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Prediction Models for Delay in Pipeline Construction Projects in the Oil and Gas Industry

Thesis submitted in partial fulfilment of the requirements for the Master Degree
in Engineering Management

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Thesis Discussion Committee Decision

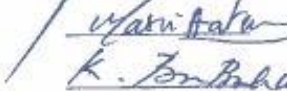
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- ☐ Without making any changes to the thesis
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Abstract

The aim of this research was to develop a prediction model for delays in pipeline construction in the oil and gas industry in Bahrain. A mixed methods research design guided by a pragmatic philosophical stance was implemented. Focus group discussions with experts ($N = 8$) in pipeline construction were used to develop a list of 47 delay factors that were most applicable to the research problem. A web-based questionnaire ($N = 93$) was administered to collect quantitative data on the importance and occurrence frequency of a delay factor. The importance of delay factors was performed using the Relative Importance Index (RII) while ranking of frequency of occurrence was performed using the Frequency Adjusted Importance Index (FAII). Multiple linear regression was performed in SPSS to model the prediction of both duration of delay and cost of delay in USD. Multiple linear regression using real Key Performance Index (KPI) data from an existing company was also employed to validate the prediction models.

The findings of this study established that inadequate project planning, budgeting, and scheduling, scope variation, and late materials delivery were the main delay causing factors in the pipeline construction in the oil and gas industry in Bahrain. Of significant importance is that most of the main delay factors were related to owners or their representatives and contractors.

The respective regression model showed that scope variations and delay in drawings preparation of the projects were the significant predictors of duration of project delays in days. However, the two variables could predict for almost 34% of duration of delay. On the other hand, the prediction model for cost of delay revealed a higher prediction power with more delay variables. The regression model showed that poor site management and supervision; inefficient and poor performance of contractors/subcontractors; contractor's lack of planning at preconstruction; weather effect; rework due to errors, mistakes and defective works during construction; and delay in drawings preparation of the projects were the main predictors of project cost increase due to delays. However, these variables could almost predict 69% of the cost increase resulted from delays.

Dedication

To my parents, wife, and to my family,,,,

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List of Notations

RII	Relative Importance Index
FI	Frequency Index
FAII	Frequency Adjusted Importance Index
w_i	Importance weighting of each factor
A	Highest possible score of 5
w_f	Frequency weighting of each factor
r_s	Spearman's Rank Correlation Coefficient
R	Multiple correlation coefficient
R^2	Coefficient of determination
β	Standardized regression coefficient

List of Abbreviations

KPI	Key Performance Index
A-B	Aramco Bapco Pipeline
GCC	Gulf Cooperation Council
DPSA	Development and Production Sharing Agreement
NOGA	National Oil and Gas Authority
GIS	Geographic Information System
GDU	Gas Dehydration Unit
PCR	Principal Component Regression
NN	Neural Network
CBR	Case Based Reasoning
MPP	Modified Project Price
MPD	Modified Project Duration
SPSS	Statistical Package for the Social Sciences

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Chapter One

Introduction

1.1 Background

1.2 Research Problem

1.3 Research Questions

1.4 Research Objectives

1.5 Research Significance

1.6 The Study Setting

1.7 Thesis Outline

1.8 Research Terminology

Chapter 1: Introduction

1.1 Background

Disruptions and delays that result in schedule and budget overruns construction projects are a major concern globally. Typically, timely project completion ranks highly as a project success metric alongside adherence to budget, satisfaction of quality standards, and conformance with benchmarks for safety (Gebrehiwet and Luo, 2017). Even though these factors appear standalone, numerous studies across diverse disciplines and industrial fields have reported relationships between these variables (Karami and Olatunji, 2017). For example, Kaliba et al. (2009) reported a strong positive relationship between project cost and quality and the project's lifecycle performance. It has also been argued that the ultimate outcome of the combination of all these variables is driving project stakeholders' gratification. These stakeholders include end-users, project owners, and the project team led by project managers and construction engineers.

Although all construction projects put into consideration the importance of time, cost and quality. The oil and gas pipeline construction projects give greater attention to those factors due to the fact that they cause massive revenue losses and economic standstills if not managed properly. Moreover, the importance of these factors lies in the fact that they directly affect the country's economy and thus will affect infrastructure and development projects in the country.

Ahiaga-Dagbui et al. (2015) contested that the subject of mitigating and understanding the causes of project overruns has remained redundant and noticeably stagnated. Based on this view, these authors called for

further research studies that deviate from the conventional simplistic approach of research by considering diverse dimensions to project delay and overruns. More recently, Karami and Olatunji (2017) investigated project delays overruns. Although they included under water pipelines in dams within marine projects, their research did not cover oil pipelines. Yet, the accurate identification of delay causations within particular project environments enables the comprehensive and precise development of both preventive and corrective strategies of mitigation. This is because capturing this correctly enhances project value.

In the oil and gas industry, one of the major objectives of pipeline construction engineers is to ensure prompt completion of projects within budget as is the case in other industry sectors that involve construction. Even so, linear construction projects such as oil pipeline construction projects also suffer delays occasioned by a multitude of diverse, inherent complexities (Orangi et al., 2011). Specific to pipeline construction delays, any factor that exceeds the project timeline is also expected to escalate costs in numerous ways. Examples include losses associated with low well production following the extension of the production commencement date of a unit. This is why construction companies have developed measures to enable them to complete their projects within the specified timeline. Nevertheless, this has not been easy in most cases.

Construction engineers and project managers working in the oil and gas industry have been recognized as major influencers of prompt, quality and efficient project completion (Ruqaishi and Bashir, 2015). This is because they are responsible for overseeing all oil and gas development pipeline projects in their respective oil-driven countries. Petroleum companies are a good example of companies that heavily rely on the

pipeline construction industry for their growth and productivity. The researcher has chosen a company in the oil and gas industry in the Middle East as the subject for this research. However, due to confidentiality of the chosen company, the researcher will refer to the company as XYZ Company. XYZ Company has greatly invested in this industry in order to fuel its growth. Despite the noted positive intervention by the company executive management, construction projects have always experienced significant delays, forcing the project development team to incur more cost than initially estimated (Chan and Kumaraswamy, 2002).

1.2 Research Problem

Inadequate understanding or lack of knowledge on how to predict delays in pipeline construction within the oil and gas industry continues to cause significant challenges and shortfalls. These include massive revenue losses, economic standstills, and unemployment. For example, 25,000 barrels of crude black oil were lost over a period of seven years starting from 2011 due to delays in the completion of pipeline construction projects in Bahrain alone. This translated to a loss of nearly USD 2.5 million computed based on an average, annual crude oil price based on the oil price supplied by the Organization of Petroleum Exporting Countries (OPEC). Such huge amounts could otherwise be channelled to other oil well projects to boost the total oil production of Bahrain.

An in-depth desk research performed by the researcher revealed numerous studies about project delays have attempted to explain the reasons behind project delays and overruns (Love et al., 2012; Karami and Olatunji, 2017; Gebrehiwet and Luo, 2017). Most of these authors identified issues in various project types including conservation projects, marine projects, dams, transport infrastructure, and marine projects.

Ruqaishi and Bashir (2015) studied delays in oil and gas construction projects within the Gulf Cooperation Council (GCC). However, none of these studies have attempted to investigate delays specific to pipeline construction in the oil and gas industry. Moreover, there are few studies to the best of the knowledge of the researcher that have attempted to develop a prediction model for delays in pipeline construction in the oil and gas industry. The focus of previous studies was to find delay factors in construction projects and rank them from top to bottom without focusing on the risk analysis of these factors by using the risk analysis matrix. In addition, few studies have integrated the findings and arrangements of delay factors with the creation of models predicting the delay and cost caused by this delay.

1.3 Research Questions

The aim of this research is to develop a prediction model for delays in pipeline construction in the oil and gas industry in Bahrain. Consistent with this research aim, the following research questions guided the implementation of this research:

- 1) What are the main factors causing delays in pipeline construction projects in the oil and gas industry in Bahrain?
- 2) What is the impact of delays in pipeline construction projects in the oil and gas industry in Bahrain?
- 3) What is the appropriate model that can help the management to predict causes of delays in the upcoming pipeline construction projects?

1.4 Research Objectives

Based on the research questions listed in the previous section, the study objectives are shown below:

- 1) To identify the main factors that cause delays in the pipeline construction projects in the oil and gas industry in Bahrain
- 2) To investigate the impact of delays in the pipeline construction projects in the oil and gas industry in Bahrain
- 3) To develop a prediction model of delays in pipeline construction projects in the oil and gas industry in Bahrain

1.5 Research Significance

The pipeline construction industry is a major contributor in increasing the oil production of Bahrain. The annual field oil, condensate production and black oil production increased to an average of 47,900 barrels per day (bpd). However, delays in the development and delivery of pipeline construction projects have greatly affected the well production rate global economic growth. This implies that there is a great need to carry out a research aimed at identification of the best way to reduce such delays. Although various studies have been carried out on the delay in oil and gas construction projects. However, effective solutions to the specific pipeline construction delays have not been identified. Therefore, this study will be highly significant as it will form a framework through which delays in construction pipeline projects can be managed or avoided. Furthermore, it will provide a better understanding of causes of delays and enhance the understanding of the management to the effects of delays on oil production loss.

1.6 The Study Setting

This study was conducted in the Kingdom of Bahrain (hereinafter referred to as Bahrain). A hereditary, constitutional monarchy comprising 33 islands situated in the Arabian Gulf on the western side of Asia, Bahrain has a population estimate of 1.316 million as per the 2014 census (Ministry of Information Affairs (MIA), 2014). Oil and natural gas are the top natural resources having been the first country within the GCC to begin refining in 1936 upon discovering crude oil in 1932. Bahrain's oil sectors is the principal income source where crude oil production accounted for approximately 0.8 percent of the entire Arab production in 2013 with 48,000 bpd from its fields. With the Bahrain Refinery refining over 274,000 bpd, the country also imports approximately 150,000 barrels from the Saudi Arabia-Bahrain joint venture at the Abu Safa offshore field (MIA, 2014).

The Bahrain Economic Development Board (2017a) reported that in the first six months of 2017, Bahrain's oil production stood at a mean of 203,556 bpd with the daily mean output in the second quarter of 2017 averaging 204,575 bpd. In the same year, the value of Bahraini infrastructure project pipeline was estimated at USD 6 billion as of mid-June, 2017 (Bahrain Economic Development Board, 2017a). The projects includes the multi-billion Bapco modernization program, Bahrain Liquefied Natural Gas (LNG) Terminal and Bahrain National Gas Expansion Project. The A-B-1 pipeline was commissioned in 1945 to ferry crude oil from the Aramco Abqaiq plant in Saudi Arabia to Bahrain's Sitra Refinery. The government has since entered into a joint venture with Saudi Arabia to construct a new pipeline with a diameter of 30 inches. The new crude oil pipeline runs 73 kilometres on land and 42 kilometres subsea

covering a total of 115 kilometres. The projection are that the USD 325 million project will increase transport capacity by 120,000 bpd to reach 350,000 bpd. The A-B pipeline is also expected to have the flexibility of increasing transport capacity to reach 400,000 bpd once completed in 2018 (Bahrain Economic Development Board, 2017b).

The company responsible for revitalization and stewardship of the Bahrain Field is XYZ Company, which was known as Bahrain Field Development Company W.L.L. until December 2009. XYZ Company also undertakes every activity that concerns petroleum operations in line with the guidelines issued under the Development and Production Sharing Agreement (DPSA) of April 26, 2009. The DPSA is an agreement between Occidental Petroleum Corporation and National Oil and Gas Authority (NOGA) on the one hand and the Oil and Gas Holding Company or the Nogaholding. As the NOGA investment and business arm, Nogaholding wholly owns XYZ Company. NOGA oversees the investment of the Government of the Kingdom of Bahrain through diverse energy-related firms. The primary goal of XYZ Company is to increase oil production and gas availability to satisfy the Kingdom's future demands for energy in accordance with the Economic Vision 2030.

Despite declining oil prices, XYZ Company successfully drilled an additional 958 wells from 2010 to 2017, which makes the total number of active wells in oil and gas to 1,120. This ensured the maintenance of a mean condensate and oil production level of 48,500 bpd and a 2.1 billion cubic feet per day production of non-associated gas. However, this was a decline in oil production from the 2015 production of 50,600 bpd. In 2016, XYZ Company completed 958,000 man hours on maintenance programs to improve field asset safety, reliability, and mechanical integrity to avoid

delivery interruptions of oil and associated gas to refinery and delivery points respectively.

In an attempt to improve stakeholder coordination and data accuracy of the Geographic Information System (GIS), the company installed smart application tools for better management of its maintenance and design complexity of its pipeline networks. Although the company reported enhanced efficiencies in drilling and performance of wells including reduced well drilling periods, it still faces challenges of delays in completion of construction projects. For example, 11 appraisal projects including three gas injection tests, five water floods, one high volume lift, and two steam floods were still being evaluated as at December 31, 2016. In addition, the construction of a Gas Dehydration Unit (GDU) that commenced in June 2016 was 63 percent complete at the end of 2016. With construction of the A-B pipeline having commenced on the Saudi side, avoiding delays in its completion is crucial for both production and investment returns.

1.7 Thesis Outline

Chapter 1 includes an introduction of the study which summarizes the background, the research problem, research questions, research objectives, research significance, the study setting, and research terminology. Chapter 2 of this thesis presents theoretical and empirical literature on the delay factors that have been found to have a significant effect on the overall project completion based on findings from various studies. This chapter highlights project delay factors in pipeline construction projects based on theoretical literature as well as findings from various empirical studies. The chapter also reviews prediction models developed for estimation of cost

and time overrun in construction projects. Chapter 3 presents and evaluates the research design and methodology approaches that have been used by a number of researchers to identify delay factors in construction projects especially within the oil and gas industry. In addition, Chapter 3 also presents common research and data collection tools that have been employed in formulating models for predicting delay factors in construction projects. Chapter 4 presents the results obtained by multiple linear regression models for predicting delay in pipeline construction projects within the oil and gas industry. Chapter 4 highlights importance of the stated delay factors in construction projects using the Relative Importance Index (RII), while the frequency of occurrence in the stated delay factors are measured using the Frequency Adjusted Importance Index (FAII). On the other hand, Chapter 5 formulates and presents validation models for predicting the stated delay factors in pipeline construction projects. Finally, Chapter 6 provides a discussion on implications of the results based on multiple linear regression models for predicting delay factors in pipeline construction projects within the oil and gas industry in Bahrain. This is followed by the conclusions and recommendations on the key delay factors that project managers operating in the pipeline construction projects should give serious considerations.

1.8 Research Terminology

Delay: also interchangeably referred to as “construction delays” and “project delays”, they refer to the “case when the actual work of a construction project is slower than the planned schedule or late accomplishment of the projects” (Al-Fadhali and Zainal, 2017, p.393).

Delay causing factor: a combination of numerous, related delay reasons that cause delays such as contractor/sub-contractor related delays, owner related delays, and so on.

Chapter Two

Literature Review

2.1 Introduction

2.2 Delays in Construction Projects

2.3 Prediction Model for Delays

2.4 Conclusion

Chapter 2: Literature Review

2.1 Introduction

This section looks into the previous studies that are relevant to the current study. Delay in construction projects can have dire implications on the stakeholders of the construction industry. Such stakeholders may include owners, consultants, engineers, quantity surveyors, governments, project managers and contractors. Therefore, developing a model for prediction of delays and the ways of mitigating these challenges is essential. This will be achieved by examining previous studies that deal with some of the causes of construction delays in the oil and gas and other industries. The objective of this literature review is to identify the research gaps and develop a prediction model for delay and its associated cost in pipeline construction projects in the oil and gas industry.

2.2 Delay Factors in Construction Projects

Several studies have been conducted to investigate the causes of delay in numerous construction projects. Elhag and Boussabaine (1999) conducted a study on the evaluation of construction cost and time attributes. The objective of the study was to evaluate and rank the causes of delays according to their degree of influence on time and cost overruns in construction projects. The researchers carried out a literature survey and identified 67 main factors that influence cost and duration overruns in construction projects. The results ranked the top-four factors with the highest influence as: consultant and design parameters (82%), client characteristics (77%), project characteristics (75%) and market conditions (72%). A detailed analysis was done at the group level for each cluster. Finally, an overall ranking was statistically done without considering the

clusters. It was found that the highest influence factor was late changes in design, followed by the experience of the management, and deadline requirements. The findings of the study demonstrated that evaluating and ranking key influence factors is an effective strategy of determining cost and duration overrun issues.

