delay factors.

- **Scenario-6: Red chain-7: Two factors and six rules**

I. Critical delay factors:

1- Poor contract management
2- Unrealistic time duration

II. Rule building- Red chain-7:

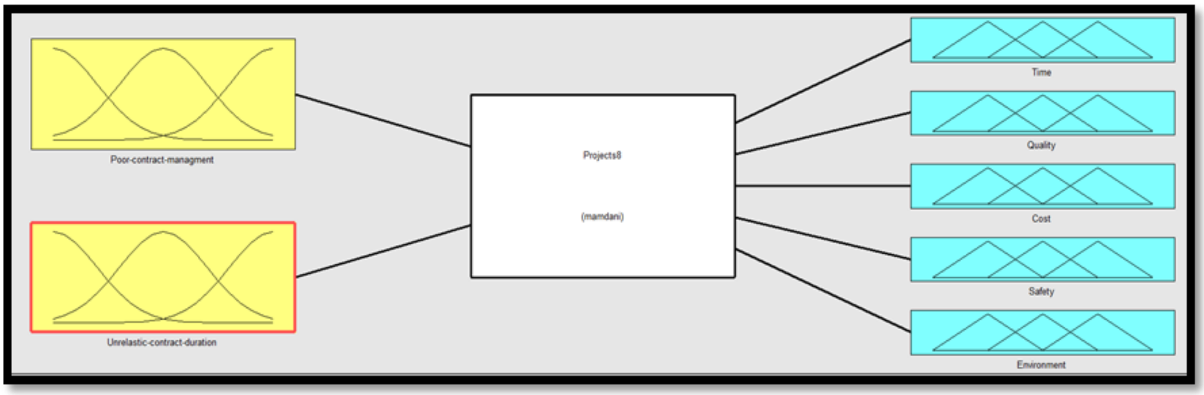


Figure 5.45: Red Chain-7

III. Fuzzy sets modeling:

TABLE 5.19: SCENARIO-6 RED CHAIN-7 OF 2 FACTORS AND 6 RULES

		Chain-7	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6
1	Factors	poor cntract management	Professional	Qualified	Poor	Not qualified	Qualified	Not qualified
2		unrealistic cont. duration	Conservative	Realistic	Resanable	Risky	Risky	Realistic
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed
2		Quality	Perfect	Meets scope	Corrective	Bad	Meets scope	Corrective
3		Cost	Thrift	As planned	Over-run	Crises	As planned	Over-run
4		Safety	Secured	Adheared	Concerned	Risky	Adheared	Adheared
5		Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared

IV. Rules viewer-1:

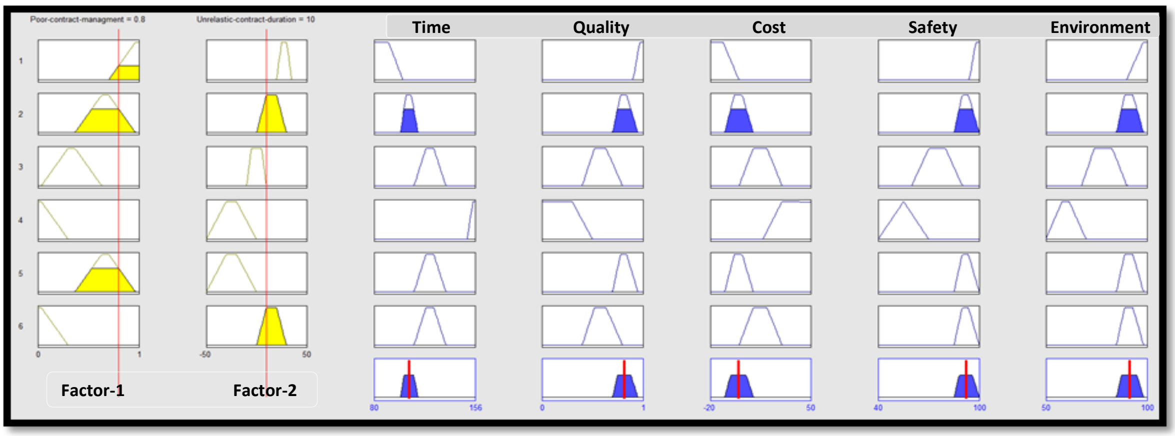


Figure 5.46: Red Chain-7 Fuzzy Logic Viewer 1

Iutput-1:

1- Poor contract management: 80%
2- Unrealistic contract time duration: 10%

Output-1:

1- Time: 6% delayed from the agreed schedule
2- Quality: 82% adherence
3- Cost: -1.61% as planned.
4- Safety: 92.3% adherence
5- Environment: 91.4% adherence

V. Rules viewer-2:

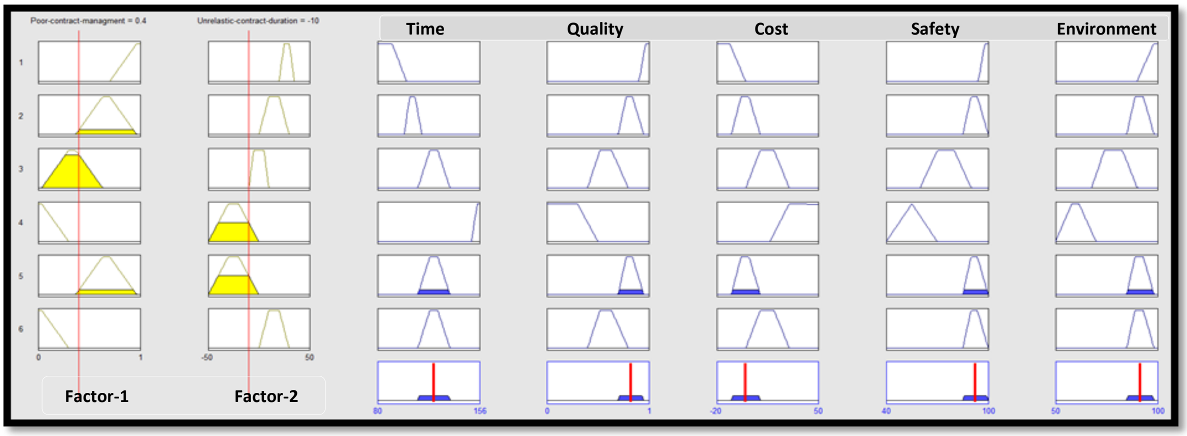


Figure 5.47: Red Chain-7 Fuzzy Logic Viewer 2

Iutput-2:

1- Poor contract management: 40%
2- Unrealistic contract time duration: -10%

Output-2:

1- Time: 22% delayed from the agreed schedule
2- Quality: 82.3% adherence
3- Cost: -0.03% as planned.
4- Safety: 92.5% adherence
5- Environment: 91.5% adherence

VI. Rules viewer-3

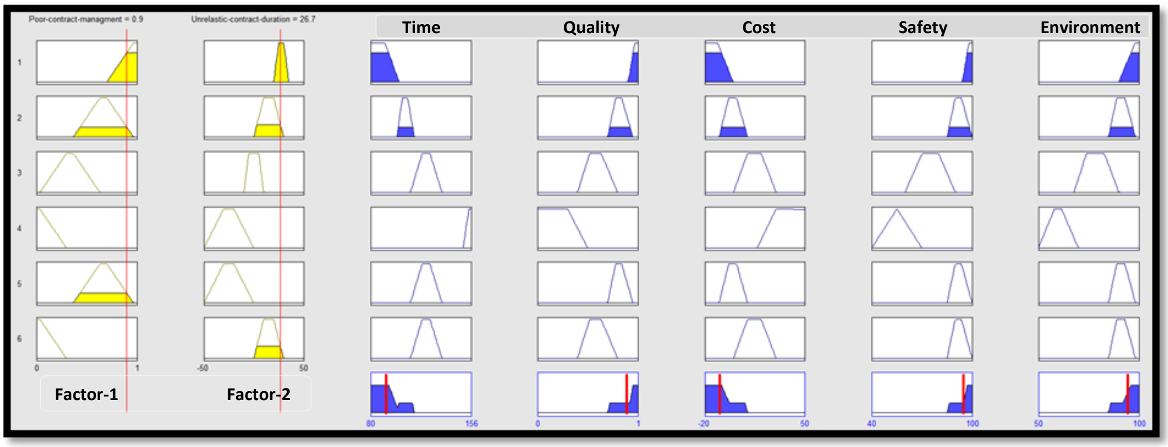


Figure 5.48: Red Chain-7 Fuzzy Logic Viewer 3

Iutput-3:

1- Poor contract management: 90%
2- Unrealistic contract time duration: 26.7%

Output-3:

1- Time: - 8.1% earlier to the agreed schedule
2- Quality: 89.3% adherence
3- Cost: -9.27%. Thrift.
4- Safety: 94.9% adherence
5- Environment: 94.7% adherence

TABLE 5.20 RED CHAIN-7 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1- Poor contract management: 90% 2- Unrealistic contract time duration: 26.7%	(-0.81%) delay from schedule	89.3% Adherence	(-9.27%) Overrun	94.9% Adherence	94.7% Adherence	97.80%	Scenario-6	74%
Scenario-2 (Moderate Condition)	1- Poor contract management: 80% 2- Unrealistic contract time duration: 10%	6% delay from schedule	82% Adherence	(-1.61%) Overrun	97.3% Adherence	91.4% Adherence	93.26%		
Scenario-3 (Extreme Condition)	1- Poor contract management: 40% 2- Unrealistic contract time duration: -10%	22% delay from schedule	82.3% Adherence	(-0.03%) Overrun	92.5% Adherence	91.5% Adherence	88.86%		

Verification of Scenario-6:

Table 5.20 shows a positive result. The performance measures responded proportionally with inputs. The overall rating matched the conditions of delay factors.

- **Scenario-7: Blue chain-1: Four factors and eight rules**

I. Critical delay factors:

1- Shortage of technical staff
2- Loose safety rules & regulations
3- Improper technical study by the contractor
4- Slow preparation of changed order by the contractor

II. Rule building- Blue chain-1

TABLE 5.21: SCENARIO-7 BJUE CHAIN-1 OF 4 FACTORS AND 8 RULES

		Chain-1	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
1	Factors	Short. Of tech Prof.	No shortage	Low shortage	Med shortsge	High shortsge	Low shortage	Med shortsge	High shortsge	No shortage
2		Loose safety rules & reg	Fully adheared	Average	Poor	Not Adheared	Average	Poor	Average	Poor
3		Improper tech study cont	Super-Detailed	Standard	Weak	Cursory	Weak	Standard	Weak	Standard
4		slow prep changed order	Proactive	Responsive	late	languid	late	Responsive	Responsive	languid
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Delayed	Delayed	Delayed	Delayed
2		Quality	Perfect	Meets scope	Corrective	Bad	Meets scope	Corrective	Bad	Meets scope
3		Cost	Thrift	As planned	Over-run	Crises	Over-run	Over-run	Over-run	As planned
4		Safety	Secured	Adheared	Concerned	Risky	Adheared	Adheared	Concerned	Concerned
5		Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared	Concerned	Concerned

III. Fuzzy sets modeling:

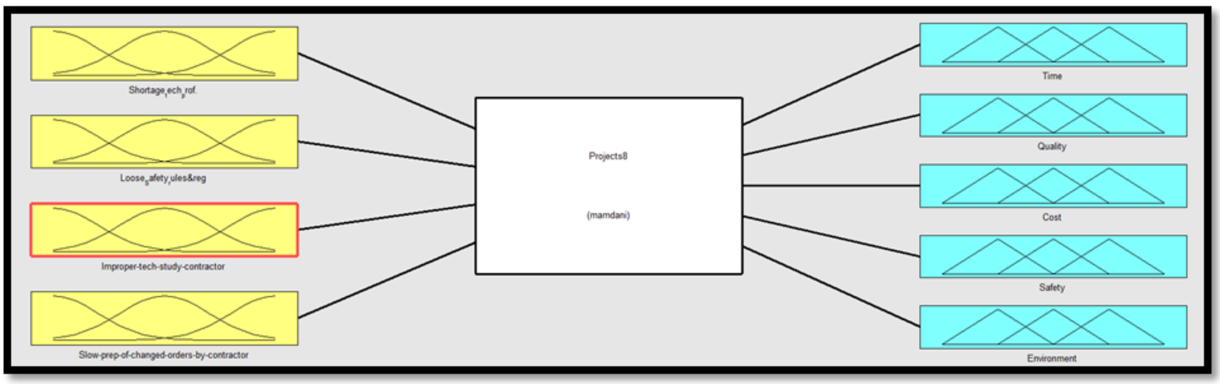


Figure 5.49: Blue Chain-1

VII. Rules viewer-1:

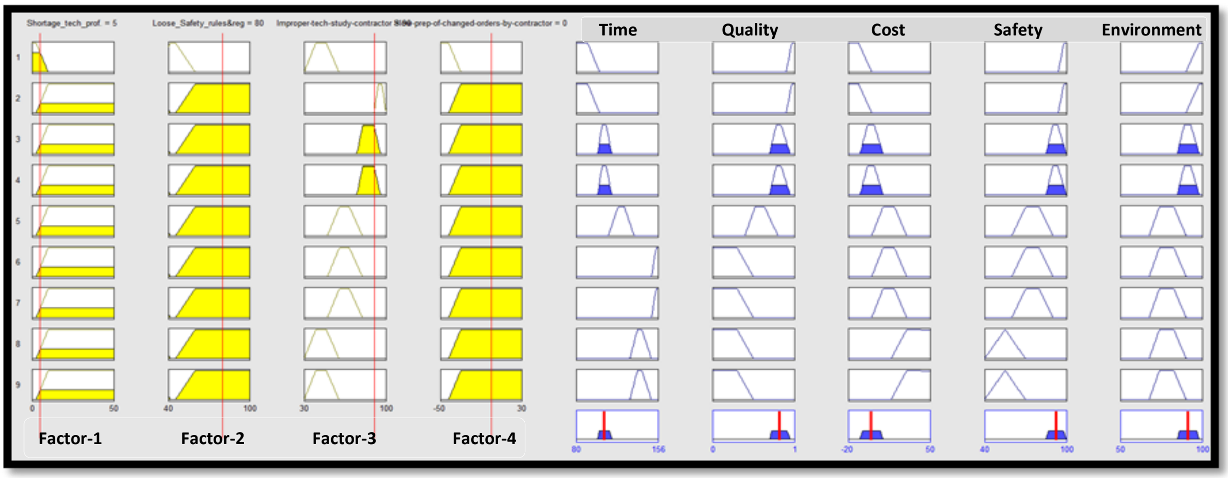


Figure 5.50: Blue Chain-1 Fuzzy Logic Viewer 1

Iutput-1:

1- Shortage of technical staff: 5%
2- Loose safety rules & regulations: 80%
3- Improper technical study by the contractor: 80%
4- Slow preparation of changed order by the contractor: 0% on time

Output-1:

1- Time: 6% on the agreed schedule
2- Quality: 82.22% adherence
3- Cost: - 0.8 %, as planned.
4- Safety: 92.4%, adherence
5- Environment: 91.5%, adherence

VIII. Rules viewer-2:

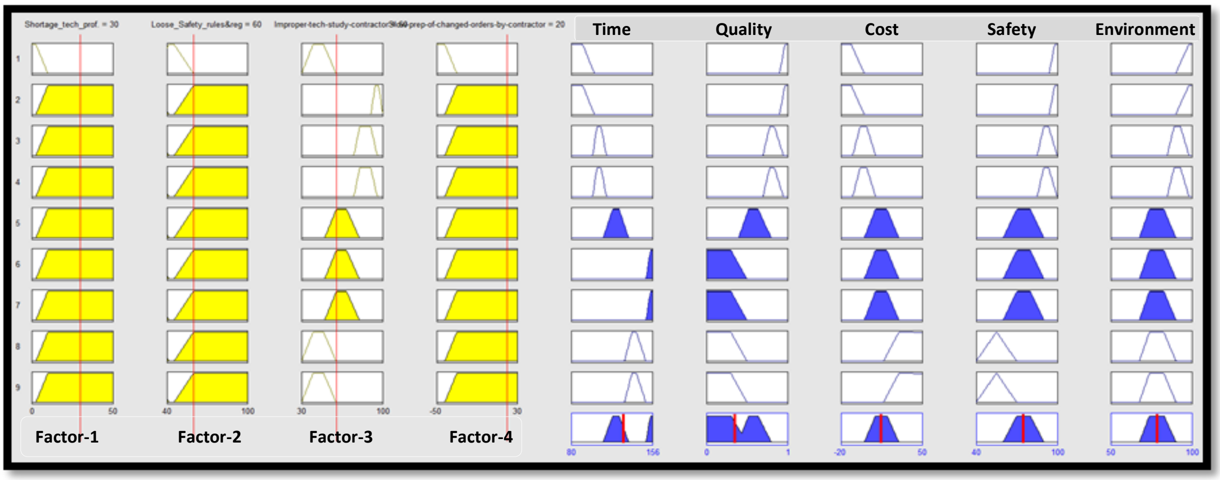


Figure 5.51: Blue Chain-1 Fuzzy Logic Viewer 2

Iutput-2:

1- Shortage of technical staff: 30%
2- Loose safety rules & regulations: 60%
3- Improper technical study by the contractor: 60%
4- Slow preparation of changed order by the contractor: 20%

Output-2:

1- Time: 29 % late from the agreed schedule
2- Quality: 35.2% adherence
3- Cost: 14.9%, overrun.
4- Safety: 75%, adherence
5- Environment: 87.7%, adherence

IX. Rules viewer-3:

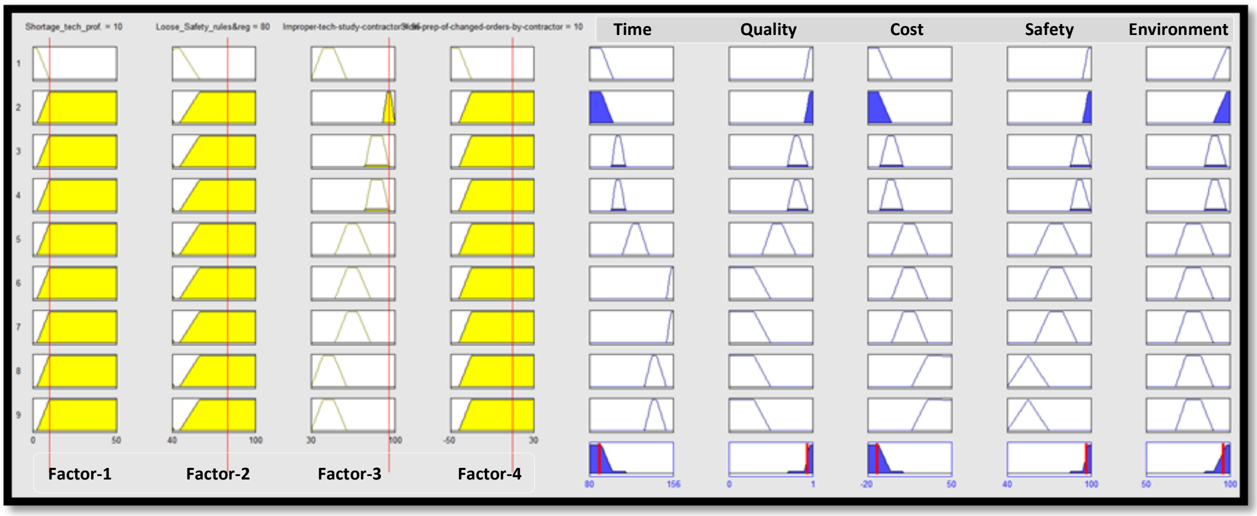


Figure 5.52: Blue Chain-1 Fuzzy Logic Viewer 3

Iutput-3:

1- Shortage of technical staff: 10%
2- Loose safety rules & regulations: 80%
3- Improper technical study by the contractor: 95%
4- Slow preparation of changed order by contractor: 10%

Output-3:

1- Time: -10.8%% earlier to the agreed schedule
2- Quality: 93.9% adherence
3- Cost: -11.8%, thrift.
4- Safety: 96.9%, adherence
5- Environment: 96.2%, adherence

TABLE 5.22 BLUE CHAIN-1 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1- Shortage of technical staff: 10% 2- Loose safety rules & regulations: 80% 3- Improper technical study by the contractor: 95% 4- Slow preparation of changed order by the contractor: 10% on time	(-10.8%) delay from schedule	93.9% Adherence	(-11%) Overrun	96.9% Adherence	96.2% Adherence	97.40%	Scenario-7	71.50%
Scenario-2 (Moderate Condition)	1- Shortage of technical staff: 5% 2- Loose safety rules & regulations: 80% 3- Improper technical study by the contractor: 80% 4- Slow preparation of changed order by the contractor: 0% on time	6% delay from schedule	82.2% Adherence	(-0.8 %) Overrun	92.4% Adherence	91.5% Adherence	92.22%		
Scenario-3 (Extreme Condition)	1- Shortage of technical staff: 30% 2- Loose safety rules & regulations: 60% 3- Improper technical study by the contractor: 60% 4- Slow preparation of changed order by the contractor: 20% on time	29% delay from schedule	35.2% Adherence	14.9% Overrun	75% Adherence	87.7% Adherence	70.78%		

Verification of Scenario-7:

Table 5.22 shows a positive result. The performance measures responded proportionally with inputs. The overall rating matched the conditions of delay factors.

- **Scenario-8: Blue chain-9: Three factors and eight rules**

I. Critical delay factors:

1- Selecting the lowest bidding contractor

2- Cash flow problem by the contractor

3- Unrealistic contract time duration

II. Rule building- Blue Chain-9:

TABLE 5.23: SCENARIO-8 BLUE CHAIN-9 OF 3 FACTORS AND 8 RULES

		Chain-9	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
1	Factors	gov. tendering sys.	Selective	Fair	considerable	cheaply	Fair	cheaply	Fair	cheaply
2		cash flow problem	Secured	Funded	insuffecint	Overdraft	insuffecint	Funded	insuffecint	Secured
3		unrealstic cont duration	Conservative	Realistic	Resanable	Risky	Resanable	Realistic	Realistic	Conservative
			⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Faliure	Ontime	Delayed	Ontime
2		Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Corrective	Meets scope	Bad
3		Cost	Thrift	As planned	Over-run	Crises	Over-run	As planned	As planned	Thrift
4		Safety	Secured	Adheared	Concerned	Risky	Concerned	Adheared	Adheared	Adheared
5		Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Adheared	Adheared	Adheared

III. Fuzzy sets modeling:

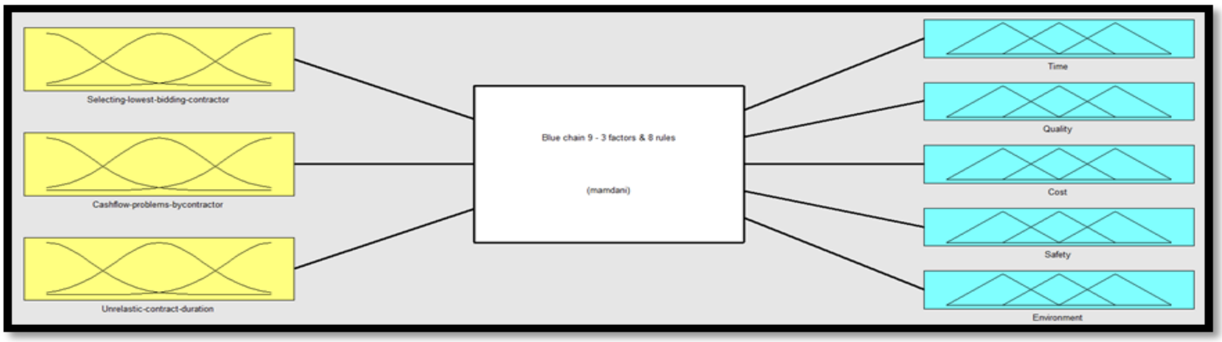


Figure 5.53: Blue Chain-9

IV. Rules viewer-1:

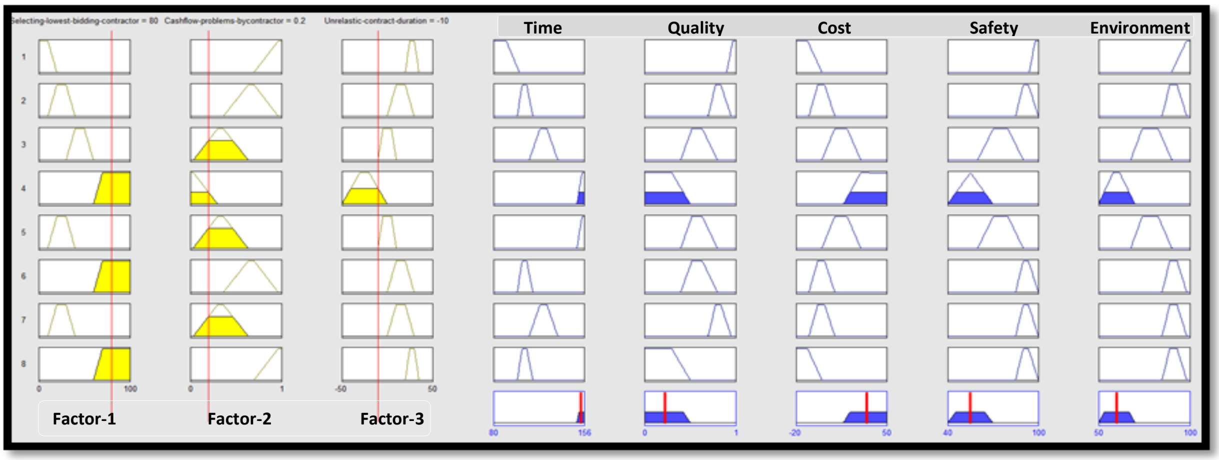


Figure 5.54: Blue Chain-9 Fuzzy Logic Viewer 1

Iutput-1:

1- Selecting the lowest bidding contractor: 80%
2- Cash flow problem by the contractor: 20%
3- Unrealistic contract time duration: -10%

Output-1:

1- Time: 54% “failure” for the agreed schedule
2- Quality: 22.9 % Risky
3- Cost: 34.7% overrun.
4- Safety: 55%, adherence
5- Environment: 59.9 %, adherence

V. Rules viewer-2:

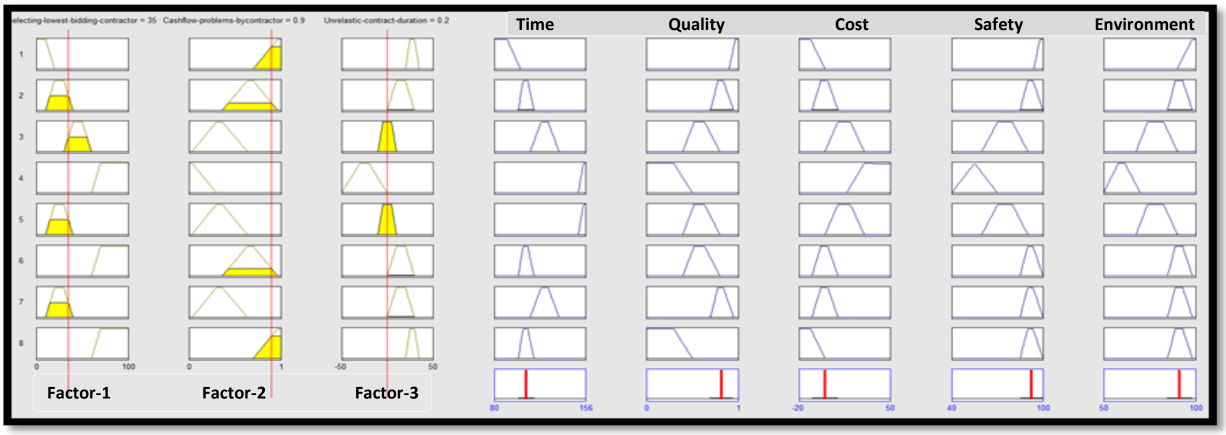


Figure 5.55: Blue Chain-9 Fuzzy Logic Viewer 2

Iutput-2:

1- Selecting the lowest bidding contractor: 35%
2- Cash flow problem by the contractor: 90%%
3- Unrealistic contract time duration: 20%

Output-2:

1- Time: 7% “on time” to the agreed schedule
2- Quality: 82.2 % adherence
3- Cost: -0.5 %, as planned.
4- Safety: 92.5%, adherence
5- Environment: 91.5 %, adherence

VI. Rules viewer-3:

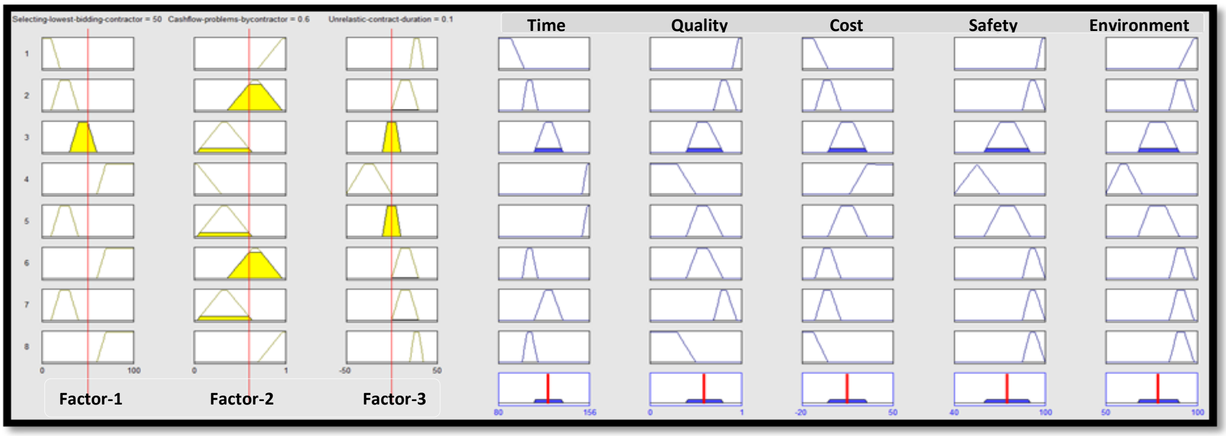


Figure 5.56: Blue Chain-9 Fuzzy Logic Viewer 3

Iutput-3:

1- Selecting the lowest bidding contractor: 50%
2- Cash flow problem by the contractor: 60%
3- Unrealistic contract time duration: 10%

Output-3:

1- Time: 22% “Delayed” from the agreed schedule
2- Quality: 59.8 % adherence
3- Cost: 15 %, overrun.
4- Safety: 75%, adherence
5- Environment: 78.8 %, adherence

TABLE 5.24 RED CHAIN-9 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1- Selecting the lowest bidding contractor: 35% 2- Cash flow problem by the contractor: 90%% 3- Unrealistic contract time duration: 20%	7% delay from schedule	82.2% Adherence	(-0.5)% Overrun	92.5% Adherence	91.5% Adherence	91.94%	Scenario-8	70.10%
Scenario-2 (Moderate Condition)	1- Selecting the lowest bidding contractor: 50% 2- Cash flow problem by the contractor: 60% 3- Unrealistic contract time duration: 10%	22% delay from schedule	59.8% Adherence	15 % Overrun	75% Adherence	78.8% Adherence	75.36%		
Scenario-3 (Extreme Condition)	1- Selecting the lowest bidding contractor: 80% 2- Cash flow problem by the contractor: 20% 3- Unrealistic contract time duration: -10%	54% delay from schedule	22.9% Adherence	34.7% Overrun	55% Adherence	59.9% Adherence	60.26%		

Verification of Scenario-8:

Table 5.24 shows a positive result. The performance measures responded proportionally with inputs. The overall rating matched the conditions of delay factors.

- **Scenario-9: Blue chain-4: Four factors and eight rules**

I. Critical delay factors:

1- Poor communication with all parties by the contractor
2- Slow perpetration of changed orders by the contractor
3- Ineffective control of the project by the contractor
4- Poor contract management.

II. Rule building- Blue chain-1

TABLE 5.25: SCENARIO-9 BLUE CHAIN-4 OF 4 FACTORS AND 8 RULES

		Chain-4	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8
1	Factors	Cont poor coordination	Progrissive	Communicative	Weak	Disconnected	Communicative	Weak	Weak	Communicative
2		slow prep changed order	Proactive	Responsive	late	languid	Responsive	late	Responsive	late
3		ineff. Control of project	Advanced	effective	inactive	Messy	inactive	effective	inactive	effective
4		poor contract management	Professinal	controler	weak	ignorant	weak	controler	controler	weak
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Failure	Delayed	Delayed	Delayed	Delayed
2		Quality	Perfect	Meets scope	Corrective	Bad	Corrective	Corrective	Corrective	Meets Scope
3		Cost	Thrift	As planned	Over-run	Crises	Overrun	As planned	As planned	As planned
4		Safety	Secured	Adheared	Concerned	Risky	Adheared	Adheared	Adheared	Adheared
5		Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Adheared	Adheared	Adheared

III. Fuzzy sets modeling:

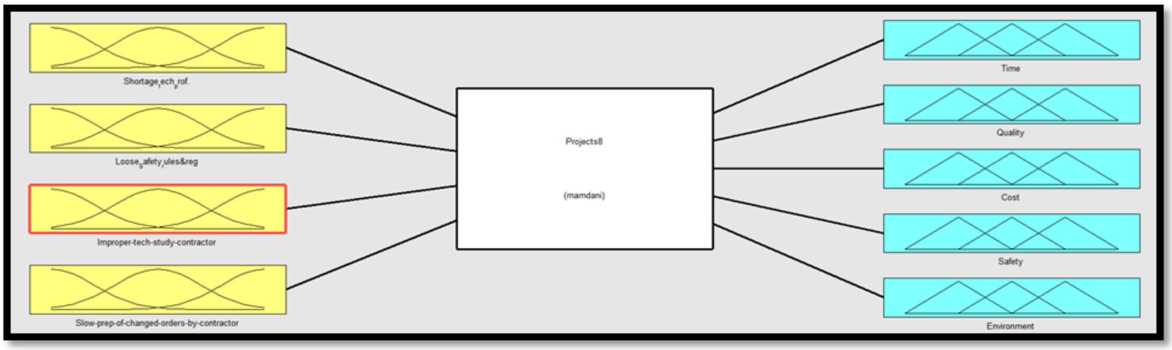


Figure 5.57: Blue Chain-4

IV. Rules viewer-1:

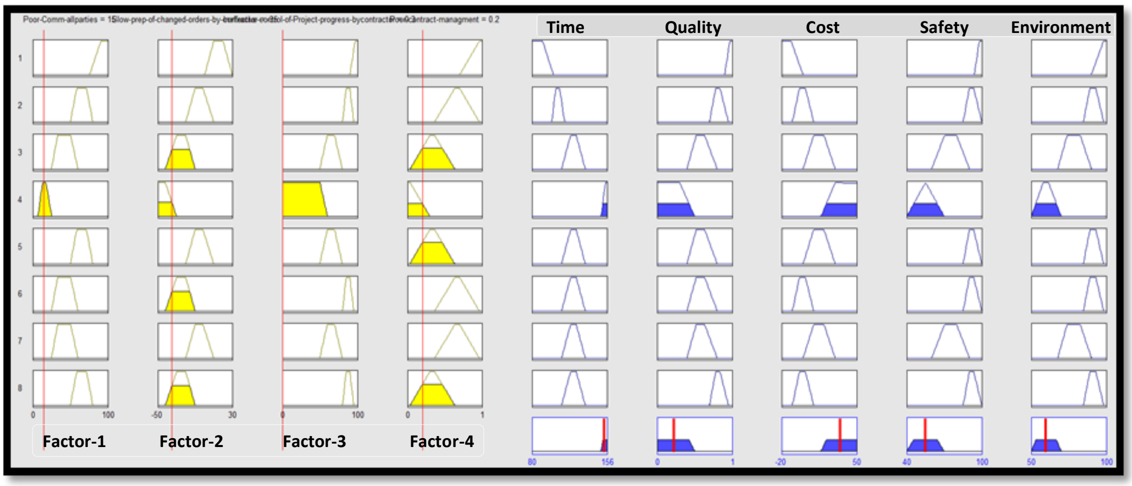


Figure 5.58: Blue Chain-4 Fuzzy Logic Viewer 1

Iutput-1:

1- Poor communication with all parties by the contractor: 15%
2- Slow perpetration of changed orders by the contractor: -25%
3- Ineffective control of the project by the contractor: 0%
4- Poor contract management: 20%

Output-1:

1- Time: 54% “Failure” for the agreed schedule
2- Quality: 22.9 %, “Bad” adherence
3- Cost: 34.7%, overrun.
4- Safety: 55%, adherence
5- Environment: 59.9 %, adherence

V. Rules viewer-2:

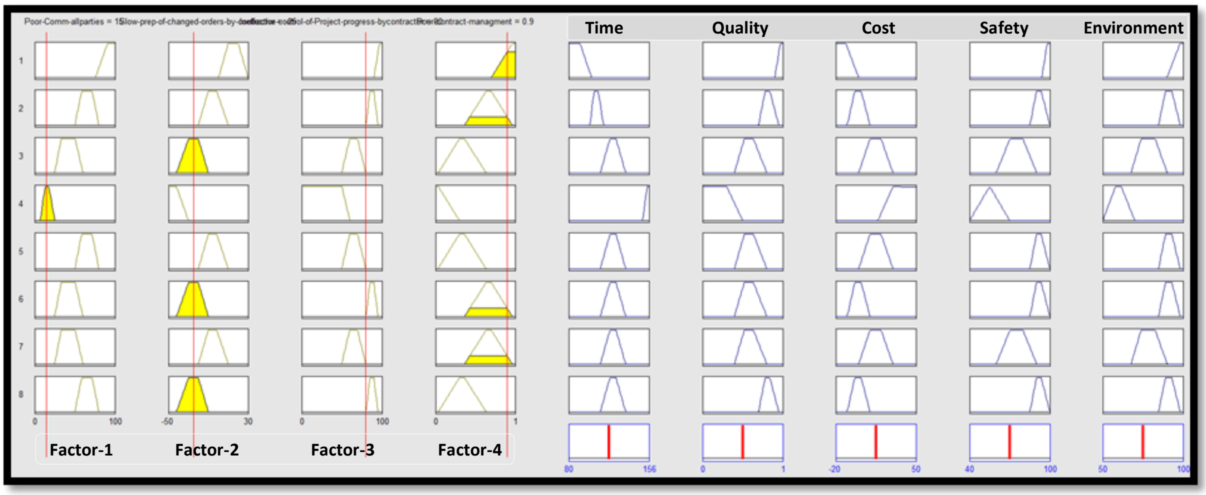


Figure 5.59: Blue Chain-4 Fuzzy Logic Viewer 2

Iutput-2:

1- Poor communication with all parties by the contractor: 15%
2- Slow perpetration of changed orders by the contractor: -25%
3- Ineffective control of the project by the contractor: 80%
4- Poor contract management: 90%

Output-2:

1- Time: 18% “Delayed” from the agreed schedule
2- Quality: 50%, “Bad” adherence
3- Cost: 15%, overrun.
4- Safety: 70%, adherence
5- Environment: 75 %, adherence

TABLE 5.26 BLUE CHAIN-4 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1- Poor communication with all parties by contractor: 15%	18% delay from schedule	50% Adherence	15% Overrun	70% Adherence	75% Adherence	72.40%	Scenario-9	69.60%
	2- Slow perpetration of changed orders by contractor: -25%								
	3- Ineffective control of the project by the contractor: 80%								
	4- Poor contract management: 90%								
Scenario-2 (Extreme Condition)	1- Poor communication with all parties by contractor: 15%	54% delay from schedule	22.9% Adherence	34.7% Overrun	55% Adherence	59.9% Adherence	49.76%		
	2- Slow perpetration of changed orders by contractor-25%								
	3- Ineffective control of the project by contractor: 0%								
	4- Poor contract management: 20%								

Verification of Scenario-9:

Table 5.26 shows a positive result. The performance measures responded proportionally with inputs. The overall rating matched the conditions of delay factors.