Al-Momani (2000) carried out a study on delays in public construction works in Jordan. The researcher focused on randomly selected sample of 130 public building projects in diverse regions constructed between 1990 and 1997. The researcher used the planned and actual construction times of the projects to examine the causes of delays. Out of the 130 projects, 106 experienced delays. Furthermore, the researcher found out that poor design was the main reason for the project delays. Poor designs accounted for 24.6% of the projects, followed by change of client order at 15.4%. The study also found that in overall, with the study period, the actual construction duration exceeded the predetermined duration. The study established the main reasons of construction delays as changes made to design, clients changing orders, climatic conditions, etc. The findings suggested that special attention of the factors identified can help practitioners to minimize the risk of construction claims and disputes.

Thuyet and Ongunlana (2007) carried a study on the process of managing risk in the petroleum industry in Vietnam. The objective of the research was to determine the major risks affecting the industry and in turn, propose the means of mitigating these risks. The main methods used in the research were questionnaires and structured interviews. The interviews revealed the top risks of project delays as manpower incompetence and lack of systematic structures. The study proposed the improvement of management competence, skills, and the capabilities of the owners and

workers as appropriate strategies for mitigating these risks. The risks associated with other reasons for construction delays were thoroughly investigated. The hypothesis was that the job position, work group or company type did not affect the judgment of project managers on the risks. The major strategies for managing major risks were: bureaucratic system and delayed approval, (mitigated by governmental administrative reform and developing good working relationships with stakeholders, and understanding approval procedures); and poor design, (mitigated by partnering, and using familiar and experienced design companies). The study also proposed appropriate strategies for the top-ten major risks identified in the research. Therefore, the study succeeded in identifying the risks and proposing practical solutions for construction delays from the perspective of experienced project managers.

Naimi et al. (2008) studied construction delays and their consequences in the construction of Iranian petrochemical plants. The primary aim of study was to determine the main reasons for construction delay in the petrochemical projects in Iran. The researchers carried out a literature review to determine the main causes of delays in the industry. The researchers investigated petrochemical construction projects for the past 15 years in Bushehr and Khuzestan provinces using questionnaire. Sixty five questionnaires were given to the stakeholder in the construction industry. The study found that 31 out of 34 projects experienced delays up to 63.4% of the estimated duration. Over sixty one percent of the contracts were valued at over USD 100 million. Over seventy six percent of the project awards were based on the minimum price. Based on the payment mechanism, it was found that 26 projects worked on a fixed price basis. RII was applied to investigate the causes of delay. The most significant causes of delay were identified as: delay in delivery of materials, lack of

competent workforce, inflation and unrealistic estimation. The consequences of the delays were both technical and cultural. Technical consequences were caused by the clients, while cultural consequences were related to the collectivism-nature of the Iranian people.

In another study, Salama et al. (2008) investigated the reasons of delay in petroleum projects in the United Arab Emirates (UAE). The researchers used a set of semi-structured interviews with experts in order to identify the main causes of time overruns. Based on the outcomes of the semi-structured interviews, a questionnaire was sent to a randomly selected sample of 100 practitioners with the view to determine the most significant factors. Based on RII, the study identified the main delays in purchasing, late equipment delivery and lack of experience.

In another different study, Ganiyu and Zubairu (2010) did a research on developing a prediction model for cost overruns using the principal component regression (PCR) for public building projects in Nigeria. The main objectives of the study were: to identify the factors that affect project costs, investigate the significance of the factors identified and developing a predictive cost model. The research method focused on the main players in the industry; that is, contractors, owners and consultants. The study covered complete construction projects, and it mainly focused on building works. Random sampling was used in the study. Fifteen out of 38 factors were selected from literature review and data analysis techniques used. Two analytical techniques were selected: principal component regression (PCR) and multiple regression models for predictive purposes. From the literature review, 38 factors were identified. The study also found that the six most influential factors were design-related factors and related with cost of public building projects. A predictive model was developed. It

indicated that the R^2 and adjusted R^2 values were approximately 20% and 24% respectively, which compared favourably with the values in the literature.

In another study, Khoshgoftar et al. (2010) did a research on the causes of delays in the Iranian construction industry. The objective of the study was to investigate the causes of delays in the Iranian construction industry. The main methods of collecting data were questionnaires. The survey was done with the view to seek the perspectives of clients, consultants and contractors. From 125 sets of questionnaires, the results of the study showed that the most significant delay factors were: financing and payment of finished work, lack of proper planning, site management and poor communication. These results corroborated those in Ayodele and Alabi's (2011) study, which showed dominance of the client factors for construction delays as poor communication, lack of proper project objectives, irregular payments and lack of adequate time.

Abedi et al. (2011) studied the effects of construction delays on the objectives of construction projects. The main aim of the study was to determine the impact of delays on the objectives that construction companies have. A chart of six impacts of delay was identified through a review of previous studies, namely: duration overruns, cost overruns, disagreements, mediations, lawsuits and relinquishing of the project. The research found that duration overruns may affect contractor and client-related objectives. Cost overrun was found to be most affected by inflation and rising material prices, client's change of design, climatic changes and late payment of contractors by owners. Litigation was also recognized as a cause of delay in payment, disputes of the site conditions. Finally, total abandonment of the project, temporarily or permanently, was noted as a

cause of the delays in construction projects.

Orangi et al. (2011) did a study to explore construction delay in pipeline projects in Victoria, Australia. The objective of the research was to study the reasons of time and cost spills in Victoria and determine the extent of the impact of the causes on time and costs in linear pipeline projects. The study found that issues regarding approval were the most significant cause for delays in linear pipeline construction projects based on both frequency of occurrence and the extent of time impact. The targeted interviews found that rationalized management of linear projects may be used with suitable risk mitigations. This study demonstrated that linear projects can also be affected by delays. The top-five major causes of construction delays identified in the study were: changes in design, design discrepancies, communication problems, issues related to customers, and investigations issues. The study also demonstrated the importance of case studies and evaluation of best practices as essential tools for rational planning.

Mohammed and Isah (2012) carried out a study with the objective of investigating the reasons for construction delays in the Nigerian building sector. The study had three main objectives, namely: determining the major reasons for delays in building projects in Nigeria, the effects of those delays in the building industry, and propose strategies for the improvement in constructions. The researchers categorized the delay factors into: delays caused by the mistakes and inadequacies of the contractor that could be ignored, and those that have cost implications on the constructions projects. The latter were classified into those factors that can be compensated such as money lost and those that cannot be compensated such as time. The researchers conducted a review on previous literature and developed

questionnaires that were used to carry out the assessment. The reasons of construction delays were placed in six clusters as determined by the way they occurred and when they occurred. The survey results were then analyzed for recommendations. The main cause of delay was found to be inappropriate planning, followed by lack of proper communication. Supply shortage and design errors were ranked third as cause for delays while the fourth was slow decision making and financing problems. The fifth was shortage of materials. The researcher ranked 43 factors that led to project delays in the Nigerian construction industry. The researchers identified four impacts of delays in the construction industry as loss of interest by stakeholders, being blacklisted by government authorities, time and money wastage and declining reputation. The study proposed various ways of dealing with project delays. They included: risk management, proper planning, and timely payment by clients.

Fallahnejad (2013) studied construction delay causes in the Iranian gas pipeline industry. The major aim of the study was to investigate and rank the main reasons of construction delays in pipeline projects in Iran. In this regard, the researcher studied 24 completed gas pipeline projects. Fallahnejad's study sought to recognise the reasons of construction delays from the perspective of 10 professionals from different fields in the oil and gas industry. The study's findings were tabulated in a 43-items list. In turn, the outcomes were subjected to a survey, which identified 10 major delay factors in the oil and gas industry as imported materials, rigid projects timelines, client-related materials, land confiscation, change orders, contract selection methods, payments to contractors, delays in getting permits, supply-related factors, and contractor's cash flow. The findings in this study were similar to those of Abd El-Razek et al. (2008) who concluded that some of the factors that causing construction delays were

lateness in paying contractors, partial payment for progress, material samples and getting approvals.

Shehzad (2015) analyzed the reasons of delays in the oil construction industry. This was achieved by carrying out a pilot survey to evaluate real data in order to explain the factors that cause time and cost overruns. Questionnaires were sent to the senior employees involved in the implementation of projects in the oil and gas projects industry. The secondary data was collected from historical data, reports and related information. After this, a factor-based analysis was done on the primary data collected. From the study, 70 factors were identified from causes found in related literature and tabulated in a factor distribution table. A scatter plot for frequency of occurrence, relative importance, severity, and overall importance indices were also performed for linearity test. For secondary data, two case studies revealed the reason for construction delays as changes in the scope of the contract, shortage of skilled labor and poor planning. Therefore, the results from the primary and secondary data were comparable.

Al Hammadi and Nawab (2016) did a critical study of the delay factors in construction projects. The primary objective of the study was to determine the most significant causes of delays when building structures in Saudi Arabia. The factors were categorized into 11 factors related to: owner, contractor, project, client, consultant, financial, design, plant equipment, materials, workforce, and external factors. The quantitative research carried out had two objectives, which were: to identify knowledge and understanding of completion of projects, and explore delay factors. The analysis was done to find the top-20 most significant delay factors. These factors were: slowness of owner decisions, delays in contractor

payment, owners not paying for progress, owners changing orders in the middle of projects, rigid owners, and delays in approval of the test samples, among others. The study also categorized the factors based on those identified by consultants, project managers and engineers. The researchers concluded that the main causes of delays in construction projects were due to the client's responsibility, contractor-related, material-related and engineer's drawing designs. However, a study done by Abd El-Razek et al. (2008) on construction delays found that the most important factors that lead to construction delays are financing by contractor, delays in contractor payment, uncooperative owners, partial payment and non-utilization of professional and construction management.

In a different study, Mali and Warudkar (2016) did an analysis to determine the reasons for delay in the construction industry in Pune City, India. The aims of the study were to identify the causes of delay, analyze the collected data and to study the differences in ideas of clients, contractors and consultants. A pilot study was done on previous data and it was found that delays may have impact on critical and non-critical activities. The study identified 4 critical and non-critical delays, 13 excusable and non-excusable delays (which were in turn broken into compensable and non-compensable delays). Average Index was applied to get the results while the Frequency Importance Index was used to analyze the delays. The questionnaire design was meant to get information from the respondents. The survey results identified contractor and material-related factors as contributing to construction delay. The consultant-related factors identified were misunderstanding of client necessities, and lack of proper project information. The study ranked the top ten causes of construction delays based on the RII and Average Index. The study ranked the top cause for construction delay as project-related. Material-related

factors were also found to have the most severe effects as compared to the other groups. The researchers concluded the study with some recommendations, which included: improving the knowledge of technical staff, improving procurement strategies and improving site mobilization.

Shehu et al. (2016) studied the effects of construction delays on the contractor's reputation in Nigeria from a professional perspective. The study sought to identify the causes of delays and their consequences. A literature review was carried out and 78 factors that affect delays in the construction sector were identified. However, the most common factors from the literature review were design problems, construction defects, materials and management of construction sites. The study used different methods of collecting data such as surveys and structured interviews. The researchers concluded that one of the effects of construction delays, based on the literature review, was loss of confidence in the contractor, which in turn affected the reputation of the organization. These findings were similar to those of Akinsiku and Akinsulire (2012) who found that one of the significant effects of delays is the loss of confidence in the company.

Gunduz et al. (2017) carried out study to explore the reasons of lagging projects in Qatar. The primary aim of the study was to determine the main causes of delays in construction projects. The methodology used was an online survey. It was used to measure the importance of the cause of delays according to the main industry leaders. Eighty three causes of delays were identified from a literature review. They were then further revised to 42 factors according to expert opinions and recommendations. From these factors, a questionnaire was developed. The outcomes were analyzed using standard statistical methods. Internal inconsistency was measured using the Cronbach's Alpha coefficient. The Relative

Importance Index (RII) and Frequency Index (FI) were applied in the assessment of the project construction delay factors. Majority of the participants (85.5%) were from Qatar. The study found that the top-five ranking factors for construction delays were: lateness in decision making by the owners, site management issues, inadequate construction materials, change of projects by the owner, and shortage of labor – in that order. Based on the FI, the ranking of factors from the highest to the lowest were: low productivity, delays related to contractors, change of the project by the owner, delay in approving documents and unqualified work force. The researcher concluded that the findings of this study were consistent with the findings of Shehzad's (2015) study who found that some of main sources of delay factors were lack of skilled labor, scope variation, delays in drawing documents, long contract award processes, and poor subcontract performance.

In addition to the literature reviewed and presented so far, other studies have also attempted to identify and classify the main causes of delay in construction. Appendix B shows a summary of 42 delay factors classified into seven categories that were deduced from previous studies upon combining the delay causing factors identified in this chapter so far and those in other literature sources. The seven categories are owner or agency-related delays, consultant-related delays, contractor-related delays, material-related delays, labor-related delays, construction site delays, and external delay factors.

2.3 Prediction Model for Delays

Hegazy and Ayed (1998) did a research using neural network (NN) approach to manage cost data and create a prediction model for highway projects. Cases of highway projects in Canada were analyzed. A simple neural network simulation was developed in a spread sheet format using two techniques to determine the network weights: simplex optimization, and genetic algorithms. The developers created a model to test the sensitivity of changes in cost related parameters to determine their relative significance. The developers incorporated an adaptive module that allowed the user to input new data to re-optimize the model to the required future project environment.

Elhag and Boussabaine (1999), did a research on Evaluation of Construction Cost and Time Attributes. The researchers made Statistical analysis that was held out to create a priority rating of the prompting factors. The results indicated that the group that contained consultant and design parameters was classified top. Whereas, the second and third ranks were occupied by project characteristics and external market conditions, respectively. These reasons were gathered into six different classifications. This study represented a basis for a future exploration directing to develop price estimation models using cost and time characteristics.

Trost and Oblender (2003) did a study on predicting the precision of early approximation of costs using factor analysis and multivariate regression. The main objective of his study was to come up with a model for establishing the accuracy of early estimates. Data was drawn from the completed building projects in the process industry. The participants in the survey were required to rate 45 drivers of estimate precision on a scale of

1 to 5 for each specific value. An analysis was performed on the data based on factor analysis and multivariate regression. A multivariate regression was then performed on the 11 groups in order to determine if it was suitable as a predictive model. The study developed a process through which project managers and their team can determine the estimates and predict the precision of the estimates. Additionally, a software program, the Estimate Score Program, was created in order to automate the process. The multivariate regression analysis identified 5 significant groups out of the 11 factors. The study concluded that from the model, the 5 most significant factors were process design, experience of the team and data on cost, estimated timelines, and process of bidding and the climate of the labor market. This was related to the findings in Mubarak's (2010) study that concluded that the most significant factors were design issues, poorly qualified staff, financial constraints and tedious contract process.

David et al. (2006) did a research on Forecasting Building Cost by Multiple Regression Methods. Six models were developed. Five variables appeared in each of the six models: gross internal floor area, function, duration, mechanical installations, and piling. All six simulations completed consistently. While the top regression model was appealed to be the log of cost backward model, which presented an R^2 of 0.661 and a mean absolute percentage error (MAPE) of 19.3%. Identifying the major cost as an independent input variables was less accurate than a model that was using demonstrative values.

Dogan et al. (2006) did a study to identify attribute weights in Case Based Reasoning (CBR) prediction model to estimate the costs in construction projects. The objective of the study was to investigate the application of the Excel sheet based CBR model of prediction through

determining the effects of factor weights that were generated using three different optimization techniques. The three techniques were: counting features, gradient descent, and genetic algorithm. First of all, the spreadsheet was simulated for the study. This simulation was carried out in six steps: organizing and formatting data, calculating attribute similarities, establishing attribute weights, calculating weighted case similarities, identifying similarities of weight attributes and affiliated outputs, and calculating errors. A test was performed by populating data from a residential building construction project into a CBR Excel template. This data was from study reports investigating the cost of construction projects in residential buildings in Turkey. The data was then run and the results evaluated. The procedure was done 10 times for the test set and the best results were recorded. The findings from the study indicated that the GA-augmented CBR model was the best, with an estimated 16.23% error, followed by CBR + feature counting with 17.63% error and CBR plus gradient descent with 21.20% error. The study demonstrated the importance of CBR prediction model, especially in the performance of the attribute weights.

Sweis et al. (2008) conducted a research on prediction models for cost and time overruns. The researchers carried out a pilot study on real data for 140 projects that were selected using systematic random sampling. The projects were constructed between 1994 and 2002. A non-parametric test for the project time and costs was conducted. Generic multiple regression models were then used to predict project duration and costs. This was followed by a statistical analysis of percent prediction errors. Lastly, custom multiple regression models were used to develop each project type with the view to get statically reliable outcomes. The projects were then classified according to job type and project type. The project type were

then coded from 1-8 for different classifications and the job type from 1-3. The variables used for the study were project type, job type, modified project price (MPP), original project price, original project duration and modified project duration (MPD). Regression analyses were performed on the MPP and MPD. The results showed a linear correlation between each of the two variables. The researchers found that the original projects price variables had significant impact on the results of the MPD provided 95% confidence intervals for regression model coefficients. A correlation existed between the predetermined project time and the regression model duration due to underbidding by the contractors. Therefore, the predictive model for construction costs and duration was at the disposal of the contractor who could then easily determine the cost and duration of the construction project by using the change clause. The researchers concluded that risk could be mitigated in the course of reliable prediction.

Du Y. Kim et al. (2009) developed a structural equation model (SEM) in order to predict the project success of uncertain international construction projects. The data was extracted from 126 construction projects to develop the SEM, and an additional 15 sample projects were used to validate the model. A comparative analysis of SEM with a multiple regression analysis and artificial neural network was conducted. The comparison analysis indicated that SEM had a strong potential to accurately and reliably predict the probable performance of international construction projects. Furthermore, the use of SEM revealed how those complicated variables were connected aiding the understanding of the complex system and its underpinned causes that critically affect the project success.

RunZhi Jin et al. (2011) conducted a study that aimed to improve the prediction performance of a cost prediction model based on the Case-Based Reasoning (CBR) technique. In order to achieve this particular aim, an improved CBR model was developed. The improved CBR model uses the Multiple Regression Analysis (MRA) technique in the revision phase of the CBR technique. The prediction performance of the proposed model was verified through a case study on 41 business facilities and 99 multi-family housing projects. The results showed that the prediction performance of the revised CBR model for business facilities and multi-family housings improved by 17.23% and 4.39%, respectively, compared to that of the existing CBR model. The proposed MRA-based revised CBR model expected to be useful in predicting the construction cost in the initial phase of a project.

Yahia et al. (2011) conducted a study to identify the most important factors affecting time contingency in construction projects based on a comprehensive survey among a collected sample of the Egyptian construction experts. Furthermore, an artificial neural networks model (ANN) was developed in order to help the project planner to have a more reliable prediction for the amount of time contingency that should be added to the scheduled completion time. Fifty four real life projects were collected from Egypt construction industry with an average time contingency of 28%.

Imad (2012) conducted a study to identify the delay factors in the acquisition process of the right-of-way (ROW) for the highway construction project. Thirty-five projects, with 1,478 parcels, acquired by the Mississippi Department of Transportation (MDOT) were randomly selected for analysis to determine the factors affecting acquisition duration.

The data were analysed using Statistica7 software with t-test, correlation, scatter plot, and analysis of variance to gain understanding of the dataset; to test the null hypothesis (H_0) that no correlation exists between the control and experimental variables; and to statistically quantify the factors that contribute to acquisition duration delay through significance and standard multi- regression analysis. The statistical analysis identified the significant factors associated with increasing the duration of the acquisition process, which were condemnation ratio, number of revisions (design changes), and number of parcels per project. The significant factors were then used to develop a regression model that would predict the acquisition duration of new projects and show where to focus efforts for the duration reduction. The model was then tested with a separate set of data to prove its applicability and validity in general terms.

El-Kholy (2015) carried out a study on models of predicting cost overruns in construction projects. El-Kholy proposed two models for predicting cost overruns. The researchers identified 44 factors that caused cost overruns in construction projects from literature. These factors were then used as independent variables. The financial condition of the owners was the most significant factor for cost overrun in construction projects followed by the cash flow of the contractor. For the regression model, data from 30 projects was collected. The data was divided into two sets. Twenty projects were used for model building and 10 for validation. SPSS 13 was used to analyze the data with 11 variables. CBR was established using the first set. The case with high similarity was used to estimate the cost overrun percentages. A comparison between the regression and CBR models estimates were then made. The researcher found out that the regression based model was more accurate than CBR.

2.4 Conclusion

This chapter presented a range of studies that investigate delay factors in construction projects. Most of the studies that have been surveyed investigate the causes of delays of constructions projects. Limited number of studies are done in the delays related to the oil and gas pipe line projects. Additionally, the available construction delay studies investigate the effects of these causes on cost and time overruns only without considering other effective factors. Researchers have also adopted different scientific models in ranking the most significant causes of construction delays such as RII model, FI model and FAII ranking model. Generally, the findings of these studies have revealed similar causes which have been derived from previous works and can be used in future studies in order to make accurate conclusions. Researchers have also investigated the methods of analysis and their accuracy in delivering accurate results. It is essential to use methods that will provide the most significant factors for construction delays such as lack of communication and scope variation. The previous studies either covered in their analysis developing of a prediction model or a survey with factors ranking. Limited studies had combined analysis with both ranking the factors and establishing prediction models for the delay main causes.

The findings of these studies will be very beneficial for the current study. These findings range from the causes of delays, effects on cost and time overruns, risk effects, developing the most effective delay prediction models, and analyzing the performance of different research methodologies. The main methods used for collection of information in the studies are literature reviews, surveys and interviews. Various scientific techniques that have been used in different studies to mitigate

inconsistencies and increase the accuracy of the findings will also come in handy. The focus of these reviewed studies in this chapter is closely related with the subject of this study.

Most of the scientific methods, models and findings are relevant in making some comparative analysis to determine the accuracy and effectiveness of this study. The methodological approaches, data collection procedures, and samples involved in the studies reviewed inform the development of the research methodology for the achievement of the study objectives. Altogether, the review of the previous studies further reaffirmed the research gap in extant literature about the inexistence of prediction models for delay in pipeline construction projects in the oil and gas industry.

The importance of this research lies in the fact that most of the previous studies did not cover all of the following topics in a single study, such as identification of the delay factors, ranking of the delay factors, developing of risk assessment for the delay factors, and modelling of the duration of delay along with the cost of delay. The previous studies were either focused on identifying the delay factors alone or the ranking of delay factors without carrying out the risk assessment analysis for those factors or developing of prediction models for delays. In addition to that, there was no research found to study this specific topic in the Kingdom of Bahrain and precisely in pipeline construction projects. Therefore, this study is aimed to identify the causes of delay and their associated risk in the pipeline construction projects in Bahrain along with the modelling of the delay in terms of duration and cost based on real case studies in this field. Finally, it is providing the management with some recommendations to mitigate those risks in the future.

Chapter Three

Methods and Procedures

3.1 Introduction

3.2 Methodology Used and Justification

3.3 Research Tools

3.4 Data Collection/Procedures

Chapter 3: Methods and Procedures

3.1 Introduction

This chapter is a presentation of the research methodology and methodological techniques employed towards the execution of this research. For the purposes of this research, a research methodology is understood as a scientific undertaking aimed at guiding the means through which the research progressed in undertaking and developing this research. This chapter is organized into three major sections. The first section is about the research methodology used and the justification of the techniques employed thereof. It contains a discussion about the research philosophy, the chosen research approach and the research strategy respectively. Being an academic research, the research design is also included in the first section. The second section is about the research tools. Under this section, the researcher highlights and justifies the choice of tools and instruments used to aid in the achievement of the research objectives. Finally, the third section is a discussion of the procedures involved in collecting data used to inform the research findings. Procedures involved in analyzing the data are also discussed in the third section. The section also serves as a signpost for the commencement of the next chapter.

The following flow chart provides a summary of the key steps that will be used in the design, formulation and analysis of data obtained using the primary research questionnaire survey.

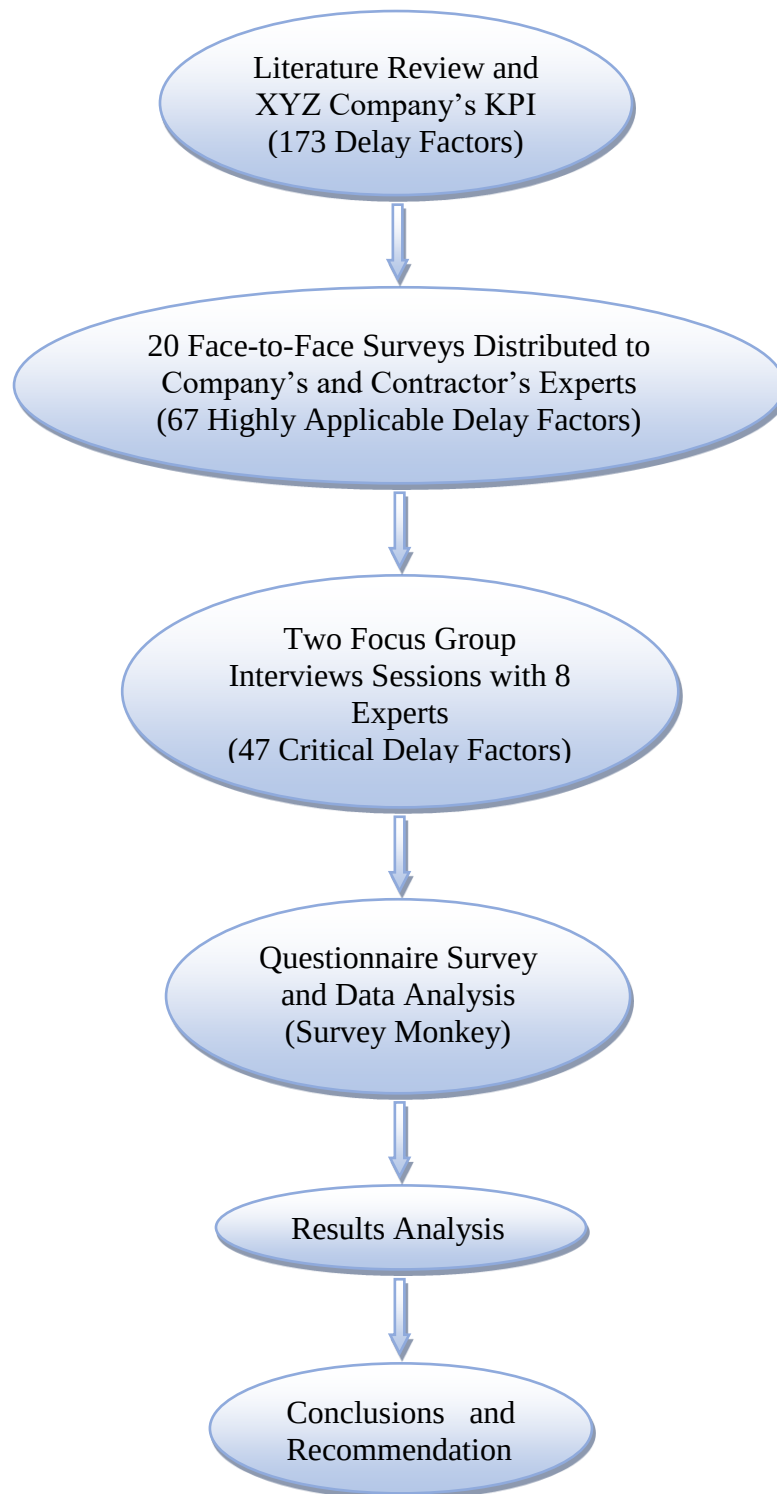


Figure (1)
Research and Design Methodology Flow Chart

3.2 Methodology Used and Justification

The definition of the research philosophy for the current research preceded other methodological procedures. This is because the research philosophy outlined the researcher's assumptions concerning the tools of research and procedures deployed during the completion of this research. This definition enabled the researcher to clarify the research design that would work best in accordance with the research questions. Upon reviewing the various extensive discussions about the different epistemologies defined by various scholars (Bryman, 2016), the researcher opted for a pragmatist epistemology.

The choice for pragmatism was driven by the nature of this research, which required flexibility in terms of integrating different assumptions towards the achievement of the research objectives by responding to the research questions. Since pragmatism does not lean on either post-positivist/positivist or constructionist/interpretivist epistemologies, it was suited to this research where according to views of the physical and social worlds of pipeline construction delays equal significance was necessary. This way, the research questions remained the most crucial research aspects. This implied the application of the most suitable methods towards generating insights that would help build a reliable prediction model for delay in pipeline construction projects. Besides, delays in pipeline construction projects in Bahrain are a real world problem, and pragmatism is applicable to research that entails real world, practical problems as opposed to establishing itself upon assumptions made concerning the nature of knowledge.

In terms of the ontological view (reality's nature), which about the way people view the social world, the application of a purely objectivist or subjectivist view was not possible. This was especially true considering that the researcher has vast experience working in the Bahraini oil and gas industry. Therefore, the researcher assumed an insider-outsider position while undertaking the research by allowing the research to be as data driven as possible. The realization of an effective prediction model for delay in pipeline construction projects in Bahrain required the incorporation of both industry knowledge and views about the delays from involved experts. Thus, a largely objectivist ontology was assumed.

An abductive research approach, which implicates both deductive and inductive reasoning towards drawing out conclusions, was assumed in this research. The implication of an abductive research approach was that it allowed the researcher to oscillate between empirical observations and existing theory about delay in pipeline construction projects iteratively (Dubois and Gadde, 2002). The abductive research approach was also suited for this research since the current research was not about the development of a new theory for construction delays per se although the aim was to come up with a prediction model for delays in pipeline construction projects in the oil and gas industry. Instead, this research was about testing, application, and refinement of the extant theories from diverse construction fields to suit the context of pipeline construction projects in the oil and gas industry.

An exploratory, the researcher used both qualitative and quantitative research methods for data collection and analysis in the order mentioned. The idea was to ensure the generation of stronger, robust evidence through triangulation of findings. This was also likely to generate more information

and insights about delay in pipeline construction that might be missed using mono-methods. By using mixed methods in this research, the limitations of qualitative research were overcome by integrating them with quantitative methods and vice versa although more time and effort were invested than would have been the case with either qualitative or quantitative methods only. Besides, the research questions required both non-numeric and numeric data to understand delays in-depth and determine the prediction power of various delay factors to delay. Respectively, this implicated qualitative and quantitative research methods. The research tools used in the implementation of the sequential mixed methods research strategy are discussed in the next section.

3.3 Research Tools

Two major research tools were used in this research in consistency with the data collection procedures explained in the next section of this chapter. These included focus group interviews with industry experts and a survey questionnaire designed using Survey Monkey. In focus group interviews, the researcher conducted interviews with a group of participants in order to gather a variety of information. The methodology applied an interview protocol, just like other interviewing techniques; however, the use of prompts was largely applied and this allowed the conversations to take place naturally. The aim of using this method was to gather not only narrative data but also observational data. The survey method, on the other hand, involved the sampling of representatives from a population and the collection of accurate responses regarding the study topic. This technique was especially useful in the collection of descriptive data which could not be directly observed, for example opinions.

After deducing 173 delay causing factors that were found to be relevant to the pipeline construction projects in the oil and gas industry from the literature review and company KPI data, the researcher distributed 20 surveys by hand to the company's and contractor's experts to reduce the 173 delay factors to 67 highly applicable ones as an accumulative from at least 12 respondents (Appendix B). After that, the researcher conducted two focus group sessions with eight industry experts ($N = 8$) with at least five years' experience to verify the resulted delayed factors from the survey results. The interviewees were project managers, engineers, supervisors and contractors working in Bahrain oil and gas field. A delay factor was considered main critical if at least five out of the eight interviewees considered it highly applicable to pipeline construction in the Bahraini oil and gas industry (Appendix B). Before selecting the focus groups, the researcher surveyed the available sources based on their experience in pipeline construction and number of projects they have accomplished in the same field, studied widely, and attended two focus group sessions by students at advanced education levels as a guest to learn the techniques for eliciting data from the focus group. Upon developing the draft interview protocol, the researcher consulted with two doctoral students and one senior lecturer about the suitability of the protocol to generate data that would inform the quantitative phase adequately. Following the feedback obtained during this exercise, which was a form of a pilot study to enhance the reliability and validity of the tool, the researcher refined the interview protocol by changing the order, vocabulary, and phrasing of the prompts.

The face-to-face focus group interviews were guided by the general interview protocol appearing at (Appendix B). The self-designed interview protocol contained prompts developed by the researcher based on three principal rationales. These rationales included the relevance, impact

significance, and frequency of each delay factor to pipeline construction projects. The focus group sessions emulated a semi-structured interview approach although the interviewees were free to identify factors that had not been identified in the literature and recommend their inclusion in the final list of critical factors. As the main outcome of the focus group sessions, forty one main critical factors were identified for further consideration in the quantitative phase of this research as well as six factors were added according to the XYZ Company. Those six factors were very important to be added to the main critical factors as they were already included in the XYZ Company KPI.

For the quantitative phase, the researcher designed a survey questionnaire for numerical data collection. The questionnaire (Appendix D) comprised three main sections. The first section contained the research information including the research title, aim, and objectives and the ethical safeguards of confidentiality, anonymity, data protection measures, and voluntary participation and withdrawal from the research. The second section of the questionnaire contained prompts sourcing for demographic data of respondents. The prompts sourced for current project location, organization type, job designation, industry type, total experience in pipeline construction, highest education, and based on size of the company they represent.