- **Scenario-10**: **Blue chain-7: Two factors and six rules**

I. Critical delay factors:

1- Low skills of manpower

2- Unrealistic time duration

II. Rule building- Blue chain-7:

TABLE 5.27: SCENARIO-10 BLUE CHAIN-7 OF 2 FACTORS AND 6 RULES

		Chain-7	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6
1	Factors	Low skills of manpower	No shortage	Low shortage	Med shortsge	High shortsge	Low shortage	High shortage
2		unrealistic cont duration	Conservative	Realistic	Resanable	Risky	Risky	Realistic
1	Customer Attributes	Time	Earlier	Ontime	Delayed	Faliure	Faliure	Delayed
2		Quality	Perfect	Meets scope	Corrective	Bad	Meets scope	Corrective
3		Cost	Thrift	As planned	Over-run	Crises	Over-run	As planned
4		Safety	Secured	Adheared	Concerned	Risky	Concerned	Concerned
5		Environment	Circumspect	Adheared	Concerned	incurious	Concerned	Concerned

III. Fuzzy sets modeling:

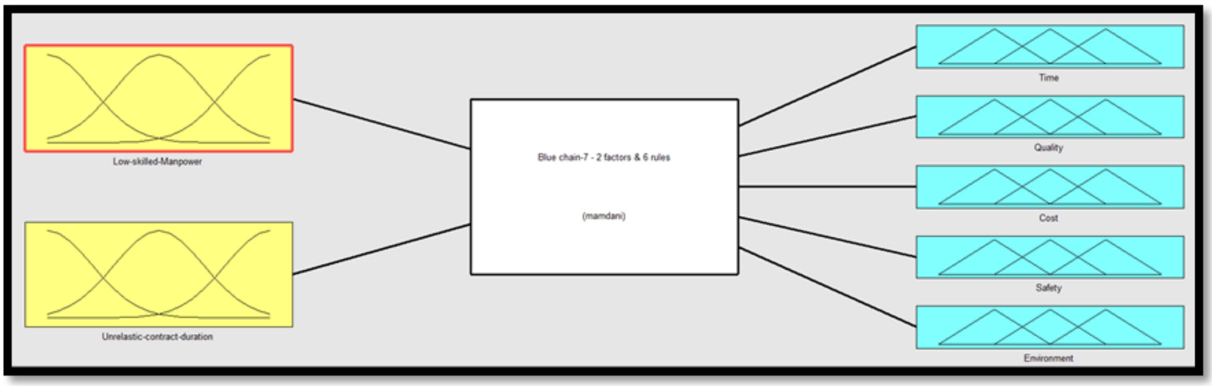


Figure 5.60: Blue Chain-7

IV. Rules viewer-1:

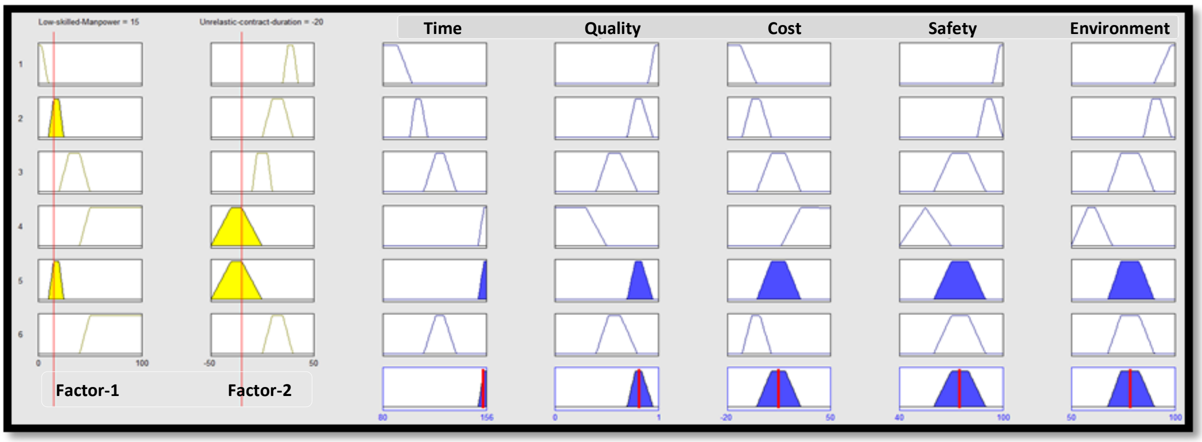


Figure 5.61: Blue Chain-7 Fuzzy Logic Viewer 1

Iutput-1:

1- Low skills of manpower: 15%
2- Unrealistic time duration: -20%

Output-1:

1- Time: 24%, delayed from the agreed schedule
2- Quality: 81.8% adherence
3- Cost: 14.9%, overrun.
4- Safety: 75%, concerned
5- Environment: 78.7%, concerned

V. Rules viewer-2:

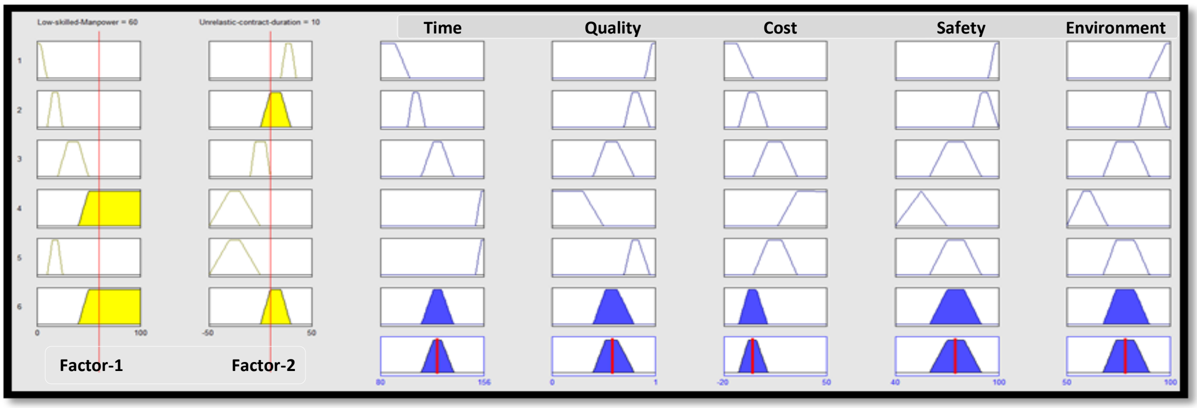


Figure 5.62: Blue Chain-7 Fuzzy Logic Viewer 2

Iutput-2:

1- Low skills of manpower: 60%
2- Unrealistic time duration: 10%

Output-2:

1- Time: 22% Delayed from the agreed schedule
2- Quality: 59% adherence
3- Cost: 2.34%, as planned.
4- Safety: 75 %, adherence
5- Environment: 78.7%, adherence

VI. Rules viewer-3:

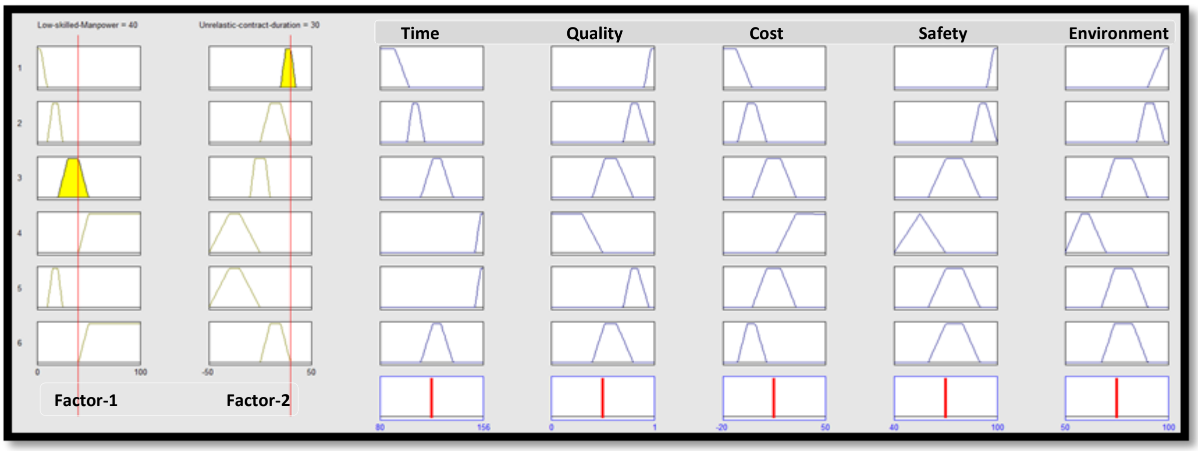


Figure 5.63: Blue Chain-7 Fuzzy Logic Viewer 3

Iutput-3:

1- Low skills of manpower: 40%
2- Unrealistic time duration: 30%

Output-3:

1- Time: 18% Late from the agreed schedule
2- Quality: 50% adherence
3- Cost: 15%, Overrun
4- Safety: 70%, adherence
5- Environment: 75%, adherence

TABLE 5.28 BLUE CHAIN-7 SCENARIOS & RESULTS COMPARISONS

	Group of Factors Scenarios	Time	Quality	Cost	Safety	Envirnt	Overall		Collective Risk %
Scenario-1 (Perfect Condition)	1- Poor skills of manpower: 15% 2- Unrealistic time duration: -20%	24% delay from schedule	81.8% Adherence	14.9% Overrun	75% Adherence	78.7% Adherence	79.32%	Scenario-10	66.30%
Scenario-2 (Moderate Condition)	1- Poor skills of manpower: 60% 2- Unrealistic time duration: 10%	22% delay from schedule	59% Adherence	2.4 % Overrun	75% Adherence	78.7% Adherence	77.66%		
Scenario-3 (Extreme Condition)	1- Poor skills of manpower: 40% 2- Unrealistic time duration: 30%	18% delay from schedule	50% Adherence	15% Overrun	70% Adherence	75% Adherence	72.40%		

Verification of Scenario-10:

Table 5.28 shows a positive result. The performance measures responded proportionally with inputs. The overall rating matched the conditions of delay factors.

In conclusion, using fuzzy logic for verifying the collective impacts of delay factors was a good idea and was effective for dealing with nonlinear relationships. This is also could be very helpful if a project manager would like to anticipate the expected impacts of any projects based on input assumptions. These assumptions may vary from one project to another, but it would help tremendously in the initial stage of a project by indicating how risky it is going to be based on those assumptions.

Applying fuzzy logic to the ten different scenarios resulted in positive impacts on the PPMs except for scenario seven, which got a negative response. Few scenarios produced lower impacts than expected; however, this could be due to the human evaluation of the rules in the fuzzification process. These rules could be subjected to a further review and assessment for future studies.

5.13 Summary

This chapter provided a full analysis of the results obtained from the administrated survey. The analysis included the respondents' experience, types of contracts commonly used, tenders affecting the time overruns and analysis referred to the party most responsible for delays. The chapter provided a clear analysis that identified the party with a decisive answer justified by extended analysis.

Part two of this chapter concerned ranking the delay factors by applying the RII, which was based on the factors' severity and frequency as reported by respondents to the survey. The top 20 factors of delay were further analyzed by applying the DR-HOQ to improve the quality of the ranking process. Additional indices were created to interpret the non-linear relationships between the factors of delays and the performance measures which was introduced by the CA index. Moreover, embedded relationships between factors of delay have been identified that corresponded to the EC index.

This novel concept of ranking the singular factors was validated by administrating an extended survey using a real project undertaken in Saudi Arabia. This chapter also introduced FL using MATLAB to verify the collective impacts of the top ten risky chains (group of factors) in construction projects with reference to the PPMs (time, cost, quality, safety and environment). The verification process included ten scenarios in respect to three possible conditions (Perfect, Normal, and Poor) for each group of factors. Process verification and result validation were extensively explained with the inclusion of the final findings. Based on the research analysis in Chapter Four and the findings presented in Chapter Five, research Goals 3, 4, 5, 6 and 7 have been addressed and achieved.

Chapter Six presents further interpretation and discussion mainly in two sections. The first section discusses the singular and collective impact of the delay factors contributing to the project delay, while the second section discusses the project party most responsible for delay.

CHAPTER 6: RESEARCH DISCUSSION

6.1 Chapter 6 (Research Discussion) layout.

Figure 6.1 outlines the structure of Research Discussion.

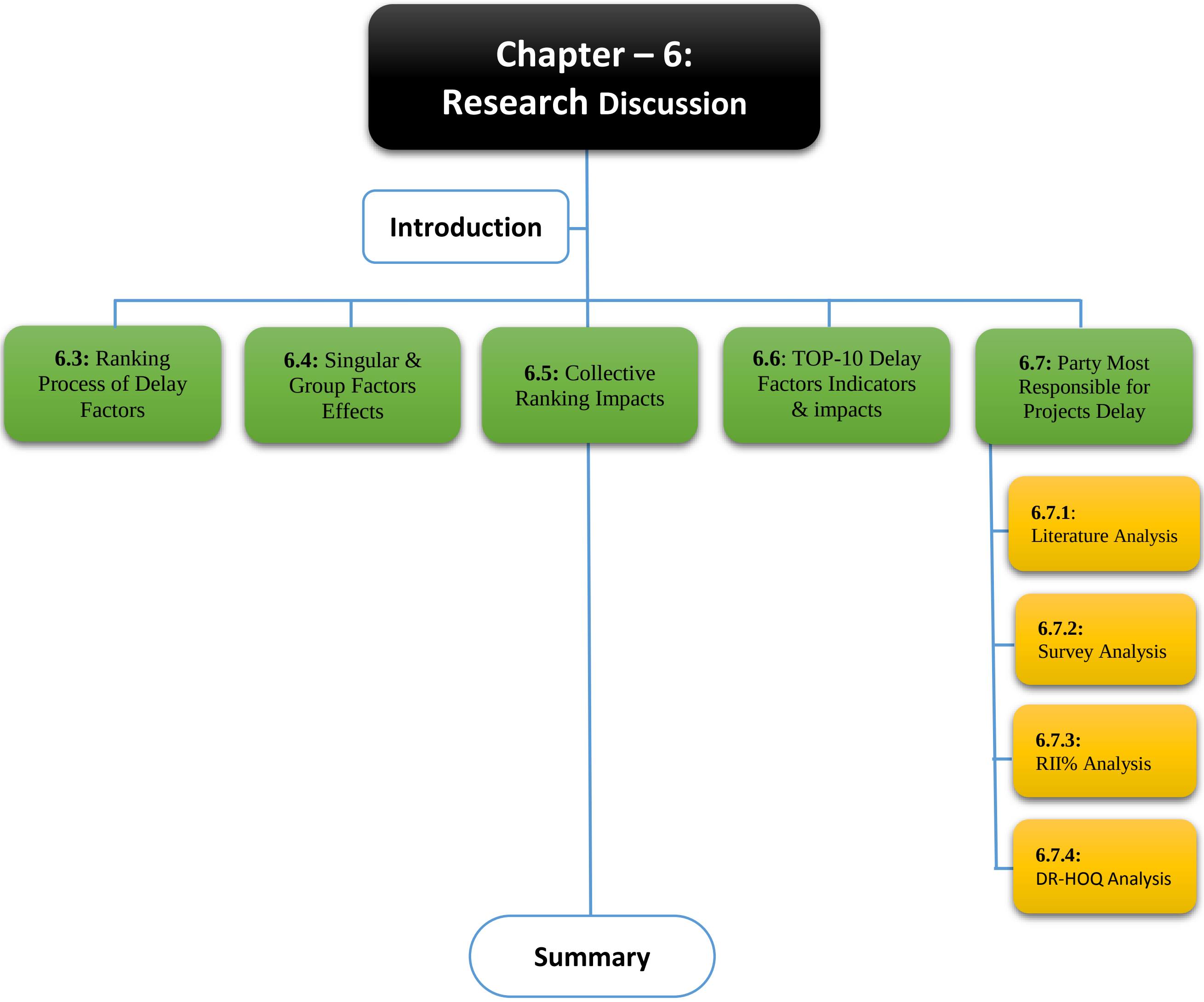


Figure 6.1: Chapter-6 General Layout

6.2 Introduction

This chapter interprets and discusses the findings presented in the previous chapters. The links between the chapters of the thesis are identified before drawing conclusions and reflecting on the implications of the research findings. The present study was designed to evaluate and then rank the delay factors in construction projects in Saudi Arabia. It was also designed to reveal the singular and collective impacts of delay factors to the construction project delivery outcomes.

It was essential to fulfill the above research objectives to propose and develop a model (protocol) to enhance the projects management performance in Saudi Arabia, as clearly defined in Chapter 1. To achieve this aim, the research goals were carefully developed: Goal 3 To identify the extent to which the contractor, consultant, and owner agree on the ranking of the importance of delay factors; Goal 4 To measure the frequency of occurrence, the severity of impact and importance of construction delay factors in KSA; Goal 5 To evaluate and build membership functions between the most critical delay factors and PPMs; Goal 6 To identify the relationships between the most critical factors of delay and PPMs to achieve more rational ranking of these factors and Goal 7 To evaluate the collective impacts for the grouped of delay factors (chains) to the PPMs.

The literature review in Chapter 2 and 3 provided an overview of the topic and addressed research Goal 1 and Goal 2. It also helped to integrate the findings with the existing body of knowledge to examine research hypothesis one: the contractor is the party most responsible for delays. Chapter 3, sections 3.5 and 3.6 provided a background on the construction types and factors of delay classifications from the prospective of project management. In Chapter 4, the research methodology outlined the steps taken to investigate the research problem. A research design process was developed to frame the five main steps and related activities in the present study, as presented in Chapter 4, Figure 4.2. Chapter 5 presented the findings of the statistical analysis of the data collected from the survey. Descriptive statistical analyses of the relevant individuals and organisational surveying were provided for evaluating the severity and frequency of the 66-factors of delay. This part of the analysis was focused on the research Goal 4. It also investigated to what extent the contractor, consultant, and owner agree on the ranking of the delay factors, covering Goal 3.

The ranking of the singular factors of delay was further analyzed by applying DR-HOQ, which involved the development of three indices. The final ranking was validated by administrating an extended survey to a real ongoing project in Saudi Arabia. This sensitivity analysis of ranking process addressed Goals 5 and 6. The analysis was also extended to verify the collective impacts of the project delay factors using FL, which was implemented in the MATLAB application and addressed Goal 7.

6.3 Ranking Process of Delay Factors

One of the main research goals was to rank the factors of delay in the fields of construction and industrial projects. The quality of ranking the factors of delay is a key successful point for the second goal of the research to be able to improve and control the five PPMs of the stumbled projects in general, specifically the project delay (overrun). Previous studies have shed light on ranking the factors according to one PPM (time), ignoring the other measures at the time of their analyses. Bennet and Grice (1990) indicated time is often seen as the main indicator of project success. This could be due to a belief that time is the main contributing measure influencing project delay or to the complications of ranking the factors with respect to more than one measure at a time. Indeed, both of these reasons are true, which the pre-evaluation process confirmed in Chapter 4 (Figure 4.11), with time as the most critical measure, followed by cost. The customer importance degree resulting from the DR-HOQ demonstrated time and cost measures were the highest compared to other measures at 78.3% and 67.7%, respectively. Safety was third at 64.4%, while quality and environment were the least important measures at 59% and 42.2%, respectively. By addressing Goals 5, 6, and 7 in Chapter 1, the author demonstrated the relationships between the factors of delay and the project PPMs were genuine and may impacts the ranking process. Moreover, the existence of the embedded relationships between the factors of delay causing higher interference was expected. This early anticipation of the existence of relationships and their effects on the ranking process was due to the author's vast experience in the field. The extended analysis using DR-HOQ confirmed Hypothesis 2: Delay factors have non-linear relations with PPMs and Hypothesis 3: Delay factors have effective inner relations with each other.

The ranking methods of delay factors used in previous studies referred to two principles. Firstly, the literature directly identified delay factors, which were ranked according to the parties involved in projects and their categories. Secondly, advanced ranking of the delay factors was dependent on applying statistical or mathematical methods to the ranking process. These methods were briefly explained in Chapter 2, tables 2.1 and 2.2, such as administrated surveys, importance index, RII and mean scores. The present study adapted a higher level of sensitivity analysis compared to the previous studies through a novel approach using DR-HOQ for effective ranking. Figure 6.2 shows the six ranking indices used in this research. Indices 5, 6, and 7 were developed from the sensitivity analysis using DR-HOQ. The total contribution of these indices is an addition to this research, which eventually represented the critical delay factors effects on the five PPMs and to what extent they are influenced by their inner relationships between each other. All indices were collated and consolidated into one index.

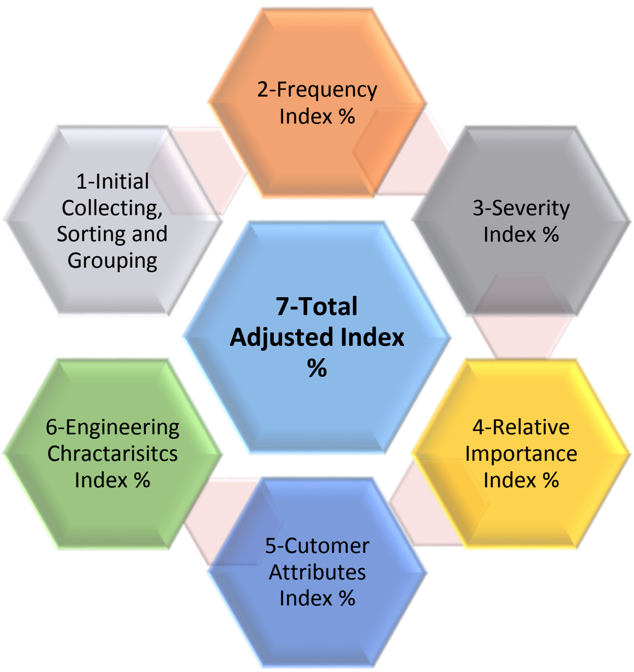


Figure 6.2: Ranking Process Steps

Table 6.1 presents the six indices development stages, advantages and limitations of each stage with respect to their identification approach and involvement with the PPMs.

TABLE 6.1: 6-INDICES IDENTIFICATION, ADVANTAGES AND LIMITATIONS

	Ranking Process	Identification Approach	Test/Validity	Literature	Survey	VoC	EC	Time	Cost	Quality	Safety	Environ	Nobility
1	Collecting, Sorting and Grouping	Literature Review	Focus Group	0									No
2	Frequency Index %	Survey	N/A		0			one measure only					No
3	Severity Index %	Survey	N/A		0			one measure only					No
4	RII %	Mathematical Formula	N/A		0			Combining FI% & SI%					No
5	Customer Attributes Index %	HOQ	Focus Group			0		0	0	0	0	0	Yes
6	Engineering Charact. Index %	DR-HOQ	Focus Group				0	0	0	0	0	0	Yes
7	Total adjusted Index	DR-HOQ	Extend Survey	0	0	0	0	0	0	0	0	0	Yes

The table demonstrates how each step of ranking process was created, identified, validated, and related to each PPM. The first step in ranking was developed from the collecting, sorting and grouping of the delay factors from previous studies. The severity and frequency indices were identified from the administrated survey, and, accordingly, the RII was calculated to represent their combined effects on the time measure. The first roof of the house of quality was used for the creation of the Customer Attributes Index (CA %), which represents the values of the relationships between the factors of delay and PPMs. The second roof was developed to create the Engineering Characteristic Index (EC %), which represents the inner (embedded) relationships between the factors of delay. The Total Adjusted Index (TA %) was developed from the total contribution of these indices and used for the final ranking process.

6.4 Singular and Group Delay Factors Effects

Most of the previous studies were concerned with ranking the delay factors based on their impacts on the project's time schedule. The authors attempted to determine these factors of delay with respect to the cost or time overrun only. Contractors are concerned primarily with quality, time and cost, but most construction projects are procured based on only time and cost (Bennet & Grice, 1990; Al-Sulami et al., 2014). Time is often seen as the main indicator of project success. This approach seems to lack robustness to meet the objective of the present study. Accordingly, the effective ranking of delay factors has encompassed different level of impacts on other PPMs such as quality, safety and environment. Hence, the impacts on PPMs may increase or decrease the importance level (criticality) of these factors with respect to project time overrun. For example, the delay factor “Ambiguities, Mistakes and inconsistencies in Specs Drawings” caused by the client, as shown in Chapter 5, figure 5.18, had a severe impact not only on the time measure, but also extended to other PPMs. As a result, the CA Index, which represented these impacts was significantly high 51%. The greater the impacts on other PPMs, the worse the outcome to the time measure. There were opposite effects on the time measure if the influence of the delay factor to the cost and quality was limited. Similarly, group of factors had a higher impact on the PPMs as compared to one factor only. In reality, evaluating the group (collective) impact of the delay factors looks practical and more applicable in the projects field.

Projects in Saudi Arabia suffer from facing many factors of delay in one project, which calls for special attention. Examples of the problems experienced in construction projects in Saudi Arabia include cost and time overruns, disputes, errors, uncertainties in plans and specifications, and increased maintenance costs. Completing projects on time indicates efficiency, but the construction process is prone to many variables and unpredictable factors from several sources, such as performance of the parties, resource availability, environmental conditions, involvement of other parties and contractual relations. Due to these unknowns, the completion of a project within the specified time is rare (Assaf, 2006).

On balance, the collective risk for group of factors would be more useful for a project manager as compared to the singular effect of the delay factor. The singular effect of the delay factor, however, would help the project manager to mitigate its direct risk in isolation from the other factors. In some cases, giving more attention to one or two factors of delay may produce better results for the project’s performance; however, cost and schedule overruns are caused by a wide range of factors, which need to be addressed and discussed. If project costs or schedules exceed their planned targets due to delay causes deficiencies, client satisfaction would likely decrease. When the funding profile no longer matches the budget requirements, further delays in the schedule are inevitable (Kaliba et al., 2009).

According to the importance of the collective risk, Goal 5 was addressed to identify and evaluate the embedded relationships between critical delay factors (TOP-20 Factors) and their impacts to the PPMs. To fulfill this goal, the author called for invitations, which was planned for five sessions. The aim of these sessions was to identify and sort the relationships, into two stages:

- Stage-1: Relationships between the factors of delay and PPMs to create the CAI %.
- Stage-2: Embedded Relationships between the delay factors to create the ECI %.

Consequently, the values of these relationships were created during the last two sessions of the focus group and then developed by using the DR-HOQ as explained in Chapter 4, section 4.5.4.2. Figure 6.3 shows the basic difference between the collective impact and the singular impact to the PPMs.

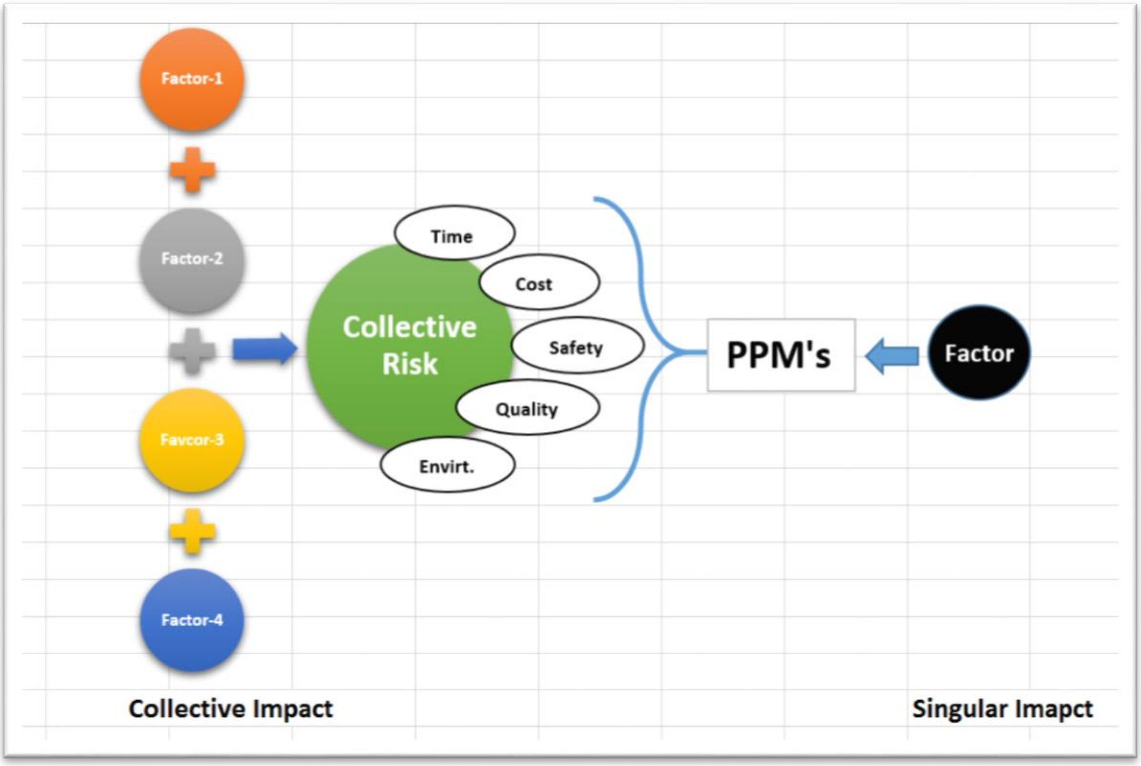


Figure 6.3: Collective vs. Singular Impact to PPMs

6.5 Collective Ranking Impacts:

Goal 7 refers to evaluating the collective impact of the grouped delay factors (chains) with respect to the PPMs. The process of calculating the collective risk was initially based on the empirical formula developed by the author and then was verified by using FL (Chapter 4, section 4.5.4.3-B). The results demonstrated by the verification process was positive, which confirmed the results of the developed formula. The ten demonstrated scenarios concerning the risky chains resulting from the grouping of delay factors successfully represented three proposed conditions (perfect, normal, and bad) for the five PPMs.

Figure 6.4 illustrates the positive proportional responses of each scenario with PPMs. Scenario 6 produced adversely response against the norm of the analysis; this could have resulted from the improper creation of rules for the factors involved in this scenario. The other scenarios showed similar positive responses of varying degrees based on the input values of each scenario. According to the verification results using FL modeling, the escaladed collective impacts of these scenarios are justified and give clear evidence for the potential risk created from these groups of factors (Chains).

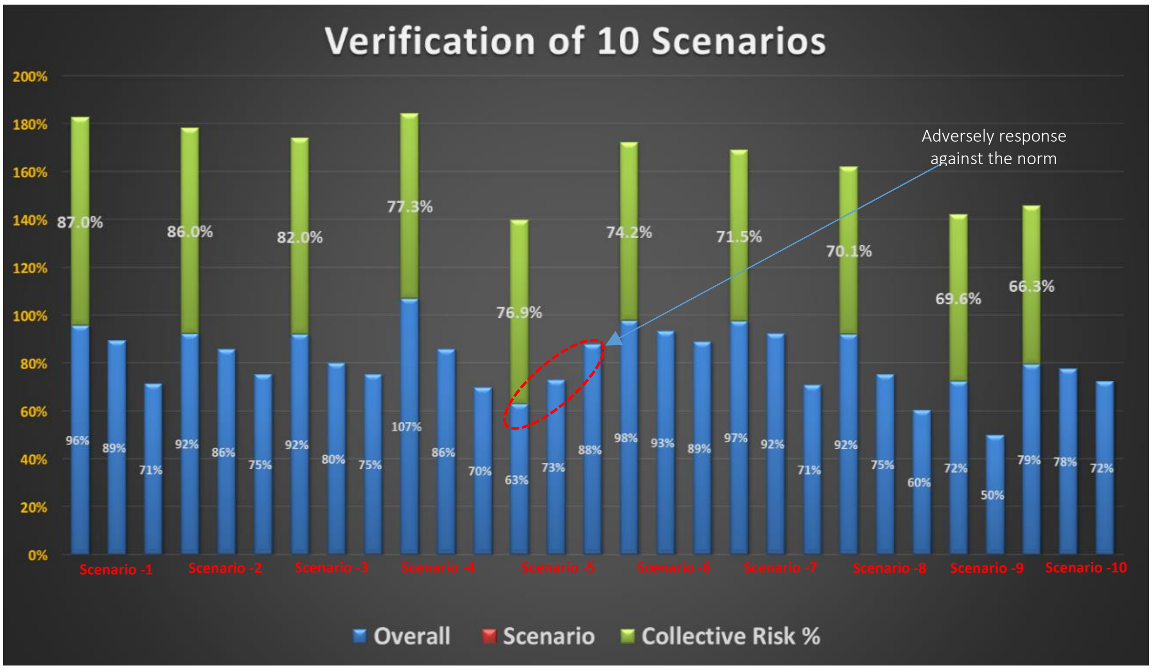


Figure 6.4: Verification Scenarios – Groups of Factors

As explained in Chapter 5, section 5.12, the process of verification using FL modeling can be used as simulation program for any project that has a clear status (inputs) for any factor of delay. The inputs of the selected factors are processed assuming that the remaining delay factors are in the best conditions. The fuzzification process turns the inputs into tangible outputs (PPMs) based on the edited rules. The resulting PPMs are translated into ratios (±100%). This simulation process was done in a student's version of MATLAB, which has a limited capacity of rules creation compared to the full version. Results reading could be further improved by using the full version and may become more sensitive if additional features are applied. For example, commands like "and, or, none, etc." can improve factors of delay conditions while creating the rules and, accordingly, improve the final results.

As indicated on Figure 6.5, eight chains (1, 2, 3, 4, 5, 6, 7, and 10) from the TOP-10 list referred to design related matters, time, contract management, labor skills and availability by all parties. Two chains (8 and 9) were found to be related to project design, control, time, cash flow, contract management and labor skills availability. Consequently, the project design was a key element of success that involved the client, consultant, and the contractor during the five phases of the project cycle. The project activates control, cash flow, labors skills and availability involved the contractor, while the project time and contract management involved the client and consultant.

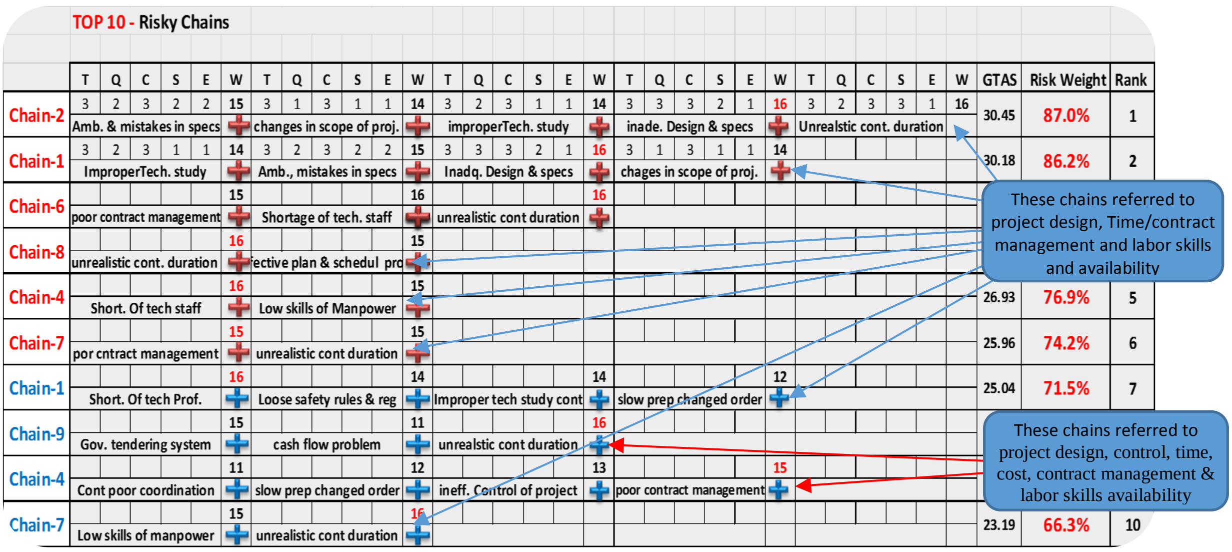


Figure 6.5: TOP-10 Ranking of Risky Chains

6.6 TOP-10 Critical Factors of Delays Indices and Impacts

After ranking the factors of delay according to the five main indices -- frequency index (FI), severity index (SI), relative important index (RII), customer attributes index (CAI) and engineering characteristic index (ECI)-- the total adjusted index (TAI) becomes the six index, which used for the effective ranking of delay factors showing a wider prospective.

This section aimed to present and discuss the six indices' contributions and impacts of each factor in the TOP-10 list with respect to the five PPMs. The indices were presented together in a single graph to clarify the gaps of risk corresponding to each factor of delay in comparison with the 66 factors of delay. The gap of each index was contrasted between the highest and lowest value among the full list of the 66 factors of delay. This contrast presents the risk performance of the critical factors against the frequency, severity, impact to PPMs and the influence to other delay factors. The individual impacts were presented and discussed according to each factor.

Before navigating to the final journey for discussing the ranking results, it is important to discuss the ranking validity of the singular ranking process. Figure 6.6 illustrates the comparison between the final ranking using the DR-HOQ and the ranking resulting from the extended survey. The extended survey measured the real impact of the TOP-20 factors of delay on the PPMs, as explained in Chapter 5, section 5.10.

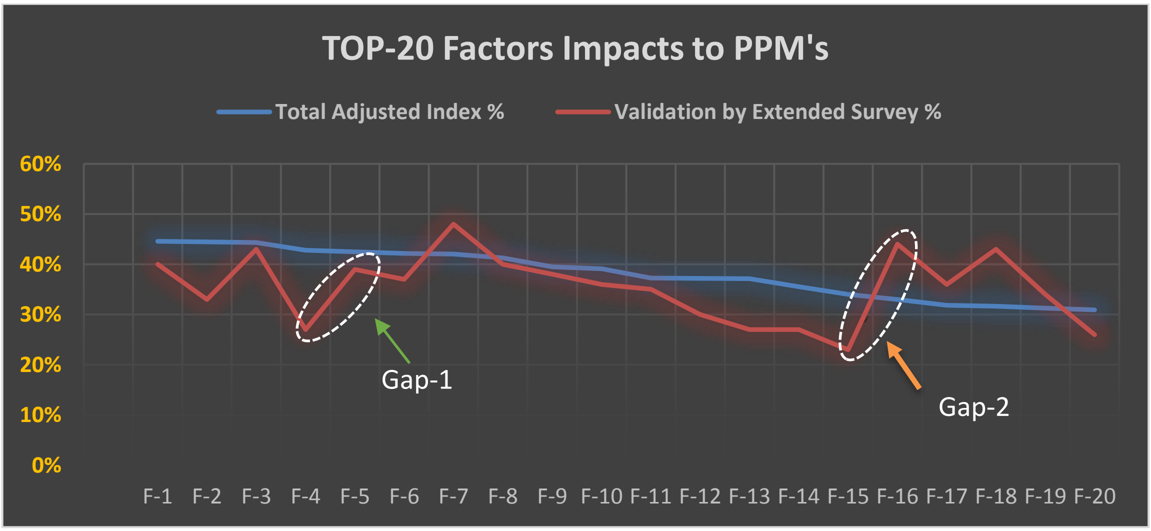


Figure 6.6: TOP-20 Factors of Delay Validation Results

Figure 6.6 shows the BLUE curve, representing the TAI and the RED curve, relating to the validity index resulting from the extended survey. The results of the validation showed similarity among 16 factors of delay, while four factors of delay diverted from the norm. Indeed, the results of the validation may differ from project to anther based on status of the project under investigation, which is likely the main reason for the two gaps found in the results.

The average gap as indicated in Chapter 5, table 5.10 is equal to 9.2% and the highest gap is +23% for the fourth factor (Ambiguities, mistakes and inconsistence in specs/drawings), followed by the second factor (shortage of tech. professional) at +19%. The lowest gap was +1% for both the 7th factor (Selecting lowest bidding contract) and 17th factor (contractor poor coordination between parties), followed by the 19th factor (cash flow problem faced by contractor) at 2%. The final ranking of delay factors indicated by the TAI seemed to be realistic and effective for the field of construction projects in Saudi Arabia. Although the average gap indicated from Chapter 5, table 5.10 was 9.2%, the overall ranking's reliability of 80% was acceptable.

Overall Reliability % $= \frac{(Average\ TAI\%) - (Average\ gap\%)}{(Average\ TAI\%)} \times 100 = \frac{9.15\%}{44.5\%} \times 100 = 0.795$ = **79.5%**

The performance impact of the TOP-10 factors of delay was analyzed and then compared to the highest and lowest scores that were identified for all indices regarding the 66 factors of delay. All indices were presented in a single graph to provide a better understanding of the rankings. This illustrates the real positions of the ranked factors compared to others, with the gaps clearly indicated. Accordingly, the risks involved in general, such as severity, frequency and impacts to all delay factors including the PPMs are presented in figures 6.6 to 6.16.

The list of figures below discusses the top 10 factors of delays highlighting the main factors of delay indices such as Frequency Index, Severity Index, Customer Attributes Index, Engineering Characteristics Index, RII, and the Total Adjusted Index. Moreover, the impact of each factor of delay was discussed based on the interpretation of the indices involved, research literature and the perspective of the author.

1- Unrealistic contract Schedule (Time) duration, Figure 6.7.

- Symbol: URCD-CL
- Type: (Client) responsibility
- Frequency Index: 73.1%
- Severity Index: 71.8%
- RII: 52.5%
- CA Index: 53%
- EC Index: 32.9%
- **Total Adjusted Index: 44.7%**

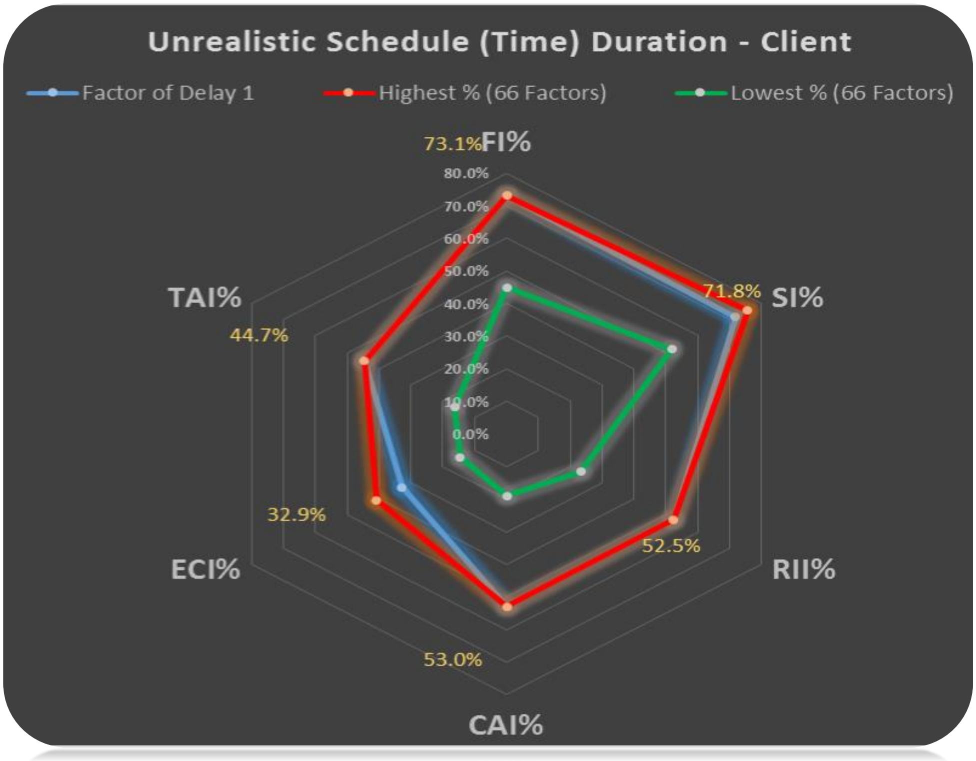


Figure 6.7: Rank-1 Unrealistic Contract Time Duration (Client)

Impacts:

This factor of delay significantly leads to project time overrun. It would increase the possibility of harming the quality of the project as well as the safety of the laborers on site. An unrealistic time duration often puts pressure on the project contractor to rush the work activities on the site. Meeting a tight project schedule is a big risk, or even impossible, which creates ongoing debates between all parties in the project. The client mainly is seen the reason behind this delay factor, triggered by the advantage of reaping the benefits earlier and shortening the payback period of the project. Faridi & El-Sayegh (2007) found significant owner risks, such as unrealistic construction schedules, improper intervention and changes. The completion date is not generally set by the specialist, i.e., the contractor, or based on a reasonable time to complete the scope of works within, but is often, instead, determined by the client based on commercial needs, sometimes without a full appreciation of the time needed (Winch & Kelsey, 2004). The contractor who does not clearly study the full project elements, site limitations, material procurements plan and the overlapping activities in light of the surrounding facts will be a victim of these severe mistakes. Project management best practices advise including 10-15% as a contingency of time from the total project schedule to manage any unexpected issues and site's force majeure. The client could use an incentive rewarding scheme to motivate the contractor to finish earlier than the agreed plan. This factor is seen the most frequent factor of project delay at 73.1% and the most contributing factor to the PPMs at 53%.

2- **Shortage of Technical Professionals in Contractor Org. (contractor), Figure 6.8.**

- Symbol: STP-C
- Type: (Contactor) responsibility
- Frequency Index: 73.2%
- Severity Index: 71.8%
- RII: 52.5%
- CA Index: 46.8%
- EC Index: 32.9%
- **Total Adjusted Index: 44.5%**

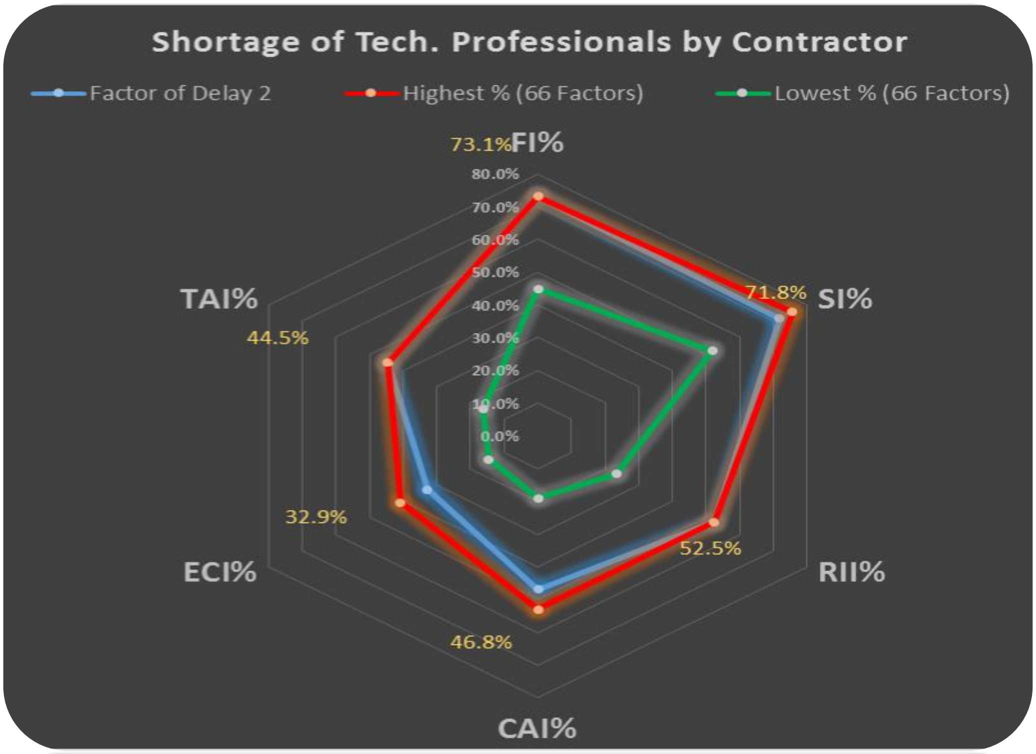


Figure 6.8: Rank-2 Shortage of Tech. Professional (Contractor)

Impacts:

This factor of delay has a huge impact on meeting the agreed time duration of the projects. The lack of technical professionals by the contractor would impact the project in all stages. This impact usually starts in the initial project stage: the contractor by then is required to evaluate the project tender perfectly covering all elements, such as the time plan, project scope/design, materials specifications, and quality requirements. Poor estimation of these elements usually results from the shortage of professional staff by the contractor and could lead to an extreme early failure of the project. Assaf et al. (1995) identified the shortage or low experience of the local labor force as one of the main seven critical factors of delay in large construction projects. Sambasivan & Soon (2006) identified a lack of a labor force as one of the top ten causes of construction delays. Faridi & El-Sayegh (2007) took a broader view by citing the general shortage in skilled labor supply to projects as critical to the project time's overrun. Azlan et al. (2010) found that labor shortage was one of the seven most reported reasons for delay. Mohamad (2010) more specifically named a shortage of manpower to include skilled, semi-skilled and unskilled labor and also named a problem surrounding productivity. After conducting a case study, Indhu & Ajai (2014) expanded this same perception of manpower shortage to include frequent change of staff.

The shortage of qualified staff by contractor leads to work reparation and correction, consuming the project consultant's efforts to maintain the quality. This factor had the highest frequency score compared to the 66 factors of delay and was the most frequent factor of delay observed in the project field at 73.1%.

3- **Inadequate design specifications, Figure 6.9.**

- Symbol: IDS-E
- Type: (Consultant) responsibility
- Frequency Index: 60.3%
- Severity Index: 75%
- RII: 45.2%
- CA Index: 52.3%
- EC Index: 31.6%
- **Total Adjusted Index: 44.3%**

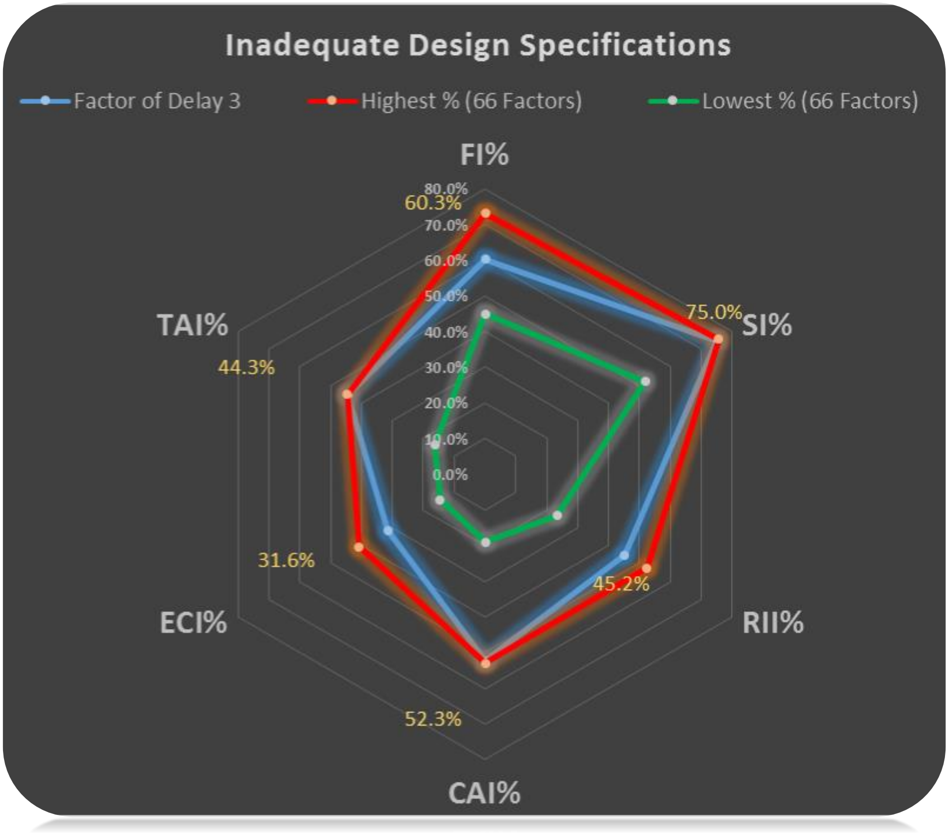


Figure 6.9: Rank-3 Inadequate Design Specs (Consultant)

Impacts:

Many projects were rejected, stumbled or strongly delayed when the assigned engineering office (Consultant) failed to draft a comprehensive work design and engineering specifications. This inadequacy of the work design (specifications) has a severe impact on the time duration which could lead to a major delay exceeding 100% from the assigned time schedule. The inadequacy of design might require a full work revamping or an even much worse scenario of restarting the project from scratch. Many projects have been canceled because the remaining works could not be changed or modified. The corrupted design would necessitate a full design revision and returning the project to step one.

Alsalim (2013) referred delays mainly to errors in the project design and weak supervision of all parties involved. One primary reason for these deficiencies is the lack of planning and design, caused by insufficient client involvement in the project processes (Althynian, 2010). This factor was found to be very severe to the PPMs in general and specifically to time and quality at 75%.

4- **Ambiguities, mistakes, and inconsistencies in specs & drawing, Figure 6.10.**

- Symbol: AMSD-O
- Type: (Client) responsibility
- Frequency Index: 61.5%
- Severity Index: 74.4
- RII: 45.76%
- CA Index: 51%
- EC Index: 27.6%
- **Total Adjusted Index: 42.8%**

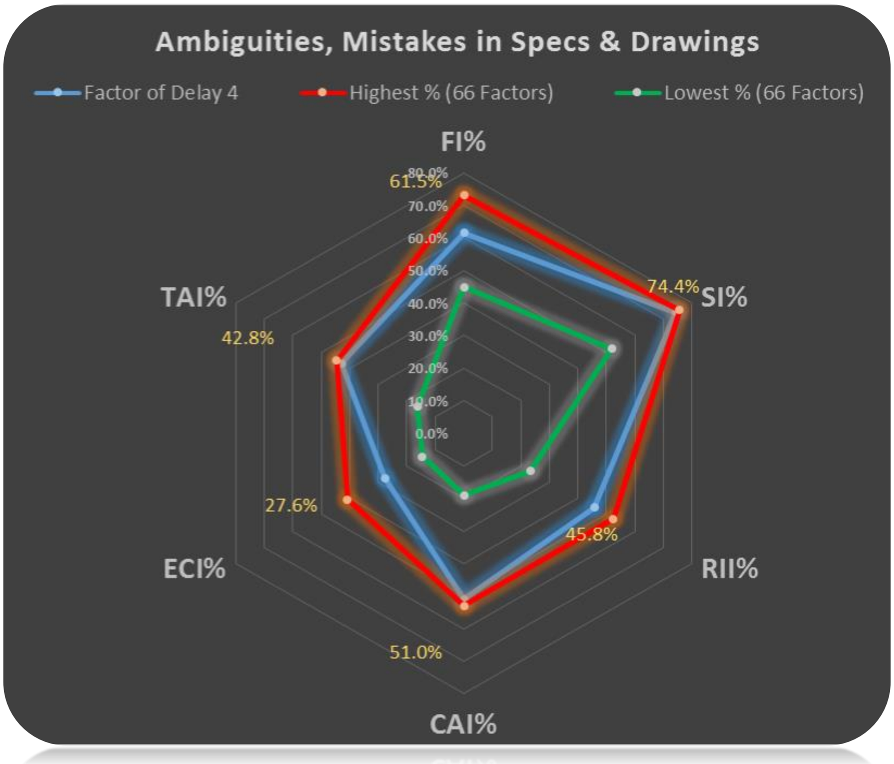


Figure 6.10: Rank-4 Ambiguities, Mistakes and Inconsistencies in Specs Drawings (Client)

Impacts:

During the initiation stage, many clients tend to draft the scope of projects by their engineering team or by delegating this task to an engineering office. Lack of experience or unfamiliarity with the nature of some projects may lead to ambiguities, mistakes and inconsistencies in the main scope of work specification and its drawings. Accordingly, the contractor will carry out all the works detail of the time needed for each task based on this assumption. As a result, much work will to be corrected and re-performed according to the right concept, procedure. Ambiguities may have a strong delay impact on time and cost. Al-Kharashi & Skitmore (2009) cited many problems that included cost and time overruns, but ambiguities in planning, disputes between parties, omissions and errors reduced the life span of construction products and increased maintenance costs. This factor had a very severe impact on the PPMs at 74.4%, while their impact on other delay factors was limited at 27.6%.

5- Poor contract management, Figure 6.11.

- Symbol: PCM-E
- Type: (Consultant) responsibility
- Frequency Index: 62.2%
- Severity Index: 71.8%
- RII: 44.64%
- CA Index: 48.3%
- EC Index: 31.6%
- **Total Adjusted Index: 42.5%**

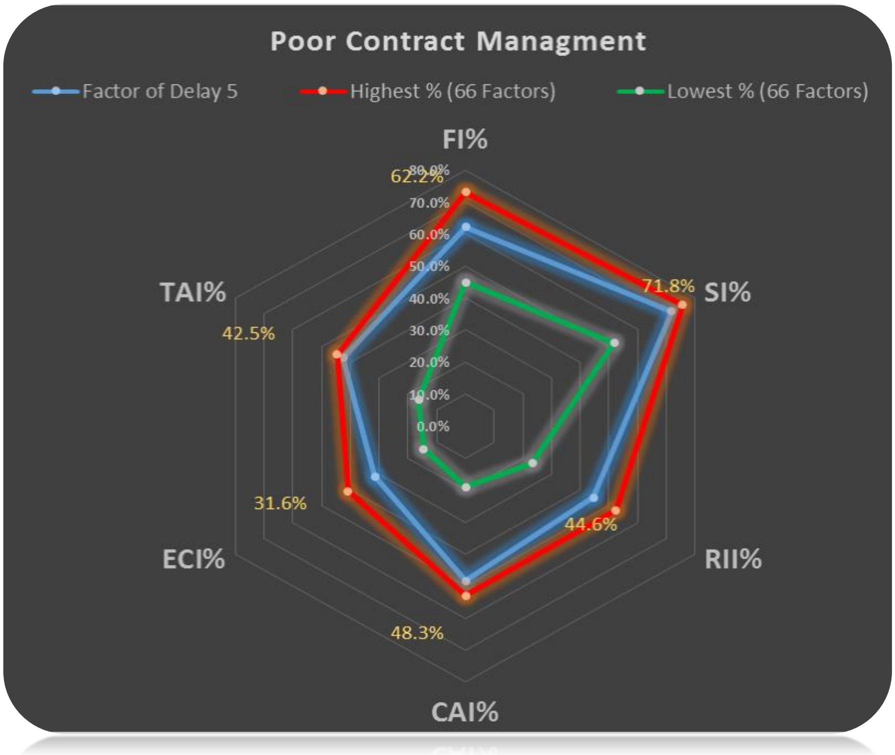


Figure 6.11: Rank-5 Poor Contract Management (Consultant)

Impacts:

A contract, when it is done correctly helps keeps the project moving along with minimal arguments. Azlan et al. (2010) reported poor contract management to be a main cause for construction delays. Indhu & Ajai (2014) also found not only poor site management to be a problem but also improper management of the engineers. Common mistakes in construction projects are the limited knowledge of the client or the weak leadership of the appointed consultant to manage the contract and understand its legal aspects. The International Federation of Consulting Engineers (FIDIC) offer the *Red Book*, which is designed to handle building and engineering related works, would effectively help the clients or their engineers reserve their rights. The poor contract management factor is very severe at 71.8% and has a relative impact on PPMs of 48.3%.

6- Low skills of manpower, Figure 6.12.

- Symbol: LSMP-C
- Type: (Contractor) responsibility
- Frequency Index: 64.1%
- Severity Index: 71.2%
- RII: 45.61%
- CA Index: 44.3%
- EC Index: 35.5%
- **Total Adjusted Index: 42.2%**

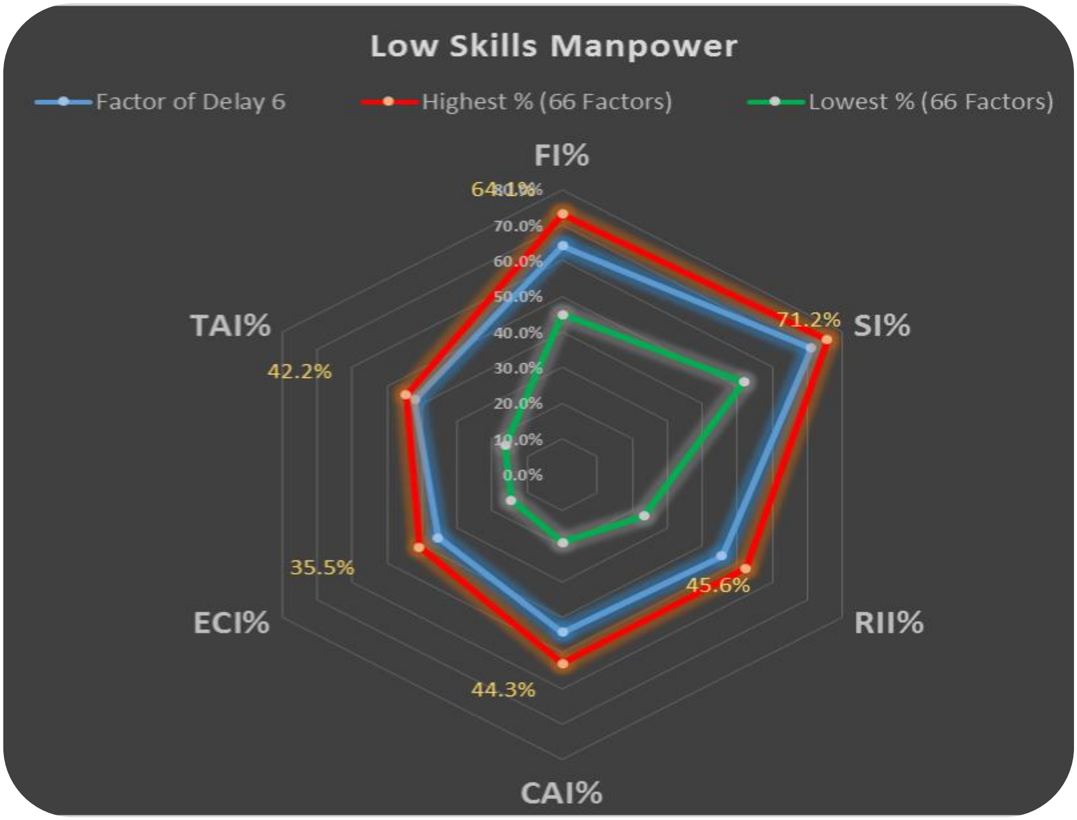


Figure 6.12: Rank-6 Low Skills Manpower (Contractor)

Impacts:

This is a very common issue for most contractor organizations. Skilled manpower is a highly paid sector and usually is not available in the local market. It is often very difficult to assign skilled manpower to the rural areas of Saudi Arabia, where most of the mega projects are located. Dakhil (2013) found the risk of delay is more concentrated in developing countries due to the prevalence of unskilled labor forces and low levels of productivity. Many contractors tend to use subcontractors when they are overextended in covering assigned projects. Subcontracting increases the lack of skilled laborers, which would prevent the contactor to have control over the project. Quality and safety are the most impacted measures due to high dependency on craftsmanship. The severity index is relatively high at 71.2%.

7- Gov. tendering system of selecting the lowest bidding contractor, Figure 6.13.

- Symbol: GTLB-O
- Type: (Client) responsibility
- Frequency Index: 65.4%
- Severity Index: 69.2%
- RII: 45.27%
- CA Index: 45.9%
- EC Index: 32.9%
- **Total Adjusted Index: 42%**

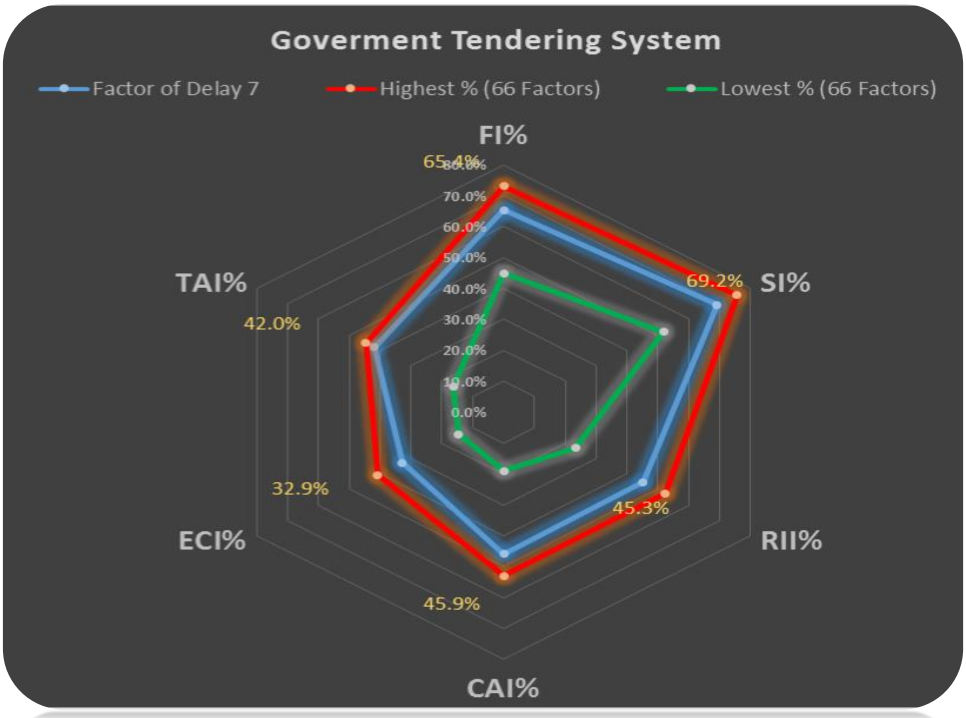


Figure 6.13: Rank-7 Government Tendering- Selecting the Lowest Bidding Tender (Client)

Impacts:

Many projects fail to be delivered on time due to the wrong selection of the project's contractor. Historically, over 50% of the construction industry in most of the countries involve the government (Okpala & Aiekwu, 1988). Many governmental projects experience extensive delays, causing them to exceed time and cost estimates. This problem is more prevalent with traditional contracts in which the contract is awarded to the lowest bidder (Odeh & Bataineh, 2002). Officials in Saudi Arabia started to rank local companies based on the size of the organization, capital investment, the number of labourers, past project experience and successes, level of know-how and related experience, financial stability, qualification for bank guarantee, project portfolio management capabilities and adherence to safety and quality. This ranking has largely helped eliminate unqualified contractors participation in critical future projects. Furthermore, the successful contractors able to execute old projects with minimal disturbances were allowed once again to bid with limited conditions and offer more facilities and advantages.

The main criteria on selecting a suitable contractor for any project is to meet the client expectations from all angles. Time and quality are usually impacted when the project budget is not realistic. Contractors who tend to take projects at very low costs utilize the vagueness of the contract or the weakness of the assigned project consultant. A low project estimation by the contractor leads the client to award the project to him or her; however, a client should call for many technical reviews with all bidders to the select the best tender. In this study, the risk performance was found relatively high and almost equal among the main indices.

8- Improper technical studies by the contractor during bidding stage, Figure 6.14.

- Symbol: IMTS-C
- Type: (Contactor) responsibility
- Frequency Index: 65.4%
- Severity Index: 75.6%
- RII: 49.46%
- CA Index: 44%
- EC Index: 28.9%
- **Total Adjusted Index: 41.3%**

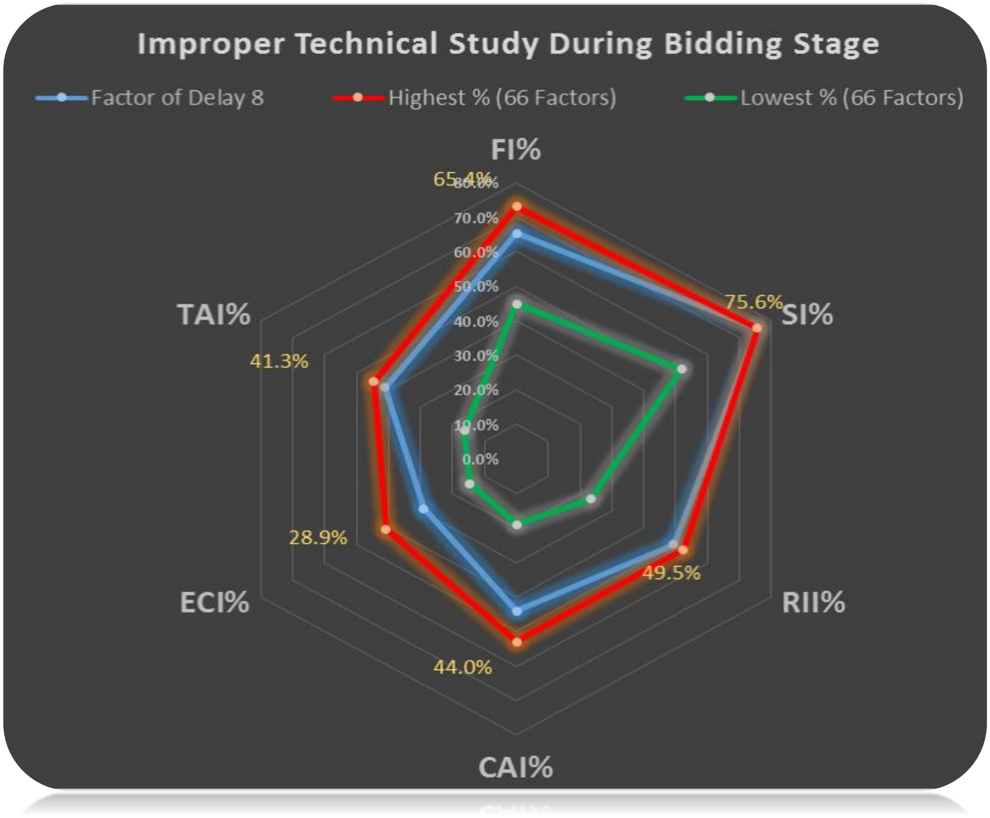


Figure 6.14: Rank-8 Improper Tech. Studies by Contractor during Bidding Stage (Contractor)

Impacts:

Utilizing improper technological studies is a very common mistake made by many contractors. A lack of awareness for the scope details during the bidding stage leads to project time and cost overruns. A weak study of the tender by the contractor should be an alert for the client, indicating that what comes next will be much worse and would escalate arguments between all parties at later stages. Al-Barak (1993) indicated poor estimation practices in the early stages of a project cycle are severe. Project success begins with positive planning and proper design involvement by the contractor in the early stages of a project, with the client playing a major role in these stages (Shen et al., 2004). As a result, problems due to incomplete or inaccurate engineering details often become serious and costly, sometimes not being discovered until the project had been completed. These problems include cost and time overruns as well as disputes between parties (Al-Kharashi & Skitmore, 2009). Many contractors fall into this trap by not dedicating a professional team and allocating enough time for performing a study. This factor was found to have the highest severity impact among the 66 factors at 75.6%.

9- Loose safety rules & regulations within the contractor's org., Figure 6.15.

- Symbol: LSRR-C
- Type: (Contractor) responsibility
- Frequency Index: 68.6%
- Severity Index: 72.4%
- RII: 49.68%
- CA Index: 37.1%
- EC Index: 32.9%
- **Total Adjusted Score: 39.5%**

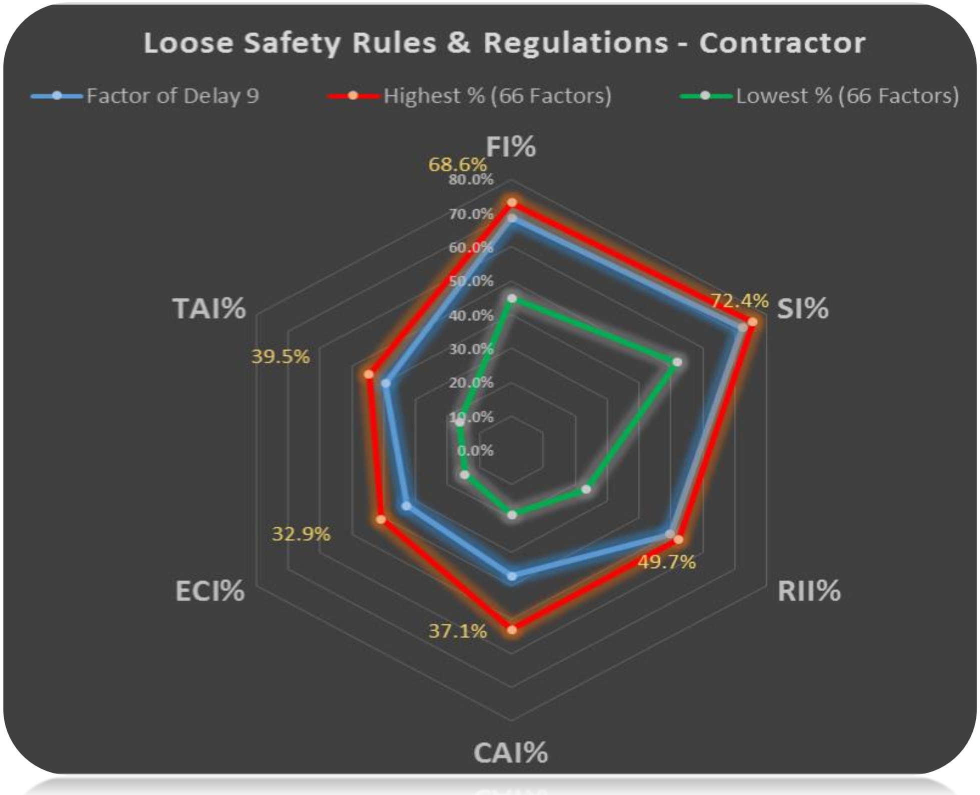


Figure 6.15: 9-Loose Safety Rules & Regulations by Contractor (Contractor)

Impacts:

Loose safety awareness and rules during the project execution is mostly witnessed in small and medium projects. A major safety issue may lead to suspending most of the project activities and would establish an atmosphere of instability and inconvenience to all labourers on site. One main duty of a contractor is to plan and manage the construction so it is executed in a way that controls health and safety risks (Robinson, 2011). The client may contribute to this factor as well by reducing the scope of safety systems on the site. The project time schedule will be impacted mostly by low productivity and staff morale due to the absence of safety during the execution stage. The factor is found very critical to severity and severity indices at 68.6 % and 72.4 %, respectively.