The third section comprised forty seven 5-point Likert-type prompts for scoring the delay factors in terms of frequency and importance of the delay impact on the construction projects (where 1= Very Low to 5= Very High). An example of a prompt on the importance of poor managerial skills as a delay causing factor read, “What is the impact of “poor managerial skills” on pipeline construction projects?” As for the frequency of the same

delay causing factor, the prompt read, “How often is “poor managerial skills” or does it occur in pipeline construction projects?” The choice for Likert-type prompts was informed by four major reasons associated with this prompt types. First, using Likert-type prompts offered the respondents more response options than using Yes/No type of responses. In addition, the researcher figured that data obtained through Likert-type prompts enabled the generation of more inferential statistical operations than other tools that would generate nominal data. In any case, Likert-type prompts are more straightforward for the respondent especially since the survey was not administered by the researcher, as explained in the next section. Finally, the data collected through Likert-type prompts made it easier to rank the delay causing factors and the respective attributes (Monette et al., 2014).

However, the researcher exercised caution during presentation of findings and drawing of inferences from the Likert-type data because Likert data often summarizes responses containing underlying information that could be lost or hidden. For example, Likert-type prompts let the respondent to rank or score an item, but they do not allow for the respondents to explain why they chose a particular score over another. Therefore, it is possible that the Likert prompt’s summary score might hide information about patterns of variation in responses” (Monette et al., 2014). The prompts were also obtained from the Key Performance Indicators of XYZ Company to ensure that they related to reality as much as possible. International Business Machines’ (IBM) Statistical Package for the Social Sciences (SPSS) version 23 was the main data analysis tool for the development and testing of the prediction model.

As explained in the next section, reliability tests were conducted in SPSS as well. Concerning the internal validity of the questionnaire, the prompts were designed to address the respective research questions and objectives directly. The design of the online questionnaire prevented the submission of incomplete questionnaires for data analysis procedures. To ensure external validity, the researcher pre-tested the questionnaire with a small sample of construction experts ($n = 6$) from non-Bahraini oil and gas industry and discussing the research tool to check for its potential to collect the requisite data and measure the intended constructs. This led to the rephrasing of ambiguously worded prompts and the elimination of irrelevant or redundant prompts.

3.4 Data Collection/Procedures

The researcher collected both secondary and primary data for this research. The initial set of secondary data informed the development of the theoretical framework and the literature review. Sources of such secondary data included the company website and annual reports, journal databases including Scopus, Elsevier, IEEExplore, EBSCOHost, Google Scholar, and the university library. The second set of secondary data was obtained from the company KPI, minutes of meeting and contractor progress reports for pipelines construction projects carried out in the past 7 years.

As for the primary data and consistent with the survey research design, the researcher administered 20 paper-based questionnaires to experts in the pipeline construction in the oil and gas industry who included site supervisors, construction engineers, and project managers among others. As mentioned in Section 3.3, the rationale for this survey exercise was to identify the most critical delay causing factors from the 173 delay

factors identified through the literature review and company KPI data. It should be noted that the researcher selected this sample purposively based on their experience in pipeline construction projects at the case company. The sample that was selected for this face-to-face survey exercise was not involved in the focus group discussions to avoid response bias.

On the other hand, the use of focus groups and their role in identifying 47 critical delay factors has already been highlighted in the previous section. Purposive sampling was used to select the focus group interviewees. This involved the definition of criteria for qualifying as an interviewee (Bryman, 2016). Interviewees had to have worked in the oil and gas industry in Bahrain for at least five years and be working in the respective role at the time of the interview. The researcher, being in the oil and gas industry himself, had access to information about potentially qualified interviewees. The researcher contacted them either in person or via email to request their participation. Upon confirmation, interview dates were set where all eight interviewees were available. The focus group sessions were conducted at the company facilities in Bahrain. On request by the focus group interviewees, the sessions were not recorded. Instead, the researcher took notes during the discussions and eliminated irrelevant factors one by one. Later, the researcher compiled 47 delay causing factors (Appendix C) that were considered relevant to the context of pipeline construction delays in the oil and gas industry in Bahrain based on the expert opinion of the focus group interviewees.

Upon the verification of the 47 delay causing factors and the data collection instrument as valid and reliable, the researcher designed a self-administered web-based questionnaire using Survey Monkey to collect data from a bigger pool of respondents. A web-based questionnaire was

deemed suitable to enable the collection of data from a big sample of respondents over a short period (Bryman, 2016). Since it was necessary to ensure that the respondents were knowledgeable about and involved in the issues surrounding pipeline construction in the oil and gas industry in Bahrain, the survey link was only sent to individuals that were working in the industry with instructions on the criteria for inclusion in the study. The criteria was similar to the one employed for the selection of focus group participants. To increase the sample response, the researcher also posted the link in closed oil and gas employee forums on professional networks and social media groups. Although this allowed for convenience sampling, questionnaire responses that indicated that the respondent did not meet the minimum criteria for participation were excluded from further research. For example, any responses where the respondent had fewer than five years' experience in their respective positions were excluded from analysis.

Several statistical operations were performed on the web-based survey data in SPSS. First, reliability analysis were performed for the respective delay factors to assess the internal consistency of the data collected. Cronbach's alpha has been described as a relevant reliability test for multiple-item measures due to its ability to measure internal consistency, stability, and validity of many variables (Bryman, 2016). George and Mallery (2003) explained that Cronbach's alpha coefficients range from 0 to 1. When the coefficient is 0.70, the reliability is said to be acceptable. Values from 0.8 and over indicated excellent internal consistency. For the 47 delay factors, a Cronbach's alpha coefficient of 0.96 was realized thereby affirming that the data exhibited higher internal consistency.

In order to rank the delay factors in terms of their importance as ranked by the respondents through the survey, the researcher opted for the Relative Importance Index as employed in the study by Gunduz et al. (2014). The same formula employed by them in their RII application for the analysis of delays in Turkish construction projects based on a 5-point Likert scale was used in this study. Equation (1) below illustrates the formula:

$$RII (j) = \frac{\sum_{i=1}^A n_{ij} * i}{A * N}, \quad \text{For } j = 1, 2, \dots, 4 \quad \text{Equation (1)}$$

In Equation (1) above, $RII (j)$ is the RII of factor j ($j = 1, 2, \dots, 47$); n_{ij} is the number of respondents who gave Importance score i ($i = 1, 2, \dots, 5$) to factor j ; and n'_{ij} is the number of respondents who gave Frequency score i ($i = 1, 2, \dots, 5$) to factor j . While N is the total number of respondents and A denotes the highest possible score of 5. Based on the equation, the value of the RII is between 0 and 1 whereby a score closer to 1 ranks more significantly compared to the rest of the factors.

Concerning the ranking of the delay factors in terms of their occurrence rate, the researcher adopted the Frequency Adjusted Importance Index (FAII or FII). Yahya (2014) employed the FAII to rank the project success factors of the construction industry in the UAE and Middle East. The FAII technique is more robust and checks for both the frequency and importance of a factor also based on the 5-point Likert scores from the survey data. The fundamental requirement of determining the FAII is to measure and compute both the Frequency Index (FI) percent and the RII based on response data from the survey. Equation (2) below is used in the computation of the FI values where n'_{ij} , A , and N represent the number of respondents who gave Frequency score i ($i = 1, 2, \dots, 5$) to

factor j , highest possible weighting of 5, and the total respondents' count, respectively:

$$FI(j) = \frac{\sum_{i=1}^A n_{ij} * i}{A * N}, \quad \text{For } j = 1, 2, \dots, 4 \quad \text{Equation (2)}$$

By combining Equation (1) and Equation (2) for both RII and FI%, respectively, the FAII was computed using Equation (3) below:

$$FAII = RII \times FI\% \quad \text{Equation (3)}$$

The researcher used the Frequency Adjusted Importance Index (FAII) because of its aspect of ranking. The FAII can be used to rank different attributes. The FAII is also used together with the RII, and since RII has been used in multiple regressions, it was also necessary to apply it in this research. Unlike other ranking techniques, FAII considers occurrence frequency of an attribute and its implementation, together with the importance of the attribute. Therefore, the use of this index would not only rank the delay factors in terms of their occurrence rate, but also in terms of their importance. These aspects could be useful in the identification of the factors used in prediction models for delay in pipeline construction projects.

Further data analysis performed in SPSS to ascertain data precision and accurateness included Spearman's Rank Correlation. Spearman's Rank Correlation Coefficient was applied in the evaluation of the correlation between two different measures. For example, the test was useful in testing the correlation between FAII and RII for all the responses collected. In addition, the test was employed in measuring both the relationship and the accuracy in comparative responses based on the

demographic data including job designation, organization type, and location. Equation 4 below demonstrates the formula for computing Spearman's Rank Correlation Coefficient (r_s):

$$r_s = 1 - \left[\frac{6 \sum_{i=1}^{47} d_i^2}{n^3 - n} \right] \quad \text{Equation (4)}$$

In Equation (4) above, d_i refers to the difference between RII and FAII assigned by respondents to each factor. On the other hand, n denotes the number of rank pairs. The number of rank pairs in this research equals the count of all 47 delay factors. George and Mallery (2003) explained that the Spearman's Rank Correlation Coefficient ranges from -1 through +1. On the one hand, a -1 coefficient implies disagreement between the variables in terms of a negative correlation. On the other hand, a +1 coefficient means the two variables relate perfectly and values close to +1 means that the values relate positively or are in agreement. Faridi and El-Sayegh (2006) used the Spearman's Rank Correlation test to study the significant factors that cause delay in the construction industry in the UAE.

Since the 47 delay factors tested in the questionnaire were grouped under different delay categories, it was important to test for the extent to which each of these factors fitted into the respective category if at all. Thus, the researcher invoked factor analysis, which is a dimension reduction procedure that "is basically used to condense a larger set of correlated variables into a smaller number of unrelated factors to describe the phenomenon of interest" (Rajaretnam, 2016, p.247). A similar application of factor analysis was executed by Doloi et al. (2012) in a similar study in the construction industry in India.

Bartlett's Test of Sphericity and the KMO (Kaiser-Meyer-Olkin) measure of sampling adequacy were used to check for the extent to which the data was suitable for the factor reduction exercise. The requisite KMO index threshold value was 0.50 while Bartlett's Test of Sphericity value was required to be statistically significant ($p < 0.05$) based on a confidence interval of 95%, as advised by Hair et al. (2010).

To enhance understanding of the risks associated with all the delay factors, the researcher came up with the standard XYZ Company's Risk Assessment Map. This helped to illustrate the impact nature of the risks resulting from the delay factor presented in the form of a matrix. As a visual tool, the risk mapping matrix is applied in the presentation of risks associated with the frequency and importance of delay factors. The researcher plotted the data based on the mean values obtained from the response data. In line with XYZ Company's Risk Assessment Matrix, the vertical and horizontal axes represent the mean values of frequency (Likelihood) and impact (Consequence) respectively. As a result of the data extracted from the total number of respondents ($N = 93$), through the web-based questionnaire according to the importance and frequency scores, the mean values for importance and frequency, which were used for mapping the 47 delay factors on the risk mapping matrix, were calculated using the following equations:

$$\text{Importance Mean } (j) = \sum_{i=1}^5 \frac{n_{ij} * i}{N}, \quad \text{For } j = 1, 2, \dots, 4 \quad \text{Equation (5)}$$

$$\text{Frequency Mean } (j) = \sum_{i=1}^5 \frac{n'_{ij} * i}{N}, \quad \text{For } j = 1, 2, \dots, 4 \quad \text{Equation (6)}$$

Where n_{ij} is the number of respondents who gave Importance score i ($i = 1, 2, \dots, 5$) to factor j ; n'_{ij} is the number of respondents who gave

Frequency score i ($i = 1, 2, \dots, 5$) to factor j ; and N is the total number of respondents.

The scale adopted for plotting the frequency and importance mean values is illustrated at Table (1) below.

Table (1)
Scale Used to Map Risk Factor Frequency and Impact

Scale	Color Coding	Zones	X-axis (Importance)	Y-axis (Frequency)
1.00 - 1.80	Blue	A	Very low (VL)	Very low (VL)
1.81 - 2.60	Green	B	Low (L)	Low (L)
2.61 - 3.40	Yellow	C	Moderate (M)	Moderate (M)
3.41 - 4.20	Orange	D	High (H)	High (H)
4.21 - 5.00	Red	E	Very high (VH)	Very high (VH)

The various color codes in the Table above denote different risk categories and imply different issues. Blue color code, A, implies no need for further studies or action on the risk factor although there is need for asset management for the documentation of all risk studies. Green color code, B, calls for asset management to consider how feasible it is to institute measures to reduce risk. Documentation at this level includes potential hazards, risk studies, and measures to reduce risk. As for yellow color code, C, it demands that asset management evaluates extra measures for reducing risk, implementing the measures considered feasible and approving ongoing operations. The rationale for taking particular actions is noted along with documentation of potential hazards, risk studies, and measures for reducing risk.

Asset management for orange color code, D, involves performing suitable quantitative or qualitative risk analysis for the verification of the risk level. At this level, facility management is required to institute suitable

measures for reducing the risk. Moreover, facility management needs to inform higher authority levels such as senior management when they figure that the risk is irreducible to a lower category promptly. Documentation of potential hazards, risk studies, and measures for reducing risk also happens. Finally, risks coded with the red color, E, calls for the utilization of the opportunities noted during risk analysis to inform the implementation of measures to mitigate or reduce the risk. For risks deemed irreducible or impossible to lower to other categories promptly, quantitative risk analysis is performed to ascertain the level of risk and evaluate the opportunities for mitigation. There is a need to review the opportunities for risk reduction every year. Documentation of potential hazards, risk studies, and measures for reducing risk also happens, as is the norm with the previous color code. However, re-authorization upon expiry of agreed timeframe is necessary.

The scale used to a risk factor's frequency and importance is demonstrated in Figure (2) below.

		IMPORTANCE (CONSEQUENCE)				
		(VL)	(V)	(M)	(H)	(VH)
FREQUENCY (LIKELIHOOD)	(VH)	B	C	D	E	E
	(H)	B	C	C/D	D	E
	(M)	A	B	C	D	D
	(L)	A	B	B	C	D
	(VL)	A	A	B	B	C

Figure (2)
The Scale Used to Map a Risk Factor's Frequency and Importance

Chapter Four

Analysis of Results

- 4.1 Sample Size and Reliability Test**
- 4.2 Demographic Data**
- 4.3 Evaluating the Delay Factors of Pipeline Construction**
- 4.4 RII Ranking of Delay Factors**
- 4.5 FI Ranking of Delay Factors**
- 4.6 FAII Ranking**
- 4.7 Spearman's Rank Order Correlation for RII and FAII**
- 4.8 Ranking Comparison between Respondent Groups**
- 4.9 Factor Analysis**
- 4.10 Risk Mapping Matrix**

Chapter 4: Analysis of Results

4.1 Sample Size and Reliability Test

The researcher selected a group of specialists working in the oil and gas pipe line construction to conduct the research questionnaire. The sample size reflects the common causes of delays in such field that can be analysed to construct a prediction model for the general reasons of delays. Accordingly a reliability test was made for the data collected from the questioner to check its accuracy and relevant to the delay factors. The internal consistency of the questioner was tested using Cronbach Alpha to measure the hypothesis of importance and frequency.

4.1.1 Sample size

In this chapter, the results of the survey data are presented starting with the summary of respondents' profile. At the end of the online data collection period, the researcher received a total of 120 responses. Majority of the questionnaires were received from respondents working in Bahrain (n = 102) followed by those working in GCC (n = 18). The fact that a majority of the responses were from owner side did not have any significant impact on the results. The objective of the research was to predict model for delay in pipeline construction projects in the oil and gas industry. Therefore, whether the responses could come from the owner side or the client/worker side, they would not affect the results as they were giving information concerning a shared issue which needs to be addressed. Consequently, the responses from the owner side were the most preferred because the owners are the ones most affected by the delay and overruns in pipeline construction projects. However, the criteria for participation in this research and questionnaire completeness led to the dropping of 27 questionnaires, i.e. only 93 were considered. The sample size was

computed based on the following Hogg and Tannis' (2009) formula (where n is the sample size of limited population; m is the unlimited sample size of the population; and N is the size of the available population):

$$n = \frac{m}{1 + \left(\frac{m-1}{N}\right)} \quad \text{Equation (7)}$$

However, the value of m in Equation (7) is computed using the formula presented as Equation (8) below. In the equation, z denotes the confidence level's statistical value such as 1.96 for a confidence level of 95%. On the other hand, p and ε denote the value of the population proportion under estimation and the point estimate's sampling error, respectively.

$$m = \frac{z^2 \times p \times (1-p)}{\varepsilon^2} \quad \text{Equation (8)}$$

With the value of p being unknown, the suggestion is the use of a conservative 0.5 value to obtain maximum sample size. Thus, a 95% confidence interval yields a 5% significance level rendering m (unlimited population sample size) as follows:

$$m = \frac{(1.96)^2 \times 0.50 \times (1-0.50)}{(0.05)^2} = 385$$

Substituting m in Equation (7) results in 92 respondents as the representative sample:

$$n = \frac{385}{1 + \left(\frac{385-1}{120}\right)} = 91.667$$

The sample size obtained for the research study was 93 out of the possible 120. The representative sample was narrowed down to the figure obtained because of various challenges and difficulties the researcher faced while collecting data. One of the difficulties faced was uncompleted questionnaires. While filling the questionnaires, there are chances that some questions were left out or ignored making the data collection tool incomplete and unreliable. Accessibility issues were also a threat in data collection. Furthermore, based on the responses given, it was clear that some questions were difficulty for the respondents to analyze. Because of this set back, some questionnaires were left out because they could not be correctly answered or the answers given were irrelevant.