10- Changes in the scope of the project, Figure 6.16.

- Symbol: CSP-O
- Type: (Client) responsibility
- Frequency Index: 64.7%
- Severity Index: 73.7%
- RII: 47.73%
- CA Index: 40.1%
- EC Index: 28.9%
- **Total adjusted Score: 39.1%**

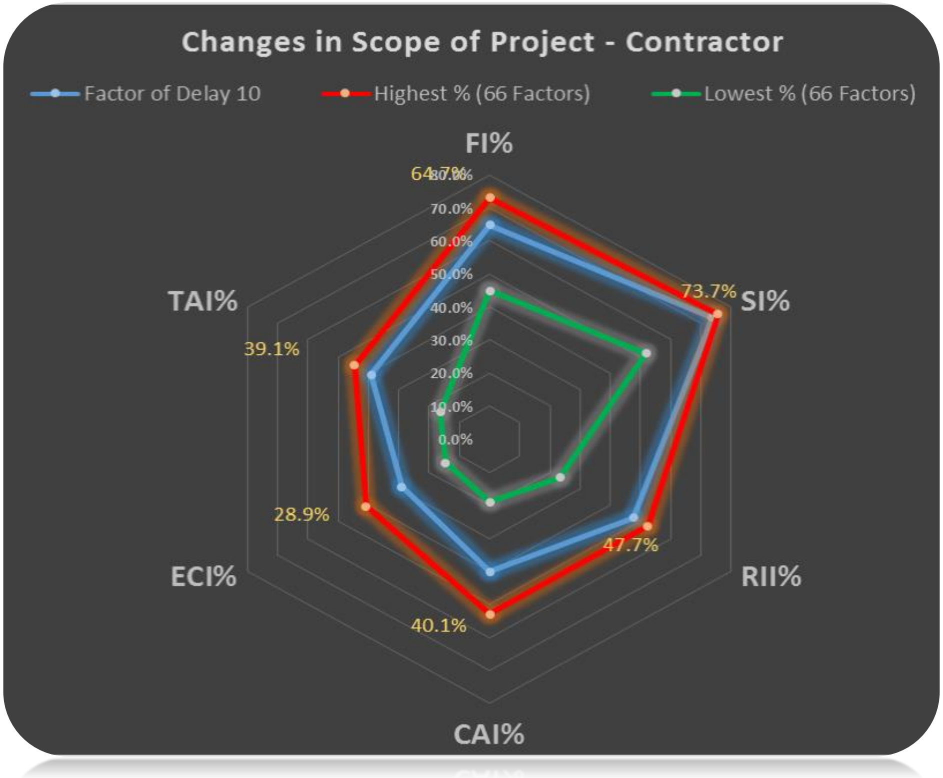


Figure 6.16: Rank-10 Changes in Scope of the Project (Client)

Impacts:

Many clients tend to make sudden changes on the agreed scope of the work due to improper planning and weak tendering development in the initial stage of the project cycle. Some changes may happen due to the market dynamics or technological updates that appear during a long project's schedule. It is obvious some clients resort to reduce the project cost overrun by partially eliminating the scope to meet the deadline; however, this is possibly an acceptable practice. Al-Ghafly (1999) found the main important factors were changes in design and scope, difficulties in obtaining work permits as well as coordination and communication problems. Raqraq (2010) pointed to problems such as shortage of equipment, weak time scheduling, weak budgeting and the scope of work changes as leading causes of construction delay. Mohamad (2010) cited changes in design and materials in construction involving large amounts of money led to cost overrun. This factor frequently happens and has a severe impact at 73.7%, mainly on both the time and the cost.

Four factors (3, 4, 8, and 10) from the TOP-10 list referred to design related matters by all parties. Three factors (1, 5, and 7) referred to time and contract management by the client, and two factors (2, 6 and 9) concerned labour safety, skills and availability of the contractor. Project design related matters from the TOP-10 list was involved four times, time and contract management was involved three times, while labour skills and availability was involved twice. Consequently, project design is a key element of success that involves the client, consultant, and the contractor during the five phases of the project cycle.

6.7 Party Most Responsible for Projects Delay

Researchers are not in agreement concerning the main party responsible for project delay as many factors were attributed to this selection. The factors varied from one study to another due to reasons such as the respondent experience or field of work, the nature of the respondent project experience and the methodology used in the study.

6.7.1 Literature Studies Analysis

Table 6.2 below shows the main responsible party for delay among sixteen studies. It is obvious that the contractor was viewed to be the first one, followed by the client. The consultant was perceived as the party least responsible for delay at 14%. The majority agreed the contractor and the client are the main parties causing delay at 59% and 21%, respectively. The comparison was applied to 16 credible studies identified through the literature review (Chapter 2, section 2.3.4).

TABLE 6.2: PARTY RESPONSIBILITY RANKING OF DELAYS IN MAJOR STUDIES

	Party of Delay			
Party of Delay - 16 Studies, (136) Factors	Contractor	Consultant	Client	Others
Total Factors Related to Each Party of Delay	87	20	31	10
Party of Delay Contribution %	58.8%	13.5%	20.9%	6.8%

6.7.2 Survey Analysis

Most of the respondents represented by contractors, consultants, and owners in Saudi Arabia agreed the contractor was the party most responsible for project delays. Figure 6.17 highlights this general consensus as 54% of the respondents expressed this view. Owners came in second, with little difference as compared to the contractors; while 44% of the respondents believed the delays were due to the client. A very low percentage (3%) claimed the consultant as being the most responsible party causing delays.

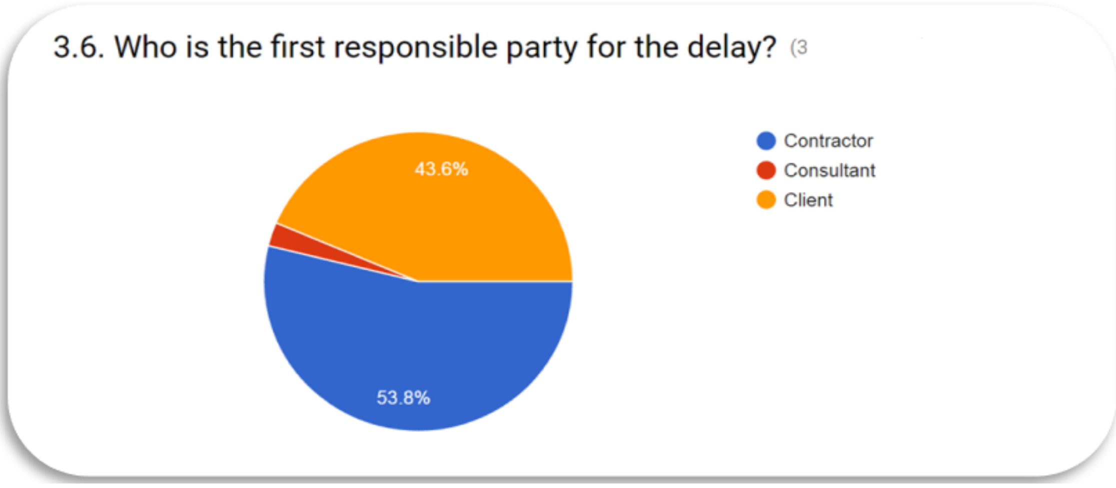


Figure 6.17: First Responsible Party of Delay-Survey Result

Agreement regarding the party most responsible for delays was concluded from the results of all respondents to the research survey. This agreement among the 167 respondents needed more analysis to confirm the finding. The applied analysis during the calculation of the RII% in Chapter-4 supported the results from the survey.

6.7.3 RII Analysis

The RII ranking was applied, based on severity and frequency of the 66 factors, to conduct this assessment. As per Table 6.3, each party was given a score based on the designated points for each factor. The highest factor was given 65 points while the lowest one was given 0. The total ranking score was created to calculate the summation of all factors' ranking scores for each party. Early planning and design as well as governmental regulations were assumed to be under the client responsibility as most of their activities are managed by him/her.

TABLE 6.3: PARTY RESPONSIBLE FOR DELAY BY RII%

Party of Delay	RII Scores 66 Factors	RII%
Contractor weight:	1086	50.6%
Consultant Weight:	293	13.7%
Client Direct Weight:	440	20.5%
Client-A Early plan & Design	171	8.0%
Client-B Gov. Regulation	116	5.4%
External factors	39	1.8%
Total	**2145**	100%

According to the scores calculation as shown in this table, the contractor ranking score gained 1086, points which represented an influence weight of 51%. The client, early design and government regulation were placed in one group representing the owner, with the total ranking scores gaining 727 points with an influence weight of 34%. The lowest score was found for the consultant (293 points) at approximately 13% influence weight. The ranking for project parties remained the same in this part, which reinforces the initial analysis at this stage.

The contractor is the usual party responsible for project delays in general. The contractor's contribution to delays is relatively high compared to other parties due to the factors of delay they influence. This finding cannot be generalized for all stumbled projects in the field of construction in Saudi Arabia. The conclusion of this section will be summarized as per the following points:

- The contractor is generally responsible for projects delay in Saudi Arabia.
- In more than 50% of the current to be stumbled projects, the contractor was found the main reason for delay.
- The contractor involvement in project management activities is relatively higher compared to the other parties. This is could be the main reason.
- The client is the second party responsible for delay, which in some cases might be the main one responsible for delay.
- The consultant was found to be the least responsible party for delay, representing the lowest contribution at 13%.
- In the list of 10 critical delay factors, 7 factors were related to the contractor, 3 were factors for the client, and nothing was referred to the consultant. The ratio for these connections is 7:3:0.

- In the list of 15 critical delay factors, 10 factors were related to the contractor, 3 were factors for the client, and only 1 was referred to the consultant. The ratio for these connections is 6.7:2:0.7.

- In the list of 20 critical delay factors, 12 factors were related to the contractor, 6 were factors for the client, and only 2 were referred to the consultant. The ratio for these connections is 6:3:1.5.

- Ranking parties for a delay is not a decisive decision. The probability from one project to another is based on contractor selection, client management and consultant quality.

6.7.4 DR-HOQ Analysis

The total calculated scores based on the final ranking using the DR-HOQ were used to express the parties' involvement in each factor of delay. Table 6.4 illustrates which party is more responsible for the delay according to the sensitivity analysis carried out using the DR-HOQ. The process of evaluation was limited to the TOP-20 factors of delay as per the analysis of the DR-HOQ.

TABLE 6.4: PARTY RESPONSIBLE FOR DELAY BY DR-HOQ

DR-HOQ Final Rank	TOP-20 Factors of Delays	Scores	
1	Unrealistic contract duration	20	
2	Shortage of technical professionals in the contractor's org.	19	
3	Inadequate design specifications	18	
4	Ambiguities, mistakes, and inconsistencies in specs & drawings	17	
5	Poor contract management	16	
6	Low skill of manpower	15	
7	Gov. tendering system of selecting the lowest bidding contractor	14	
8	Improper technical studies by the contractor during bidding stage	13	
9	Loose safety rules & regulations within the contractor's org.	12	
10	Changes in the scope of the project	11	
11	Inefficient quality control by the contractor	10	
12	Ineffective control of project progress by the contractor	9	
13	Delay in the settlement of contractor claims by the client	8	
14	Ineffective planning & scheduling of the project by the contractor	7	
15	Poor qualifications of contractor's tech. staff assigned to the project	6	
16	Slow preparation of changed orders requested by contractor	5	
17	Contractor's poor coordination with parties' invol. in project	4	
18	Shortage of manpower (skilled, semi-skilled, unskilled labor)	3	
19	Cash flow problems faced by the contractor	2	
20	Slow decision making by the client's organization	1	
	Total Scores	**210**	
	Contractor Weight	105	50.0%
	Consultant Weight	34	16.2%
	Owner Weight	71	33.8%

Once again, the results confirmed the contractor is the first party responsible for delay, with the ranking score gaining 105 points, representing an influence weight of 50%. The client came next, with the total ranking scores gaining 71 points with an influence weight of 34%. The lowest score was for the consultant at 34 points and 16% influence weight. The ranking of parties involved in the construction sector was unchanged for the literature analysis, survey analysis, RII analysis and DR-HOQ analysis).

Table 6.5 gives the final overall evaluation. The contractor was perceived as the party most responsible for delay. Consequently, the final results support Hypothesis1: The contractor is the party most often responsible for delays, as stated in Chapter1 of this research.

TABLE 6.5: PARTIES OF DELAY RESULTS' COMPARISON

Party of Delay	Literatures	Survey	RII%	DR-HOQ	Overall	Final Rank
	16-Studies	167 Respondents	66 Factors Scores	TOP-20 Factors Scores		
Contractor	58.80%	53.80%	50.60%	50.0%	53.3%	1
Owner (Client)	20.90%	43.60%	33.90%	33.8%	33.1%	2
Consultant (Engineer)	13.50%	2.60%	13.70%	16.2%	11.5%	3
Others	6.80%	0%	1.80%	0%	2.2%	4

6.8 Summary

This chapter interpreted and discussed the findings from the previous chapters and eventually identified the links between the chapters of the thesis. The present study was designed to investigate the steps involved for the ranking process and to ensure the effectiveness of ranking the factors of delays in construction in Saudi Arabia. The chapter discussed the validation of ranking and the reliability of the results. The indicators of the TOP-10 critical delay factors were presented, and the real impacts were clarified. The discussions included the effects of the nonlinear relationships identified by using the DR-HOQ for estimating and verifying the collective impact to the PPMs.

Most of the findings of this research support the existing literature. This chapter also presented the steps of concluding the main party responsible for the project delay, and the four steps (Literature findings, survey findings, RII findings, and the DR-HOQ findings) were discussed in detail.

The next chapter presents the conclusions of this research based on the research analysis and findings. A proposed management protocol was developed by the author to enhance and improve the public and private projects execution in Saudi Arabia is presented and recommended to be applied in the construction industry. The limitations of the research are identified and the recommendations for future study are put forward.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 Chapter (Conclusion and Recommendations) Layout.

Figure 7.1 outlines the structure of Conclusion and Recommendations.

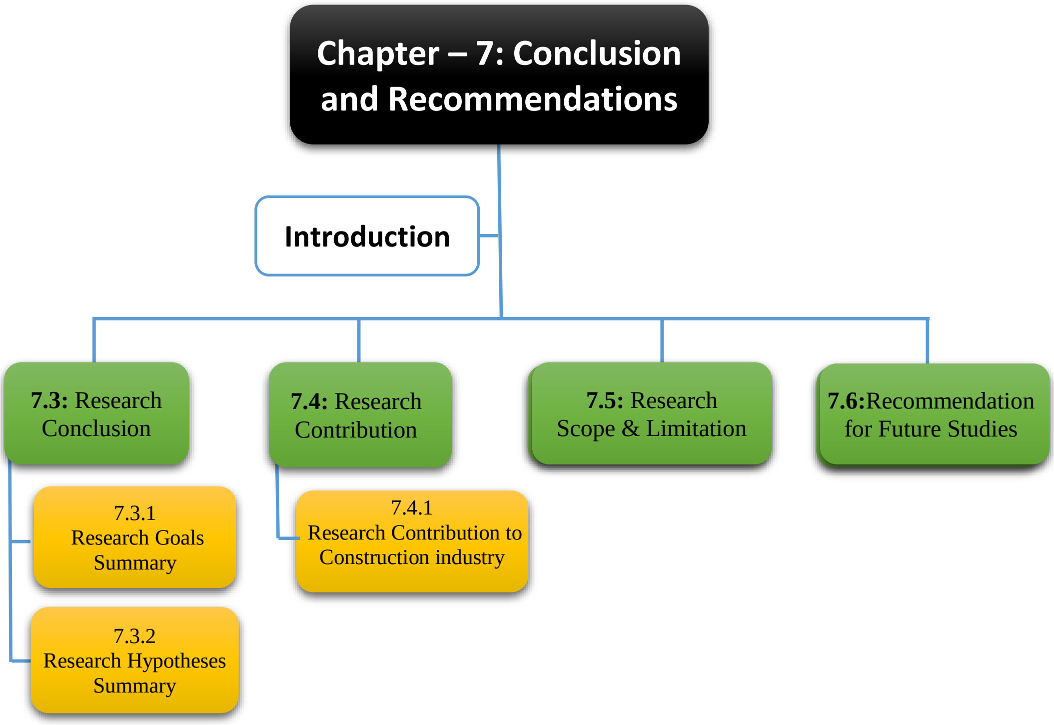


Figure 7.1: Chapter-7 General Layout

7.2 Introduction

This research was motivated by the need to investigate and apply an effective ranking process of delay factors in construction and industrial projects in Saudi Arabia, as outlined in Chapter 1. The study was designed to identify the most important critical factors of delay on the PPMs in order to improve time and cost overrun for construction and industrial projects in Saudi Arabia.

To achieve this aim, a set of research goals was articulated: (1) To provide a general overview of construction delays from previous studies; (2) To identify the main factors of delay in construction projects in Saudi Arabia; (3) To identify the extent to which the contractor, consultant and owner agree on the ranking of the importance of delay factors; (4) To measure the frequency of occurrence, the severity of impact and importance of construction delay factors in KSA; (5) To evaluate and build the relationships between critical delay factors and project performance measures; (6) To identify the inter-relationships between the most critical factors of delay and PPMs to achieve more rational ranking; (7) To evaluate the grouped factors of delay (chains) with PPMs; (8) To propose a practical protocol to enable both public and private sectors to control the projects in the initiation, planning, execution and handover stages. The literature review outlined the existing knowledge on the topic and addressed some of the research goals, mainly Goal 1 and Goal 2. It also helped to integrate the findings of the present study with the existing body of knowledge, as presented in Chapter 2 and 3. According to Ahmed et al. (2002), delays in construction projects are a universal phenomenon and are usually accompanied by cost overruns. However, few investigations have focused on the effective ranking of delay factors with respect to projects performance measures. No previous study in the literature was concerned about the impact of the group of delay factors on the PPMs. In Chapter 4, the research methodology set out the steps taken to fulfill the research Goals 3, 4, 5, 6 and 7. A research design process was developed to frame all the activities in the present study (Figure 4.2). Chapter 5 presented the findings of the statistical analyses of the data collected from the questionnaire. Descriptive statistics of the participants' demographic profiles were first introduced. The relationships between delay factors and performance measures were also measured and identified. The collective impacts of delay factors on the PPMs were investigated in relation to the developed formula, with outcomes verified using Fuzzy Logic Modeling.

Chapter 6 demonstrated the ranking process used to investigate the results' reliability for the TOP-10 influences and the impact of individual (singular) factors to the performance measures. Using the extended survey for validating the ranking result, research Goals 3, 4, 5, and 6 were used as well to evaluate the grouped factors of delay (chains) impacts and to help achieve research Goal 8.

The findings related to the research goals were interpreted and discussed in the context of highlighting the risks for the TOP-10 critical delay factors and the impacts on construction and industrial projects in Saudi Arabia. Finally, this current chapter highlights the conclusions and implications of the research findings. It also outlines the contribution of the study and makes a final recommendation for future studies.

7.3 Research Conclusion

The construction industry makes a significant contribution to the nations' economy. This contribution ranges from 4-50% of the total GDP; however, this is greater in the developing countries. The construction industry has a consistently poor record with respect to low quality, excessive budgets, missing timeliness, unsafe construction and client dissatisfaction (Ibrahim et al., 2010; Kashiwagi et al., 2012; Hai et al., 2014; Xiong et al., 2014). Completing projects on time is an indicator of efficiency, but the construction process is subject to many variables and unpredictable factors, which result from many sources (Assaf, 2006). The sources of delays also affect both quality and safety of the work because attempting to push the project activities forward to overcome delays can lead to quality and safety concerns being neglected (AbuKwaik et al., 2018). Projects delay is a global phenomenon and is not unique to developed countries but is being experienced in most of the developing economies (Ahmed et al., 2002; Sambasivan & Soon, 2007; Luu et al., 2015).

The construction sector in Saudi Arabia is the largest, strongest and fastest growing industry in the Middle East and the Gulf Region (MEED, 2017; Samargandi et al., 2013). Construction projects in Saudi Arabia experience major delays and suffer of total losses reached $ 40 Billion per annum. Among them, 41% experienced cost overruns, and 82% did not meet the time scheduled between 1992 and 2009. This figure tends to be worse over time, since 14% of the projects were finished on time and 44% of them exceeded 6% of their budgets as per last evolutional wave of projects (2009 - 2017). Some of the risks and challenges are unique to the Kingdom, while others are inherent in any construction industry, causing severe time delay, cost overruns and variability in quality among the projects executed by both the government and private sectors (Bubshait, 1994; Assaf & Al-Hejji, 2006; Odeh & Bataineh, 2002; MEED, 2010).

Factors of delays concluded from the relevant literature were identified, sorted, grouped and evaluated by administrating surveys and were initially analysed by the Relative Important Index (RII). This approach was commonly used in previous studies; however, they failed to consider other important measures such as; Quality, Safety and Environment. In this research, these performance measures (PPMs) were modeled by experts as part of a focus group using a 'House of Quality Tool' with an innovative double roof. This novel concept revealed that non-linear relationships exist between the critical factors of delay and the five PPMs. During the analysis, inter-relationships were revealed within the factors of delay which were critical for their effective ranking. These approaches were combined and contributed significantly to the ranking order of delay factors.

The research confirmed through multiple processes that the contractor is mainly the first party responsible for the delay, followed by the client. The unrealistic contract duration by client, the shortage of technical professionals by contractor and inadequate design and specifications by consultant were found to be the most critical factors. The lowest ranked factors included the contractor cash flow problems and slow decision making by the client. The ranking outputs found to be most reliable (≤ 0.8) were determined from an extended survey conducted on a real mega-project used for this purpose. The probability of a group of delay factors appearing in a project is higher and more critical than when a single factor appears by itself. The collective impacts of groups of delay factors were investigated and evaluated using a novel formula developed as part of this research, and the outcomes of the formula were verified using Fuzzy Logic Modeling. This is a main contribution to the body of knowledge in the area of project management. A project management protocol which was developed by the author based on the main results, was retrospectively applied to a major construction project in KSA (AbuKwaik et al., 2018). It is envisaged that this protocol could be adopted by the High Projects Authority in Saudi Arabia for application in construction projects.

7.3.1 Research Goals Summary:

Goal-1: To provide a general overview of construction delays from previous studies. This goal was addressed and achieved by highlighting the importance of construction delay and overviewed the economical and construction status of Saudi Arabia. Numerous previous studies have been presented for comparison and analysis to achieve this goal.

Goal-2: To identify the main factors of delay in construction projects in the Kingdom of Saudi Arabia and other developing countries facing considerable construction booms that have similar geographical and cultural characteristics so efforts can be made to rank these factors and to provide more control for the PPMs. This goal was partly achieved in Chapter 2 by identifying 136 critical factors of delay that were collected from sixteen different studies including ten countries in three main regions. The remaining part was fully achieved in Chapter 4, 4.5.1 which included further analysis.

Goal-3: To identify the extent to which the contractor, consultant and owner agree on ranking the importance of delay factors. The goal was addressed by involving all parties in the survey. Result showed no common agreement with regards to the ranking.

Goal-4: To measure the frequency of occurrence, the severity of impact/importance of construction delay factors in KSA. The survey analysis concluded the frequency of occurrence ranges (44.87% - 73.08%) and the severity of impact ranges (51.92% -75.64%) for the 66 critical factors of delay which were shortlisted from 303 factors. These figures have addressed this goal.

Goal-5: To evaluate and build membership functions between the most critical delay factors and PPMs (time, cost, quality, safety and environment). More than 100 relationships were created and evaluated to achieve this goal. The House of Quality (HOQ) was applied during the focus group sessions to address each individual relationship between the factor of delay and PPMs.

Goal-6: To identify and evaluate, if any, the inter-relationships between the most critical factors of delay to achieve more rational ranking. Around 340 interrelationships were identified and evaluated in the second roof of the (DR-HOQ). Therefore, this goal was addressed and achieved.

Goal-7: To evaluate the grouped factors of delay (Critical Chains) with PPMs. This goal was addressed by introducing 10 critical group of factors. An empirical formula developed by the author was used to achieve this goal.

Goal-8: To propose a universal mechanism for enabling both public and private sectors to control the projects in the initiation, planning, control, execution and handover stages. The goal was addressed and achieved. This will be used as a main result of the research and is recommended to be applied in the construction industry.

In summary, Table 7.1 is designed with three sections (goals, conclusion and reference) to overview how and where each goal was addressed and achieved in this study.

TABLE 7.1: RESEARCH GOALS & CONCLUSIONS

Research Objective (8-Goals)	Conclusion	Reference
1. To provide a general overview of construction delays from previous studies.	Chapter 2 is divided into three parts related to the research aim and objectives. The first two parts are presented to address **Goal 1**. In the first part (3.3), a brief overview of the construction industry and its importance in developing countries is provided. The second part (3.4) provides an overview of the construction industry in Saudi Arabia. In particular, this part considers the literature revealing the construction background and development stages in public and private sectors for the construction projects in Saudi Arabia. It provides the economic profile and the status of the construction sector over the last 25 years.	**Chapter** 3.3 & 3.4
2. To identify the main factors of delay in construction projects in the Kingdom of Saudi Arabia and other developing countries facing considerable construction booms that have similar geographical and cultural characteristics so efforts can be made to rank these factors and to provide more control for the PPMs.	This Goal was addressed to select the main factors of delay that have been identified from the literature. A total of (136) critical factors of delay were collected from sixteen different studies including 10 countries in three main regions represented by KSA & GCC, Middle East and Far East in the field of construction projects. Tables 2.3, 2.4, and 2.5 illustrate the ranking of project delays that were carried out in the major studies in KSA, UAE, Turkey, Jordan, Libya, India, Pakistan, Indonesia, Hong Kong and Malaysia. Table 2.6 illustrates the number of occurrences of each factor of delay per region.	**Chapter** 2.3.3

3. To identify the extent to which the contractor, consultant, and owner agree on the ranking of the importance of delay factors.	-All parties were involved and participated in the research survey. The participation of each party was as follow: Client: 35.9%, Consultant: 25.6%, Contractor: 20.5% and Others: 17.9%. -Survey findings showed no common agreement between the project parties with regard to the ranking of factors. -Survey findings showed that approximately 39% of the participants reported that the client authorized delays up to 25% of delay time, while approximately 28% of respondents reported that the client contributed to all delay time in their projects. Only about 10% of participants indicated the client made no contribution to the project delays. Contractors are obliged to compensate liquidated damages if the delay was not caused by the client.	**Chapter** 5.5.4 **Chapter** 5.6
4. To measure the frequency of occurrence, the severity of impact and importance of construction delay factors in KSA.	Data collected from the survey was analyzed using descriptive statistical techniques. RII is an advanced and accurate analysis method and was used to arrange the large amount of data in a systematic, fast and reliable way. The impact of frequency and severity for each factor of delay was interpreted in Chapter 4, Table 4.3.	**Chapter** 4.5.3
5. To evaluate and build membership functions between the most critical delay factors and PPMs (time, cost, quality, safety and environment).	The values and the degrees of all relationships were identified and, accordingly, the membership functions were developed by the focus group, which included the author and six experts in the field of the project management. The total numbers of relationships reached 457. **Part-A: Table 4.11 & Table 4.12** •100 relationships out of 457 represent (21%) were created between the factors of delays and customer attributes (PPMs). These relationships were developed in the rectangular correlation box of the (HOQ). •16 relationships out of 457 represent (4%) were created for the relationships of customer attributes among each other. These relationships were developed in the first roof of the (HOQ).	**Chapter** 4.5.4.2

6. To identify and evaluate, if any, the inter-relationships between the most critical factors of delay to achieve more rational ranking.	The values and the degrees of all relationships were developed during the last 2 sessions of the focus group. **Part B: Table 4.14** •341 relationships out of 457 represent (75%) were created for the inter-relationships between factors of delay. These relationships were developed in the second roof of the (DR-HOQ).	**Chapter** 4.5.4.2
7. To evaluate the grouped factors of delay (Critical Chains) with PPMs.	The sensitivity analysis was applied by using the Double Roof House of Quality (DR-HOQ). The analysis has helped to identify those groups and to sort them in a way that would be easily interpreted to help in the final analysis. Table 5.21 illustrates the TOP-10 critical group (Chains) of delay factors.	**Chapter** 4.5.4.3 & 5.11
8. To propose a universal mechanism for enabling both public and private sectors to control the projects in the initiation, planning, control, execution and handover stages.	The five success elements listed below were concluded from the TOP-10 singular and collective impact of delay factors to PPMs, which helped eventually to address the final research **Goal 8.** This outcome has directed the author to propose a universal management mechanism for enabling both public and private sectors to control projects in the initiation, planning, execution, control and handover stages. **Protocol Key Success Elements:** 1- Projects design related matters by client, consultant and contractor 2- Projects time, cost and activities control management by contractor 3- Projects contract management by client and consultant 4- Labour skills and availability by contractor 5- Selection of the contractor by client A proposed protocol was developed in order to tackle the five key success elements concluded from the research goals and objective. The protocol proposed eight stages to control each success element decisively. These stages have detailed processes with control gates so the projects will be moved steadily, meeting all requirements at each entry gate. The Figure in the Appendix I shows the eight sequential stages flowing from the proposal stage until the takeover stage, highlighting the recommended steps in each stage.	**Appendix-I**

7.3.2 Research Hypotheses Summary

The following hypotheses were tested, evaluated and confirmed:

Hypothesis -1: The contractor is the party most often responsible for delays. The contractor is found the most responsible party of delay followed by the owner and then by the consultant. This hypothesis was confirmed.

Hypothesis -2: Delay factors have non-linear relationships with PPMs. Most of delay factors do have non-linear relationships with project performance measure (PPMs) as different values were presented according to each measure. This hypothesis was confirmed.

Hypothesis -3: Delay factors have effective inter-relationships with each other. The majority of delay factors have different degrees of interrelationships (embedded relationships) with other factors of delay. Around 75% of these interrelationships do exist.

Hypothesis -4: The ranking of delay factors may encounter changes based on Hypothesis 2 and Hypothesis 3. Relationships resulting from H-2 and H-3 were represented by the (CA Index) and the (EC Index). Both indices contributed radically to the ranking orders of delay factors.

In summary, Table 7.2 is designed with three sections (hypotheses, conclusion and reference) to overview how and where each hypothesis was tested, evaluated and confirmed in this study.

TABLE 7.2: RESEARCH HYPOTHESIS & CONCLUSIONS

Research Hypotheses (4)	Conclusion	Reference
1. The contractor is the party most often responsible for delays.	The results in Chapter 6 confirmed the contractor is the first party responsible for delay, representing an influence weight of 50%. The client came next, with an influence weight of 34%. The consultant came last at 16% influence weight. Table 6.5 demonstrates the four steps used for this determination.	**Chapter** 6.7

2. Delay factors have non-linear relationships with PPMs.	While carrying out the focus group that included many sessions for sorting and grouping the factors of delays, it was discovered that many factors have nonlinear relationships with respect to the project performance measures. Figures 4.6 A, B and C illustrate three examples of non-linearity occurring between the factors of delays and the project performance measures.	**Chapter** 4.5.3.3
3. Delay factors have effective inter-relationships with each other.	DR-HOQ analysis has mostly identified the inter-relationships between the factors of delays which contributed for prioritizing the factors of delays in a detailed analysis by combining three indices. Figure 4.10 represents in the 2nd roof the inter-relations between the (factors of delays). 341 relationships out of 457 represent (75%) were created for the inter-relationships between factors of delay. These relationships were developed in the second roof of the (DR-HOQ).	**Chapter** 4.5.4.1
4. The ranking of delay factors may encounter changes based on hypothesis 2 and hypothesis 3.	Many factors of delay lost their order according to the initial ranking process and some others gained higher ranking levels. This occurred due to depending solely on the RII) For example, factor 1 (shortage of technical professional in contractor's organization) stepped down one level, and factor20 (unrealistic time duration) jumped up by 19. Figure 4.15 illustrates the re-ranking process after calculating the TA Index.	**Chapter** 4.5.4.2 Part-C

7.4 Research Contributions

Numerus studies have been highly regarded on ranking the factors of delay, but very few studies focused on the effective ranking and evaluation of the delay factors in public construction and industrial projects in Saudi Arabia. Moreover, no previous study in the literature was concerned with the evaluation of the collective impact of delay factors according to the PPMs, and this study seems the first to do so. Therefore, the current study makes several contributions to fill this gap in knowledge.

First, building on the existing knowledge about the research methodology, this study provided greater insight into the research design process. The design was based on three elements: philosophical paradigms, strategies or approaches of the research inquiry and specific methods used in the research (Chapter 4, Figure 4.2). The research plan took a controlled and structural approach by initially identifying the research topic, constructing appropriate research questions, adopting a suitable research approach, collecting data and then creating and analysing the relationships between the variables (performance measures and factors of delay).

Second, this study modified the House of Quality (HOQ) technique and introduced a new concept called the Double Roof House of Quality (DR-HOQ). A conceptual mechanism can be developed to understand and predict the relationships (Zikmund et al., 2010). The study examined the complex relationships of 457 relationships, with 116 in Part 1: Creation of 100 relationships between the critical factors of delays and PPMs and 16 correlations among the five PPMs. These relationships were developed in the first roof of the HOQ and its rectangular correlation box to create the (Customer Attributes Index). Moreover, the remaining 341 relationships were developed in Part 2: The creation of the inter-relationships between the critical factors of delay, which were developed in the second roof to create the (Engineering Characteristic Index). Both Indices were used to determine the cumulative influence of all indices (Total Adjusted Index), which contributes to the final ranking of delay factors.

Third, a novel formula was developed to evaluate the collective impact of the relationships between the relevant factors of delay for the critical chains identified from the second roof. These chains were identified using the bond strengths between the delay factors and then were categorized into four groups. Accordingly, four tables were created to demonstrate the collective impacts of the entire risk on the performance measures.

The tables contained 58 different risky chains (Group of Factors) that possibly appear in the field of construction projects. The collective impact of each chain was identified, with a total score ranging from 0 to 35 points. The TOP-10 risky chains were highlighted and impacts were concluded and clarified. It is planned to publish this new approach in *the Journal of Project Management* during 2019.

Fourth, this study adapted a novel concept for the verification process using Fuzzy Logic Modeling to verify the collective impacts of the delay factors identified by the newly developed formula. This concept can simulate the collective impacts of any group of factors based on the edited rules that were created by the previous focus group sessions as explained in Chapter 5, Section 5.12. This verification tool was developed from a student version of MATLAB, which can be further developed and enhanced using more sophisticated rules for sensitive results and can be involved in a higher scale of project management control.

Fifth, this study revealed that the contractor is the first party responsible for the delay in the construction sector in Saudi Arabia through a multiple process. This process included four sequential steps of analysis, which is considered a new approach to produce the final decision. The steps, as explained in Chapter 6, Table 6.2, included literature analysis, survey analysis, RII analysis, and DR-HOQ analysis, reaching the conclusion that the contractor was perceived to be the first party responsible for delay.

7.4.1 Research Contribution to the Construction industry

According to the singular ranking process, four factors (3, 4, 8, and 10) from the TOP-10 list were found to refer to design related matters involving all parties. Three factors (1, 5, and 7) were found to be related to improper selection of the contractor and time/contract management by the client, while three factors (2, 6 and 9) were concerned with labor safety, skills and availability as provided by the contractor. In the collective ranking process, eight chains (1, 2, 3, 4, 5, 6, 7, and 10) from the TOP-10 list referred to the design related matters, time, contract management, labour skills and availability by all parties. Two chains (8 and 9) were found to be related to project design, control, time, cash flow and labour skills availability by contractor.

Accordingly, project design related matters are the key risk that involve the client, consultant, and the contractor during the five stages of the project cycle. The client was found responsible for project time and contract management during the initiation and planning stages. The contractor was seen the party most responsible for delay and mainly involved for the remaining risks such as site activities control, cash flow and labour skills/availability during the five stages. The results of the research have revealed five major risks which were concluded from the final ranking of the delay factors as follows:

1. Project design related matters by client, consultant and contractor
2. Project time, cost and activity control management by contractor
3. Project contract management by client and consultant
4. Labour skills and availability by contractor
5. Selection of the contractor by client

Consequently, these risks were mainly the result of the improper selection process of the contractor. This demonstrated a lack performance of managing the project time and cost due to a limited skilled labour, engineering and financial capability by the contractor. Hence, the author developed a protocol which includes eight stages of control for supporting both the public and private sectors in managing projects in Saudi Arabia. The protocol integrates 11 criteria used for the classification of Stage 4, and its use as a prototype has been demonstrated in a critical project – the King Abdullah Stadium -- that was executed in Saudi Arabia between 2014 and 2016. It is intended that this protocol will be applied by the High Projects Authority in Saudi Arabia. This protocol was published under the title "A new proposed project overrun management protocol using a project classification matrix" in the *Journal of Advance Management Science* (AbuKwaik et al., 2018). A full copy of the protocol and the paper is attached in Appendix-I.

7.5 Research Scope & Limitations

The focus of this study was on the effective ranking of delay factors in construction and industrial projects in Saudi Arabia. As such, it is important to acknowledge the following limitations:

1- Only the critical factors of delay and the PPMs (5 Measures) were used.
2- Only construction and industrial projects were considered; projects of other types were not included.
3- Only projects built in KSA were considered; others were not included.
4- Only delays that occurred during the initiation, planning, control and execution stages were considered.

7.6 Recommendations for Future Research

Based on the findings of the research and the limitations that have been noted, a number of directions for future research endeavors can be recommended:

- This research mechanism could be applied in different countries for future studies. The on-line survey could be used once again and administered to new participants in any area of the research study. Similarly, RII ranking and DR-HOQ nonlinearity analysis could be applied again, allowing some relationships to be re-evaluated based on the practitioner's experience in the area of the new research.

- It would also be useful if a comparative study of construction delay factors were to consider more than two countries. Studies in the same field could be conducted in parallel with this type of research, perhaps for the same countries in the region or countries in different continents.

- An innovative idea could be a study that compares groups of countries in relation to construction delay factors that reflect the repetition of the critical delay factors in those countries; however, that requires frequent surveys using cases studies rather than relying on the experience of professionals.

- The sole effect of delay on the cost (project budget) and quality may provide different impressions and hidden dimensions that are behind the delay and could be a subject of a further analysis derived from the defined critical factors of delay.

- The Fuzzy Logic modeling presented in this research incorporates limited features and rules, which could be further improved using an advanced version or integration with similar simulation system. The result of the advance modeling and simulation could be used for academic and commercial purposes and could generate high profits.

- Author Recommendations during Project Stages. In this section, the common mistakes usually observed by the author, consultants and projects managers, as well as issues covered in literature reviews, are highlighted to emphasize the essence of eliminating them at the earliest. The common mistakes are discussed and addressed in the five stages of the projects, from the initiation stage until the handover stage. A full copy is attached in Appendix-H.

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Appendixes

A- List of Projects Delay Factors

B- On-line Copy of the Questionnaire

C- Manual Copy of the Questionnaire

D- Double Roof House of Quality (Tables of Analysis)

E- Group Factors Analysis

F- Relative Important Index (Table of Ranking)

G- Project Management Protocol Chart

H- Author Recommendations for Project Mangers during the five Stages

I- Public & Private Project Management Protocol

Appendix A List of Projects Delay Factors (+300)

TABLE-1: GENERAL LIST OF DELAY FACTORS

1-Collecting → 2-Sorting → 3-Merging → 4-Grouping →  → Final List

No.	Factors of Projects Delay
1	Absenteeism
2	Accidents during construction
3	Actual completion data
4	Additional work
5	Ambiguities, mistakes and inconsistencies in specifications and drawings
6	Approval by the owner
7	Approving workshops drawings
8	Award project to the lowest bid price
9	Budget overrun
10	Bureaucracy in bidding/tendering method
11	Bureaucracy of owner
12	Bureaucracy of the provincial municipality
13	Cash flow difficulties
14	Cash flow issues by contractor
15	Change in labor allocation
16	Change in material
17	Change in material prices or price escalation
18	Change of design
19	Change order by owner during construction
20	Change orders
21	Changes in government regulations and laws
22	Changes in material types and specifications during construction
23	Changes in material types and specifications during construction
24	Changes in materials prices
25	Changes in materials specifications
26	Changes in the scope of the project
27	Changes in the design and scope
28	Client delay in furnishing and delivering the site to the contractor
29	Client's failure to coordinate with government authorities during planning
30	Client's poor communication with construction parties and govert. authorities
31	Complex geological condition
32	Complexity of project (project type, project scale, ….etc.)
33	Complexity of project design
34	Conflicts between consultant and design engineer
35	Conflicts between joint-ownership
36	Conflicts related to the drawings and specifications
37	Construction mistakes and defective work

38	Construction works which involve huge amounts of money
39	Contractor financial issues
40	Contractor's improper planning
41	Contractor's poor site management
42	Contractors' financial difficulties
43	Coordination and communication problems
44	Coordination problems
45	Damage of sorted materials
46	Date of notice to proceed
47	Decentralization in approving adjustments (complying with legal process)
48	Decentralization in approving bidding results (complying with legal process)
49	Decentralization in approving design and cost estimate (complying with legal process)
50	Decentralization in approving payment (complying with legal process)
51	Decentralization in approving the project (complying with legal process)
52	Defective design made by designers
53	Deficiencies between consultants and contractors
54	Delay in approval of completed work by owner
55	Delay in approving design documents
56	Delay in approving major changes in scope of work by consultant
57	Delay in finance and payments of completed work
58	Delay in issuing of change orders by the client
59	Delay in making decisions
60	Delay in manufacturing materials
61	Delay in material supply
62	Delay in materials delivery
63	Delay in obtaining permits from municipality
64	Delay in payment by the client
65	Delay in payment to contractors of completed works
66	Delay in performing final inspection and certification by third party
67	Delay in performing inspection and testing
68	Delay in progress payments (Funding problems)
69	Delay in progress payments by the client
70	Delay in providing services from utilities (water, electricity, etc.)
71	Delay in running bill payments to the contractor
72	Delay in site delivery
73	Delay in site mobilization
74	Delay in submission of drawings
75	Delay in the settlement of contractor claims by the client
76	Delay of owner in acceptance of completed works
77	Delay of owner in solving the arising during the project implementation
78	Delay to furnish and deliver the site to the contractor
79	Delays encountered during construction
80	Delays in approvals by government entities
81	Delays in contractor's payments
82	Delays in contractor's payments to subcontractors
83	Delays in producing design documents

84	Delays in sub-contractors
85	Delays of material supply by suppliers
86	Design changes
87	Design changes by owner during construction
88	Design changes by owner or his agent during construction
89	Design discrepancies
90	Design errors and omissions made by designers
91	Different tactics patterns for bribes
92	Difficulties in financing project by contractor
93	Difficulties in financing project by owner
94	Difficulties in obtaining work permits
95	Dispute on land usage
96	Disputes
97	Effects of social and cultural conditions
98	Effects of subsurface conditions (type of soil, utility lines, water table)
99	Equipment allocation problem
100	Equipment availability and failure
101	Escalation of material prices
102	Evaluation of completed works
103	Excessive bureaucracy in the client's administration
104	Experience of the contractor
105	Extreme weather conditions
106	Failure of equipment
107	Financial difficulties
108	financial difficulties faced by the contractor
109	Financial problems
110	Financial capabilities
111	Frequent change of staffs
112	Frequent change of subcontractors
113	Frequent equipment breakdowns
114	Global financial crisis
115	Govt. tendering system requirement for selecting the lowest bidding contractor
116	Inadequate client's financing and payments for completed works
117	Inadequate contractor experience
118	Improper construction methods implemented by contractor
119	Improper equipment
120	Improper intervention and changes in design
121	Improper project feasibility study
122	Inaccurate material estimation and degree of complexity
123	Inaccurate site investigation
124	Inadequacy of sub-contractors
125	Inadequate contractor experience
126	Inadequate definition of substantial completion
127	Inadequate design specifications
128	Inadequate design team experience
129	Inadequate equipment used for the works

130	Inadequate modern equipment
131	Inadequate planning
132	Inadequate production of raw material in the country
133	Inadequate project management assistance
134	Inadequate project structure
135	Inadequate site investigation
136	Inappropriate construction methods
137	Inappropriate contractor's policies
138	Inappropriate contractual procedure
139	Inappropriate government policies
140	Incompetent contractor
141	Incompetent design consultant
142	Incompetent owner
143	Incompetent project management consultant
144	Incompetent project team
145	Incompetent supervision consultant
146	Incomplete and unclear drawings
147	Incomplete project design
148	Ineffective delay penalties
149	Ineffective planning and scheduling of project by contractor
150	Ineffective project planning and scheduling
151	Inflation and sudden changes in the prices
152	Information delays, and lack of information exchange between the parties
153	Insufficient data collection and survey before design
154	Interference by the client in the construction operations
155	Internal subcontractors disputes due schedule changes
156	Labor injuries on site
157	Labor productivity
158	Labor shortage
159	Labor strikes due to revolutions
160	Labor supply is significant
161	Lack of teamwork
162	Lack of capable representative
163	Lack of communication between parties
164	Lack of consultant experience in construction projects
165	Lack of continuous updating of the project implementation process by owner
166	Lack of coordination between the parties
167	Lack of design team experience in construction projects
168	Lack of detail drawings during the municipality application
169	Lack of effective change management
170	Lack of experience of the contractor
171	Lack of high technology mechanical equipment
172	Lack of incentives for contractor to finish ahead of schedule
173	Lack of motivation among contractor's members
174	Lack of owner experience in construction projects
175	Lack of skilled operators for specialized equipment

176	Lack of strictness and binding in the contract documents
177	Lack of understanding of technique and constructional legislation of owner
178	Lack or departure of qualified staff from the contractor
179	Late delivery of material and equipment
180	Late in reviewing and approving design documents
181	Late in revising and approving design documents by owner
182	Late procurement of materials
183	Legal disputes between owner and contractor
184	Legal disputes between project participants
185	Local problems like strikes
186	Long period between design and time of bidding/tendering
187	Long waiting time due to owner's authority
188	Loss of time by traffic control and restriction at job site
189	Low efficiency of equipment
190	Low motivation and morale of labor
191	Low productivity level of labor
192	Low productivity of labor
193	Low skills of manpower
194	Material cost increase due to inflation
195	Material shortage
196	Mistakes and delays in producing design documents
197	Mistakes and discrepancies in design documents
198	Mistakes during construction stage
199	Misunderstanding of owner’s requirements by design engineer
200	Mode of financing and payment for completed work
201	Natural disasters (flood, hurricane, earthquake)
202	Negative cash-flow
203	Non-availability of suitable contractors
204	Notifications
205	Obsolete technology
206	Old fashion equipment and tools
207	Organization that lacks sufficient resources
208	Organizational deficiencies
209	Original contract duration is short
210	Past preferences
211	Payment procedure is complex
212	Payments delay
213	Performance and management of subcontractors
214	Personal conflicts among labor
215	Planned duration of contract
216	Political, social and cultural risks
217	Political/bureaucratic influences
218	Poor communication and coordination between consultant and contractor
219	Poor communication and coordination between owner and contractor
220	Poor communication management
221	Poor contract administration and management with subcontractors

222	Poor contract management
223	Poor coordination by the client with the various parties during construction
224	Poor estimation practices
225	Poor financial control on site
226	Poor labor productivity
227	Poor planning by both owner and contractors
228	Poor procurement of construction materials
229	Poor qualification of the contractor technical staff
230	Poor quality of construction materials
231	Poor Risk Management
232	Poor site management
233	Poor site management and improper management of the engineers
234	Poor site management and supervision by contractor
235	Poor use of advanced engineering design software
236	Price fluctuations of construction materials
237	Problem with neighbors
238	Problems in material procurement
239	Problems with subcontractors
240	Project degree of complexity
241	Project management
242	Quality preferences
243	Remote location of site
244	Resource shortages
245	Rework due to change of design or deviation order
246	Rework due to error in execution
247	Rise in the prices of materials
248	Schedule delays
249	Scope of work changes
250	Selecting inappropriate contractors
251	Severe weather conditions on the job site
252	Shortage in HR resources
253	Shortage in material
254	Shortage in material and labor
255	Shortage of **construction** materials in market
256	Shortage of contractor's administrative personnel
257	Shortage of equipment of contractor
258	Shortage of labor
259	Shortage of manpower (skilled, semi-skilled and unskilled labor)
260	Shortage of required equipment
261	Shortage of required materials
262	Shortage of technical professionals in the contractor's organization
263	Shortage of tools and equipment
264	Shortages of qualified employees of the subcontractors
265	Site space constraints
266	Slow decision making by the client's organization
267	Slow mobilization of equipment

268	Slow mobilization of labor
269	Slow response from the consultant engineer to contractor inquiries
270	Slow site clearance
271	Slowness in decision making
272	Slowness in decision making process by owner
273	Subsurface site conditions differing materially from contract documents
274	Sudden failures actions
275	Suspension of work by the client's organization
276	Team capability
277	The complexity of project
278	The failure records
279	The shortage or low experience of the local labors
280	The weather condition
281	Thefts done on site
282	Tight construction schedule
283	Time extensions
284	too many change orders by the owner
285	Traffic control and restrictions on the job site
286	Unavailability incentives for contractor to finish ahead of schedule
287	Unclear and inadequate details in drawings
288	Uncooperative client complicating contract administration
289	Unexpected surface & subsurface conditions (soil, water table, etc.)
290	Unfavorable contract clauses
291	Unfavorable weather conditions
292	Unpunctually material delivery
293	Unqualified/inadequate experienced labor
294	Unqualified/inexperienced labor
295	Unrealistic contract duration
296	Unreliable subcontractors
297	Unreliable suppliers
298	Variation orders/changes of scope by owner during construction
299	Weak budgeting
300	Weak design by the engineers
301	Weak project administering and supervision
302	Weak time scheduling
303	Work interference between various contractors

Appendix-B Questionnaire [Online Version]

Section one - Questions related to the respondent's experience.
* Required

Email address *

1.1. What is your business?

Mark only one oval.

- Contractor
- Consultant
- Client/ Client representative
- Other:

1.2. What is the sector type you work for?

Mark only one oval.

- Public
- Private
- Both

1.3. How long have you been dealing with construction projects?

Mark only one oval.

- <5 years
- 5-10 years
- 11-15 years
- >15 years

1.4. What is your specialty in building construction?
Check all that apply.

- ☐ Commercial buildings
- ☐ Industrial buildings
- ☐ Governmental buildings
- ☐ Residential Buildings
- ☐ Other:

1.5 What is/are the size of project/s have you participated in? (You might select more than one)
Check all that apply.

- ☐ Very large "above MSR 30"
- ☐ Large "MSR 5-30"
- ☐ Medium "MSR 1-5"
- ☐ Small "less than SR 1000, 000"

Section two – Questions related to the contractual arrangements

2.1. What is/are the procurement method/s have you dealt with? (You might select more than one) *
Check all that apply.

- ☐ Traditional
- ☐ Management contracting
- ☐ Design and build
- ☐ Construction management
- ☐ Other:

2.2. What is/are the tendering arrangement/s have you experienced? (You might select more than one)
Check all that apply.

- ☐ Negotiation
- ☐ Open tendering
- ☐ Selective tendering
- ☐ Two-stage selective tendering
- ☐ Serial or contentious
- ☐ Other:

2.3. What is/are the tendering arrangement/s that has the most impact to project delay? (You might select more than one)
Check all that apply.

- ☐ Traditional
- ☐ Management contracting
- ☐ Design and build
- ☐ Construction management
- ☐ Other:

2.4. What is/are the tendering arrangement/s that has the most impact to project over budget? (You might select more than one)
Check all that apply.

- ☐ Traditional
- ☐ Management contracting
- ☐ Design and build
- ☐ Construction management
- ☐ Other:

Section three – Questions related to the performance of project/s you have been involved in.

3.1. How many construction projects have you participated in? Please specify ________

3.2. Was one or more of them delayed?
Check all that apply.

- Yes
- No
- Other:

3.3. How many of them were delayed? Please specify ________

3.3-1 What percentage % of delay?
Mark only one oval.

- > 25%
- 30% to 40%
- 41% to 50%
- 51% to 60%
- 61% to 70%
- More than 70%
- Other:

3.4. What is the average delay time of the delayed project/s? based on the original CPS

Mark only one oval.

- ◯ > 10%
- ◯ 10% to 30%
- ◯ 31% to 50%
- ◯ 51% to 100%
- ◯ More than 100%

3.5. What is the average of delayed time that was authorized by client/s?

Mark only one oval.

- ◯ All the delayed time
- ◯ About 75% of delayed time
- ◯ About 50 % of delayed time
- ◯ About 25% of delayed time
- ◯ The contractor paid the liquidated damages for all delayed time

3.6. Who is the first responsible party for the delay?

Mark only one oval.

- ◯ Contractor
- ◯ Consultant
- ◯ Client

3.7. Please write down the most important 5 causes of delay of construction projects in order "1-5" as per Delete repeated word region? (See the causes of delay in section four)

1-
2-
3-
4-
5-

3.8. What is the average project/s that finished under quality?

Mark only one oval.

- > 10%
- 10 % to 30%
- 31% to 50%
- 51% to 100%

3.9. Please write down the most important 5 causes of construction projects led to be under quality in order in your region?

1-
2-
3-
4-
5-

Section four – Causes of delay

Figure the following causes regarding to their frequency and severity weight. The range of weighting in the research survey scaled from 1 to 4, as shown below:

4.1. Figure the following causes regarding to their frequency and severity weight. The range of weighting in the research survey scaled from 1 to 4, as shown below:

Scale	Frequency	Severity
1	Never	No effect
2	Occasionally	Fairly severe
3	Frequently	Severe
4	Constantly	Very severe

Check all that apply.

- Other:

Contractor "frequency" - Shortage of required material

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Shortage of required material

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	Very severe

Contractor "frequency" - Delay in materials delivery

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Delay in materials delivery

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Changes in materials prices

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Changes in materials prices

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Changes in materials specifications

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Changes in materials specifications

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Equipment - Shortage of required equipment
Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "severity" - Equipment - Shortage of required equipment
Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "Severity" - Equipment - Failure of equipment
Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Equipment - Shortage of supporting and shoring installations for excavations
Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Equipment - Shortage of supporting and shoring installations for excavations
Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Equipment - Inadequate equipment used for the works
Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Equipment - Inadequate equipment used for the works
Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Manpower- Shortage of manpower (skilled, semi-skilled, unskilled labor)
Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Manpower- Shortage of manpower (skilled, semi-skilled, unskilled labor)

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Manpower - Low skills of manpower

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Manpower - Low skills of manpower

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Lack of motivation among contractor’s members

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Lack of motivation among contractor’s members

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Shortage of contractor’s administrative personnel

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Shortage of contractor’s administrative personnel

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Shortage of technical professionals in the contractor’s org.

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Shortage of technical professionals in the contractor's org.

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Contractor's poor coordination with parties' involvement in project

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Contractor's poor coordination with parties' involvement in project

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Slow preparation of changed orders requested by contractor

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Slow preparation of changed orders requested by contractor

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Ineffective contractor head office involvement in the project

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Ineffective contractor head office involvement in the project

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Delays in mobilization

Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Contractor "Severity" - Project Management - Delays in mobilization

Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Contractor "frequency" - Project Management - Poor controlling of subcontractors by contractor

Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Contractor "Severity" - Project Management - Poor controlling of subcontractors by contractor

Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Contractor "frequency" - Project Management - Loose safety rules & regulations within the contractor's org.

Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Contractor "Severity" - Project Management - Loose safety rules & regulations within the contractor's org.

Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Contractor "frequency" - Project Management - Poor qualifications of contractor's tech. staff assigned to the project

Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Contractor "Severity" - Project Management - Poor qualifications of contractor's tech. staff assigned to the project

Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Contractor "frequency" - Project Management - Improper technical studies by the contractor during bidding stage

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Improper technical studies by the contractor during bidding stage

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Ineffective planning & scheduling of the project by the contractor

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Ineffective planning & scheduling of the project by the contractor

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Delays to field survey by the contractor

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Delays to field survey by the contractor

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Management - Ineffective control of project progress by the contractor

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Management - Ineffective control of project progress by the contractor
Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Contractor "frequency" - Project Management - Inefficient quality control by the contractor
Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Contractor "Severity" - Project Management - Inefficient quality control by the contractor
Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Contractor "frequency" - Project Management - Delay in the preparation of contractor submissions
Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Contractor "Severity" - Project Management - Delay in the preparation of contractor submissions
Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Contractor "frequency" - Project Management - Improper construction methods implemented by contractor
Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Contractor "Severity" - Project Management - Improper construction methods implemented by contractor
Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Contractor "frequency" - Project Finance - Difficulties in financing the project by the contractor

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Finance - Difficulties in financing the project by the contractor

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Finance - Cash flow problems faced by the contractor

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Finance - Cash flow problems faced by the contractor

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Contractor "frequency" - Project Finance - Problems between the contractor and his subcontractors with regard to payments

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Contractor "Severity" - Project Finance - Problems between the contractor and his subcontractors with regard to payments

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Consultant "frequency" - Poor qualification of cons. engineer's staff assigned to the project

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Consultant "Severity" - Poor qualification of cons. engineer’s staff assigned to the project

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Consultant "frequency" - Delay in the preparation of drawings

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Consultant "Severity" - Delay in the preparation of drawings

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Consultant "frequency" - Delay in the approval of contractor submissions by the consultant

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Consultant "Severity" - Delay in the approval of contractor submissions by the consultant

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Consultant "frequency" - Poor com. between the consultant engineer and other parties involved

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Consultant "Severity" - Poor com. between the consultant engineer and other parties involved

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Consultant "frequency" - Poor coordination by the cons. engineer with other parties involved

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Consultant "Severity" - Poor coordination by the cons. engineer with other parties involved

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Consultant "frequency" - Delays in performing inspection and testing by the cons. engineer

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Consultant "Severity" - Delays in performing inspection and testing by the cons. engineer

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very sever

Consultant "frequency" - Slow response from the cons. engineer to contractor inquiries

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Consultant "Severity" - Slow response from the cons. engineer to contractor inquiries

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Consultant "frequency" - Inadequate design specifications

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Consultant "Severity" - Inadequate design specifications

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Consultant "frequency" - Poor contract management

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Consultant "Severity" - Poor contract management

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Client "frequency" - Delay in furnishing & delivering the site to the contractor by client

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Client "Severity" - Delay in furnishing & delivering the site to the contractor by client

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Client "frequency" - Unrealistic contract duration

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Client "Severity" - Unrealistic contract duration

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Client "frequency" - Delay in the settlement of contractor claims by the client

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Client "Severity" - Delay in the settlement of contractor claims by the client

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Client "frequency" - Suspension of work by the client's organization

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Client "Severity" - Suspension of work by the client’s organization
Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Client "frequency" - Delay in issuing of change orders by the client
Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Client "Severity" - Delay in issuing of change orders by the client
Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Client "frequency" - Slow decision making by the client’s organization
Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Client "Severity" - Slow decision making by the client’s organization
Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Client "frequency" - Interference by the client in the construction operations
Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Client "Severity" - Interference by the client in the construction operations
Mark only one oval.

	1	2	3	4	
No effect	◌	◌	◌	◌	very severe

Client "frequency" - Uncooperative client with the contractor complicating contract administration
Mark only one oval.

	1	2	3	4	
Never	◌	◌	◌	◌	constantly

Client "Severity" - Uncooperative client with the contractor complicating contract administration

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Client "frequency" - Delay in progress payments by the Clint

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Client "Severity" - Delay in progress payments by the Clint

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Client "frequency" - Client's poor com. with the construction parties and gov. authorities

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Client "Severity" - Client's poor com. with the construction parties and gov. authorities

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Client "frequency" - Client's failure to coordinate with gov. authorities during planning

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Client "Severity" - Client's failure to coordinate with gov. authorities during planning

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Client "frequency" - Poor coordination by the client with the various parties during const.

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Client "Severity" - Poor coordination by the client with the various parties during const.
Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Client "frequency" - Excessive bureaucracy in the client's administration
Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Client "Severity" - Excessive bureaucracy in the client's administration
Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Early planning & Design "frequency" - Changes in the scope of the project
Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Early planning & Design "Severity" - Changes in the scope of the project
Mark only one oval.

	1	2	3	4	
Never No effect	◯	◯	◯	◯	very severe

Early planning & Design "frequency" - Ambiguities, mistakes, and inconsistencies in specs & drawings
Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Early planning & Design "Severity" - Ambiguities, mistakes, and inconsistencies in specs & drawings
Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Early planning & Design "frequency" - Subsurface site conditions materially differing from contract documentation

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Early planning & Design "Severity" - Subsurface site conditions materially differing from contract documentation

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Early planning & Design "frequency" - Original contract duration is too short

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Early planning & Design "Severity" - Original contract duration is too short

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Governmental regulations "frequency" - Ineffective delay penalty

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Governmental regulations "Severity" - Ineffective delay penalty

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Governmental regulations "frequency" - Difficulties in obtaining work permits

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Governmental regulations "Severity" - Difficulties in obtaining work permits

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Governmental regulations "frequency" - Gov. tendering system of selecting the lowest bidding contractor

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Governmental regulations "Severity" - Gov. tendering system of selecting the lowest bidding contractor

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Governmental regulations "frequency" - Changes in government regulations and laws

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

Governmental regulations "Severity" - Changes in government regulations and laws

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

External Factors "frequency" - Severe weather conditions on the job site

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

External Factors "Severity" - Severe weather conditions on the job site

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

External Factors "frequency" - Effects of subsurface conditions (type of soil, utility lines, water table)

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

External Factors "Severity" - Effects of subsurface conditions (type of soil, utility lines, water table)

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

External Factors "frequency" - Traffic control and restrictions on the job site

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

External Factors "Severity" - Traffic control and restrictions on the job site

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

External Factors "frequency" - Effects of social and cultural conditions

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

External Factors "Severity" - Effects of social and cultural conditions

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

External Factors "frequency" - Rise in the prices of materials

Mark only one oval.

	1	2	3	4	
Never	◯	◯	◯	◯	constantly

External Factors "Severity" - Rise in the prices of materials

Mark only one oval.

	1	2	3	4	
No effect	◯	◯	◯	◯	very severe

Other comments *

[null,null,"0"]¶

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Appendix-C Questionnaire [Manual Version]

Section one – ***Questions related to the respondent's experience*.**

1.1. What is your business?

☐ Contractor
☐ Consultant
☐ Client/ Client representative
☐ Other. Please specify ____________________

1.2. What is the sector type you work for?

☐ Public
☐ Private
☐ Both

1.3. How long have you been dealing with construction projects?

☐ <5 years
☐ 5-10 years
☐ 11-15 years
☐ >15 years

1.4. What is your specialty in building construction?

☐ Commercial buildings
☐ Industrial buildings
☐ Governmental buildings
☐ Residential Buildings
☐ Other. please specify ______________________________________

1.5. What is/are the size of project/s have you participated in?
(You may select more than one)

☐ Very large "Above MSR 30"
☐ Large "MSR 5-30"
☐ Medium "MSR 1-5"
☐ Small "less than SR 1000, 000"

Section two – ***Questions related to the contractual arrangements***

2.1. What is/are the procurement method/s have you dealt with?
(You may select more than one)

☐ Traditional
☐ Management contracting
☐ Design and build
☐ Construction management
☐ Other. please specify_______________________________________

2.2. What is/are the tendering arrangement/s have you experienced?
(You may select more than one)
☐ Negotiation
☐ Open tendering
☐ Selective tendering
☐ Two-stage selective tendering
☐ Serial or contentious please specify______________________________

2.3. What is/are the tendering arrangement/s that has the most impact to project delay?
(You may select more than one)
☐ Traditional
☐ Management contracting
☐ Design and build
☐ Construction management
☐ Other. please specify____

2.4. What is/are the tendering arrangement/s that has the most impact to project over budget?
(You may select more than one)
☐ Traditional
☐ Management contracting
☐ Design and build
☐ Construction management
☐ Other. please specify____

Section three – *Questions related to the performance of project/s you have been involved in.*

3.1. How many construction projects have you participated in?
Please specify ________

3.2. Was one or more of them delayed?
☐ Yes
☐ No
If the answer to question 3.2 is NO, please go to question 3.6

3.3. How many of them were delayed?
Please specify ________ and what %

3.3.1 What is the average delay time of the delayed project/s?
☐ Less than 25%
☐ 30 to 40 %
☐ 41 to 50 %
☐ 51 to 60 %
☐ 61 to 70 %
☐ Over 70 % please specify __________________

3.4. What is the average delay time of the delayed project/s? based on the original CPS

☐ Less than 10%
☐ 10 to 30 %
☐ 31 to 50 %
☐ 51 to 100 %
☐ Over 100 %, please specify ___________________

3.5. What is the average of delayed time that was authorized by client/s?

☐ All the delayed time
☐ About 75% of delayed time
☐ About 50 % of delayed time
☐ About 25% of delayed time
☐ The contractor paid the liquidated damages for all delayed time. The compensation payable to someone for a civil wrong, as opposed to a criminal wrong, for which a different system applies

3.6 Who is the first responsible party for the delay?

☐ Contractor
☐ Consultant
☐ Client

3.7. Please write down the most important 5 causes of delay of construction projects in order in your region? (See the causes of delay in section four)

1. ____
2. ____
3. ____
4. ____
5. ____

3.8. What was the average project/s that finished under quality?

☐ Less than 10%
☐ 10 to 30 %
☐ 31 to 50 %
☐ 51 to 100%
☐ Over 100 % please specify ____________________

3.9. Please write down the most important 5 causes of delay of construction projects in order in your region? (See the causes of delay in section four)

1. ____
2. ____
3. ____
4. ____
5. ____

Section four – *Causes of delay*

Figure -1 the following causes regarding their frequency and severity weight. The range of weighing in the research survey scaled from 1 to 4, as shown below:

Scale	Frequency	Severity
1	Never	No effect
2	Occasionally	Fairly severe
3	Frequently	Severe
4	Constantly	Very severe

Figure 4.4

Causes of delay **Frequency / Severity**

Contractor	Frequency				Severity			
Materials:	1	2	3	4	1	2	3	4
1. Shortage of required material	☐	☐	☐	☐	☐	☐	☐	☐
2. Delay in materials delivery	☐	☐	☐	☐	☐	☐	☐	☐
3. Changes in materials prices	☐	☐	☐	☐	☐	☐	☐	☐
4. Changes in materials specifications	☐	☐	☐	☐	☐	☐	☐	☐
Equipment:								
5. Shortage of required equipment	☐	☐	☐	☐	☐	☐	☐	☐
6. Failure of equipment	☐	☐	☐	☐	☐	☐	☐	☐
7. Shortage of supporting and shoring installations for excavations	☐	☐	☐	☐	☐	☐	☐	☐
8. Inadequate equipment used for the works	☐	☐	☐	☐	☐	☐	☐	☐
Manpower:								
9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	☐	☐	☐	☐	☐	☐	☐	☐
10. Low skill of manpower	☐	☐	☐	☐	☐	☐	☐	☐
Project Management:								
11. Lack of motivation among contractor's members	☐	☐	☐	☐	☐	☐	☐	☐
12. Shortage of contractor's administrative personnel	☐	☐	☐	☐	☐	☐	☐	☐
13. Shortage of technical professionals in the contractor's org.	☐	☐	☐	☐	☐	☐	☐	☐
14. Poor com. by contractor with the parties' invol. In project	☐	☐	☐	☐	☐	☐	☐	☐
15. Contractor's poor coordination with parties' invol. in project	☐	☐	☐	☐	☐	☐	☐	☐
16. Slow preparation of changed orders requested by contractor	☐	☐	☐	☐	☐	☐	☐	☐
17. Ineffective contractor head office involvement in the project	☐	☐	☐	☐	☐	☐	☐	☐
18. Delays in mobilization	☐	☐	☐	☐	☐	☐	☐	☐
19. Poor controlling of subcontractors by contractor	☐	☐	☐	☐	☐	☐	☐	☐

20. Loose safety rules & regulations within the contractor’s org. ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
21. Poor qualifications of contractor’s tech. staff assigned to the project ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
22. Improper technical studies by the contractor during bidding stage ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
23. Ineffective planning & scheduling of the project by the contractor ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
24. Delays to field survey by the contractor ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
25. Ineffective control of project progress by the contractor ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
26. Inefficient quality control by the contractor ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
27. Delay in the preparation of contractor submissions ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
28. Improper construction methods implemented by contractor ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Project Finance:

29. Difficulties in financing the project by the contractor ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
30. Cash flow problems faced by the contractor ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
31. Problems between the contractor and his subcontractors with regard to payments. ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Consultant:

32. Poor qualification of cons. engineer’s staff assigned to the project ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
33. Delay in the preparation of drawings ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
34. Delay in the approval of contractor submissions by the consultant ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
35. Poor com. between the consultant engineer and other parties involved ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
36. Poor coordination by the cons. engineer with other parties involved ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
37. Delays in performing inspection and testing by the cons. engineer ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
38. Slow response from the cons. engineer to contractor inquiries ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
39. Inadequate design specifications ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
40. Poor contract management ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Client:

41. Delay in furnishing & delivering the site to the contractor by client ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
42. Unrealistic contract duration ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
43. Delay in the settlement of contractor claims by the client ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
44. Suspension of work by the client’s organization ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
45. Delay in issuing of change orders by the client ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
46. Slow decision making by the client’s organization ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
47. Interference by the client in the construction operations ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
48. Uncooperative client with the contractor complicating contract administration ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
49. Delay in progress payments by the client ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
50. Client’s poor com. with the construction parties and gov. authorities ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
51. Client’s failure to coordinate with gov. authorities during planning ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
52. Poor coordination by the client with the various parties during const. ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
53. Excessive bureaucracy in the client’s administration ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Early Planning and design

54. Changes in the scope of the project
55. Ambiguities, mistakes, and inconsistencies in specs & drawings ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
56. Subsurface site conditions materially differing from contract docum. ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
57. Original contract duration is too short ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Government Regulations

58. Ineffective delay penalty ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
59. Difficulties in obtaining work permits ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
60. Gov. tendering system of selecting the lowest bidding contractor ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
61. Changes in government regulations and laws ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

External Factors

62. Severe weather conditions on the job site	☐	☐	☐	☐	☐	☐	☐	☐
63. Effects of subsurface conditions (type of soil, utility lines, water table)	☐	☐	☐	☐	☐	☐	☐	☐
64. Traffic control and restrictions on the job site	☐	☐	☐	☐	☐	☐	☐	☐
65. Effects of social and cultural conditions	☐	☐	☐	☐	☐	☐	☐	☐
66. Rise in the prices of materials	☐	☐	☐	☐	☐	☐	☐	☐

Other Comments:

Thank you very much; your response is highly appreciated.
Please send your response to:
Abkwaik@hotmail.com

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The Analysis of Project Delay Factors Using the Double-Roof House of Quality

Abdulwahab Abu Kwaik,[1] Enda Fallon,[2] and Pat Donnellan[2]

Abstract— One of the biggest engineering concerns in the Middle East is the major delays in infrastructural projects which impact on both their quality and cost. A significant number of projects do not finish on time, are subject to cost overruns and are not completed to the specified quality. The Kingdom of Saudi Arabia (KSA) claims losses of the order of $ 40 Billion per annum as a result of these issues. Information on the factors contributing to project delays was studied. A literature review which determined the main project delay factors was first carried out. An online survey incorporating 66 of these was then developed with the purpose of identifying the most critical factors contributing to project delays. The survey was administered to over 200 specialists in the area of project engineering. This cohort included; Consultants, Business Owners, Project Directors, Project Engineers, Safety and Quality Managers and Contracting Managers. The resulting delay factors were ranked in order of priority based on a weighted index incorporating dimensions of Frequency and Severity. The non-linear relationships between 'customer attributes' and 'critical delay factors' in infrastructural projects was modeled using a 'House of Quality Tool 'with an innovative double roof. The method enabled the identification of the top 20 delay factors with respect to the following customer attributes; "Time, Cost, Quality, Safety and Environment". The highest ranked factors which impacted on all the customer attributes were; the shortage of technical professionals, unrealistic specified times and inadequate design and specification. The lowest ranked factors included; contractor cash flow problems and slow decision making by the client. The Double-Roof House of Quality Tools proved to be useful in determining and representing the relationships between 'customer attributes' and 'critical delay factors'. The next phase of the work is to model the non-linear nature of the relationship using Fuzzy Logic. The ultimate goal is to provide expert guidance on strategy with respect to the focus on delaying factors in major infrastructural projects. (Abstract)

Keywords— Project Management, House of Quality, Quality Function Deployment, Integrated Weighted Index and Fuzzy Logic.

I. Introduction

It is almost axiomatic of construction management that the project may be regarded as successful if the building is completed on time, within budget, and is of the desired quality. It is commonly said, however, that whereas two out of those three can often be achieved, because of the complexities involved in a construction contract, and in particular the many different trades and professions that are commonly involved.

Realistic construction time is now increasingly of the essence because it often serves as a crucial benchmark for assessing the performance of a project and the efficiency of the project organization. A fundamental specification of the construction contract is the project period or time of project execution, which is established prior to bidding. The successful execution of construction projects and keeping them within estimated cost and prescribed schedules depend on a methodology that requires sound engineering judgment).

Project completion for the owner means that he can make use of his new assets on time by habitation, renting, or selling. Any delay in project completion will disturb his/her plans. The client will not be able to make use of the property, and his/her business will be affected in almost all areas, especially finance. For the contractor, any delay in completion of the project gives rise to indirect overhead expenses and additional payments to the project staff and workforce. It also means that he will possibly be subjected to compensation claims. His next project might be cancelled as a result of delays in the present project, and loss of future opportunities will be made more likely by damage to his reputation and credibility. The consultants and all other parties involved will also lose if the project is delayed: they will at least lose time, which may mean losing money.