4.1.2 Reliability test

Reliability statistics measure the internal consistency of the questionnaire by generating the Cronbach's alpha coefficient for both importance and frequency of the delay factors. Values of Cronbach Alpha fall between 0 and 1. A value of 0.7 is considered to be acceptable and 0.8 or higher indicates good internal consistency (George and Mallery, 2003). Thus, importance and frequency recorded Cronbach's alpha coefficients of 0.960 and 0.963, respectively. This implied high internal consistency of the data and suitability for further statistics, as shown in Table (2) below.

Table (2)
Reliability Statistics for the Importance
and Frequency of the 47 Delay Factors

Scale	Cronbach's Alpha
Importance	0.960
Frequency	0.963

4.2 Demographic Data

Descriptive statistics were generated for the demographic prompts. Specifically, frequency tables were generated for each of the demographic prompts. Most of the current projects of the 93 respondents were located in Bahrain (n = 81, 87.1%), while respondents working on current projects located at other GCC locations accounted for 12.9% (n = 12).

Majority of the respondents were working in organizations that classified as project owners (n = 51, 54.8%). Contractors recorded a distant second highest frequency at (n = 15, 16.1%), which was one respondent higher than consultants (n = 14, 15.1%). The lowest frequency was from individuals working in other roles (n = 13, 14%), as shown in Figure (3) below.

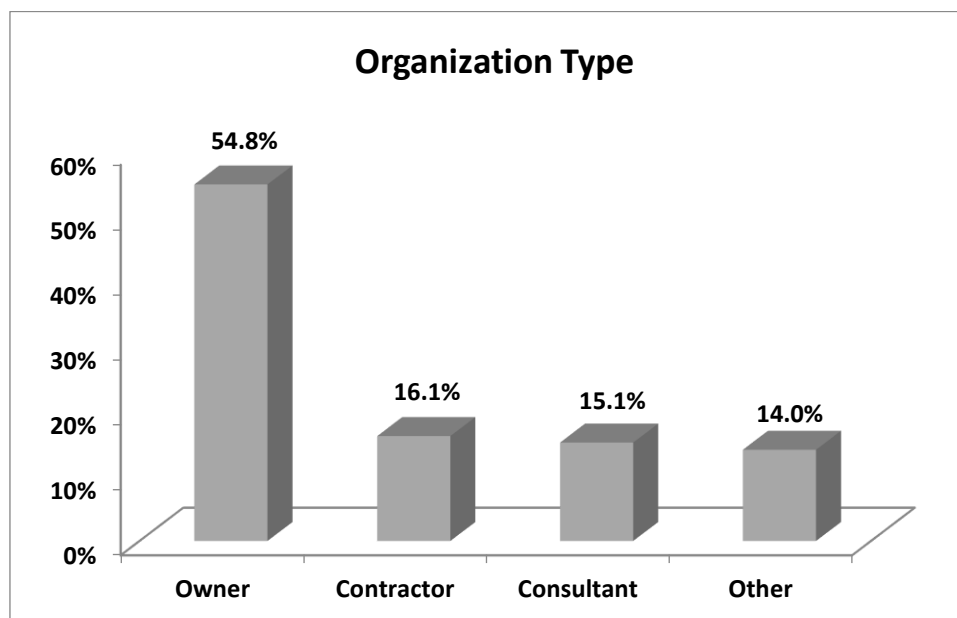


Figure (3)
Distribution of Respondents by Organization Type

In terms of job designation, the highest number of respondents were project engineers (n = 28, 30.1%). Unlisted categories of job designations (such as Quality Assurance/Quality Control Engineers, Planning Engineers, and Design Engineers) for 22.6% (n = 21) of all respondents, while site supervisors registered the third highest frequency (n = 18, 19.4%). Project/construction engineers (n = 15, 16.1%) and associate engineers (n = 11, 11.8%) had the fewest respondents, respectively. Figure (4) below is an illustration of the demographic data about respondents' job designation.

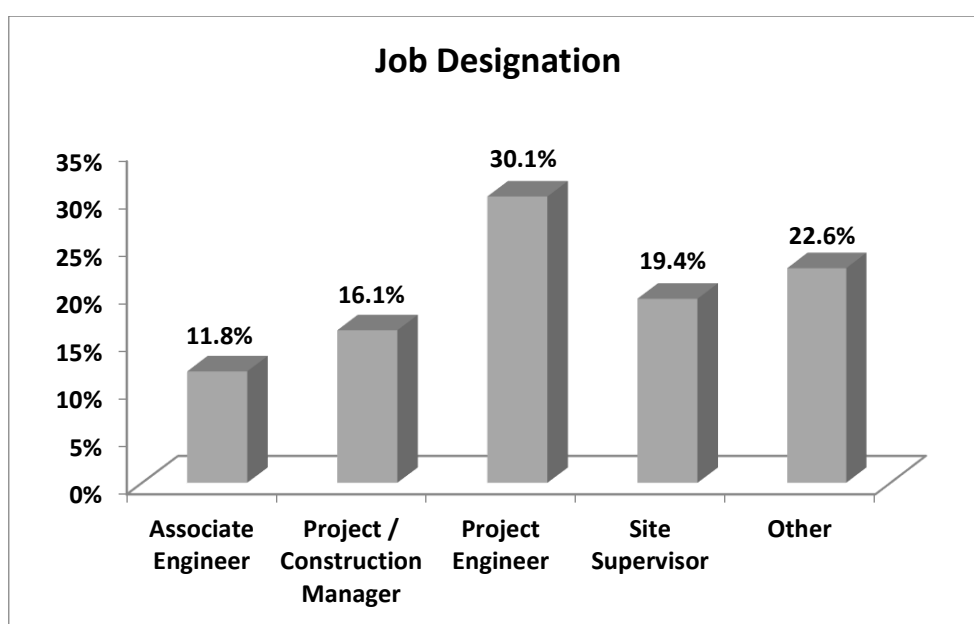


Figure (4)
Distribution of Respondents by Job Designation

The highest number of respondents were working in the oil and gas industry (n = 73, 78.5%). The number of respondents working in other industry types including industrial, superstructure, and infrastructure sectors was 20 thereby representing 21.5 percent of all responses. Respondents from other sectors i.e. industrial superstructure and infrastructure were included in the research because a majority of the

industries greatly rely on the oil and gas industry for their operation. However, the oil and gas industries and projects are the major focus for this thesis. Nevertheless, the oil sector has multiple facets as well including exploration, refining and distribution which all directly or indirectly lie in other industries. Hence, the researcher found it necessary to include their responses and data in the study because of their direct interaction with the oil and gas industry.

Respondents with experience equal to or more than 16 years in pipeline construction were the majority (n = 31, 33.3%). They were followed in frequency by respondents that had five years' experience or below (n = 30, 32.3%). Respondents with between 6 and 10 years were the fewest (n = 12, 12.9%) after those with between 11 and 15 years (n = 20, 21.5%), as illustrated in Figure (5) below.

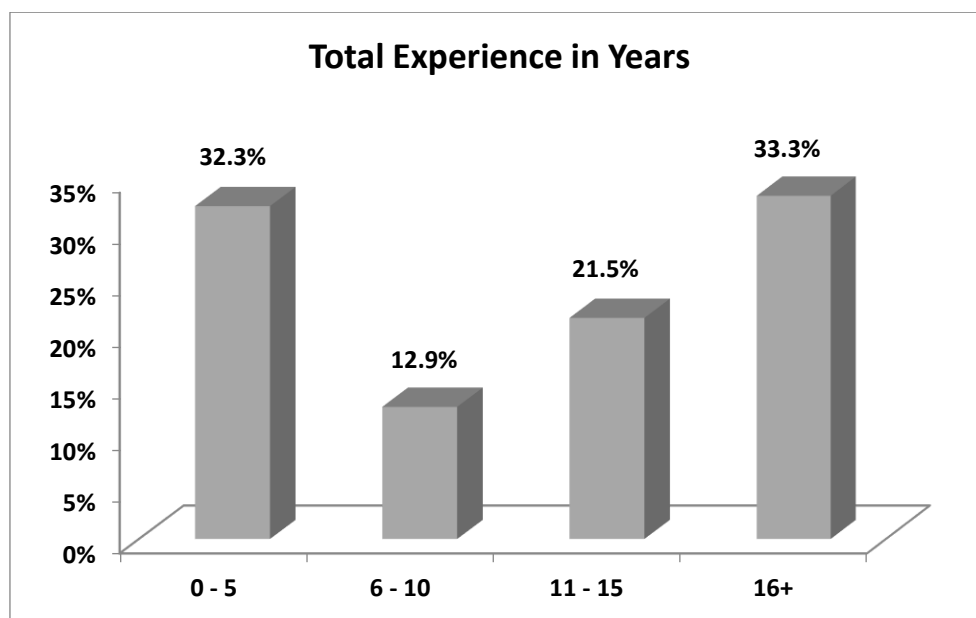


Figure (5)
Distribution of Respondents by Total Experience in Years

Concerning the highest Diploma and Bachelor degree holders (n = 67, 72.0%) were more than Master and PhD holders (n = 26, 28.0%). Moreover, the highest number of respondents (n = 87, 93.5%) came from large companies employing over 250 employees. Respondents from smaller companies were considerably fewer (n = 6, 6.5%).

The demographic data collected is important for the study because the data significantly influences the quality of responses received. In this study, demographic data provided data regarding the respondents' organizations, their job designations, and their experiences in the construction industry. Depending on these factors, some respondents gave detailed and in-depth information, while others gave information that could be described to be shallow. For instance, a respondent who has worked in the industry for a long time had more experience and therefore gave broad information concerning delays and overrun costs in pipeline construction projects in the oil and gas industry. This information was crucial in the evaluation of prediction models for delay. The responses from respondents who had little experience or had lower job designations, on the other hand, could not give quality information that for the evaluation of prediction models; however, the responses were factored in the study.

All the relevant data from the respective frequency tables generated based on the demographic data of the respondents were combined into summary form. The outcome of this combined summaries appears in Table (3) below.

Table (3)
Summary of All Demographic Data

Category	Sub-category	n	%
Current Projects Location	Bahrain	81	87.1%
	Other GCC	12	12.9%
Organization Type	Owner	51	54.8%
	Contractor	15	16.1%
	Consultant	14	15.1%
	Other	13	14.0%
Job Designation	Associate Engineer	11	11.8%
	Project / Construction Manager	15	16.1%
	Project Engineer	28	30.1%
	Site Supervisor	18	19.4%
	Other	21	22.6%
Industry Type	Oil and Gas	73	78.5%
	Other	20	21.5%
Total Experience in Pipeline Construction in Years	0 – 5	30	32.3%
	6 - 10	12	12.9%
	11 - 15	20	21.5%
	16+	31	33.3%
Highest Education	Diploma / Bachelor	67	72.0%
	Master / PhD	26	28.0%
Size of Company	Large (>250 employees)	87	93.5%
	Other	6	6.5%

4.3 Evaluating the Delay Factors of Pipeline Construction

This section contains the results of the descriptive statistics based on the importance (consequence) and frequency (likelihood) data of the delay

factors of pipeline construction projects based on survey responses. From Table (4), it is evident that most of the delay factors were ranked as moderate through very high. This overview implied that all the factors deduced from the literature were relevant to pipeline construction according to the respondents.

Besides the generation of the scores for each item according to each Likert point on the scale, the researcher also generated the mean, mode, and standard deviation scores. Of all the 47 delay factors, inadequate project planning, budgeting, and scheduling recorded the highest mean of 4.31 (i.e. $[(2 \times 1) + (1 \times 2) + (7 \times 3) + (39 \times 4) + (44 \times 5)] / 93$), with standard deviation of 0.83 and a mode of 5 in terms of importance. On the other hand, lack of site utilities with a mean of 2.96, standard deviation of 0.99, and mode of 3 was the least important delay factor of all the 47 studied. Table (4) below demonstrates the distribution and statistics of each delay factor in terms of importance.

On the other hand, Table (5) illustrates the raw frequency values as obtained from the survey directly. The occurrence of most of the delay factors ranged between low and moderate.

In terms of frequency in the pipeline construction, inadequate project planning, budgeting, and scheduling again topped the list with a mean of 3.30 (i.e. $[(3 \times 1) + (18 \times 2) + (31 \times 3) + (28 \times 4) + (12 \times 5)] / 92$) and a standard deviation of 1.03. On the other hand, changes in laws and regulations had the lowest mean of 1.89 and standard deviation of 1.07. Table (5) below demonstrates the distribution and statistics of each delay factor in terms of frequency.

Table (4)
Distribution and Statistics of Importance for Delay Factors

Delay factors		Importance scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
Management-Administrative related										
1	Poor managerial skills	1	0	23	48	21	93	3.95	4	0.76
2	Inadequate project planning, budgeting and scheduling	2	1	7	39	44	93	4.31	5	0.83
3	Slow decision making within all project teams	1	8	27	39	18	93	3.70	4	0.92
4	Lack of communication between client, consultant and contractor	1	9	18	36	29	93	3.89	4	0.99
5	Unrealistic contract duration imposed by client	3	9	43	25	13	93	3.39	3	0.96
6	Incompetence of project team	3	4	23	40	23	93	3.82	4	0.97
7	Lack of experience of owner (or owner representative) in construction projects	1	11	32	30	19	93	3.59	3	0.98
Design related										
8	Inadequate design team experience	1	13	38	31	10	93	3.39	3	0.90
9	Scope variations	2	2	28	28	33	93	3.95	5	0.97

Delay factors		Importance scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
10	Long wait for approval of drawings/documents	2	11	38	32	10	93	3.40	3	0.91
11	Improper selection of project location	4	26	32	19	12	93	3.10	3	1.08
12	Poor design	1	8	20	45	19	93	3.78	4	0.91
13	Delay in revising and approving documents (design, shop drawings, submittals, etc.)	3	15	37	27	11	93	3.30	3	0.99
14	Delay in drawings preparation of the projects	3	11	25	43	11	93	3.52	4	0.96
Materials related										
15	Late materials delivery	2	5	13	44	29	93	4.00	4	0.93
16	Late materials issuance	2	5	39	34	12	92	3.53	3	0.87
17	Materials shortage	2	8	17	40	26	93	3.86	4	1.00
18	Poor procurement programming of materials	2	19	32	28	12	93	3.31	3	1.01
19	Unavailability/shortage of equipment	2	25	21	30	15	93	3.33	4	1.11

Delay factors		Importance scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
Construction related										
20	Poor site management and supervision	3	3	16	43	28	93	3.97	4	0.95
21	Inadequate contractor experience	4	8	16	41	24	93	3.78	4	1.06
22	Contractor's lack of planning at preconstruction	3	6	21	44	19	93	3.75	4	0.96
23	Delay in fabrication	3	9	25	42	14	93	3.59	4	0.97
24	Inefficient and poor performance of contractors/subcontractors	1	9	15	47	21	93	3.84	4	0.92
25	Rework due to errors, mistakes and defective works during construction	3	9	17	31	33	93	3.88	5	1.10
26	Inappropriate construction methods	5	14	36	32	6	93	3.22	3	0.97
27	Unsafe practice at site (Poor safety conditions on site)	3	17	28	29	16	93	3.41	4	1.08
28	Unqualified workforce	4	7	15	46	21	93	3.78	4	1.02
29	Unforeseen site conditions	0	13	25	36	19	93	3.66	4	0.96
30	Lack of site utilities or services	6	24	36	22	5	93	2.96	3	0.99

Delay factors		Importance scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
31	Accident during construction	8	7	15	40	23	93	3.68	4	1.18
32	Insufficient contractor's manpower (or resources)	1	10	13	33	36	93	4.00	5	1.03
Financial / Economical related										
33	Economic and financial crisis	2	7	18	24	42	93	4.04	5	1.07
34	Delay of financing and payments by owner	6	3	21	46	17	93	3.70	4	1.02
35	Difficulties in financing the project by contractor	5	10	26	38	13	92	3.48	4	1.04
36	Unavailability or late approval of project budget	2	10	16	43	22	93	3.78	4	1.00
Statutory laws and regulations related										
37	Changes in laws and regulations	3	8	33	38	10	92	3.48	4	0.92
38	Insufficient laws on projects	4	17	40	26	6	93	3.14	3	0.94
39	Inefficiency of legal process	5	22	33	28	5	93	3.06	3	0.99
40	Government interference and approvals	3	12	28	33	17	93	3.53	4	1.04
41	Delay or long way leave approval process by other parties	3	6	29	42	13	93	3.60	4	0.92

Delay factors		Importance scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
External factors related										
42	Dispute with residents around site	4	14	38	25	12	93	3.29	3	1.02
43	Corruption and bribery	7	12	20	37	17	93	3.48	4	1.16
44	Lack of coordination among public agencies concerned	5	12	37	30	9	93	3.28	3	0.99
45	Environmental protection pressure by stakeholders	3	16	44	24	5	92	3.13	3	0.88
46	Damage to work by third party	3	16	42	25	7	93	3.18	3	0.92
47	Weather effect (heat, rain, wind, sand storm, etc.)	4	9	23	22	35	93	3.81	5	1.17

Table (5)
Distribution and Statistics of Frequency for Delay Factors

Delay factors		Frequency scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
Management-Administrative related										
1	Poor managerial skills	10	24	37	20	2	93	2.78	3	0.98
2	Inadequate project planning, budgeting and scheduling	3	18	31	28	12	92	3.30	3	1.03
3	Slow decision making within all project teams	7	27	39	15	4	92	2.80	3	0.95
4	Lack of communication between client, consultant and contractor	4	27	33	21	8	93	3.02	3	1.02
5	Unrealistic contract duration imposed by client	9	28	26	19	11	93	2.95	2	1.17
6	Incompetence of project team	9	31	36	10	7	93	2.73	3	1.03
7	Lack of experience of owner (or owner representative) in construction projects	9	41	29	7	7	93	2.59	2	1.02
Design related										
8	Inadequate design team experience	11	34	36	10	2	93	2.55	3	0.92
9	Scope variations	3	13	47	20	10	93	3.23	3	0.93

Delay factors		Frequency scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
10	Long wait for approval of drawings/documents	7	28	33	19	6	93	2.88	3	1.03
11	Improper selection of project location	14	51	18	8	2	93	2.28	2	0.90
12	Poor design	12	38	29	9	5	93	2.54	2	1.02
13	Delay in revising and approving documents (design, shop drawings, submittals, etc.)	8	32	34	12	7	93	2.76	3	1.04
14	Delay in drawings preparation of the projects	3	27	50	11	2	93	2.81	3	0.77
Materials related										
15	Late materials delivery	5	23	38	17	10	93	3.04	3	1.04
16	Late materials issuance	6	27	48	9	3	93	2.74	3	0.85
17	Materials shortage	9	22	41	14	7	93	2.87	3	1.03
18	Poor procurement programming of materials	13	28	27	21	4	93	2.73	2	1.09
19	Unavailability/shortage of equipment	14	39	22	13	5	93	2.53	2	1.08

Delay factors		Frequency scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
Construction related										
20	Poor site management and supervision	5	25	40	16	7	93	2.95	3	0.98
21	Inadequate contractor experience	7	35	30	13	8	93	2.78	2	1.06
22	Contractor's lack of planning at preconstruction	10	16	43	18	6	93	2.94	3	1.03
23	Delay in fabrication	10	35	34	13	1	93	2.57	2	0.90
24	Inefficient and poor performance of contractors/subcontractors	4	27	36	18	8	93	2.99	3	1.01
25	Rework due to errors, mistakes and defective works during construction	9	26	40	15	3	93	2.75	3	0.95
26	Inappropriate construction methods	24	32	25	9	3	93	2.30	2	1.06
27	Unsafe practice at site (Poor safety conditions on site)	15	35	27	11	5	93	2.53	2	1.07
28	Unqualified workforce	13	39	23	13	5	93	2.55	2	1.07
29	Unforeseen site conditions	5	40	34	10	3	92	2.63	2	0.87
30	Lack of site utilities or services	26	26	24	12	5	93	2.40	1	1.18

Delay factors		Frequency scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
31	Accident during construction	32	30	22	4	5	93	2.14	1	1.11
32	Insufficient contractor's manpower (or resources)	5	22	39	20	7	93	3.02	3	0.99
Financial / Economical related										
33	Economic and financial crisis	35	25	19	7	7	93	2.20	1	1.24
34	Delay of financing and payments by owner	22	37	20	6	8	93	2.37	2	1.17
35	Difficulties in financing the project by contractor	15	43	24	7	4	93	2.38	2	0.99
36	Unavailability or late approval of project budget	19	24	36	9	5	93	2.54	3	1.09
Statutory laws and regulations related										
37	Changes in laws and regulations	46	22	15	9	1	93	1.89	1	1.07
38	Insufficient laws on projects	31	32	21	6	3	93	2.12	2	1.05
39	Inefficiency of legal process	25	42	15	6	3	91	2.12	2	1.00
40	Government interference and approvals	25	29	23	11	4	92	2.35	2	1.13
41	Delay or long way leave approval process by other parties	3	18	49	15	7	92	3.05	3	0.89

Delay factors		Frequency scores						Statistics		
No.	Description	VL (1)	L (2)	M (3)	H (4)	VH (5)	Total	Mean	Mode	Standard deviation
External factors related										
42	Dispute with residents around site	23	35	19	10	5	92	2.34	2	1.13
43	Corruption and bribery	33	30	13	8	8	92	2.22	1	1.27
44	Lack of coordination among public agencies concerned	23	29	24	10	5	91	2.40	2	1.14
45	Environmental protection pressure by stakeholders	21	35	30	6	0	92	2.23	2	0.88
46	Damage to work by third party	31	32	18	9	2	92	2.12	2	1.06
47	Weather effect (heat, rain, wind, sand storm, etc.)	10	20	38	21	3	92	2.86	3	1.00

4.4 Ranking of Delay Factor

The researcher tried in this study to get the feedback of the oil and gas professionals on the most critical causes of the delay factors. The questionnaire participants valued each delay factor based on its importance and frequency. Data of the questionnaire was analysed to develop the RII, FI and FAII values of each factor. Delay factors were ordered in an ascending order based on the RII, FI and FAII values which will be listed and discussed later.

4.4.1 RII Ranking of Delay Factors

The RII computation using Equation (1) resulted in the ranking of the various delay factors using the survey data obtained from the questionnaires. As was the case with the results of the descriptive statistics, inadequate project planning, budgeting, and scheduling ranked highest with an RII% score of 86.24%. With an RII% score of 80.86%, economic and financial crisis ranked second highest followed by late materials delivery with a score of 80%. Lack of site utilities or services had the lowest RII% score of 59.14%, which was lower than the scores of inefficiency of legal process and environmental protection pressure by stakeholders with RII % scores of 61.29% and 61.94% respectively. Table (6) below provides the RII% scores and ranking of the 47 delay factors tested for in this research. The above mentioned RII% score for inadequate project planning, budgeting and scheduling was computed as follows:

$$RII(j) = \frac{\sum_{i=1}^A n_{ij} * i}{A * N}$$
$$RII = \frac{(2 \times 1) + (1 \times 2) + (7 \times 3) + (39 \times 4) + (44 \times 5)}{5 \times 93} \times 100 = 86.24\%$$

4.4.2 FI Ranking of Delay Factors

As was the case with the importance ranking of the delay factors (RII) and the descriptive tally, inadequate project planning, budgeting, and scheduling had the highest FI% at 65.38%, calculated using Equation (2), at top of the list. Although this was not expected while undertaking the research and even after the generation of the RII, scope variations ranked second highest in frequency (FI% = 64.52). Notably, both delay factors were related to owner or agency i.e. owner representative. Late material delivery (FI% = 60.86) occurred more frequently than 44 other delay factors (FI Rank = 3). On the other hand, damage to work by third party was the third lowest ranking delay factor (FI% = 41.94) at an FI rank of 45. The second lowest ranking delay factor was inefficiency of legal process at rank 46 with an FI% score of 41.51. Finally, the least occurring delay factor in the pipeline construction in the oil and gas industry in Bahrain was changes in laws and regulations with an FI% score of 37.85. Table (6) below provides a detailed outline of all the 47 delay factors and their respective FI% scores and FI ranking.

The above mentioned FI% score for inadequate project planning, budgeting, and scheduling was computed as follows:

$$FI(j) = \frac{\sum_{i=1}^A n'_{ij} * i}{A * N}$$

$$FI = \frac{(3 \times 1) + (18 \times 2) + (31 \times 3) + (28 \times 4) + (12 \times 5)}{5 \times 93} \times 100 = 65.38\%$$

4.4.3 FAII Ranking

As expected based on the RII and FI ranking results, inadequate project planning, budgeting, and scheduling had the highest FAII rank with an FAII score of 56.38 (By using Equation (3), $FAII = RII \times FI \% = 86.24 \times 65.38 / 100$). Scope variations also recorded the second highest FAII score ($FAII = 50.92$) with both top two factors being related to the owner or owner representative. Late material delivery, which was an attribute of material related delay factor, ranked third highest in terms of FAII with a score of 48.69. On the lower side, the FAII score of insufficient laws on projects (26.60) ranked third lowest among the 47 delay factors. It was followed closely by changes in laws and regulations ($FAII = 26.60$, FAII rank = 46). Inefficiency of legal process recorded the lowest ranking FAII score (25.44) of all delay causing factors. The FAII scores and ranking of all the 47 delay factors considered in this research appear at Table (6) below.

Table (6)
Ranking Comparison between RII, FI, and FAII

Delay factors		Ranking Comparison					
No.	Description	RII%	Rank	FI%	Rank	FAII%	Rank
Management-Administrative related							
1	Poor managerial skills	78.92	6	55.70	15	43.96	10
2	Inadequate project planning, budgeting and scheduling	86.24	1	65.38	1	56.38	1
3	Slow decision making within all project teams	73.98	19	55.48	17	41.05	16
4	Lack of communication between client, consultant and contractor	77.85	8	60.43	4	47.04	5
5	Unrealistic contract duration imposed by client	67.74	34	58.92	8	39.92	17

Delay factors		Ranking Comparison					
No.	Description	RII%	Rank	FI%	Rank	FAII%	Rank
6	Incompetence of project team	76.34	12	54.62	21	41.70	15
7	Lack of experience of owner (or owner representative) in construction projects	71.83	24	51.83	24	37.23	25
Design related							
8	Inadequate design team experience	67.74	35	50.97	26	34.53	31
9	Scope variations	78.92	7	64.52	2	50.92	2
10	Long wait for approval of drawings/documents	67.96	33	57.63	11	39.17	19
11	Improper selection of project location	61.94	44	45.59	39	28.24	42
12	Poor design	75.70	14	50.75	28	38.42	21
13	Delay in revising and approving documents (design, shop drawings, submittals, etc.)	66.02	38	55.27	18	36.49	27
14	Delay in drawings preparation of the projects	70.32	27	56.13	14	39.47	18
Materials related							
15	Late materials delivery	80.00	3	60.86	3	48.69	3
16	Late materials issuance	69.89	28	54.84	20	38.33	23
17	Materials shortage	77.20	10	57.42	12	44.33	8
18	Poor procurement programming of materials	66.24	37	54.62	22	36.18	28
19	Unavailability/shortage of equipment	66.67	36	50.54	30	33.69	33
Construction related							
20	Poor site management and supervision	79.35	5	58.92	9	46.76	6
21	Inadequate contractor experience	75.70	15	55.70	16	42.16	14

Delay factors		Ranking Comparison					
No.	Description	RII%	Rank	FI%	Rank	FAII%	Rank
22	Contractor's lack of planning at preconstruction	75.05	18	58.71	10	44.06	9
23	Delay in fabrication	71.83	25	51.40	25	36.92	26
24	Inefficient and poor performance of contractors/subcontractors	76.77	11	59.78	7	45.90	7
25	Rework due to errors, mistakes and defective works during construction	77.63	9	55.05	19	42.74	13
26	Inappropriate construction methods	64.30	41	46.02	38	29.59	40
27	Unsafe practice at site (Poor safety conditions on site)	68.17	32	50.54	31	34.45	32
28	Unqualified workforce	75.70	16	50.97	27	38.58	20
29	Unforeseen site conditions	73.12	22	52.04	23	38.05	24
30	Lack of site utilities or services	59.14	47	47.96	32	28.36	41
31	Accident during construction	73.55	21	42.80	43	31.48	36
32	Insufficient contractor's manpower (or resources)	80.00	4	60.43	5	48.34	4
Financial / Economical related							
33	Economic and financial crisis	80.86	2	44.09	40	35.65	29
34	Delay of financing and payments by owner	73.98	20	47.31	34	35.00	30
35	Difficulties in financing the project by contractor	68.82	30	47.53	33	32.71	35
36	Unavailability or late approval of project budget	75.70	17	50.75	29	38.42	22

Delay factors		Ranking Comparison					
No.	Description	RII%	Rank	FI%	Rank	FAII%	Rank
Statutory laws and regulations related							
37	Changes in laws and regulations	68.82	31	37.85	47	26.05	46
38	Insufficient laws on projects	62.80	43	42.37	44	26.60	45
39	Inefficiency of legal process	61.29	46	41.51	46	25.44	47
40	Government interference and approvals	70.54	26	46.45	36	32.77	34
41	Delay or long way leave approval process by other parties	72.04	23	60.43	6	43.54	11
External factors related							
42	Dispute with residents around site	65.81	39	46.24	37	30.43	39
43	Corruption and bribery	69.68	29	43.87	42	30.57	38
44	Lack of coordination among public agencies concerned	65.59	40	46.88	35	30.75	37
45	Environmental protection pressure by stakeholders	61.94	45	44.09	41	27.30	43
46	Damage to work by third party	63.66	42	41.94	45	26.69	44
47	Weather effect (heat, rain, wind, sand storm, etc.)	76.13	13	56.56	13	43.06	12

4.5 Spearman's Rank Order Correlation for RII and FAII

The researcher performed a Spearman's Rank Order Correlation test in SPSS to determine the extent to which RII and FAII were related. Having established that the two variables satisfied the fundamental assumptions of the test by having a monotonic relationship and being outcome variables of ordinal Likert-type data, the results revealed a

statistically significant strong correlation $r_s = 0.841$ by Equation (4) as shown below.

$$r_s = 1 - \left[\frac{6 \sum_{i=1}^{47} d_i^2}{n^3 - n} \right]$$

$$r_s = 1 - \frac{6 \times 2758}{47^3 - 47} = 0.841$$

Since FAII was an outcome of a computation involving both the importance and frequency of the delay factors in pipeline construction projects in the oil and gas industry in Bahrain, it was considered prudent to use it as the main tool for ranking the different respondent groups and undertaking further analyses henceforth. This approach was also recommended by George and Mallery (2003). The results of the Spearman's Rank Order Correlation test are demonstrated in Table (7) below.