Despite the great effort that has been put into the evolution of construction project planning and control during the last four decades, delay is still a very common feature of construction projects in Saudi Arabia. These often result in adversarial relationships between construction stakeholders (clients, contractors, consultants, etc.): distrust, litigation, arbitration, cash-flow problems, and a general feeling of apprehension towards each other. In recent years, Saudi Arabia's construction enterprises increased greatly in many fields. According to recent analysis, the level of uncompleted projects reached to more than 40% which requires a strong attention [7]. Factors of delays differ from one country to another as well as the type and also the purpose the projects.

II. Materials and Methods

The analysis that has been used was divided into 3-stages. The 1st stage was concerned with identifying critical delay factors from the previous studies in the literature reviews. More than 300 different factors were collected and they have been grouped and filtered to 66 critical factors of delays. The 2nd stage involved an analysis of a survey that was administrated to 167 specialists from projects & engineering fields to prioritize the factors based on frequency and severity. The 3rd stage was based on using a newly developed tool inspired from the House of Quality. The new tool was named "Double Roof House of Quality [DRHOQ].

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A. *Methods of Analysis (Delay Factors) Ranking*

Data collected from the survey was analyzed using descriptive statistical techniques [3]. An advanced and accurate analysis method was needed to arrange the large amount of data in a systematic, fast and reliable way. Google online survey Statistical Computing and Excel-Office were chosen to be used in this stage.

The respondents were asked to share their views for rating the factors of delays based on their frequency and severity weightings. The scales provided ranges from 1 to 4 as shown in Table I. However, in order to complete the quantitative measure of the frequency and the severity, it was decided to give an equal weight for both "Frequency & Severity".

TABLE I. FREQUENCY AND SEVERITY WEIGHTING

Scale	Frequency	Severity
1	Never	No effect
2	Occasionally	Fairly severe
3	Frequently	Severe
4	Constantly	Very severe

The average score or the Index of frequency (FI) and severity (SI) for each delay factor was calculated by the following formula:

- **Equation-1** Frequency Index F.I.%

$$F.I. = \frac{\sum_{0}^{4} a_i n_i}{4N}$$

- **Equation-2** Severity Index S.I.%

a = constant expressing the weight assigned to each responses (ranges from 0 for No happen to 4 for Always), n = frequency of each response, N = total number of responses

$$S.I. = \frac{\sum_{0}^{4} a_i n_i}{4N}$$

a = constant expressing the weight assigned to each responses (ranges from 0 for No happen to 4 for Always), n = frequency of each response. N = total number of responses

The Important Index (IMP. I) was calculated by multiplying the S.I x F.I. The Important Weighted Index (IWI) was resulting by multiplying the IMP.I. x m as follow:

- **Equation-3** Important Index IMP.I.%

$$IMP.I. = F.I. \times S.I.$$

- **Equation 4** Importance Index of the category

$$\mathbf{IWI = AW * m}$$

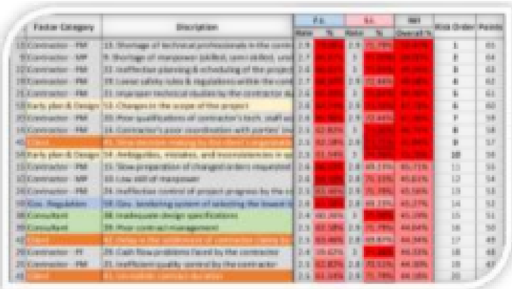
While,

$$m = \frac{\text{The number of category causes}}{\text{Total number of all causes}}$$

B. *Top 20 Causes of Delays:*

After the analysis, it was found that 12 factors out of top 20 were related to the contractors. The most important factor found was "shortage of technical professionals in the contractor organization" with important weight index (IWI) 53%. Table II indicates the top 20 factors of delays with their rankings. The general conclusion from these factors there is a shortage of the qualified technical staff and allocating them to the right positions. Improper technical studies, weak planning/ scheduling, losing safety roles, frequent changes in the scope and finally the poor communication between all parties are mostly the critical reasons behind projects delay.

TABLE II. TOP 20 FACTORS OF DELAYS



C. *Top 10 (highest severity) Factors of Delays:*

One of the important things to know after identifying the top 20 factors of delays, the factors that have high severity in order to give an alerts in the last chapter about what should be avoided or at least not to elevate their impacts to the major undertaken projects.

TABLE III. TOP 10 (HIGHEST SEVERITY) FACTORS OF DELAY

23

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No.	Factor Category	Discription	F.I. Ratio	F.I. %	S.I. Ratio	S.I. %	RII Overall %	Risk Order	Points
22	Contractor - PM	22. Ineffective planning & scheduling of the project	2.6	[illegible]	3.03	[illegible]	[illegible]	3	62
21	Contractor - PM	21. Improper technical studies by the contractor d[illegible]	2.6	[illegible]	3.03	[illegible]	[illegible]	5	61
28	Contractor - PF	28. Difficulties in financing the project by the contr[illegible]	2.3	57.00%	3.03	[illegible]	[illegible]	25	41
9	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, un[illegible]	2.7	[illegible]	3.00	[illegible]	[illegible]	2	64
38	Consultant	38. Inadequate design specifications	2.4	[illegible]	3.00	[illegible]	[illegible]	15	51
14	Contractor - PM	14. Contractor's poor coordination with parties' in[illegible]	2.5	[illegible]	2.97	[illegible]	[illegible]	8	58
54	Early plan & Design	54. Ambiguities, mistakes, and inconsistencies in sp[illegible]	2.5	[illegible]	2.97	[illegible]	[illegible]	10	56
29	Contractor - PF	29. Cash flow problems faced by the contractor	2.4	[illegible]	2.97	[illegible]	[illegible]	18	48
53	Early plan & Design	53. Changes in the scope of the project	2.6	[illegible]	2.93	[illegible]	[illegible]	6	60
45	Client	45. Slow decision making by the client's organization	2.5	[illegible]	2.93	[illegible]	[illegible]	9	57

As shown in the table III above that highest severity index (S.I.%) is 76% and most of the participants admitted that the difficulties in financing the project by contractor is the highest concern and has a big influence in delaying any project. The second one is the improper technical studies by contractor during the bidding and followed by the ineffective planning & scheduling by contractor.

D. *Top 10 (highest frequency) Factors of Delays:*

Describing the critical factors of delays was giving the impacts based on both the severity and frequency and in this part will be talking about the factors that are mostly repeated in general projects and all parties are facing them in their daily projects. Eight factors out of 10 are related to the contactors and they seem to be a chronic and the projects mangers suffer for getting them repeated and seen every time particularly in the execution stage.

TABLE IV. Top 10 (Highest Frequency) Factors of Delay

No.	Factor Category	Discription	F.I. Ratio	F.I. %	S.I. Ratio	S.I. %	RII Overall %	Risk Order	Points
13	Contractor - PM	13. Shortage of technical professionals in the contr[illegible]	2.9	[illegible]	2.87	[illegible]	[illegible]	1	65
19	Contractor - PM	19. Loose safety rules & regulations within the cont[illegible]	2.7	[illegible]	2.90	[illegible]	[illegible]	4	62
9	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, un[illegible]	2.7	[illegible]	3.00	[illegible]	[illegible]	2	64
22	Contractor - PM	22. Ineffective planning & scheduling of the project	2.6	[illegible]	3.03	[illegible]	[illegible]	3	62
15	Contractor - PM	15. Slow preparation of changed orders requested	2.6	[illegible]	2.77	[illegible]	[illegible]	11	55
21	Contractor - PM	21. Improper technical studies by the contractor d[illegible]	2.6	[illegible]	3.03	[illegible]	[illegible]	5	61
20	Contractor - PM	20. Poor qualifications of contractor's tech. staff as[illegible]	2.6	[illegible]	2.90	[illegible]	[illegible]	7	59
39	Gov. Regulation	39. Gov. tendering system of selecting the lowest b[illegible]	2.6	[illegible]	2.77	[illegible]	[illegible]	14	52
53	Early plan & Design	53. Changes in the scope of the project	2.6	[illegible]	2.93	[illegible]	[illegible]	6	60
10	Contractor - MP	10. Low skill of manpower	2.6	[illegible]	2.80	[illegible]	[illegible]	12	54

Table IV above shows the top 10 factors that are frequently appear as they go day after day. The most frequent factor is shortage of technical professionals in the contractor's organization. Lose safety rules & regulation is ranked the 2nd in the contractor's organization followed by shortage of the general staff skills from high to low. Ineffective planning & scheduling, Slow preparation of change orders during bedding time, improper technical studies and poor qualification for staff assigned to the project by contractor are ranked respectively the 4th, 5th, 6th and 7th.

III. *Double Roof House of Quality*

House of Quality is a diagram, whose structure resembles that of a house which aids in determining how a product or service is living up to customer needs. Although quite intricate, it is capable of storing a lot of information and comparing large amounts of data used for defining the relationship between customer desires and the firm/product capabilities.[1] It is a part of the quality function deployment (QFD) and utilizes a planning matrix to relate what the customer wants to how a firm (that produces the products or service) is going to meet those wants. It looks like a house with a "correlation matrix" as its roof, customer wants versus product features as the main structure, competitor evaluation as the porch, etc. It is based on "the belief that products should be designed to reflect customers' desires and tastes".[4] It also is reported to increase cross functional integration within organizations using it, especially between marketing, engineering and manufacturing. The basic structure is a table with "Whats" as the labels on the left and "Hows" across the top. The roof is a diagonal matrix of "Hows vs. Hows" or What's vs Whats and the body of the house is a matrix of "Whats vs. Hows". Both of these matrices are filled with indicators of whether the interaction of the specific item is a strong positive, a strong negative, or somewhere in between. Additional annexes on the right side and bottom hold the "Whys" (market research, etc.) and the "How Muches". Rankings based on the Whys and the correlations can be used to calculate priorities for the Hows.
House of Quality analysis can also be cascaded, with "Hows" from one level becoming the "Whats" of a lower level; as this progress the decisions get closer to the engineering & manufacturing details. The double-roof concept has been developed in the research so that it can consider both Hows vs. Hows and Whats vs. Whats especially if the relations are strong and effective between them. This is kind of concept is very new and innovative since nothing found in the previous studies have investigated the relations between the technical delay factors. The fig. 1 below shows the both roofs, the 1st roof is fixed in the top of the structure to reflect the relation between the customers attributes. The 2nd roof is fixed in the left side of the structure to reflect as well the inter-relations between the top 20's factors of delays.

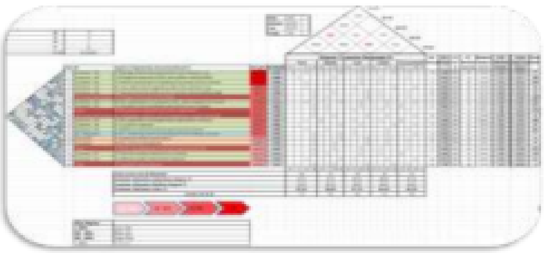

Figure 1. Double Roof House of Quality

Single-roof house of quality described the both relations between Hows and Whats relations in the main structure i.e. "0, 1, 2 and 3" while the 2nd relations have been built in the top roof between the Whats vs. Whats i.e. "nothing, low, Medium and high".

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Fig. 2 below shows how the customer attributes such as time, cost, quality, safety and environment have inter-relations between each one of them. Hence, relation degrees have been interpreted in each one of them based on expert's opinions and decisions that was called for this purpose.

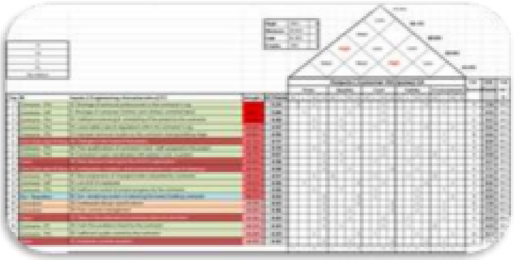

Figure 2. First -Roof House of Quality

The left fixed roof represented all relations between the Engineering Characteristics or the top 20's critical factor of delays. The degree of relations where described as follows:

- No-relation
- Very-low
- Low
- Medium
- High

The total number of relations was 361 relations were interpreted to points that reflect how each factor of delays interacts or getting influenced by others. An (engineering degree index) was created to represent this kind of relations by giving an independent weight for each factor of delay. The range of degree was (17% to 41%). Figure-3 below shows the degree of relations between all factors of delays.

Figure 3. Second Roof House of Quality

Total numbers of relations reached to 477 relations, 361 out of them were relations between factors of delays and a 100 for relations between factors of delays vs. customer attributes and the last 16 were for customer attributes among each other.

IV. Results

As a result of the three stages of analysis, table v. below shows clearly how the ranking of the factors got changed and how the additional weights that have been created by the influence of house of quality contributed to further adjustments in order to give a more rational for the proper ranking of each critical factor. As example factor-1 "shortage of technical staff" changed from R-1 to R-2 and F-15 "Inadequate design specification changed from R-15 to R-3.

TABLE V. Factors Of Delays Adjusted Ranking

The ranking for the critical delay factors were completely reordered after the realization of all influenced factors as discussed before. The contribution of all relations "EC weight, EC-Index and CA-Index" have been formulated to the total adjusted weight. The highest score was giving the 1st rank and the lowest was considered the last. Figure-4 below gives the three different indexes influences with each critical factor of delay.

IV. Discussions

Most of the previous studies were concerned about finding the critical factors of delays by using different methods and techniques. Some of them have done further analysis assuming all factors have linear relations but in fact and after detailed analysis, it has been found that most of the factors have non-linear relations with customer attributes and even among each other. Here in this research, the critical delays factors have been evaluated thoroughly in many workshops to find wither these relations got influenced by other factors or not in order to give sensitive weights that reflects the reality.

This research has a unique principle of considering the effects between all delay factors which represented around 477 different degrees of relations which helped to create three additional indexes that have recharged the complete rankings. In the fig. 4 below shows how the top 20's factors of delays are influenced by the expert ratings, other factors of delays and customer attributes such as time, cost and quality.

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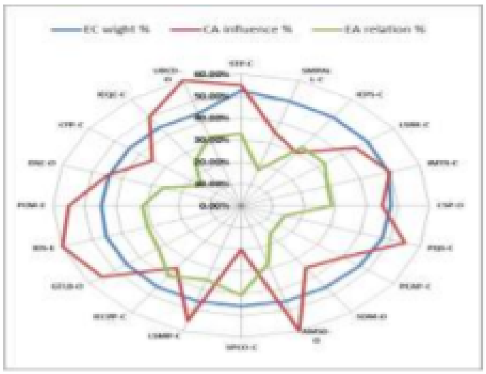

Figure 4. All Indexes Relations With Factors Of Delay

The final adjusted ranking has shown that the unrealistic time duration that is usually planned at the very beginning of the project is the main reason of delayed followed by shortage of professional in the contractor organization. The inadequate design and specification by consultant was ranked as a 3rd critical factor. Figure 4 gives full details of ranking for the top factors of delays from highest to lowest.

Acknowledgment

Thanks to the Almighty Allah for enabling me to complete my research. Big thanks to the ministry of education for giving me this chance of the higher education and helping me to excel in the rest of my life. Special thanks for all who supported me during the stage of data collections and analysis.

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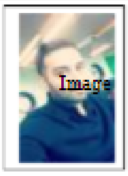
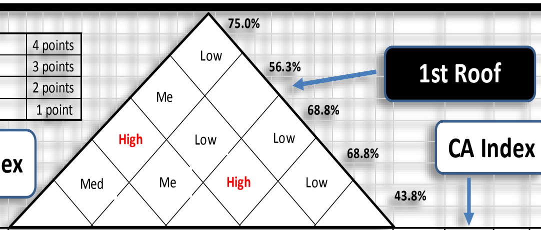


I hope to continue building my acting career and work more in projects that fulfill my artistic thirst

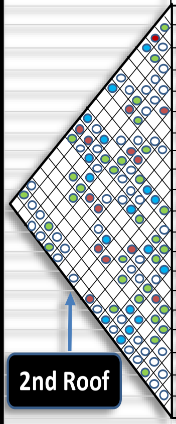
TABLE-2: DUBLE ROOF HOUSE OF QUALITY (MAIN TABLE)

76% to 100%	●	High:	4 points
51% to 75%	●	Medium:	3 points
26% to 50%	●	Low:	2 points
0% to 25%	○	V. Low:	1 point
0%	Empty	No relation:	0

High	4 points
Meduim	3 points
Low	2 points
Empty	1 point



RII Index CA Index EC Index TA Index



Top 20	Factors of Delay	Inputs (Engineering Characteristics) EC	RII %	EC Points	Time				Quality				Cost				Safety				Environment				CA Scores	CA Points	CA Inf. %	EC Relation Scores	Relation Degree EC %	EC Relation Points	Total Adjusted Score	Final Rank
					N	L	M	H	N	L	M	H	N	L	M	H	N	L	M	H	N	L	M	H								
1	Contractor - PM	13. Shortage of technical professionals in the contractor's org.	52.47%	5.25			2					3			2					3		1			11	7.0	73%	25	32.9%	3.3	15.56	2
2	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	50.00%	5.00		1					2				2			1				1			7	4.4	47%	13	17.1%	1.7	11.07	18
3	Contractor - PM	22. Ineffective planning & scheduling of the project by the contractor	49.94%	4.99			2			1					2			1			0				6	4.2	40%	25	32.9%	3.3	12.44	14
4	Contractor - PM	19. Loose safety rules & regulations within the contractor's org.	49.68%	4.97			2			1				1						3			2		9	5.6	60%	25	32.9%	3.3	13.83	9
5	Contractor - PM	21. Improper technical studies by the contractor during bidding stage	49.46%	4.95				3			2					3		1				1			10	6.6	67%	22	28.9%	2.9	14.45	8
6	Clint- Early plan & Design	53. Changes in the scope of the project	47.73%	4.77				3		1						3		1				1			9	6.0	60%	22	28.9%	2.9	13.68	10
7	Contractor - PM	20. Poor qualifications of contractor's tech. staff assigned to the project	47.36%	4.74			2					3			2				2				2		11	5.7	73%	11	14.5%	1.4	11.91	15
8	Contractor - PM	14. Contractor's poor coordination with parties' invol. in project	46.71%	4.67				3		1					2				2		0				8	5.0	53%	11	14.5%	1.4	11.15	17
9	Client	45. Slow decision making by the client's organization	45.84%	4.58				3		1				1				1				1			7	4.7	47%	12	15.8%	1.6	10.83	20
10	Clint- Early plan & Design	54. Ambiguities, mistakes, and inconsistencies in specs & drawings	45.76%	4.58				3			2					3			2				2		12	7.7	80%	21	27.6%	2.8	14.99	4
11	Contractor - PM	15. Slow preparation of changed orders requested by contractor	45.71%	4.57			2		0					1				1			0				4	2.9	27%	31	40.8%	4.1	11.54	16
12	Contractor - MP	10. Low skill of manpower	45.61%	4.56		1						3			2					3			2		11	6.6	73%	27	35.5%	3.6	14.76	6
13	Contractor - PM	24. Ineffective control of project progress by the contractor	45.56%	4.56			2			1				1					2			1			7	4.5	47%	30	39.5%	3.9	13.03	12
14	Gov. Regulation	59. Gov. tendering system of selecting the lowest bidding contractor	45.27%	4.53				3				3		1					2				2		11	6.9	73%	25	32.9%	3.3	14.70	7
15	Consultant	38. Inadequate design specifications	45.19%	4.52				3				3				3			2			1			12	7.8	80%	24	31.6%	3.2	15.52	3
16	Consultant	39. Poor contract management	44.64%	4.46				3			2					3			2			1			11	7.3	73%	24	31.6%	3.2	14.87	5
17	Client	42. Delay in the settlement of contractor claims by the client	44.34%	4.43				3			2				2			1				1			9	5.9	60%	20	26.3%	2.6	12.99	13
18	Contractor - PF	29. Cash flow problems faced by the contractor	44.33%	4.43				3		1					2			1			0				7	4.9	47%	12	15.8%	1.6	10.95	19
19	Contractor - PM	25. Inefficient quality control by the contractor	44.30%	4.43			2					3		1					2				2		10	6.1	67%	19	25.0%	2.5	13.03	11
20	Client	41. Unrealistic contract duration	44.18%	4.42				3			2					3				3		1			12	7.9	80%	25	32.9%	3.3	15.60	1
					0	2	14	33	0	7	12	18	0	6	16	18	0	8	16	12	0	10	12	0	Out of 15			Out of 76			Out of 35	

	Time	Quality	Cost	Safety	Environment
Total scores out of 60 points	49	37	40	36	22
Customer Attriputes - Aggregate Degree % (20 Delay Factors)	81.7%	61.7%	66.7%	60.0%	36.7%
Customer Attriputes Relation Degree %	75.0%	56.3%	68.8%	68.8%	43.8%
Customer Attriputes - Average index %	78.3%	59.0%	67.7%	64.4%	40.2%
Points out of 10	7.8	5.9	6.8	6.4	4.0

RII % 30 - 39% 40- 45% 45.3- 49% < 50%

TABLE-3: DUBLE ROOF HOUSE OF QUALITY (TOP-10 FACTORS INDICES)

1- Unrealistic contract time duration..			
· Symbol: URCD-CL			
· Type: (Client) responsibility			
	Delay Factor	Lowest	Highest
Frequency Index: 61.5%	61.50%	44.90%	71.30%
Severity Index: 71.8%	71.80%	51.90%	75.60%
RII: 44.2%	44.20%	23.30%	52.50%
CA Index: 60%	60.00%	27%	80%
EC Index: 32.9%	33%	14.50%	40.80%
Total adjusted Score: 15.6/30	52.00%	36.10%	52.00%
2- Shortage of technical Professional in the contractor Organization (cor			
· Symbol: STP-C			
· Type: (Contactor) responsibility			
	Actual	Lowest	Highest
Frequency Index: 73%	73%	44.90%	71.30%
Severity Index: 71.8%	71.80%	51.90%	75.60%
RII: 52.5%	52.50%	23.30%	52.50%
CA Index: 55%	55%	27%	80%
EC Index: 32.9%	32.90%	14.50%	40.80%
Total adjusted Score: 15.56/30	51.87%	36.10%	52.00%
3- Inadequate design specifications			
· Symbol: IDS-E			
· Type: (Consultant) responsibility			
	Delay Factor	Lowest	Highest
Frequency Index: 60.3%	60.30%	44.90%	71.30%
Severity Index: 75%	75%	51.90%	75.60%
RII: 45.2%	45.20%	23.30%	52.50%
CA Index: 60%	60%	27%	80%
EC Index: 31.6%	31.60%	14.50%	40.80%
Total adjusted Score: 14.87/30	50%	36.10%	52.00%
4- Ambiguities, mistakes, and inconsistencies in specs & drawings			
· Symbol: AMSD-O			
· Type: (Client) responsibility			
	Delay Factor	Lowest	Highest
Frequency Index: 61.5%	61.50%	44.90%	71.30%
Severity Index: 74.4	74.40%	51.90%	75.60%
RII: 45.76%	45.76%	23.30%	52.50%
CA Index: 60%	60%	27%	80%
EC Index: 27.6%	27.60%	14.50%	40.80%
Total adjusted Score: 14.99/30	49.97%	36.10%	52.00%
5- Poor contract management			
· Symbol: PCM-E			
· Type: (Consultant) responsibility	Delay Factor	Lowest	Highest
Frequency Index: 62.2%	62.20%	44.90%	71.30%
Severity Index: 71.8%	71.80%	51.90%	75.60%
RII: 44.64%	44.64%	23.30%	52.50%
CA Index: 55%	55%	27%	80%
EC Index: 31.6%	31.60%	14.50%	40.80%
Total adjusted Score: 14.87/30	49.57%	36.10%	52.00%

6- Low skill of manpower			
· Symbol: LSMP-C			
· Type: (Contactor) responsibility	Delay Factor	Lowest	Highest
Frequency Index: 64.1%	64.10%	44.90%	71.30%
Severity Index: 71.2%	71.20%	51.90%	75.60%
RII: 45.61%	45.61%	23.30%	52.50%
CA Index: 55%	55%	27%	80%
EC Index: 35.5%	35.50%	14.50%	40.80%
Total adjusted Score: 14.76/30	49.20%	36.10%	52.00%
7- Gov. tendering system of selecting the lowest bidding contractor			
· Symbol: GTLB-O			
· Type: (Client+others) responsibility	Delay Factor	Lowest	Highest
Frequency Index: 65.4%	65.40%	44.90%	71.30%
Severity Index: 69.2%	69.20%	51.90%	75.60%
RII: 45.27%	45.27%	23.30%	52.50%
CA Index: 55%	55%	27%	80%
EC Index: 32.9%	32.90%	14.50%	40.80%
Total adjusted Score: 14.7/30	49.00%	36.10%	52.00%
8- Improper technical studies by the contractor during bidding stage			
· Symbol: IMTS-C			
· Type: (Contactor) responsibility	Delay Factor	Lowest	Highest
Frequency Index: 65.4%	65.40%	44.90%	71.30%
Severity Index: 75.6%	75.60%	51.90%	75.60%
RII: 49.46%	49.46%	23.30%	52.50%
CA Index: 50%	50%	27%	80%
EC Index: 28.9%	28.90%	14.50%	40.80%
Total adjusted Score: 14.45/30	48.17%	36.10%	52.00%
9- Loose safety rules & regulations within the contractor's org.			
· Symbol: LSRR-C			
· Type: (Contactor) responsibility	Delay Factor	Lowest	Highest
Frequency Index: 68.6%	68.80%	44.90%	71.30%
Severity Index: 72.4%	72.40%	51.90%	75.60%
RII: 49.68%	49.68%	23.30%	52.50%
CA Index: 45%	45%	27%	80%
EC Index: 32.9%	32.90%	14.50%	40.80%
Total adjusted Score: 13.83/30	46.10%	36.10%	52.00%
10- Changes in the scope of the project			
· Symbol: CSP-O			
· Type: (Client) responsibility	Delay Factor	Lowest	Highest
Frequency Index: 64.7%	64.70%	44.90%	71.30%
Severity Index: 73.7%	73.70%	51.90%	75.60%
RII: 47.73%	47.73%	23.30%	52.50%
CA Index: 45%	45%	27%	80%
EC Index: 28.9%	28.90%	14.50%	40.80%
Total adjusted Score: 13.68/30	45.60%	36.10%	52.00%

TABLE-4: Indices Contributions (TOP-20 FACTORS INDICES)

Delay Factors	EC wight %	CA inf. %	EA relation %	Total Adjusted score	Rank
STP-C	52.5%	55.0%	32.9%	15.6	2
SMPALL-C	50.0%	35.0%	17.1%	11.1	18
IEPS-C	49.9%	30.0%	32.9%	12.4	14
LSRR-C	49.7%	45.0%	32.9%	13.8	9
IMTS-C	49.5%	50.0%	28.9%	14.4	8
CSP-O	47.7%	45.0%	28.9%	13.7	10
PQS-C	47.4%	55.0%	14.5%	11.9	15
PCAP-C	46.7%	40.0%	14.5%	11.1	17
SDM-O	45.8%	35.0%	15.8%	10.8	20
AMSD-O	45.8%	60.0%	27.6%	15.0	4
SPCO-C	45.7%	20.0%	40.8%	11.5	16
LSMP-C	45.6%	55.0%	35.5%	14.8	6
IECPP-C	45.6%	35.0%	39.5%	13.0	12
GTLB-O	45.3%	55.0%	32.9%	14.7	7
IDS-E	45.2%	60.0%	31.6%	15.5	3
PCM-E	44.6%	55.0%	31.6%	14.9	5
DSC-O	44.3%	45.0%	26.3%	13.0	13
CFP-C	44.3%	35.0%	15.8%	10.9	19
IEQC-C	44.3%	50.0%	25.0%	13.0	11
URCD-O	44.2%	60.0%	32.9%	15.6	1

Appendix E Group of Delay Factors

TABLES (5-13): DELAY FACTORS RELATIONS (MAIN TABLES)

RED - Relations	75%- 100%				
	Factor-1	Factor-2	Factor-3	Factor -4	Factor-5
1	Imp. Tech study	Amb. , mistakes in specs	Inadq. Design & specs	chages in scope of proj.	
2	Amb. & mistakes in specs	changes in scope of proj.	imp. Tech. study	inade. Design & specs	Unrealstic cont. duration
3	Dealy in settlement	slow decision making - Cl	cont. poor coordination		
4	Short. Of tech staff	Low skills of Manpower			
5	short. Of manpoer all skills	Low skills of Manpower			
6	Low skills of manpower	short. Of tech. staff	short. Of mapoer all skills		
7	poor cntract management	gov. tendering sys.			
8	unrealistic cont. duration	Amb. , mistakes in specs			
9	ineff. Planning & sched.	cont. poor coordination			
10	slow decision making-CL	Delay in settlement			

BLUE - Relations	50% - 75%			
	Factor-1	Factor-2	Factor-3	Factor -4
1	Short. Of tech Prof.	Loose safety rules & reg	Improper tech study cont	slow prep changed order
2	ineff. Planning & sched.	slow prep changed order	ineff. Control of project	
3	loose safett rules & reg	gov. tendering sys.		
4	Cont poor coordination	slow prep changed order	ineff. Control of project	por contract management
5	slow decision making-CL	slow prep changed order		
6	slow prep changed order	gov. tendering sys.		
7	Low skills of manpower	unrealistic cont duration		
8	ineff. Cotrol of project	gov. tendering sys.		
9	gov. tendering sys.	cash flow problem	unrealstic cont duration	

GREEN - Relations 25% - 50%

	Factor-1	Factor-2	Factor-3	Factor -4	Factor-5	Factor -6	Factor-7	Factor -8
1	short. Of tech. prof	short. manpower all skills	ineff. Planning & sched.	ineff. Cnotrol of project	ineffecient quality control			
2	short manpower all skills	Loose safety rules & reg						
3	ineff. Planning & sched.	poor coordination -cont	Inadq. Design & specs	poor cont. management	ineffecient quality control			
4	loose safett rules & reg	Low skills of Manpower	poor coordination -cont	inade. Design & specs	poor coorination - cont	short manpower all skills	Inadq. Design & specs	poor cont management
	ineff. Quality control							
5	Imp. Tech study	slow prep changed order	low skills of manpower	unrealistic cont duration				
6	change scope of project	slow decision making - Cl						
7	poor qualf. Tech staff ass.	ineff. Planning & sched.	slow prep changed order					
8	Amb. & mistakes in specs	slow prep changed order						
9	slow prep changed order	ineff. Contro of project	delay in sittlment	Amb. & mistakes in specs	poor qulif. Tech staff ass.	changer scope of project		
10	Amb. & mistakes in specs	slow prep changed order	poor cont management					
11	slow decision making-CL	changes in scope of proj.	ineff. Control of project					
12	Cont poor coordination	Loose safety rules & reg						
13	poor qualf. Tech staff ass.	ineff. Planning & sched.	slow prep changed order					
14	change scope of project	slow decision making - Cl						
15	Imp. Tech study	slow prep changed order	low skills of manpower	unrealistic cont duration				
16	loose safett rules & reg	cont. poor coordination	low skills of manpower	inade. Design & specs	poor cont. management	ineff. Qualty control		
17	ineff. Planning & sched.	poor qualif. Tech staff ass.	Inadq. Design & specs	short. Of tech. prof				
18	short. Of manpoer all skills	Loose safety rules & reg	short. Of tech prof					
19	Short. Of tech Prof.	short. Of manpower all skills	ineff. Planning & sched.	ineff. Quality control				

White - Relations 0% - 25%

	Factor-1	Factor-2	Factor-3	Factor -4	Factor-5	Factor -6	Factor-7	Factor -8
1	unrealistic cont duration	ineff. Quality control	cash flow problem	poor cont management	inade. Design & specs	ineff. Control of project	slow prep changed orde	cont. poor coordination
	changes in scope of project	Loose safety rules & reg	ineff. Planning & sched.					
2	ineff. Quality control of proj	cash flow problem	delay in sittlment	poor cont management	ineff. Planning & sched.	short. Manpower all skills	inade. Design & specs	ineff. Control of project
	change scope of project	Improper tech study cont						
3	cash flow problem	delay in sittlment	ineff. Quality control	unrealistic cont duration				
4	delay in sittlment	cash flow problem	ineff. Quality control					
5	poor cont management	unrealistic cont duration	ineff. Quality control	low skills of nanpower	slow prep changed order			
6	inade. Design & specs	unrealistic cont duration	ineff. Quality control	ineff. Control of project	slow prep changed order			
7	gov. tendering sys.	change scope of project						
8	ineff. Control of project	inade. Design & specs	ineff. Quality control	unrealistic cont duration	poor qualf. Tech staff ass.	loose safett rules & reg	short. Manpoewr all skills	
9	low skills of manpower	delay in sittlment	slow prep changed order	cont. poor coordination	poor qualf. Tech staff ass.	change scope of project	ineff. Planning & sched	
10	slow prep changed order	low skills of manpower	Inadq. Design & specs	poor cont management	unrealistic cont duration	change scope of project	short. Manpoewr all skills	
11	Amb. & mistakes in specs	Loose safety rules & reg						
12	slow decision making - clint	Improper tech study cont						
13	cont. poor coordination	poor qualf. Tech staff ass.	low skills of manpower	unrealistic cont duration				
14	poor qualf. Tech staff ass.	loose safett rules & reg	short. manpower all skills	short. Of tech. prof				
15	change scope of project	loose safett rules & reg	ineff. Planning & sched.	slow prep changed order	low skills manpower	gov. tendering sys.	ineff. Quality control	unrealistic cont duration
16	Improper tech study cont	Loose safety rules & reg	ineff. Planning & sched.	slow decision making - cl	ineff. Quality control			
17	Loose safety rules & reg	ineff. Planning & sched.	Improper tech study cont	change scope of project	poor qualf. Tech staff ass.	Amb. & mistakes in specs	unrealistic cont duration	
18	ineff. Planning & sched.	short. Manpower all skills	unrealistic cont duration	loose safett rules & reg	Improper tech study cont	change scope of project	low skills of manpower	ineff. Quality control
19	short. Manpower all skills	ineff. Planning & sched.	poor qualf. Tech staff ass.	slow prep changed order	ineff. Control of project	ineff. Quality control		
20	short. Of tech. prof	poor qualf. Tech staff ass.	cash flow problem					

RED - Relations 75%- 100%

	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	W	T	Q	C	S	E	Chain total adjusted score CTAS	Weight of Risk
Chain-1	3	2	3	1	1	14	3	2	3	2	2	15	3	3	3	2	1	16	3	1	3	1	1	14							100%	67%	100%	50%	42%	26.3	87.7%
	Imp. Tech study					+	Amb. , mistakes in specs					+	Inadq. Design & specs					+	chages in scope of proj.																			
Chain-2	3	2	3	2	2	15	3	1	3	1	1	14	3	2	3	1	1	14	3	3	3	2	1	16	3	2	3	3	1	16	100%	67%	100%	60%	40%	27.328	91.1%
	Amb. & mistakes in specs					+	changes in scope of proj.					+	imp. Tech. study					+	inade. Design & specs					+	Unrealstic cont. duration												
Chain-3						13						11						11																		20.31666667	67.7%
	Dealy in settlement					+	slow decision making - Cl					+	cont. poor coordination					+						+													
Chain-4						16						15																								22.94	76.5%
	Short. Of tech staff					+	Low skills of Manpower					+						+						+													
Chain-5						11						15																								20.295	67.7%
	short. Of manpoer all skills					+	Low skills of Manpower					+						+						+													
Chain-6						15						16						11																		24.17	80.6%
	Low skills of manpower					+	short. Of tech. staff					+	short. mapoer all skills					+						+													
Chain-7						15						15																								22.22	74.1%
	por cntract management					+	gov. tendering sys.					+						+						+													
Chain-8						16						15																								23.095	77.0%
	unrealistic cont. duration					+	Amb. , mistakes in specs					+						+						+													
Chain-9						12						11																								18.015	60.1%
	ineff. Planning & sched.					+	cont. poor coordination					+						+						+													
Chain-10						11						13																								18.405	61.4%
	slow decision making-CL					+	Delay in settlement					+						+						+													

Blue - Relations 50%- 75%

	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	Chain total adjusted score CTAS	Weight of Risk
Chain-1	Short. Of tech Prof.	16	Loose safety rules & reg	14	Improper tech study cont	14	slow prep changed order	12	23.0	76.8%
Chain-2	ineff. Planning & sched.	12	slow prep changed order	12	ineff. Control of project	13			19.0	63.4%
Chain-3	loose safety rules & reg	14	gov. tendering sys.	15					14.7	49.0%
Chain-4	Cont poor coordination	11	slow prep changed order	12	ineff. Control of project	13	por contract managemen	15	21.6	71.9%
Chain-5	slow decision making-CL	11	slow prep changed order	12					15.6	52.0%
Chain-6	slow prep changed order	12	gov. tendering sys.	15					19.0	63.4%
Chain-7	Low skills of manpower	15	unrealistic cont duration	16					21.1	70.5%
Chain-8	ineff. Cotrol of project	13	gov. tendering sys.	15					19.6	65.3%
Chain-9	gov. tendering sys.	15	cash flow problem	11	unrealstic cont duration	16			22.0	73.4%

Green - Relations 25% - 50%

	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	total adjusted scor	Weight of Ris
Chain-1	short. Of tech. prof	16	hort. manpower all skill	11	ineff. Planning & sched.	12	ineff. Cnotrol of project	13	neffecient quality contro	11			20.3	67.7%
Chain-2	hort manpower all skill	11	Loose safety rules & reg	14									16.6	55.3%
Chain-3	loose safett rules & reg	14	Low skills of Manpower	15	ineff. Quality control	13	inade. Design & specs	16	poor coorination - cont	11	hort manpower all skill	11	21.1	70.5%
	poor cont management	15												
Chain-4	ineff. Planning & sched.	12	poor coordination -cont	11	Inadq. Design & specs	16	poor cont. management	13	neffecient quality contro				19.2	63.9%
Chain-5	Imp. Tech study	14	low prep changed orde	12	low skills of manpower	15	unrealistic cont duration	16					20.8	69.3%
Chain-6	change scope of project	14	low decision making - C	11									16.4	54.6%
Chain-7	oor qualf. Tech staff ass	12	ineff. Planning & sched.	12	low prep changed orde	12							16.3	54.5%
Chain-8	Amb. & mistakes in spec	15	low prep changed orde	12									17.9	59.6%
Chain-9	low prep changed orde	12	ineff. Contro of project	13	delay in sittlment	13	Amb. & mistakes in spec	15	poor qulif. Tech staff ass	12	changer scope of project	14	20.3	67.5%
Chain-10	Amb. & mistakes in spec	15	low prep changed orde	12	poor cont management	15							19.4	64.6%
Chain-11	slow decision making-Cl	11	changes in scope of proj	14	ineff. Control of project	13							17.7	58.9%
Chain-12	Cont poor coordination	11	Loose safety rules & reg	14									16.6	55.4%
Chain-13	oor qualf. Tech staff ass	12	ineff. Planning & sched.	12	low prep changed orde	12							16.3	54.5%
Chain-14	change scope of project	14	low decision making - C	11									16.4	54.6%
Chain-15	Imp. Tech study	14	low prep changed orde	12	low skills of manpower	15	unrealistic cont duration	16					20.7	69.0%
Chain-16	loose safett rules & reg	14	cont. poor coordination	11	low skills of manpower	15	inade. Design & specs	16	poor cont. management	15	ineff. Qualty control	13	21.2	70.5%
Chain-17	ineff. Planning & sched.	12	oor qualif. Tech staff as	12	Inadq. Design & specs	16	short. Of tech. prof	16					20.5	68.5%
Chain-18	hort. Of manpoer all skil	11	Loose safety rules & reg	14	short. Of tech prof	16							19.7	65.7%
Chain-19	Short. Of tech Prof	16	ort. Of manpower all sk	11	ineff. Quality control	13							19.5	65.1%

White - Relations 0% - 25%

	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	otal adjusted scor	Weight of Ris
Chain-1	unrealistic cont duratior	16	ineff. Quality control	13	cash flow problem	11	poor cont management	15	inade. Design & specs	16	ineff. Control of project	13	18.4	61.4%
	low prep changed orde	12	cont. poor coordination	11										
Chain-2	eff. Quality control of pr	13	cash flow problem	11	delay in sittlment	13	poor cont management	15	ineff. Planning & sched.	12	hort. Manpower all skill	11	18.4	61.4%
	inade. Design & specs	16	ineff. Control of project	13	change scope of project	14	mproper tech study con	14						
Chain-3	cash flow problem	11	delay in sittlment	13	ineff. Quality control	13	unrealistic cont duratior	16					17.9	59.7%
Chain-4	delay in sittlment	13	cash flow problem	11	ineff. Quality control	13							15.0	50.1%
Chain-5	poor cont management	15	unrealistic cont duratior	16	ineff. Quality control	13	low skills of nanpower	15	low prep changed orde	12			18.3	61.0%
Chain-6	inade. Design & specs	16	unrealistic cont duratior	16	ineff. Quality control	13	ineff. Control of project	12	low prep changed orde	12			18.2	60.7%
Chain-7	gov. tendering sys.	15	change scope of project	14									16.4	54.7%
Chain-8	ineff. Control of project	13	inade. Design & specs	16	ineff. Quality control	13	unrealistic cont duratior	16	oor qualf. Tech staff ass	12	loose safett rules & reg	14	18.0	60.0%
	hort. Manpoewr all skill	11												
Chain-9	low skills of manpower	15	delay in sittlment	13	low prep changed orde	12	cont. poor coordination	11	oor qualf. Tech staff ass	12	change scope of project	14	17.4	58.0%
	ineff. Planning & sched	12												
Chain-10	low prep changed orde	12	low skills of manpower	15	Inadq. Design & specs	16	poor cont management	15	unrealistic cont duratior	16	change scope of project	14	18.9	63.1%
	hort. Manpoewr all skill	11												
Chain-11	Amb. & mistakes in spec	15	Loose safety rules & reg	14									18.6	62.0%
Chain-12	ow decision making - di	11	mproper tech study con	14									17.2	57.2%
Chain-13	cont. poor coordination	11	oor qualf. Tech staff ass	12	low skills of manpower	15	unrealistic cont duratior	16					18.0	59.9%
Chain-14	oor qualf. Tech staff ass	12	loose safett rules & reg	14	hort. manpower all skill	11	short. Of tech. prof	16					17.9	59.5%
Chain-15	change scope of project	14	loose safett rules & reg	14	ineff. Planning & sched.	12	low prep changed orde	12	low skills manpower	15	gov. tendering sys.	15	18.5	61.8%
	ineff. Quality control	13	unrealistic cont duratior	16										
Chain-16	mproper tech study con	14	Loose safety rules & reg	14	ineff. Planning & sched.	12	low decision making - c	11	ineff. Quality control	13			17.0	56.5%
Chain-17	Loose safety rules & reg	14	ineff. Planning & sched.	12	mproper tech study con	14	change scope of project	14	oor qualf. Tech staff ass	12	Amb. & mistakes in spec		18.0	59.9%
	unrealistic cont duration	16												
Chain-18	ineff. Planning & sched.	12	hort. Manpower all skill	11	unrealistic cont duratior	16	loose safett rules & reg	14	mproper tech study con	14	change scope of project	14	18.5	61.7%
	low skills of manpower	15	ineff. Quality control	13										
Chain-19	hort. Manpower all skill	11	ineff. Planning & sched.	12	oor qualf. Tech staff ass	12	low prep changed orde	12	ineff. Control of project	13	ineff. Quality control	13	15.5	51.8%
Chain-20	short. Of tech. prof	16	oor qualf. Tech staff ass	12	cash flow problem	11							17.5	58.2%

TOP-10 chains

	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	T Q C S E	W	Chain total adjusted score CTAS	Weight of Risk	
Chain-2	Amb. & mistakes in specs	15	changes in scope of proj.	14	imp. Tech. study	14	inade. Design & specs	16	Unrealstic cont. duration	15.6	27.328	91.1%	1
Chain-1	Imp. Tech study	14.5	Amb. , mistakes in specs	15	Inadq. Design & specs	15.5	chages in scope of proj.	13.7			26.3	87.7%	2
Chain-6	Low skills of manpower	15	short. Of tech. staff	16	short. mapoer all skills	11					24.17	80.6%	3
Chain-8	unrealistic cont. duration	16	Amb. , mistakes in specs	15							23.095	77.0%	4
Chain-1	Short. Of tech Prof.	16	Loose safety rules & reg	14	Improper tech study cont	14	slow prep changed order	12			23.0	76.8%	5
Chain-4	Short. Of tech staff	16	Low skills of Manpower	15							22.94	76.5%	6
Chain-7	por cntract management	15	gov. tendering sys.	15							22.22	74.1%	7
Chain-9	gov. tendering sys.	15	cash flow problem	11	unrealstic cont duration	16					22.0	73.4%	8
Chain-4	Cont poor coordination	11	slow prep changed order	12	ineff. Control of project	13	por contract management	15			21.6	71.9%	9
Chain-7	Low skills of manpower	15	unrealistic cont duration	16							21.1	70.5%	10
Chain-16	loose safett rules & reg	13.8	cont. poor coordination	11.2	low skills of manpower	14.8	inade. Design & specs	15.5	poor cont. management	14.9	21.2	70.5%	10
	ineff. Qualty control	13											

TABLE-15: RULES CREATIONS (MAIN TABLE)

	Top 10 factors chain	CASE-1	CASE-2	CASE-3	CASE-4	CASE-5	CASE-6	CASE-7	CASE-8	CASE-9	CASE-10
Factors	13. Shortage of technical professionals in the contractor's org.	No shortage	Low shortage	Med shortsge	H. shortsge	No shortage	H. shortsge	Low shortage	Med shortsge	No shortage	No shortage
	19. Loose safety rules & regulations within the contractor's org.	Fully adheared	Average	Poor	Not Adheared	Average	Poor	Fully adheared	Not Adheared	Fully adheared	Fully adheared
	21. Improper technical studies by the contractor during bidding stage	Super-Detailed	Standard	Weak	Cursory	Weak	Standard	Standard	Super-Detailed	Standard	Super-Detailed
	53. Changes in the scope of the project	Negligable	Simple	Moderate	Major	Major	Negligable	Moderate	Simple	Simple	Negligable
	54. Ambiguities, mistakes, and inconsistencies in specs & drawings	Comperhesive	Clear	Prospective	Vague	Prospective	Clear	Vague	Comperhesive	Prospective	Comperhesive
	10. Low skill of manpower	nonexistent	raerly	occoasional	cronic	raerly	occoasional	occoasional	nonexistent	occoasional	cronic
	59. Gov. tendering system of selecting the lowest bidding contractor	Selective	Fair	considerable	cheaply	Selective	cheaply	Fair	considerable	cheaply	cheaply
	38. Inadequate design specifications	Professinal	Adecuate	Prospetive	Messy	Adecuate	Prospetive	Professinal	Messy	Messy	Messy
	39. Poor contract management	Professional	Qualified	Poor	Not qualified	Poor	Qualified	Qualified	Professional	Qualified	Not qualified
	41. Unrealistic contract duration	Conservative	Realistic	Resanable	Risky	Risky	Conservative	Resanable	Realistic	Realistic	Risky
Customer Attributes	Time	Earlier	Ontime	Delayed	Failure	Delayed	Ontime	Ontime	Delayed	Ontime	Delayed
	Quality	Perfect	Meets scope	Corrective	Bad	Meets scope	Bad	Meets scope	Meets scope	Meets scope	Bad
	Cost	Thrift	As planned	Over-run	Crises	Over-run	Thrift	As planned	As planned	Thrift	Thrift
	Safety	Secured	Adheared	Concerned	Risky	Adheared	Concerned	Adheared	Concerned	Adheared	Adheared
	Environment	Circumspect	Adheared	Concerned	incurious	Adheared	Concerned	Adheared	Concerned	Adheared	Adheared

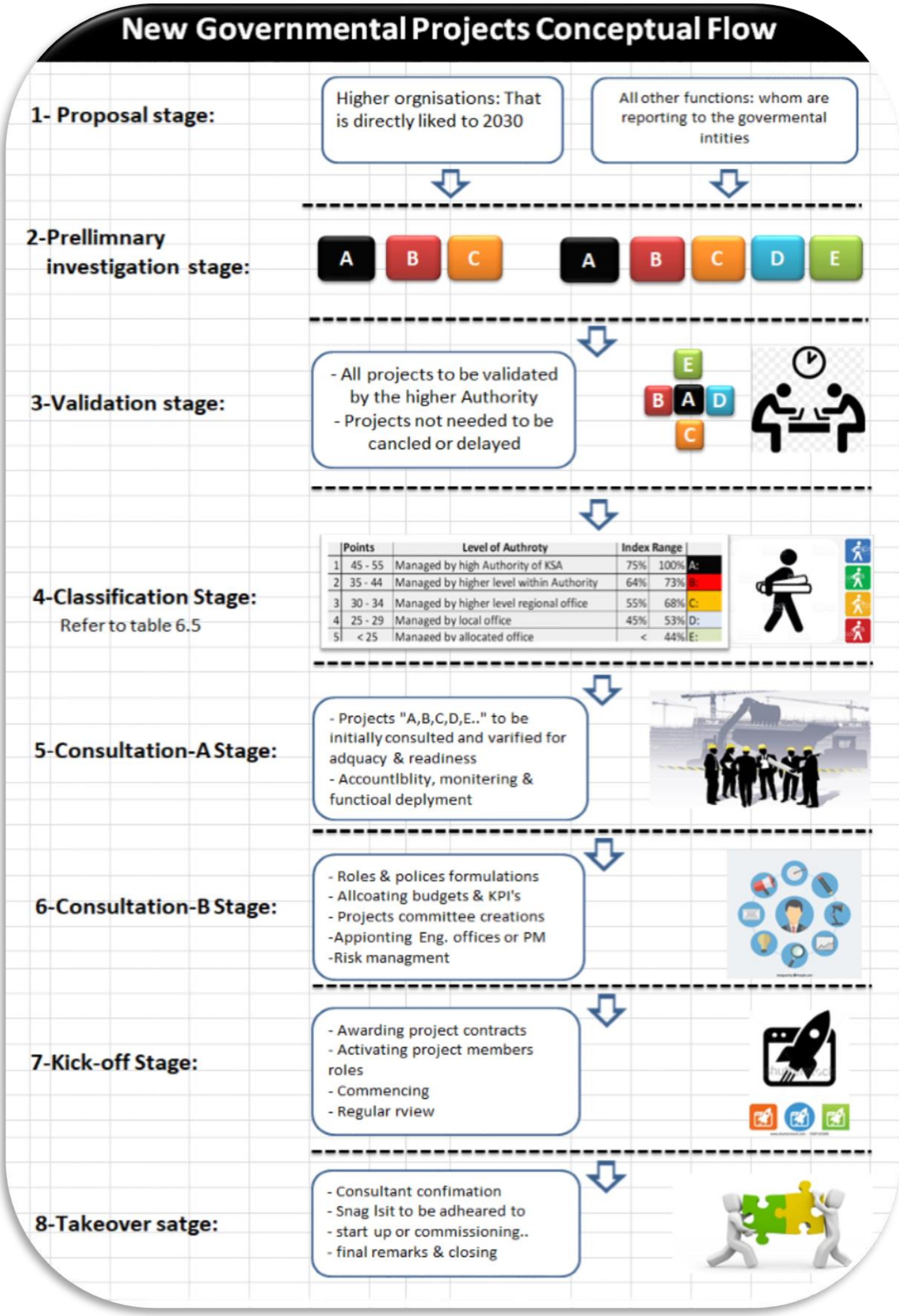
Appendix-F Full List of Factors Using RII

TABLE 14: FULL LIST-FACTORS OF DELAY USING RII

No.	Factor Category	Factors of Delay	Frquency				F.I.		Severity				S.I.		RII	Risk	Points
			1	2	3	4	Rate	%	1	2	3	4	Rate	%	Overall %	Order	
13	Contractor - PM	13. Shortage of technical professionals in the contractor's org.	4	11	16	**10**	2.9231	73.08%	2	11	16	10	2.8718	71.79%	52.47%	1	65
9	Contractor - MP	9. Shortage of manpower (skilled, semi-skilled, unskilled labor)	1	16	17	5	2.6667	66.67%	0	10	19	10	3	75.00%	50.00%	2	64
22	Contractor - PM	22. Ineffective planning & scheduling of the project by the contractor	3	10	**24**	2	2.641	66.03%	1	7	21	10	3.0256	75.64%	49.94%	3	63
19	Contractor - PM	19. Loose safety rules & regulations within the contractor's org.	2	12	19	6	2.7436	68.59%	2	13	11	13	2.8974	72.44%	49.68%	4	62
21	Contractor - PM	21. Improper technical studies by the contractor during bidding stage	3	14	17	5	2.6154	65.38%	1	13	9	**16**	3.0256	75.64%	49.46%	5	61
53	Early plan & Design	53. Changes in the scope of the project	3	19	8	9	2.5897	64.74%	2	12	11	14	2.9487	73.72%	47.73%	6	60
20	Contractor - PM	20. Poor qualifications of contractor's tech. staff assigned to the project	4	13	16	6	2.6154	65.38%	1	13	14	11	2.8974	72.44%	47.36%	7	59
14	Contractor - PM	14. Contractor's poor coordination with parties' invol. in project	5	14	15	5	2.5128	62.82%	3	6	19	11	2.9744	74.36%	46.71%	8	58
45	Client	45. Slow decision making by the client's organization	4	18	11	6	2.4872	62.18%	2	12	11	14	2.9487	73.72%	45.84%	9	57
54	Early plan & Design	54. Ambiguities, mistakes, and inconsistencies in specs & drawings	3	19	13	4	2.4615	61.54%	2	11	12	14	2.9744	74.36%	45.76%	10	56
15	Contractor - PM	15. Slow preparation of changed orders requested by contractor	3	13	18	5	2.641	66.03%	2	12	18	7	2.7692	69.23%	45.71%	11	55
10	Contractor - MP	10. Low skill of manpower	3	14	19	3	2.5641	64.10%	0	13	19	7	2.8462	71.15%	45.61%	12	54
24	Contractor - PM	24. Ineffective control of project progress by the contractor	2	18	15	4	2.5385	63.46%	0	14	16	9	2.8718	71.79%	45.56%	13	53
59	Gov. Regulation	59. Gov. tendering system of selecting the lowest bidding contractor	7	10	13	9	2.6154	65.38%	5	9	15	10	2.7692	69.23%	45.27%	14	52
38	Consultant	38. Inadequate design specifications	3	21	11	4	2.4103	60.26%	1	14	8	16	3	75.00%	45.19%	15	51
39	Consultant	39. Poor contract management	1	23	10	5	2.4872	62.18%	2	12	14	11	2.8718	71.79%	44.64%	16	50
42	Client	42. Delay in the settlement of contractor claims by the client	2	20	11	6	2.5385	63.46%	2	13	15	9	2.7949	69.87%	44.34%	17	49
29	Contractor - PF	29. Cash flow problems faced by the contractor	3	24	6	6	2.3846	59.62%	1	12	13	13	2.9744	74.36%	44.33%	18	48
25	Contractor - PM	25. Inefficient quality control by the contractor	2	20	12	5	2.5128	62.82%	1	13	17	8	2.8205	70.51%	44.30%	19	47
41	Client	41. Unrealistic contract duration	4	18	12	5	2.4615	61.54%	3	13	9	14	2.8718	71.79%	44.18%	20	46
44	Client	44. Delay in issuing of change orders by the client	2	20	12	5	2.5128	62.82%	1	14	16	8	2.7949	69.87%	43.89%	21	45
48	Client	48. Delay in progress payments by the client	3	20	11	5	2.4615	61.54%	2	14	11	12	2.8462	71.15%	43.79%	22	44
11	Contractor - PM	11. Lack of motivation among contractor's members	2	21	13	3	2.4359	60.90%	0	14	16	9	2.8718	71.79%	43.72%	23	43
33	Consultant	33. Delay in the approval of contractor submissions by the consultant	3	21	11	4	2.4103	60.26%	1	15	11	12	2.8718	71.79%	43.26%	24	42
28	Contractor - PF	28. Difficulties in financing the project by the contractor	5	20	12	2	2.2821	57.05%	3	8	13	15	3.0256	75.64%	43.15%	25	41
18	Contractor - PM	18. Poor controlling of subcontractors by contractor	5	17	12	5	2.4359	60.90%	2	15	10	12	2.8205	70.51%	42.94%	26	40
2	contractor - M	2. Delay in materials delivery	1	20	16	2	2.4872	62.18%	2	14	15	8	2.7436	68.59%	42.65%	27	39
30	Contractor - PF	30. Problems between the contractor and his subcontractors with regard	4	20	10	5	2.4103	60.26%	1	16	12	10	2.7949	69.87%	42.10%	28	38
56	Early plan & Design	56. Original contract duration is too short	4	17	16	2	2.4103	60.26%	2	13	16	8	2.7692	69.23%	41.72%	29	37
12	Contractor - PM	12. Shortage of contractor's administrative personnel	3	21	12	3	2.3846	59.62%	2	14	13	10	2.7949	69.87%	41.65%	30	36
4	contractor - M	4. Changes in materials specifications	2	22	11	4	2.4359	60.90%	0	19	12	8	2.7179	67.95%	41.38%	31	35
31	Consultant	31. Poor qualification of cons. engineer's staff assigned to the project	2	23	10	4	2.4103	60.26%	1	15	16	7	2.7436	68.59%	41.33%	32	34
34	Consultant	34 Poor com. between the consultant engineer and other parties involved	5	21	8	5	2.3333	58.33%	1	15	14	9	2.7949	69.87%	40.76%	33	33
35	Consultant	35. Poor coordination by the cons. engineer with other parties involved	3	23	9	4	2.359	58.97%	1	16	14	8	2.7436	68.59%	40.45%	34	32
51	Client	51. Poor coordination by the client with the various parties during const.	3	24	9	3	2.3077	57.69%	1	14	18	6	2.7436	68.59%	39.57%	35	31
43	Client	43. Suspension of work by the client's organization	5	22	8	4	2.2821	57.05%	2	15	12	10	2.7692	69.23%	39.50%	36	30
52	Client	52. Excessive bureaucracy in the client's administration	6	18	11	4	2.3333	58.33%	3	13	16	7	2.6923	67.31%	39.26%	37	29
60	Gov. Regulation	60. Changes in government regulations and laws	5	20	13	1	2.2564	56.41%	2	11	**20**	6	2.7692	69.23%	39.05%	39	27
50	Client	50. Client's failure to coordinate with gov. authorities during planning	3	24	11	1	2.2564	56.41%	1	15	15	8	2.7692	69.23%	39.05%	38	28
58	Gov. Regulation	58. Difficulties in obtaining work permits	6	21	8	4	2.2564	56.41%	2	13	17	7	2.7436	68.59%	38.69%	40	26
16	Contractor - PM	16. Ineffective contractor head office involvement in the project	2	25	10	2	2.3077	57.69%	1	16	17	5	2.6667	66.67%	38.46%	41	25
46	Client	46. Interference by the client in the construction operations	4	21	10	4	2.359	58.97%	2	19	11	7	2.5897	64.74%	38.18%	42	24
32	Consultant	32. Delay in the preparation of drawings	4	23	11	1	2.2308	55.77%	1	17	13	8	2.7179	67.95%	37.89%	43	23
49	Client	49. Client's poor com. with the construction parties and gov. authorities	4	24	9	2	2.2308	55.77%	2	16	13	8	2.6923	67.31%	37.54%	44	22
37	Consultant	37. Slow response from the cons. engineer to contractor inquiries	3	25	7	4	2.3077	57.69%	1	19	14	5	2.5897	64.74%	37.35%	46	20
26	Contractor - PM	26. Delay in the preparation of contractor submissions	2	25	10	2	2.3077	57.69%	0	**21**	13	5	2.5897	64.74%	37.35%	45	21
47	Client	47. Uncooperative client with the contractor complicating contract administr	4	24	9	2	2.2308	55.77%	2	17	13	7	2.641	66.03%	36.82%	47	19
55	Early plan & Design	55. Subsurface site conditions materially differing from contract docum.	3	24	11	1	2.2564	56.41%	4	14	15	6	2.5897	64.74%	36.52%	48	18
23	Contractor - PM	23. Delays to field survey by the contractor	4	20	13	2	2.3333	58.33%	3	18	14	4	2.4872	62.18%	36.27%	49	17
40	Client	40. Delay in furnishing & delivering the site to the contractor by client	4	22	10	3	2.3077	57.69%	2	21	10	6	2.5128	62.82%	36.24%	50	16
5	contractor - EQ	5. Shortage of required equipment	10	21	7	4	2.2821	57.05%	3	16	16	4	2.5385	63.46%	36.21%	51	15
66	External factors	66. Work interference between various contractors	4	**26**	8	1	2.1538	53.85%	2	15	16	6	2.6667	66.67%	35.90%	52	14
62	External factors	62. Effects of subsurface conditions (type of soil, utility lines, water table)	5	23	9	2	2.2051	55.13%	4	15	13	7	2.5897	64.74%	35.69%	53	13
1	contractor - M	1. Shortage of required material	4	24	10	1	2.2051	55.13%	4	13	19	3	2.5385	63.46%	34.99%	54	12
57	Gov. Regulation	57. Ineffective delay penalty	5	23	10	1	2.1795	54.49%	4	15	14	6	2.5641	64.10%	34.93%	55	11
27	Contractor - PM	27. Improper construction methods implemented by contractor	5	26	7	1	2.1026	52.56%	1	20	11	7	2.6154	65.38%	34.37%	56	10
65	External factors	65. Rise in the prices of materials	5	24	7	3	2.2051	55.13%	4	16	15	4	2.4872	62.18%	34.28%	57	9
36	Consultant	36. Delays in performing inspection and testing by the cons. engineer	2	26	8	1	2.1026	52.56%	2	20	12	5	2.5128	62.82%	33.02%	58	8
8	contractor - EQ	8. Inadequate equipment used for the works	9	20	9	1	2.0513	51.28%	2	18	14	5	2.5641	64.10%	32.87%	59	7
3	contractor - M	3. Changes in materials prices	7	21	9	2	2.1538	53.85%	4	18	13	4	2.4359	60.90%	32.79%	60	6
7	contractor - EQ	7. Shortage of supporting and shoring installations for excavations	8	23	6	2	2.0513	51.28%	5	18	10	6	2.4359	60.90%	31.23%	61	5
6	contractor - EQ	6. Failure of equipment	11	20	4	4	2.0256	50.64%	**7**	12	13	6	2.4103	60.26%	30.51%	62	4
63	External factors	63. Traffic control and restrictions on the job site	7	24	7	1	2.0513	51.28%	6	17	12	4	2.359	58.97%	30.24%	64	2
17	Contractor - PM	17. Delays in mobilization	6	27	4	2	2.0513	51.28%	6	17	12	4	2.359	58.97%	30.24%	63	3
61	External factors	61. Severe weather conditions on the job site	11	20	7	1	1.9487	48.72%	4	21	11	3	2.3333	58.33%	28.42%	65	1
64	External factors	64. Effects of social and cultural conditions	**15**	18	5	1	1.7949	44.87%	**7**	23	8	1	2.0769	51.92%	23.30%	66	0
							Range	44.9 -73.1%						51.9-75.6%	23.3% - 52.5%		2145

Party of Delay	RII Scores 66 Factors	RII%	TOP 10	TOP 15	TOP 20
Contractor weight:	1515	70.6%	7 factors	10 factors	12 factors
Consultant Weight:	279	13.0%	0	1 factor	2 factors
Client Direct Weight:	260	12.1%	1 factor	1 factor	3 factors
Client-A Early plan & Desi	46	2.1%	2 factors	2 factorr	2 factors
Client-B Gov. Regulation	30	1.4%	0	1 factor	1 factor
External factors	15	0.7%	0	0	0
Total	**2145**	100%			

Appendix-G Project Management Protocol Chart



	Points	Level of Authroty	Index Range		
1	45 - 55	Managed by high Authority of KSA	75%	100%	A:
2	35 - 44	Managed by higher level within Authority	64%	73%	B:
3	30 - 34	Managed by higher level regional office	55%	68%	C:
4	25 - 29	Managed by local office	45%	53%	D:
5	< 25	Managed by allocated office	<	44%	E:

Appendix-H Author Recommendations during Project 5

A- Mistakes during the initiation stage:

- Mistake: The project manager assumes he or she knows what the project sponsor (the high-level person who wants the project done and supports the project) considers to be an acceptable project outcome.

- How to avoid the mistake: It is recommended to have a detailed conversation with the project sponsor that establishes specific and realistic measurable objectives for the project. This includes the outcome (expected objectives), a defined timeline (when it starts and when it is supposed to end) and the cost of the project (how much money, labour and staff are required, and from where the resources come).

- Mistake: The project manager fails to identify all the stakeholders (those people who benefit from or are affected by the project, and those people who need to be involved at some time during the project).

- How to avoid the mistake: It is the responsibility of the project sponsor to identify the primary and secondary stakeholders. Who would be directly and indirectly affected by the project's outcome? Which stakeholders' support is needed to provide the required resources for the project? It is important to include additional stakeholders as the progression of the project reveals them.

B- Mistakes during the definition & planning stage:

- Mistake: The project manager fails to include the team when planning how the outcome is going to be achieved.

- How to avoid the mistake: It is essential to get the team's ownership of the project and their commitment to producing agreed-upon results on time and within budget. The project manager should let the team help create a written project action plan by involving them in:
    - Deciding roles and responsibilities of team members.
    - Creating a project schedule.
    - Determining the resources needed (personnel, time, material, other

resources, etc.).

- o Creating a communication plan for the project.
- o Identifying the risks to the completion of the project and creating a risk response plan if necessary.

A kickoff meeting is very helpful to define and set the expectations and would make the project team members more self-dependent and self-organized. This would create a higher level of accountability and ownership for all team members.

- Mistake: The project manager fails to keep everyone informed. It is easy to disconnect with the project team and not to give updates to all stakeholders.

- How to avoid the mistake: Projects managers and the team should create and establish a foundation of regular meetings for a communication plan that addresses how and when the team communicates with each other, with the sponsor, with each stakeholder and with each team member who is not actively involved in the project. This is often done with status reports (where the project is now), progress reports (how it got there) and change reports (major changes and how they affect the project).

C- Mistakes during the execution stage:

- Mistake: The project manager does not hold enough team meetings.

- How to avoid the mistake: Start every large project with a kickoff meeting to review the project action plan with the team and to generate excitement and then hold weekly team meetings to discuss progress. Were all activities completed on time and within budget? Did the team exceed, miss or meet targets for the week? Use this time to discuss and reconcile problems, conflicts, disputes and potential issues.

- Mistake: Letting changes get out of hand.

- How to avoid the mistake: Scope creep is pervasive in project management and difficult to manage because, as the name suggests, it creeps up on those involved. Additional requests and added features to the design can affect the focus of the project plan and without the proper control, they can severely affect project success. However, scope creep can be stopped Research Discussion by strong project management and product ownership.
- When adding features or considering changes, the project manager needs to ask a few questions. Do new feature requests align with the project plan? Do the proposed changes add value to the end user? Are they critical or nice to have? Clearly defining project goals and identifying success factors can help ensure that change requests and added features that aren't aligned with objectives don't threaten timelines.

- Mistake: The project manager doesn't celebrate success with the project team.

- How to avoid the mistake: Celebration and rewards provide a momentum for the team, so one should not wait until the team achieves the overall success identified in the project action plan. It is important to celebrate small milestones, perhaps on a weekly basis, by recognizing team and individual achievements.

D- Mistakes during the performance & control stage:

- Mistake: The project manager is not constantly looking for trouble.

- How to avoid the mistake: This is easy to fix: the project managers should constantly look for troubles. This means being aware of and managing any issue that may affect the outcome, timeframe or negatively impact the budget of the project. Examples include time slippage (keeping the project on schedule by tracking project activities), scope creep (prohibiting others from enlarging the project by saying "no") and project changes (knowing how every change may impact or jeopardize the project's success).

- Mistake: The project manager loses track of the project's outcome, timeframe, and cost by not using an appropriate tracking system.

- How to avoid the mistake: Use tracking systems (i.e., Primavera, Microsoft Project, QuickBooks, Excel) to discover any issues or problems so timely corrective action can be taken. Additionally, project documentation should be updated weekly. If something of importance comes up (e.g., a change in the methodology of work or scope of work or deadline), the project manager should update the documentation within 24 to 48 hours. This will give everyone on the project team accurate information about the project progress.

E- Mistakes during the handover stage:

- Mistake: The project manager attempts to complete or hand off the project without tying up all the loose ends.

- How to avoid the mistake: When 90 percent of the project has been completed, the project manager should meet with the project consultant, project sponsor, and primary stakeholders to develop a closing checklist or a snag list to identify any remaining uncompleted tasks. Those items must be done with a detailed time plan before handing-over the project or declaring the project completed. It is expected to keep a minimum of 10 percent in hand from the total project budget to resolve the corrections on time.

- Mistake: The project manager fails to debrief and, if warranted, celebrate with the team.

- How to avoid the mistake: Upon completion, a critical step is to hold a debriefing session about the project with the team using an after-action review to share lessons learned, mistakes made and overcome and successes achieved. The project manager and his team should discuss what went right and what went wrong and individually evaluate the team performance. If the project's objectives were met, then the project manager should celebrate, reward and recognize the individual team efforts and accomplishments. While project management is responsible for the opportunity to make mistakes, by avoiding the common ones during each phase, virtually all projects can end in success.

Early project planning benefits.

The early planning process for any project is crucial for a successful project journey. Well-preparedness in the early stage of the project is the first signal of successful accomplishment of a project. Therefore, it is important to realize how the early planning tasks are helpful for conclusion of the rest of the projects stages smoothly and on time. The main considerable benefits of early project planning are as follows:

- Provide direction

One of the challenges faced by project team members is the lack of knowing how to proceed. During the planning process, the project team determines what tasks need to be completed. The planning process provides direction for the team and its members. The team members will then know the projects goals and objectives and how it is linked to the company strategy. This clear understanding will further help further in accepting the role responsibilities with high momentum.

- Assign responsibilities and hold them accountable

During the planning process, the project manager and his team usually assign responsibilities for completing tasks to specific members. The team benefits because one employee holds responsibility for each task and can be held accountable. When an employee realizes he reaps the rewards and the consequences of not completing Research Discussion the task, he or she places a higher priority on fulfilling this requirement.

- Care for adequate resources

Many projects run out of resources before completion. Resources include labour, materials and finances. Early planning requires the team to consider what resources are needed to finish the project on time and eliminate the potential for discontinuity due to lack of resources.

- Problem Anticipation

Many projects experience problems at different stages before the project is completed. These include losing employees, missing deadlines or running out of funds. Through early planning of the project, the team can proactively address problems and reduce their impact on the project.

- Shared Resources

Many project managers work on multiple projects at a time. These project managers divide their time between the projects and run the risk of having too much or not enough work. Early planning allows the project leader to work out a schedule which maximizes the project manager's available time.

- Higher awareness and expertise

After project managers plan their assignments, they can invest more time developing the skills to complete their assignments. Some projects managers have the skills required and increase those skills during the project's progress. Other project managers could learn new skills as they go and become more aware of the issues and risks involved in each step. The company and project managers would benefit from knowledge growing as the project progresses from one stage to another. The earlier the project manager makes plans, the higher the awareness of the potential risks.

- Stepping confidant

Companies base their decisions on the assumption that a specific project will be completed on time or within its financial budget. Project teams who spend time in early planning can reliably predict most of the work consequences ahead.

- Better work deployment

When project team employees plan together, they learn which employees have the skills necessary to complete various tasks. These skills may not appear in the employee's work history, but still contain value for the company. Without early planning of each task, the company may never realize these skills and might not be able to utilize its employees effectively.

- Predictable and proactive

Through early planning, the project team monitors the results of previous projects. The team evaluates its successes and failures and would be able to predict issues before they appear. This allows the team to keep the successful processes and eliminate the failures.

- Completion and success

Some projects get started and never finish. Without early planning, project team members pursue their own ideas and forget about the project. Early planning ensures the team members know their role and how to reduce or eliminate risks for moving the project towards its original plan.

Importance of recovery plans

Recovery plans in project management, such as everyday scenarios and operations of an organization projects as well, may be prone to some form of disaster. It may be due a natural occurrence or as a result of management or technical failures. When this abnormality happens, projects should get some form of back-up to tide over these disastrous, destructive or dangerous interruptions. The disasters that occur may determine the continuity or termination of the project.

This leads to the area of management called Disaster Recovery Management, which acts as a shock absorber and helps projects bounce back. A project disaster recovery plan is a contingency plan that is prepared in detail at the early stage of the project planning phase before it goes to the execution phase and, to some extent, is practiced and tested.

The plan has a detailed set of measures that may be adopted if a disaster where to happen. In many organizations, it is very important for a disaster recovery plan to be in place. Disaster recovery plans, also known as business continuity plans (BCP) or business process contingency plans (BPCP), are part of a project and may also be treated as independent projects by themselves. Project disaster recovery plan especially required for technical back-up in case failures happen or accidents occur.

Drafting a Project Disaster Recovery Plan

A project disaster recovery plan theoretically follows the following steps:

1- **Risk Analysis:** An analysis of all possible risks in a project is vital to the creation of a disaster recovery plan. While drafting a disaster recovery plan, risks that are identified have to be grouped according to a Probability-Impact chart for seriousness and relevance and then a risk analysis report needs to be submitted. Technical risks are especially deemed important and charted for a recovery plan.

2- **Budget Allocation:** Budget allocation is a very important part of the disaster recovery plan. Without a specific budget assigned, no recovery measures can be adopted in time. This recovery budget could be allocated for prevention measures prior to expected disasters. For example, if an area is going to be subjected to power failures, the project manager may invest in a generator that will switch on within seconds of power loss and work for a period of time, during which data may be stored or enough time gained for completing a set of project tasks. In case of post-disaster fund allocation, a fixed amount may be allocated for recovery. For example, if a flood were to arise on the project site, the project team may allocate a contingency budget towards security and rebuilding expenses, which aby themselves are projects.

3- **Applying a Disaster Recovery Plan:** If the risks have been identified and a budget has been allocated for disaster recovery, a plan has to be made with a schedule and resource specifications. This follows the principles of any project plan and requires a project charter, disaster recovery management approval and initiative or responsibility of one person to lead the team.

4- **DRP-testing and verification:** Once the plan is in place, it has to be tested many times for failure or success rates, drawbacks and any suggested improvements. A plan that is not tested may not prove to be efficient in a time of need.

Finally, every project should have a backup plan, especially when it relates to technical disasters. Efficient use or allocation of time, money, resources and manpower should also be taken into consideration. A project manager with excellent leadership qualities should head the disaster recovery management team that will lead the project through a recovery process. Usually, the recovery plan budget varies from 5 to 10% of the total project budget.