Table (7)
Spearman's Rank Order Correlation Coefficient for RII and FAII
Rankings for All Respondents

No.	Delay Factors	RII rank	FAII rank	d_i^*	d_i^2
1	Poor managerial skills	6	10	4	16
2	Inadequate project planning, budgeting and scheduling	1	1	0	0
3	Slow decision making within all project teams	19	16	-3	9
4	Lack of communication between client, consultant and contractor	8	5	-3	9
5	Unrealistic contract duration imposed by client	34	17	-17	289
6	Incompetence of project team	12	15	3	9
7	Lack of experience of owner (or owner representative) in construction projects	24	25	1	1
8	Inadequate design team experience	35	31	-4	16
9	Scope variations	7	2	-5	25

No.	Delay Factors	RII rank	FAII rank	d_i^*	d_i^2
10	Long wait for approval of drawings/documents	33	19	-14	196
11	Improper selection of project location	44	42	-2	4
12	Poor design	14	21	7	49
13	Delay in revising and approving documents (design, shop drawings, submittals, etc.)	38	27	-11	121
14	Delay in drawings preparation of the projects	27	18	-9	81
15	Late materials delivery	3	3	0	0
16	Late materials issuance	28	23	-5	25
17	Materials shortage	10	8	-2	4
18	Poor procurement programming of materials	37	28	-9	81
19	Unavailability/shortage of equipment	36	33	-3	9
20	Poor site management and supervision	5	6	1	1
21	Inadequate contractor experience	15	14	-1	1
22	Contractor's lack of planning at preconstruction	18	9	-9	81
23	Delay in fabrication	25	26	1	1
24	Inefficient and poor performance of contractors/subcontractors	11	7	-4	16
25	Rework due to errors, mistakes and defective works during construction	9	13	4	16
26	Inappropriate construction methods	41	40	-1	1
27	Unsafe practice at site (Poor safety conditions on site)	32	32	0	0
28	Unqualified workforce	16	20	4	16
29	Unforeseen site conditions	22	24	2	4
30	Lack of site utilities or services	47	41	-6	36
31	Accident during construction	21	36	15	225
32	Insufficient contractor's manpower (or resources)	4	4	0	0
33	Economic and financial crisis	2	29	27	729
34	Delay of financing and payments by owner	20	30	10	100
35	Difficulties in financing the project by contractor	30	35	5	25

No.	Delay Factors	RII rank	FAII rank	d_i^*	d_i^2
36	Unavailability or late approval of project budget	17	22	5	25
37	Changes in laws and regulations	31	46	15	225
38	Insufficient laws on projects	43	45	2	4
39	Inefficiency of legal process	46	47	1	1
40	Government interference and approvals	26	34	8	64
41	Delay or long way leave approval process by other parties	23	11	-12	144
42	Dispute with residents around site	39	39	0	0
43	Corruption and bribery	29	38	9	81
44	Lack of coordination among public agencies concerned	40	37	-3	9
45	Environmental protection pressure by stakeholders	45	43	-2	4
46	Damage to work by third party	42	44	2	4
47	Weather effect (heat, rain, wind, sand storm, etc.)	13	12	-1	1
Sum					2758
Spearman's rank correlation					0.841

* d_i is the difference between RII rank and FAII rank to each factor.

4.6 Ranking Comparison between Respondent Groups

To generate a more robust view of the delay factors and ensure coverage of different categories of respondents, the researcher conducted the ranking of the delay factors for all respondent groups based on their demographic profiles. In other words, the ranking comparison was performed based on the location of current projects, organization type, job designation, industry type, total pipelines construction experience, highest education and the size of the company.

Comparisons were conducted between all categories, but 9 significantly strong agreement comparisons were found. These were between Bahrain and other GCC, between owners and contractors, owners

and consultants, between contractors and consultants, between project/construction managers and project engineers, between project/construction managers and site supervisors, and between project engineers and site supervisors. Additionally, strong correlations were found in terms of years of experience between respondents with 11 and 15 years and their counterparts with more than 16 years' experience in pipeline construction. Moreover, strong agreement was found between Diploma/Bachelor and Master/PhD holders in terms of highest education. Each of these categories are discussed below in greater detail.

The first Spearman's rank order correlation test conducted was on FAII rankings of delay factors between respondents from Bahrain and other GCC countries. A statistically significant, positive Spearman's Rank Correlation coefficient was achieved ($r_s = 0.837$, $p < 0.05$) as shown in Table (8) below. The fact that the p -value coefficient ($p < 0.05$) in the stated FAII rankings of delay factors between respondents from Bahrain and other GCC countries was less than 0.05, implication was that the pipeline construction project delay factors seem to be consistent among respondents drawn from both groups. Therefore, survey data on the project delay factors from respondents in Bahrain and other GCC should be given similar weight and consideration in data analysis. This was an indication of a strong agreement in the FAII rankings of the respondent groups whose current projects were in other GCC countries and those whose current projects were in Bahrain.

Table (8)
Spearman's Correlation Factor Matrix Between FAII Values Based on the Location of Current Projects

Project Location		Bahrain	Other GCC
Bahrain	Correlation Coefficient	1	0.837
	<i>p</i> -value		0.000
Other GCC	Correlation Coefficient		1
	<i>p</i> -value		

Another Spearman's rank order correlation test was performed on the respondent groups of different organization types as captured in the questionnaire. The results revealed statistically significant positive correlation coefficients between owner and contractor organizations ($r_s = 0.820$, $p < 0.05$). Similar results were reported for the FAII rankings of owner and consultant types of organizations ($r_s = 0.858$, $p < 0.05$). Likewise, the FAII rankings between contractor and consultant organization types ($r_s = 0.862$, $p < 0.05$). The FII ranking results reported significant moderately positive correlation between the different organizational types and the others (i.e. designer, subcontractor, supplier, etc.) with correlation coefficient values vary from 0.645 to 0.714. Table (9) below illustrates these and other results.

Table (9)
Spearman's Correlation Factor Matrix Between FAII Values Based on Organization Type

Organization Type		Owner	Contractor	Consultant	Other
Owner	Correlation Coefficient	1	0.820	0.858	0.702
	<i>p</i> -value		0.000	0.000	0.000
Contractor	Correlation Coefficient		1	0.862	0.645
	<i>p</i> -value			0.000	0.000

Organization Type		Owner	Contractor	Consultant	Other
Consultant	Correlation Coefficient <i>p</i> -value			1	0.714 0.000
Other	Correlation Coefficient <i>p</i> -value				1

As illustrated in Table (10) below, the results of the Spearman's Rank Order Correlation test for FAII values based on the job designation of the respondents revealed three sets of statistically significant relationships. The first set was between the FAII values of project/construction managers and project engineers ($r_s = 0.799$, $p < 0.05$). In this case, since *p*-value for the FAII values of project managers and project engineers was less than the significance level ($p < 0.05$), the implication was that the stated relationship was statistically significant and can be relied upon for predicting importance of the project managers and project engineers in facilitating successful project completion. The second set of positive relationships comprised project/construction managers and site supervisors ($r_s = 0.850$, $p < 0.05$). The results indicated that the *p*-value coefficient for the stated FAII ranking relationship between project/construction managers and site supervisors was less than 0.05. The implication was that the stated relationship was statistically significant and could be used as an important element in predicting delay factors that adversely affect construction project completion within the oil and gas industry. The relationship between the FAII rankings of project engineer and site supervisors were positively correlated ($r_s = 0.882$, $p < 0.05$). Similarly, in this case, the *p*-value coefficient provides an insightful perspective on the importance of the stated FAII ranking relationship between project engineers and site supervisors. In essence, since the *p*-value coefficient ($p < 0.05$), implication is that the stated FAII ranking relationship between

project engineers and site supervisors can be used as an important factor in predicting delay factors in pipeline construction projects that are undertaken within the oil and gas industry. Besides that, the correlation coefficients between the associate engineer and the other job designations are statically not significant except with the project engineer, which is significantly weak. These insignificant correlations are mainly due to the lack of experience of the associate engineer. Generally, a p -value which is less than the significance level is an indication of a strong correlation between the variables under comparison. In Table 9 above the p -values between the variables under comparison were less than 0.05. This is an indication of a strong correlation between variables that could help in the prediction of delay factors in pipeline construction projects. The correlation coefficient between the others job designations and each of project managers, project engineer and site supervisor revealed significant moderate positive correlation as indicated in the Table (10). The Spearman's Correlation Factor between the variables (project managers, project engineer and site supervisor) is positive as shown in the Table (10). Unlike the Pearson correlation used in Table (9) that determines the linear relationships, the Spearman correlation determines the monotonic relationships between the variables. As observed, the values in the table for the different variables increase and decrease with one another. The association decreases with decrease in value and increases with increase in value. In Table (10), however, the values are increasing almost in all variables related – a clear indication of a positive association between the variables.

Table (10)
Spearman's Correlation Factor Matrix Between FAII Values Based on Job Designation

Job Designation		Associate Engineer	Project Manager	Project Engineer	Site Supervisor	Other
Associate Engineer	Correlation Coefficient	1	0.164	0.354	0.180	0.084
	<i>p</i> -value		0.269	0.015	0.226	0.574
Project Manager	Correlation Coefficient		1	0.799	0.850	0.731
	<i>p</i> -value			0.000	0.000	0.000
Project Engineer	Correlation Coefficient			1	0.882	0.702
	<i>p</i> -value				0.000	0.000
Site Supervisor	Correlation Coefficient				1	0.745
	<i>p</i> -value					0.000
Other	Correlation Coefficient					1
	<i>p</i> -value					

Concerning the FAII rankings based on the industry type, the Spearman's Rank Order Correlation test revealed a statistically significant, moderate coefficient between the FAII rankings of the only two sector categories considered in this research i.e. the oil and gas sector and other sectors ($r_s = 0.656$, $p < 0.05$). These results are shown in Table (11) below.

Table (11)
Spearman's Correlation Factor Matrix Between FAII Values Based on Industry Type

Industry Type		Oil and Gas	Other
Oil and Gas	Correlation Coefficient	1	0.656
	<i>p</i> -value		0.000
Other	Correlation Coefficient		1
	<i>p</i> -value		

The computed value of 0.852 ($p < 0.05$) for Spearman's correlation coefficient appearing in Table (12) below indicates significant strong agreement (positive correlation) in FAII rankings between respondents with work experience ranging between 11 and 15 years and those with experience of more than 16 years in pipelines construction. Additionally, significant moderately positive correlation was reported for the FAII ranking values for respondents with below five years' experience and those with 6-10 ($r_s = 0.520$, $p < 0.05$), 11-15 ($r_s = 0.639$, $p < 0.05$), and 16 years or more ($r_s = 0.735$, $p < 0.05$). Respondents with 6-10 years of experience also registered statistically significant, moderate correlation coefficients with their counterparts that had 11-15 years ($r_s = 0.475$, $p < 0.05$) and 16 or more years ($r_s = 0.570$, $p < 0.05$).

Table (12)
Spearman's Correlation Factor Matrix Between FAII Values Based on Total Experience in Years

Total Experience		0 - 5	6 - 10	11 - 15	16+
0 – 5	Correlation Coefficient	1	0.520	0.639	0.735
	<i>p</i> -value		0.000	0.000	0.000
6 - 10	Correlation Coefficient		1	0.475	0.570
	<i>p</i> -value			0.001	0.000
11 - 15	Correlation Coefficient			1	0.852
	<i>p</i> -value				0.000
16+	Correlation Coefficient				1
	<i>p</i> -value				

The FAII rankings of the two categories of highest education levels also registered a strong statistically significant coefficient ($r_s = 0.826$, $p < 0.05$), as shown in Table (13) below.

Table (13)
Spearman's Correlation Factor Matrix Between FAII Values Based on Highest Education Level

Highest Education Level		Diploma / Bachelor	Master / PhD
Diploma / Bachelor	Correlation Coefficient	1	0.826
	<i>p</i> -value		0.000
Master / PhD	Correlation Coefficient		1
	<i>p</i> -value		

Although the number of respondents from large companies was significantly higher than that of respondents from other smaller companies, the Spearman's Rank Order Correlation test showed that the FAII rankings of the delay factors between these two sets of respondents had a statistically significant positive correlation ($r_s = 0.718$, $p < 0.05$), as demonstrated in Table (14) below.

Table (14)
Spearman's Correlation Factor Matrix Between FAII Values Based on Company Size

Company Size		Large (>250 employees)	Other
Large (>250 employees)	Correlation Coefficient	1	0.718
	<i>p</i> -value		0.000
Other	Correlation Coefficient		1
	<i>p</i> -value		

4.7 Factor analysis

Factor analysis was performed to reduce the 47 delay factors analyzed previously as variables into categories to inform the development of a suitable prediction model for delay in pipeline construction. The cut off

point for the factor loadings was 0.60. The sample size of the current study was 93. Thus, the rationale for the 0.60 cut off point for factor loadings was consistent with the recommendation by Hair et al. (2010) for sample sizes of between 85 and 100. Thus, all factors with loadings below 0.60 were dropped from further analysis.

Preliminary checks to ensure the suitability of the data for the factor analysis procedure were conducted in accordance with the two recommendations made by Bryman and Cramer (1997) and endorsed by Fabrigar et al. (1999). First, the researcher checked the anti-image matrix for diagonals exceeding 0.5. Second, the KMO measure and Bartlett's test of Sphericity were checked for significance, as elaborated in Chapter 3 (Section 3.4). The analysis revealed that all the data items (delay factors) satisfied these two conditions and were fit for the factor analysis procedure as shown in Table (15) below, the KMO measure of sampling adequacy index was 0.845, which is greater than 0.5, while Bartlett's test of Sphericity was significant ($p < 0.05$).

Factor analysis was used in data analysis for this study in order to facilitate an in-depth evaluation and analysis of the survey data. In essence, analysis of all the 47 delay factors was likely to obscure results for the study. Therefore, factor analysis was incorporated into data analysis in order to group all 47 project delay factors into eight manageable categories that include; statutory-related delays, contract-related delays, owner-related delays, pre-construction-related delays, labour-related delays, management-related delays, and site utilities-related delay. According to Shehzad (2015), use of factor analysis was important in studies that had a large number of explanatory variable factors. Therefore, using factor analysis, researchers could reduce the large number of variable factors into

smaller and manageable factors that would be used in developing the prediction model. In this case, use of factor analysis was expected to compress all 47 project delay factors into the stated eight categories, which would enable formulation of an appropriate prediction model for specific delay factors in pipeline construction projects that were found within the oil and gas industry in Bahrain. The implication was that the prediction model equation would be formulated and developed based on the stated eight categories rather than all 47 project delay factors.

Table (15)
KMO and Bartlett's Test of Sphericity for the Delay Factors

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.845
Bartlett's Test of Sphericity	Approx. Chi-Square	3178.251
	df	1081
	Sig.	0.000

The factor analysis procedure on the 47 delay factors yielded 8 categories by using the SPSS software. The first category contained four delay factors, which included changes in laws and regulations; insufficient laws on projects; inefficiency of legal process; and government interference and approval. Since these factors were in the original category of delays related to statutory laws and regulations, it was named accordingly.

The second category was named contractor-related delays and had three factors. These included poor site management and supervision; contractor's lack of planning at preconstruction; and unforeseen site conditions.

The third category was named owner-related delays and had five delay factors. These delay factors were inadequate project planning, budgeting, and scheduling; scope variations; delay in drawings preparation of the projects; late materials; and materials shortage.

The fourth category comprised unqualified workforce; and accident during construction. Since both factors were about labor issues during pipeline construction, the fourth factor was named labor-related delays. On the other hand, Category 5 had three factors. These included slow decision making within all project teams; long wait for approval of drawings/documents; and delay in revising and approving documents including design, shop drawings, submittals, etc. Notably, all the three factors that constituted Category 5 were under pre-construction related delays.

The three remaining categories had a single delay factor each. Category 6, which was named management related delays. Contract related delays was the seventh category with unrealistic contract duration imposed by client. Finally, Category 8 was lack of site utilities or services.

The factor analysis technique allowed the researcher to select the most effective factors and group them in different categories as an input data for the prediction model with a group of 8 categories. Based on the analysis and results, the outcome would be evaluated for the relevance of results, and if the results are not accepted, other methods such as the risk mapping matrix can be developed for stronger outcome.

In factor analysis, the binary methodology operates in such a way that all 47 project delay factors were classified and categorized into distinct

smaller manageable groups. The binary classification in the case of factor analysis ensured that each of the stated eight distinct categories had certain unique characteristics and features that could be uniquely identified with each of the stated groups. For instance, statutory-related delays category incorporated all factors that were associated with project laws, regulations and government approval. The implication was that in factor analysis, binary methodology classified all project delay factors based on their respective risk factor that was consistent with each of the eight distinct categories.

4.8 Risk Mapping Matrix

The risk mapping matrix was employed to classify each of the 47 delay causing factors under specific risk zones as shown in Figure (2) Page 50 based on the mean value of Importance (consequence) and Frequency (likelihood) as described in Table (1) Page 48. The researcher developed Table (16) below, which indicates all the 47 delay causing factors considered in this study along with their importance mean and frequency mean. Moreover, the table shows the corresponding risk zones for each of the 47 factors. From Table (16), the researcher identified the 19 high risk critical delay factors that were singled out based on the KPI data obtained from the Risk Assessment Matrix of XYZ Company. These 19 high risk delay factors had only been considered in the prediction models for delay due to their importance and criticality for management risk assessment in order to mitigate or reduce the risk as mentioned in Chapter 3 (Section 3.4, Page 48 and 49).