Appendix-I Projects Management Protocol (Journal Paper)

Research goals 1-7 were carefully developed and addressed to identify an effective ranking of the critical delay factors and then to evaluate the collective impact of the group of factors (Critical Chains) in construction and industrial projects in KSA so efforts could be made to rank these factors and provide more control of the PPMs. Accordingly, the present study generated a number of hypotheses that needed to be examined and verified to fulfill the research objective.

In the singular ranking process, four factors (3, 4, 8, and 10) from the TOP-10 list were found to refer to design related matters involving all parties. Three factors (1, 5, and 7) were found to be related to improper selection of the contractor and time/contract management by the client, while three factors (2, 6 and 9) were concerned with labor safety, skills and availability by contractor. In the collective ranking process, eight chains (1, 2, 3, 4, 5, 6, 7, and 10) from the TOP-10 list referred to the design related matters, time, contract management, labour skills and availability by all parties. Two chains (8 and 9) were found to be related to project design, control, time, cash flow and labour skills availability by contractor.

Accordingly, project design related matters are the key elements of success that involve the client, consultant and the contractor during the five stages of the project cycle. The client was found responsible for project time and contract management during the initiation and planning stages. The contractor was seen the party most responsible for delay and mainly involved for the remaining elements of success such as site activities control, cash flow and labour skills/availability during the five stages.

Consequently, the key elements were synthesized according to the performance of each party referred. The five key elements were concluded from the TOP-10 singular and collective impact of delay factors to PPMs, which eventually helped address the final research goal. These outcomes have directed the author to propose a universal mechanism to enable both public and private sectors to control the projects in the initiation, planning, execution, control and handover stages.

Protocol Key Elements:

6. Project design related matters by client, consultant and contractor
7. Project time, cost and activity control management by contractor
8. Project contract management by client and consultant
9. Labour skills and availability by contractor
10. Selection of the contractor by client

A proposed protocol was developed to tackle the five key success elements concluded from the research goals and objective. Protocol processes with eight adapted stages were proposed to control each success element decisively. These stages have detailed control gates so these projects can be moved steadily, meeting all requirements at each entry gate.

The eight stages are the proposal stage, preliminary review and investigation stage, validation stage, classification stage, consultation-a stage, consultation-b stage, kickoff stage and handover/takeover stage. All selected projects would begin at the proposal stage to be preliminarily reviewed before they move to the validation stage. In the validation stage, the unnecessary projects would be postponed or canceled by the higher authority of proposed projects. The classification stage is very critical, in which all filtered projects would be classified based on eleven criteria. A scoring method was developed with respect to these criteria. Accordingly, each project gets a proper launching so that the consultation-A phase would confirm the project's adequacy, readiness and the availability of all related documents and studies. The Consultation-B stage's role is to link the top country's vision "2030", objectives, and targets. Accordingly, the higher consultants committee would assure the compliance of the government strategy of in-house sourcing plans, technology transfers and national recruiting "Saudization". The last two stages are the "kick-off and the takeover" which refer to the contract management, final project review and proper closing process. The project classification matrix was used as an effective tool for many projects classification in KSA. Figure 6.18 illustrates the eight sequential stages flow from the proposal stage to the takeover stage, highlighting the recommended steps in each part.

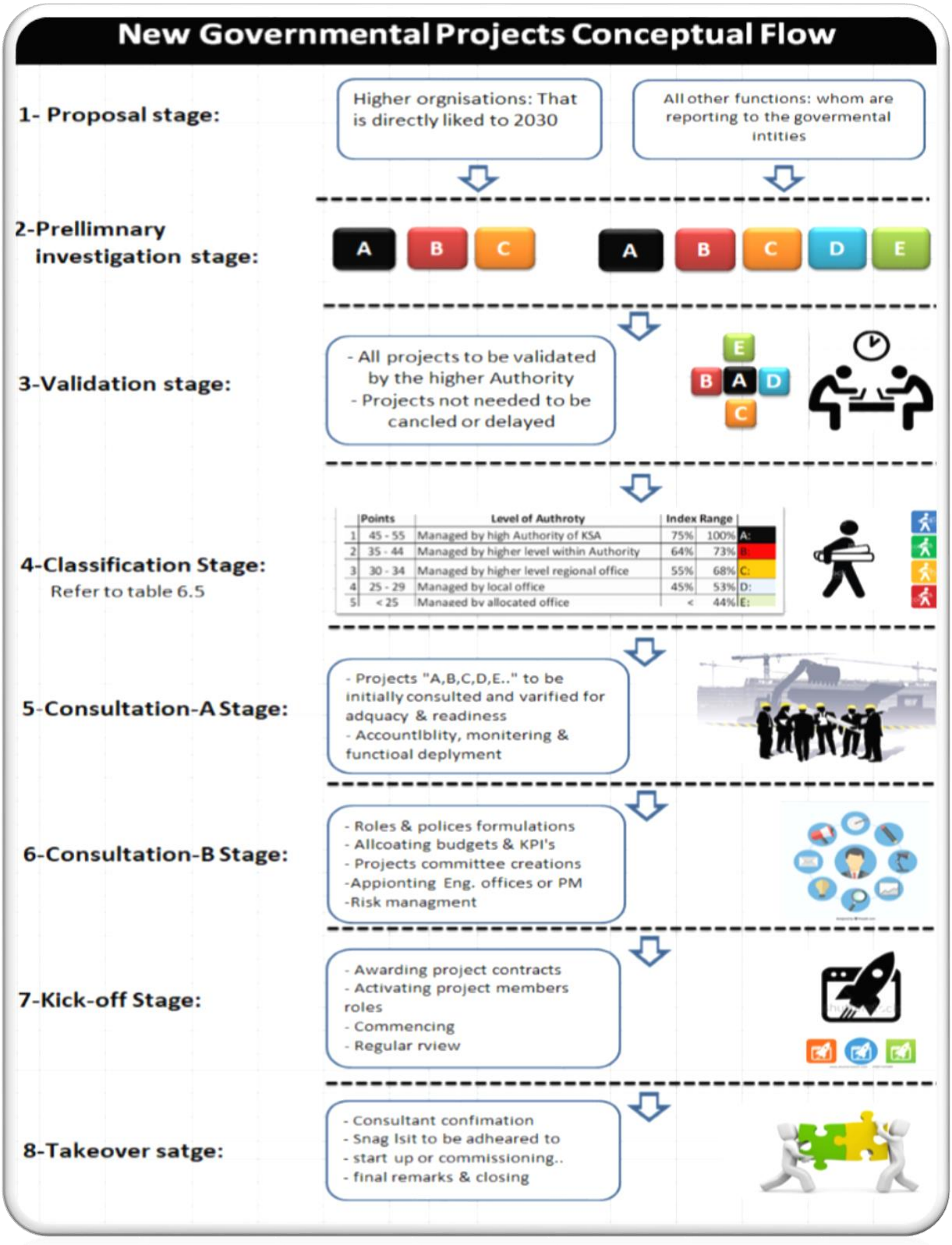


Figure-I: Proposed Project Management Protocol

I. Proposal Stage:

In this stage, it is assumed small and large organizations across the kingdom start to submit their annual project plans. Each organization works individually at this stage, depending on the agreed visions and set objectives by which such projects have been inspired and formed. The list of the initiated projects are to be grouped and further reviewed by the specialists employed by those organizations and then to be approved as per the allocated annual budget and the set objectives. The final list is expected to have projects that are classified, i.e. “A, B, C, D and E”. Projects which are tagged as A and B may be managed completely by the higher authority of projects in the kingdom.

II. Preliminary Investigation:

After the initiation stage, a large group of projects would be listed and organized in a way to help the specialists (project high authorities) to investigate if these projects are meeting the organization’s vision and objectives. This stage would also be expected to highlight the priority level and time completion plan for each project to assist in classification during later stages.

The following eleven steps elaborate in detail the recommended classification to be used for the governmental projects in KSA. Each step has five levels with five ratings from “1 to 5”, based on corresponding factors. The total is equal to 55 points, while the weight of each step may vary from one organization to another according to the organization vision and objectives.

Eleven Projects Classification Criteria and Scoring:

1- **Cost & budget:**

a. Very high expenditure	5
b. High expenditure	4
c. Medium expenditure	3
d. Low expenditure	2
e. Very low expenditure	1

2- **Priority & importance: Vision of 2030**

a.	High priority, large component of Vision 2030	5
b.	Medium priority	4
c.	Normal	3
d.	Good to have, at any time	2
e.	Not important in five year span	1

3- **Technical difficulties:**

b-	Very difficult and complicated	5
c-	Difficult	4
d-	Average	3
e-	Easy	2
f-	Very simple concept	1

4- **Level of involvements, number of authorities involved:**

a.	Very high involvement, > 7 authorities	5
b.	High, 4 to 6 authorities involved	4
c.	Average, around 3 authorities	3
d.	Manageable within ministry or authority	2
e.	Manageable within organization or department.	1

5- **Location and geographical challenges**

a.	Critical, important and vital	5
b.	Newly developed cities	4
c.	Main cities	3
d.	Small cities or towns	2
e.	Countryside or rural areas	1

6- **Category.**

"infrastructural, industrial, health, sport, education, tourism, military& defense, public residential and others"

a.	Health and education	5
b.	Urgent infrastructure	4
c.	Residential projects	3
d.	Industrial cities and projects	2
e.	Tourism and sports	1

7- Experience availability. “in house or out sourcing”

a.	Not available at all	5
b.	Very limited	4
c.	Partially available, with major help	3
d.	Available, with minor help	2
e.	Fully available, managed locally.	1

8- Project time duration. “tight, flexible or challengeable”

a.	Very short, challenged	5
b.	Short	4
c.	Average, realistic based on all parties	3
d.	Relaxed, 10% extra from the Critical Path Schedule (CPS)	2
e.	Stretched, 10-30% extra from the Critical Path Schedule (CPS)	1

9- Familiarity, frequency, and repeatability:

a.	Unfamiliar, new concept, never applied before	5
b.	Conceptually clear, needs partner	4
c.	Adaptable with experts	3
d.	Familiar, manageable	2
e.	Very familiar, repeated	1

10- Quality, Safety and Environment:

a.	Top measures is expected, world's benchmarking	5
b.	High standards, national benchmarking	4
c.	Fair, average within acceptable Request for Tender (RFT)	3
d.	Economical, value for money, lowest standard	2
e.	Low, standards not required	1

11- Risk Surroundings:

a-	Huge factors affecting success	5
b-	Many factors affecting success	4
c-	Limited factors affecting success	3
d-	Normal, risks are managed	2
e-	No risk	1

Table 6.6 shows the 11 project criteria and their corresponding factors that are scored from 1 to 10 %". The category's weights % is to be agreed by the head of the organization and connected specialists to assure a fair scores contribution and to reflect the real impact.

TABLE-I: THE 11 PROJECTS CRITERIA AND THEIR CORRESPONDING FACTORS

Projects Classification Matrix:
*** Weights vary based on the nature of the project & other criteria**

	Eleven Criteria	Scores	Category weight	Adjusted Score
1	**Cost & Budget:**		10%	
	a- Very high expenditure > SR 500 M	5		5
	b- High expenditure < SR 500 M	4		
	c- Medium expenditure < SR 100 M	3		
	d- Low expenditure < SR 50 M	2		
	e- Very low expenditure < SR 10 M	1		
				5
2	**Priority & Importance: Vision of 2030**			
	a- High priority, a big part of 2030	5	10%	
	b- Med. Priority	4		5
	c- Normal	3		
	d- Good to have, at any time	2		
	e- Not important, in 5 years span	1		
				5
3	**Technical Difficulties:**			
	a- Very difficult & complicated	5	10%	
	b- Difficult	4		4
	c- Average	3		
	d- Easy	2		
	e- Very simple concept	1		
				4
4	**Level of Involvements,** Authorities get involved:			
	a- Very high involvement, > 7 authorities	5	10%	5
	b- High, 4 to 6 authorities involved	4		
	c- Average, around 3 authorities	3		
	d- Manageable within Ministry or Authority	2		
	e- Manageable within org. or department.	1		
				5
5	**Location & Geographical challenges:**			
	a- Critical, important and vital	5	5%	5
	b- New Developed cities	4		
	c- Main cities	3		
	d- Small cities or towns	2		
	e- Country sides or rural areas	1		
				2.5

6	**Category:** Infrastructural, industrial, health, sport, education, tourism, military/defense, public residential and others			
	a- Health & education	5	5%	
	b- Urgent infrastructures	4		
	c- Residential projects	3		
	d- Industrial cities & projects	2		
	e- Tourism & sports	1		1
				0.5
7	**Experience Availability:** "In-house or outsourcing"			
	a- Not available at all	5	10%	
	b- Very limited	4		4
	c- Partially available, with major help	3		
	d- Available, with minor help	2		
	e- Fully available, managed locally.	1		
				4
8	**Project Time Duration:** "tight, flexible or challengeable"			
	a- Very short, challenged	5	10%	5
	b- Short	4		
	c- Average, realistic based on all parties	3		
	d- Relaxed, 10% extra from the CPS	2		
	e- Stretched, 10-30%	1		
				5
9	**Familiarity, Frequency& Repeatability:**			
	a- Unfamiliar, new concept "never applied"	5	10%	
	b- Conceptually clear, needs a partner	4		4
	c- Adaptable with experts	3		
	d- Familiar, manageable	2		
	e- Very familiar, repeated	1		
				4
10	**Quality, Safety & Environment:**			
	a- Top measures is expected, world's benchmarking	5	10%	
	b- High standards, national benchmarking	4		4
	c- Fair, average within acceptable RFQ	3		
	d- Economical, value for money, lowest standard	2		
	e- Low, standards not required	1		
				4
11	**Risk Surroundings:**			
	a- Huge factors affecting success	5	10%	5
	b- Many factors affecting success	4		
	c- Limited factors affecting success	3		
	d- Normal, risks are managed	2		
	e- No risk	1		
				5

Total Score -- **44 / 50**

III. Validation Stage:

The validation stage is one of the most important stages because after this stage, the project would start on designated paths that would usually be difficult to re-correct. This would be the real path in the future. Hence, it is very crucial to apply detailed analysis, if needed, and confirm the most realistic ranking from "A to D".

It is expected that some projects would be completely canceled, delayed or some of them to be called earlier. Some projects in the list, especially the infrastructural, would impact so many critical projects if they didn't commence on time or at start early.

IV. Classification Stage:

Reaping the early benefits regarding the eight stages of developing government projects would start to appear in this stage. The scores from table 6.4 would definitely help to launch each project in the right zone. For example, the new King Abdullah stadium developed by the Saudi Arabian American Oil Company (ARAMCO) was given a total score of 45 points, which means the higher authority of the projects in KSA is recommended to take it over. It is also possible to apply many existing project in this developed table to examine its efficacy in light of logic as well as the previously taken decision. It is recommended to include the major and urgent projects that need to be categorized and then include them in the list of project classification in the later stage.

Table 6.7 contains 5 categories "A, B, C, D, and E"; each one representing a certain zone with a specific project management conditions. Each zone has its own level of authorities and accountabilities towards its end target.

TABLE II: CATEGORIES "A, B, C, D, E"

	Points	Level of Authority	Index Range		
1	44 – 55	Managed by high Authority of KSA	75%	100%	A
2	35 – 43	Managed by higher level within Authority	64%	73%	B
3	30 – 34	Managed by higher level regional office	55%	68%	C
4	25 – 29	Managed by local office	45%	53%	D
5	< 25	Managed by allocated office	<	44%	E

Category-A:

This is the highest category and has the highest roles of responsibility for all projects to be executed within the kingdom's borders. The zone has a range of points 44 points to 55 points.

Category-B:

Projects scores that fall between 35 and 43 would be placed in this category, which is recommended to be managed by the higher level of authority within the ministry. Some roles and tasks would be managed by the higher level; however, the core responsibility of the project management would be done by this allocated team.

Category-C:

Medium size projects would usually be located in this category. These projects would not require a high level of project management skills, with a time schedule and budget that could reasonably be handled by a regional team within the ministry and could get any needed support from the higher level in the project authority hierarchy system. The category represents all scores between 30 and 34.

Category-D:

The local engineering or project team could handle most of the activities needed for small-to medium size project scored between 25 and 29. Most of the projects placed here would be neither critical nor urgent and usually would be expected to receive any required support from the higher functional level of authority.

Category-E:

Very small projects, routine/repeated projects and those that are completely manageable within the capability of their department would be classified as E projects. Around 50% of annual projects would fall under this category. The expected budget is to be less than SR 10 million and such projects would have no impacts on the 2030 vision. Scores below 25 points are used for this project category.

V. Consultation A- stage:

After the classification of a certain project, the project would take its place in a suitable category and then be moved to the initial stage of consultation. The consultation-A stage would assume the role of the second verification process to avoid conflict of interest as well as to double check from different perspectives to ensure the classification made was correct. The group of consultants designated to work under the high projects authority would be appointed to assure the adequacy and readiness of all project documents. The first draft of the project charter would be expected to be ready for further investigation in the upcoming stages.

Process monitoring in this stage would be tackled by the high projects authority until the project reaches the kick-off destination in order to avoid any delay in the initiation stage. It is also recommended to set and accept the accountability and functional deployments before moving to the next step.

VI. Consultation B- stage:

In this stage, all roles and policies would be applied and linked to the top vision, objectives and targets. Accordingly, the higher consultants would assure the compliance of the government strategy of insourcing plan, technology transfers and national recruiting “Saudization”. The project’s charter would need to be very comprehensive and approved before it moves to the next stage. The project charter would cover the following aspects:

A. Project objectives and goals
B. Project full scope
C. Project deliverables
D. Project imperatives
E. Project assumptions
F. Project constraints
G. Project drawbacks and consequences
H. Project risks measurements and mitigation plan
I. Project internal stake holders
J. Project external stake holders

K. Project span off teams
L. Project budget summary
M. Project CPS (Milestone plan)
N. Project highest priorities
O. Project handover report

The group of consultancies would set the project's Key Performance Indicators (KPI) in case the project is going to impact Vision 2030. This could include all projects that were classified earlier as A, B or C. It is expected to be monitored monthly through a peer review by defined members called the project committee. The high project authority would decide whether the project is going to have a project management contractor to be managed by the allocated project team supervised by a professional consultant office.

VII. Kick-Off stage:

Finally, it is now obvious the project is ready to be awarded to the main contractor or to a group of contractors, according to several factors for example: the level risk, availability of qualified parties, the capacity of the project management team and other factors that may exist during this stage. It is worth mentioning that applying a high international level of contracts such as a Fédération Internationale Des Ingénieurs-Conseils (FIDIC) contract would be easier for managing the project and including all technical and commercial aspects. The project team would now have the green light to commence the project with everything ready and at hand. The project manager would be responsible to manage all activities within his/her scope, appoint the project administrator to review the contract/contracts occasionally and apply all conditions on time. The monthly reports would be edited and reviewed before submission to the higher authority, highlighting all KPIs as per the initial agreement.

VIII. Takeover stage:

The last part before the official startup is the handover/takeover of the project. The project contractor at this stage would try to complete the project as early as possible because any single day of delay counts and affects the net profit.

The role of project management office or the consultant is vital to preserve the owner (Client) rights from any contract breach that may happen due to the low performance or the negligence of the contractor. The consultant at this stage has to make a very comprehensive snag list that would cover all aspects of project quality related matters.

The snags list is expected to be practical and doable within agreed time frame. In case the snags list has completely covered the observations, the consultant is only responsible for approving it and allows the owner to start taking over the project. It is highly advisable to keep from 5 to 20% bank guarantee for a period of one year after the takeover date. This year allows the owner to witness and have a general evaluation of the project quality in general as some critical issues may appear at later stages when the contractor would not be available.

A Proposed Projects' Overrun Management Protocol Using Projects Classification Matrix

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***Abstract*—The impact of project delays is usually intolerable and difficult to recover from. A significant number of projects don't finish on time or aren't completed up to the specified quality and are subject to cost and time overruns. Public projects in the Kingdom of Saudi Arabia (KSA) claimed losses of the order of $ 40 Billion per annum as a result of project overruns and many were delivered below quality standards. A proposed solution involving eight stages was developed in order to tackle most of the project delay issues that were determined by the author and accordingly ranked based on severity and frequency. These stages have detailed processes with control gates so that these projects will be moved steadily meeting all requirements at each entry gate. The eight stages are; the proposal stage, preliminary review & investigation stage, validation stage, classification stage, consultation-a stage, consultation-b stage, kickoff stage, and finally handover/takeover stage. All selected projects will be gathered at the proposal stage and then will be preliminarily reviewed before they move to the stage of validation. In the validation stage, the unnecessary projects will be postponed or canceled by the higher authority of projects which is proposed to be created. The classification stage is a very critical stage where all filtered projects will be classified based on eleven criteria. A scoring method was developed with respect to these criteria. Accordingly each project gets a proper parachuting so that the consultation-A phase would confirm the project's adequacy, readiness, and the availability of all related documents and studies. The Consultation-B stage's role is to link the top country's vision "2030", objectives, and targets. Accordingly, the higher consultants committee will assure the compliance of the government strategy of in-house sourcing plan, technology transfers and national recruiting "Saudization". The last two stages are the "kick-off and the takeover" which will be referred to the contract management, final project review, and proper closing process. The project classification matrix was used as an effective tool for many projects classification in KSA. The paper classified "King Abdullah Stadium" in KSA-2014 Category-A with a score of 44 out 55 which accordingly is subject to the highest project management level of control. The ultimate goal of this new project management protocol is to establish a higher projects authority to assure the implementation of 2030 strategy with special guidance and support with respect to the main project delay factors on the major infrastructural projects.**

Keywords*— *project management, projects phases, projects classification, and process validation

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I. Introduction

It is almost axiomatic of construction management that the project may be regarded as successful if the building is completed on time, within budget, and is of the desired quality [1]. It is commonly said, however, that two out of those three can't often be achieved due to the complexities involved in a construction contract and in particular the many different trades and professions that are commonly involved.

Delays in the completion of projects cause a negative effect on all areas of projects as well as all parties involved therein. The negative effects of delays are reflected in the cost of developments, the revenue from projects and the quality of those projects [2] [3] [4]. The more time taken to complete the job, the higher becomes the cost of construction; as delay means more staff members, more hours of work, more equipment, more plant, more direct and indirect overheads, potential claims between owner and contractor and more interests to be paid to financing institutions. In addition, rental or sale revenues will be lost for the duration of the delay. Other consequences represented are delaying in starting new projects and loss of reputation and credibility. Delays may also affect the quality of work because attempting to push the project activities forward to overcome delays can lead to quality being neglected.

In recent years, Saudi Arabia's construction enterprises increased greatly in many fields. According to a recent analysis, the level of uncompleted projects reached to more than 40% which requires a strong attention [5]. The construction industry has a consistently poor record with respect to the completion of projects on time. (Since it is clear that the majority of construction projects in the Kingdom of Saudi Arabia suffer delays or budget's overrun).

The proposed project management protocol incorporating a classification matrix developed by the author which helps significantly to classify projects based on eleven criteria with a total possible score (0 to 55) points. The scoring classifies the projects to 5-categories "A to E". Each category has a certain level of authority based on the total scoring number. The higher the score number, the higher the level of control to be applied. In this paper, the author's analyzed one of the mega projects which were executed in Saudi Arabia in the year 2016 by using the classification matrix. The project was called

King Abdullah Stadium which is located in Jeddah city and considered one of the best international stadiums. The methodology below shows how the protocol was applied by using the developed project classification matrix.

II. Project Management Protocol Stages

A. *Proposal Stage*

In this stage, it is assumed that the large and small organizations across the kingdom start to put their annual project plan. Each organization works individually at this stage depending on the agreed visions and set objectives on which such projects have to be inspired and formed. The list of the initiated projects to be grouped and further reviewed by the specialists employed by those organizations, and then to be approved as per the allocated annual budget and the objectives set. The final list is expected to have projects which are classified, i.e. "A, B, C, D and E". Projects which are tagged as A and B may be managed completely by the higher authority of projects in the kingdom.

B. *Preliminary Investigation:*

After the initiation stage, a big group of projects to be listed and organized in a way that would help the specialists (Projects high authority) to investigate whether these projects are meeting the organization's vision and objectives or not. In this stage, it is also expected to highlight the priority level and time completion plan for each project in order to help for the classification in later stages.

The eleven steps below elaborate in detail the recommended classification that is to be used for the governmental projects in the kingdom of Saudi Arabia. Each step has 5-levels with 5-ratings from "1 to 5" based on correspondent factors. The total summation of this number is equal to 55 points, where the weight of each step may vary from one organization to another according to the organization vision and objectives.

Eleven Projects Classification Criteria and Scoring:

1. Cost & budget
2. Priority & importance: Vision of 2030
3. Technical difficulties
4. Level of involvements and authorities involved
5. Location & geographical challenges
6. Category. "infrastructural, industrial, health, sport, education, tourism, military& defense, public residential and others"
7. Experience availability. "in house or out sourcing"
8. Project time duration. "tight, flexible or challengeable"
9. Familiarity, frequency, & repeatability:
10. Quality, Safety & Environment:
11. Risk Surroundings:

Table I below shows the 11 projects criteria and their corresponding factors that are scored from "1 to 11 %". The category's weights % is to be agreed by the head of the organization and his specialists to assure a fair scores contribution and to reflect the real impact at the end.

TABLE I. Projects Classification Matrix - Case of King Abdullah Stadium in Jeddah City

Projects Classification Matrix: * Weights vary based on the nature of the project & other criteria				
	"Proposed Project" King Abdullah Stadium	Scores	*Category's weight	Adjusted Score
1	**Cost & Budget:**		10%	
	a- Very high expenditure> SR 500 M	5		5
	b- High expenditure < SR 500 M	4		
	c- Medium expenditure < SR 100 M	3		
	d- Low expenditure < SR 50 M	2		
	e- Very low expenditure < SR 10 M	1		
				5
2	**Priority & Importance:** Vision of 2030			
	a- High priority, a big part of 2030	5	10%	5
	b- Med. Priority	4		
	c- Normal	3		
	d- Good to have, at any time	2		
	e- Not important, in 5 years span	1		
				5
3	**Technical Difficulties:**		10%	
	a- Very difficult & complicated	5		
	b- Difficult	4		4
	c- Average	3		
	d- Easy	2		
	e- Very simple concept	1		
				4
4	**Level of Involvements,** Authorities get involved:			
	a- Very high involvement, > 7 authorities	5	10%	5
	b- High, 4 to 6 authorities involved	4		
	c- Average, around 3 authorities	3		
	d- Manageable within Ministry or Authority	2		
	e- Manageable within organization or department.	1		
				5
5	**Location & Geographical challenges:**			
	a- Critical, important and vital	5	5%	5
	b- New Developed cities	4		
	c- Main cities	3		
	d- Small cities or towns	2		
	e- Country sides or rural areas	1		
				2.5
6	**Category:** Infrastructural, industrial, health, sport, education, tourism, military/defense, public residential and others			
	a- Health & education	5	5%	
	b- Urgent infrastructures	4		
	c- Residential projects	3		
	d- Industrial cities & projects	2		
	e- Tourism & sports	1		1
				0.5
7	**Experience Availability:** "In-house or outsourcing"			

	a- Not available at all	5	10%	
	b- Very limited	4		4
	c- Partially available, with major help	3		
	d- Available, with minor help	2		
	e- Fully available, managed locally	1		
				4
8	**Project Time Duration:** "tight, flexible or challengeable"			
	a- Very short, challenged	5	10%	5
	b- Short	4		
	c- Average, realistic based on all parties	3		
	d- Relaxed, 10% extra from the CPS	2		
	e- Stretched, 10-30%	1		
				5
9	**Familiarity, Frequency& Repeatability:**			
	a- Unfamiliar, new concept "never applied"	5	10%	
	b- Conceptually clear, needs a partner	4		4
	c- Adaptable with experts	3		
	d- Familiar, manageable	2		
	e- Very familiar, repeated	1		
				4
10	**Quality, Safety & Environment:**			
	a- Top measures is expected, world's benchmarking	5	10%	
	b- High standards, national benchmarking	4		4
	c- Fair, average within acceptable RFQ	3		
	d- Economical, value for money, lowest standard	2		
	e- Low, standards not required	1		
				4
11	**Risk Surroundings:**			
	a- Huge factors affecting success	5	10%	5
	b- Many factors affecting success	4		
	c- Limited factors affecting success	3		
	d- Normal, risks are managed	2		
	e- No risk	1		
				5
	Total Score			44

C. *Validation Stage*

The validation stage is one of the most important stages due to the fact that after this stage, the project is going to move on designated paths which will usually be difficult to back-track for re-correction. This would be the real path in the future. Hence, it is very crucial to apply detailed analysis, if needed, and confirm the most realistic ranking from "A to D".

It is expected that some projects will be completely canceled, delayed and some to be called earlier. Some projects in the list, especially the infrastructural once, would impact so many critical projects if they didn't commence on time or at least start early.

D. *Classification Stage*

Reaping the early benefits with regard to the 8-stages of developing the government projects would start appearing here. The gained scores in the previous Table I would definitely help to parachute each project in the right zone. For example, the new King Abdullah stadium which was developed by ARAMCO "Arabian American Oil Company" was given a total score of 44 points which means that the higher authority of the projects in the kingdom of Saudi Arabia is recommended to take it over in full from A to Z.

It is also possible to apply many existing projects here in this developed table to examine its efficacy in light of logic and sense when compared to the previously taken decisions.

Table II below contains 5 categories "A, B, C, D, and E"; each one of them represents a certain zone that was created for a specific project management conditions. Each zone has its own level of authorities and accountabilities towards its end target.

TABLE II. CLASSIFICATION CATEGUIRIS "A, B, C, D, E"

	Points	Level of Authority	Index Range		
1	44 – 55	Managed by high Authority of KSA	75%	100%	A:
2	35 – 43	Managed by higher level within Authority	64%	73%	B:
3	30 – 34	Managed by higher level regional office	55%	68%	C:
4	25 – 29	Managed by local office	45%	53%	D:
5	< 25	Managed by allocated office	<	44%	E:

- *Category-A:*

This is the highest category and has the highest roles of responsibility for all projects to be executed within the kingdom's borders. The zone has a range of points "44 points to 55 points".

- *Category-B:*

The projects scores that fall between "35-43" will be located in this category and it is recommended to be managed by the higher level of authority within the ministry. Some roles and tasks will be managed by the higher level. However, the core responsibility of the project manager will be done by this allocated team.

- *Category-C:*

The medium size projects will usually be located in this category's zone. The projects in this zone will not require a high level of project management skills. The time schedule as and the budget are reasonable to be handled by a regional team within the ministry and they could get any needed support from the higher level of the project authority's hierarchy system. The zone here represents all scores between "30-34".

- *Category-D:*

The local engineering or project team could handle most of the activities needed for small-medium size projects which will be scored between "25-29". Most of the projects here seemed to be neither critical nor urgent in the project charter. It is usually expected to take any required support from the higher functional level of authority.

- *Category-E:*

Very small projects, routine/repeated projects and those which are completely manageable within the capability of that department would be classified as E-projects. Around 50% of annual projects are expected to fall under this category. The expected budget is to be less than SR 10 million and such projects have no impacts on 2030's vision. The given score to this category is for all projects below 25 points.

Table II above contains of 5 categories "A, B, C, D, and E"; each one of them represents a certain zone for a specific project management conditions. Each zone has its own level of authorities and accountabilities towards its end target.

E. Consultation A- Stage

After the classification of a particular project, the project will be moved to the initial stage of consultation. The consultation-A will resume the role of the second verification process to avoid the conflict of interest as well as to double check from different views ensuring whether the classification which was made is perfect or not in the previous stage. The group of consultants who are supposed to work under the high projects authority would be appointed to assure the adequacy and readiness of all project documents as part of their roles and responsibility. The first draft of the project charter is expected to be ready for further investigation in the upcoming stages.

Process monitoring in this stage is to be tackled by the high projects authority until the project reaches the kick-off destination in order to avoid any delay in the "initiation stage". It is also recommended to set and accept the accountability and functional deployments before moving to the next step.

F. Consultation B- Stage

In this stage, all roles and policies will be applied and linked to the top vision, objectives, and targets. Accordingly, the higher consultants assure the compliance of the government strategy of insourcing plan, technology transfers and national recruiting "Saudization". The project's charter should be very comprehensive and approved before it moves to the next stage. The project charter is going to cover the aspects below:

(Project objectives & goals, Project full scope, Project deliverables, Project imperatives, Project assumptions, Project constraints, Project drawbacks & consequences, Project risks measurements & mitigation plan, Project internal stake holders, Project external stake holders, Project span off teams, Project budget summary, Project CPS "Milestone plan" Project highest priorities, and Project handover report).

The group of consultancies will set the project's KPI in case the project is going to impact the top vision "2030". This could include all projects which were classified earlier (A, B and C). These projects are expected to be monitored monthly and to have a peer review by defined members who are called the project committee.

The high project authority will decide whether the project is going to have a project management contractor to be managed by the allocated project team supervised by professional consultant office.

G. Kick-Off Stage

Having said the above, it is obvious now that the project is ready to be awarded to the main contractor or to a group of contractors according to many factors. For example, the level of risk, availability of qualified parties, the capacity of the project management team and other factors that may exist during this stage.

It is worth mentioning to apply a high international level of contracts such as "FIDIC" contract to be easier for managing the project and to include all technical and commercial aspects.

The project team now has the green light to commence the project and everything is ready in hand. The project manager is responsible for managing all activities within his scope, appoint the project administrator to frequently review the contract/contracts, and apply all conditions on time. The monthly reports to be edited and reviewed before its submission to the higher authority highlighting all KPIs as per the initial agreement.

H. Takeover Stage

The last part before the official startup is the part of handover/takeover of the project. The project contractor at this stage tries to complete the project as early as possible because any single day of delay counts and affects the net profit.

The role of the project management office or the consultant is vital to preserve the owner "Client" right from any contract's breach that may happen due to the low performance or the negligence of the contractor. The consultant at this stage has to make a very comprehensive snag list that would cover all aspects of the project quality related matters.

The snags list is expected to be practical and doable within agreed time frame. In case the snags list has completely covered the observations, the consultant is only responsible for approving it and allows the owner to start taking over the project. It is highly advisable to keep from 5-20% bank guarantee for a period of 1- year after the takeover's date. This year allows the owner to witness and have a general evaluation of the project quality in general due to the fact that some critical issues may appear at later stages where the contractor wouldn't be available. Fig. 1 below illustrates the conceptual flow of all concerned projects from the first stage to the end.

III. Results

As a result of the eight stages of the projects management protocol, the performance of the public projects is expected to be better, faster and within the normal budget variation. Many underperforming projects would be eliminated at earlier stages and most of the unqualified contractors wouldn't be short-listed. Most of the missing parts of the scopes would be realized early and accordingly, the projects budget initiation would be more accurate and reliable.

There is a clear need of the creation of a higher authority of projects in the kingdom of Saudi Arabia in order to regulate the protocol. This is particularly the core in relation to the public sector because of the sheer scale of the projects involved and also the limited technical capabilities of both the owners and contractors.

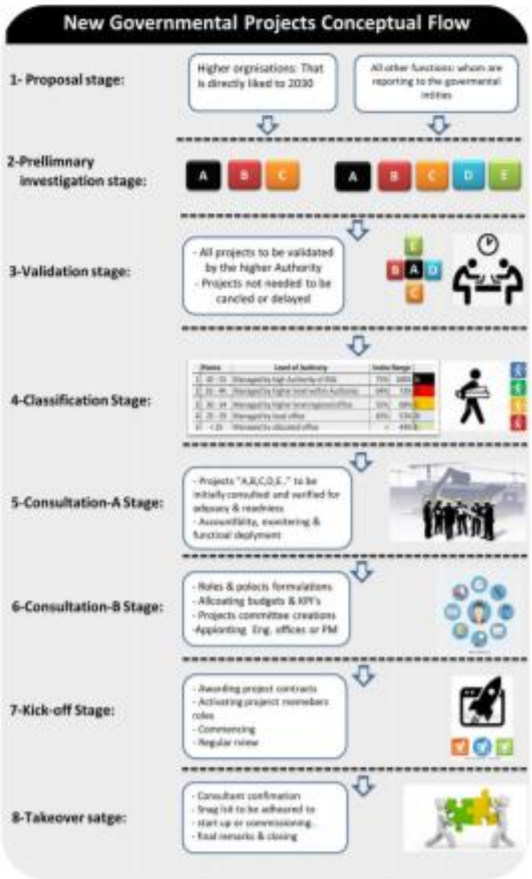

Figure 1. Proposed projects management protocol

IV. Discussions

The majority of the delayed projects in Saudi Arabia were public projects. The overrun in both time and budgets were common in general and the impact is still observed and even increased proportionally with an excess amount of projects after the huge capital deployed starting in 2007. The proposed protocol was carefully prepared after evaluating the top critical delay factors that were initially obtained, analyzed, and validated by the author which was successfully published in Rome conference [6]. The eight proposed stages have tackled the top 20 factors of delays that were mostly agreed by projects experts, main contractors, and consultants.

This research has a comprehensive principle of considering the major effects of these delay factors toward the time, cost, quality, and safety. Each stage in this protocol was prepared carefully to eliminate firmly the possibility of delay factors occurrence and repetition during the project cycle to assure a safe projects handover at the final stage.

Adapting the new proposed management protocol supported by the novel concept of Projects Classification Matrix is expected to improve both the public projects delivery time and the costs overrun by 60-70% based on the quality of the protocol implementation. The new management protocol was developed to tackle the top 20 critical factors of delay which were discovered by the author in his previous Paper.

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