Table (16)
Importance and Frequency of the 47 Delay Factors and Identification
of the 19 Most Critical Delay Causing Factors from XYZ Company's
KPI Data and Corresponding Risk Zone

Sr.	Factors	Importance Mean	Frequency Mean	Zone
1	Poor managerial skills	3.95	2.78	D
2	Inadequate project planning, budgeting and scheduling	4.31	3.3	D
3	Slow decision making within all project teams	3.7	2.8	D
4	Lack of communication between client, consultant and contractor	3.89	3.02	D
5	Unrealistic contract duration imposed by client	3.39	2.95	C
6	Incompetence of project team	3.82	2.73	D
7	Lack of experience of owner (or owner representative) in construction projects	3.59	2.59	C
8	Inadequate design team experience	3.39	2.55	B
9	Scope variations	3.95	3.23	D
10	Long wait for approval of drawings/documents	3.4	2.88	C
11	Improper selection of project location	3.1	2.28	B
12	Poor design	3.78	2.54	C
13	Delay in revising and approving documents (design, shop drawings, submittals, etc.)	3.3	2.76	C
14	Delay in drawings preparation of the projects	3.52	2.81	D
15	Late materials delivery	4	3.04	D
16	Late materials issuance	3.53	2.74	D
17	Materials shortage	3.86	2.87	D
18	Poor procurement programming of materials	3.31	2.73	C
19	Unavailability/shortage of equipment	3.33	2.53	B
20	Poor site management and supervision	3.97	2.95	D
21	Inadequate contractor experience	3.78	2.78	D

Sr.	Factors	Importance Mean	Frequency Mean	Zone
22	Contractor's lack of planning at preconstruction	3.75	2.94	D
23	Delay in fabrication	3.59	2.57	C
24	Inefficient and poor performance of contractors/subcontractors	3.84	2.99	D
25	Rework due to errors, mistakes and defective works during construction	3.88	2.75	D
26	Inappropriate construction methods	3.22	2.3	B
27	Unsafe practice at site (Poor safety conditions on site)	3.41	2.53	C
28	Unqualified workforce	3.78	2.55	C
29	Unforeseen site conditions	3.66	2.63	D
30	Lack of site utilities or services	2.96	2.4	B
31	Accident during construction	3.68	2.14	C
32	Insufficient contractor's manpower (or resources)	4	3.02	D
33	Economic and financial crisis	4.04	2.2	C
34	Delay of financing and payments by owner	3.7	2.37	C
35	Difficulties in financing the project by contractor	3.48	2.38	C
36	Unavailability or late approval of project budget	3.78	2.54	C
37	Changes in laws and regulations	3.48	1.89	C
38	Insufficient laws on projects	3.14	2.12	B
39	Inefficiency of legal process	3.06	2.12	B
40	Government interference and approvals	3.53	2.35	C
41	Delay or long way leave approval process by other parties	3.6	3.05	D
42	Dispute with residents around site	3.29	2.34	B
43	Corruption and bribery	3.48	2.22	C
44	Lack of coordination among public agencies concerned	3.28	2.4	B
45	Environmental protection pressure by stakeholders	3.13	2.23	B
46	Damage to work by third party	3.18	2.12	B

Sr.	Factors	Importance Mean	Frequency Mean	Zone
47	Weather effect (heat, rain, wind, sand storm, etc.)	3.81	2.86	D

Based on Table (16) above and the risk mapping matrix tools explained under data collection/procedures (Section 3.4) in Chapter 3, the 47 critical delay factors were mapped out based on their frequency (likelihood) and importance (consequence) regarding the pipeline construction in the oil and gas industry in Bahrain.

In contrast to the binary classification methodology in factor analysis, the binary classification methodology in the risk assessment mapping model was performed individually for each of the 19 high risk delay factors, those laid on the critical zones, the orange and red zones in the risk mapping matrix, as shown in Figure (6) below. This was different from the binary classification methodology that was previously employed in factor analysis, where risk assessment was done based on the group category where each delay factor was associated to. In the risk assessment mapping model, each project delay factor was classified into a risk zone depending on its mean importance value and mean frequency value. This process was undertaken after risk assessment was conducted for each individual project delay factor. Use of the stated binary classification methodology in the risk assessment mapping model was expected to generate significantly stronger prediction models as compared to the prediction model developed using factor analysis (Shehzad, 2015). Figure 6 below shows the matrix that was developed following the risk mapping exercise.

			IMPORTANCE (CONSEQUENCE)				
			(VL)	(L)	(M)	(H)	(VH)
FREQUENCY (LIKELIHOOD)	(VH)						
	(H)						
	(M)				5, 10, 13, 18,	1, 3, 4, 6, 9, 14, 15, 16, 17, 20, 21, 22, 24, 25, 29, 32, 41, 47	2
	(L)				8, 11, 19, 26, 30, 38, 39, 42, 44, 45, 46	7, 12, 23, 27, 28, 31, 33, 34, 35, 36, 37, 40, 43,	
	(VL)						

Figure (6)
The Risk Mapping Matrix Indicating the Zones of All the 47 Delay
Causing Factors

Chapter Five

Development and Validation of Delay Models

5.1 Regression Modelling

5.2 Validation of Models

Chapter 5: Development and Validation of Delay Models

5.1 Regression Modelling

The researcher had studied the actual reasons of delays for 80 projects to identify the applicability of 8 categories, resulted from the factor analysis method (Chapter 4, Section 4.7), by using binary analysis system as shown in Appendix E. However, the factor analysis results revealed non-significant models for both delay and cost due to their p -values which were found to be more than 0.05 with values 0.257 and 0.877 respectively as shown in Appendix F. Since the p -values for both models were non-significant, the researcher did not considered the factor analysis method as a base for the study investigation due to its feeble outcome.

Multiple linear regression analysis was performed in SPSS using secondary data for 80 historical oil and gas pipeline construction projects and the KPI. The data included the 19 high risk delay factors singled out in Section 4.8 in Table (16). Prior to undertaking the analysis, the data was divided into two sets comprising 80 and 20 projects respectively. The two data sets were used for the development of the model and its validation, respectively. A detailed breakdown of the 80 pipeline construction projects that suffered delays for the period 2011 through 2017 and the mapping out of the 19 high risk delay factors was performed (Appendix G).

From the 80 late projects in the XYZ Company KPIs, the researcher had studied the actual reasons of delays to identify the definite causes and correlate the 19 high risk delay factors, resulted from the company's risk assessment matrix, to the actual one by using binary analysis system as shown in Appendix G. After filling the binary Excel sheet for the 80

delayed projects, the resulted list was entered in the SPSS software for the delay predication models using the multi linear regression methodology.

Since late materials delivery and materials shortage featured in 3 projects only out of the 80 projects considered, they were excluded. Thus, 17 high risk delay factors were entered into the multiple linear regression model as the predictor (independent) variables. Costs of delay in USD and the duration of delay in days were the dependent variables.

The model summary results for the prediction of duration of delay in days showed that the prediction quality of the 17 high risk delay factors was good based on the multiple correlation coefficient ($R = 0.696$). The Adjusted R^2 coefficient showed that the 17 high risk delay factors could account for up to 34.3% variance in the duration of delay in days (Adj. $R^2 = 0.343$). Table (17) below shows the model summary results. The ANOVA results (Table (18) below) revealed that the overall multi linear regression model was a good fit for the data, as a statistically significant F-statistic was achieved ($F(17, 62) = 3.422, p < 0.05$) from SPSS software. In other words, this implied that the 17 high risk delay factors statistically significant in predicting duration of delay in days.

Table (17)
Model Summary Results for Multiple Linear Regression to Predict Duration of Delay in Days Based on 17 High Risk Delay Factors

R	R^2	Adjusted R^2	Std. Error of the Estimate
0.696	0.484	0.343	3.85812

Table (18)
ANOVA Analysis for Multiple Linear Regression to Predict Duration of Delay in Days Based on 17 High Risk Delay Factors

Model	Sum of Squares	df	Mean Square	F	<i>p</i> -value
Regression	865.983	17	50.940	3.422	0.000
Residual	922.878	62	14.885		
Total	1788.861	79			

Table (19) below revealed that only two critical delay factors were statistically significant predictors of duration of delay in days. These factors were scope variation ($\beta = -1.471$, $p < 0.05$) and delay in drawings preparation of the projects ($\beta = 22.900$, $p < 0.05$). These results show that scope variation and delay in drawings preparation of the projects together predicted most of the 34.3% variance in duration of delays in days. Based on the results of the regression model test, the following equation was developed for the prediction of duration of delay in pipeline construction in the oil and gas industry, considering the factors as a binary system (i.e. Applicable with “1” and Not Applicable with “0”):

$$\begin{aligned} \text{Duration of delay in days} = & -1.471 + 2.343 \times F_1 + 3.708 \times F_2 + 0.566 \times \\ & F_3 - 2.058 \times F_4 + 2.366 \times F_5 - 1.737 \times F_6 + 1.754 \times F_7 - 0.858 \times F_8 + \\ & 0.134 \times F_9 + 1.687 \times F_{10} + 2.892 \times F_{11} - 2.830 \times F_{12} + 1.387 \times F_{13} + 3.388 \\ & \times F_{14} + 22.900 \times F_{15} - 0.892 \times F_{16} + 0.089 \times F_{17} \end{aligned} \quad \text{Equation (9)}$$

Table (19)
Coefficients' for Multiple Linear Regression to Predict Duration of
Delay in Days Based on 17 Critical Delay Factors

Delay Factors		β	<i>p</i> -value
Symbol	Description		
C	Constant	-1.471	0.483
F1	Inadequate project planning, budgeting and scheduling	2.343	0.138
F2	Scope variation	3.708	0.035
F3	Insufficient contractor's manpower (or resources)	0.566	0.808
F4	Lack of communication between client, consultant and contractor	-2.058	0.097
F5	Poor site management and supervision	2.366	0.193
F6	Inefficient and poor performance of contractors/subcontractors	-1.737	0.491
F7	Contractor's lack of planning at preconstruction	1.754	0.370
F8	Poor managerial skills	-0.858	0.476
F9	Delay or long way leave approval process by other parties	0.134	0.938
F10	Weather effect (heat, rain, wind, sand storm, etc.)	1.687	0.440
F11	Rework due to errors, mistakes and defective works during construction	2.892	0.174
F12	Inadequate contractor experience	-2.830	0.206
F13	Incompetence of project team	1.387	0.528
F14	Slow decision making within all project teams	3.388	0.074
F15	Delay in drawings preparation of the projects	22.900	0.000
F16	Late materials issuance	-0.892	0.745
F17	Unforeseen site conditions	0.089	0.944

Similarly, multiple linear regression model was developed to test for the extent to which the 17 high risk delay variables (factors) could predict the cost of delay in USD. The model summary results revealed a good prediction quality of the multiple correlation coefficient ($R = 0.868$). The Adjusted R^2 coefficient showed that the 17 high risk delay factors could

account for up to 68.6% variance of the cost of delay in USD (Adj. $R^2 = 0.686$). Table (20) shows the summary of regression results. The ANOVA results shown in Table (21) below confirmed that the overall regression model was a good fit for the data. This was because a statistically significant F-statistic was achieved ($F(17, 62) = 11.140, p < 0.05$). Thus, the interpretation was that the 17 high risk delay factors statistically significant in predicting duration of delay in days.

Table (20)
Model Summary Results for Multiple Linear Regression to Predict Cost of Delay in USD Based on 17 High Risk Delay Factors

R	R^2	Adjusted R^2	Std. Error of the Estimate
0.868	0.753	0.686	33,482.30622

Table (21)
ANOVA Analysis for Multiple Linear Regression to Predict Cost of Delay in USD Based on 17 High Risk Delay Factors

Model	Sum of Squares	df*	Mean Square	F	p-value
Regression	212.314×10^9	17	12.489×10^9	11.140	0.000
Residual	69.506×10^9	62	1.121×10^9		
Total	281.820×10^9	79			

The coefficients' table of the regression model, Table (22), showed that 6 of the 17 high risk delay factors were significant predictors of the cost of delay in USD. Poor site management and supervision ($\beta = 32754.106, p < 0.05$), inefficient and poor performance of contractors/subcontractors ($\beta = -46878.255, p < 0.05$), and contractor's lack of planning at preconstruction ($\beta = 56317.855, p < 0.05$) were the first three factors. Weather effect ($\beta = 41050.981, p < 0.05$), rework due to errors, mistakes and defective works during construction ($\beta = 70034.984, p < 0.05$), and delay in drawings preparation of the projects ($\beta = 420999.707, p < 0.05$) completed the list of the statistically significant

predictor variables for cost of delay in USD. The results of the multiple linear regression model test informed the development of the following equation for predicting the cost of delay in pipeline construction in the oil and gas industry:

$$\begin{aligned} \text{Cost of delay in dollars} = & -26184.500 + 18040.552 \times F_1 + 11158.961 \times F_2 + 50.141 \times F_3 - 7687.950 \times F_4 + 32754.106 \times F_5 - 46878.255 \times F_6 + \\ & 56317.855 \times F_7 - 2580.991 \times F_8 + 20701.724 \times F_9 + 41050.981 \times F_{10} + 70034.984 \times F_{11} - 30061.376 \times F_{12} + 5277.391 \times F_{13} + 12236.998 \times F_{14} + \\ & 420999.707 \times F_{15} - 3809.442 \times F_{16} - 1632.185 \times F_{17} \end{aligned} \quad \text{Equation (10)}$$

Table (22)
Coefficients' Table for Multiple Linear Regression to Predict Cost of Delay in USD Based on 17 High Risk Delay Factors

Delay Factors		β	<i>p</i> -value
Symbol	Description		
C	Constant	-26184.500	0.153
F1	Inadequate project planning, budgeting and scheduling	18040.552	0.187
F2	Scope variation	11158.961	0.459
F3	Insufficient contractor's manpower (or resources)	50.141	0.998
F4	Lack of communication between client, consultant and contractor	-7687.950	0.471
F5	Poor site management and supervision	32754.106	0.040
F6	Inefficient and poor performance of contractors/subcontractors	-46878.255	0.035
F7	Contractor's lack of planning at preconstruction	56317.855	0.001
F8	Poor managerial skills	-2580.991	0.804
F9	Delay or long way leave approval process by other parties	20701.724	0.171
F10	Weather effect (heat, rain, wind, sand storm, etc.)	41050.981	0.033
F11	Rework due to errors, mistakes and defective works during construction	70034.984	0.000
F12	Inadequate contractor experience	-30061.376	0.123
F13	Incompetence of project team	5277.391	0.782

Delay Factors		β	p -value
Symbol	Description		
F14	Slow decision making within all project teams	12236.998	0.452
F15	Delay in drawings preparation of the projects	420999.707	0.000
F16	Late materials issuance	-3809.442	0.873
F17	Unforeseen site conditions	-1632.185	0.881

On the basis of results from the above table for the multiple linear regression model predicting the impact of the stated 17 high risk delay factors on the overall project cost, the analysis showed that only 6 factors were statistically significant in the predicting model. The implication was that 11 out of the 17 delay factors were not statistically significant in the estimating model for predicting impact of the stated delay factors in project costs overruns resulting from project delays. This because, p -values for the 11 project delay factors (F1, F2, F3, F4, F8, F9, F12, F13, F14, F16 and F17) were greater than 0.05. However, only delay factors, F5, F6, F7, F10, F11, and F15 had p -value < 0.05 .

Therefore, in order to increase the stated multiple linear regression model's predictive ability, all the 11 project delay factors (F1, F2, F3, F4, F8, F9, F12, F13, F14, F16 and F17) with p -value > 0.05 should be removed from the model formulation and replaced with other project delay factors that are likely to be statistically significant. For instance, 'lack of adequate financial resources in construction projects' should be considered for inclusion among the critical delay factors since the stated project delay factor was likely to be statistically significant in predicting the stated project costs overrun model resulting from project duration delays.

On the other Hand, the researcher did further investigation to improve the model by focusing on the significant and almost significant factors as

per the following: Significant factors were scope variation (p -value = 0.035), and delay in drawing preparation of the projects (p -value = 0.000). The almost significant factors were lack of communication between the client, consultant, and contractor (p -value = 0.097) and slow decision making within all project teams (p -value = 0.074).

The iteration model summary results for the prediction of duration of delay in days showed that the prediction quality of the four significant and almost significant factors were good based on the multiple correlation coefficient ($R = 0.614$). The Adjusted R^2 coefficient showed that the four significant and almost significant factors could account for up to 34.4% variance in the duration of delay in days (Adj. $R^2 = 0.344$). Table (23) below shows the model summary results. The ANOVA results (Table (24) below) revealed that the overall multi linear regression model was a good fit for the data, as a statistically significant F-statistic was achieved ($F(4, 75) = 11.45, p < 0.05$) from SPSS software. In other words, this implied that the four significant and almost significant factors statistically significant in predicting duration of delay in days. Comparing the model summary results and ANOVA analysis for the multiple linear regression of significant and almost significant factors with those resulted from the 17 high risk delay factors, they were almost similar.

There are no major significant differences between the model results obtained in Table (22) and previous research. The model results shown in the table shows a strong and significant association between delay factors. A majority of previous research show p -values of ($p < 0.05$) and ANOVA results with statistically significant factors that could predict duration of delay. There are other previous researches that show the delay factors to be weak in statistical significance; however, these researches are a few.

Generally, results from the model reflect findings from previous research, an indication of validity and reliability.

Table (23)
Model Summary Results for Multiple Linear Regression to Predict Duration of Delay in Days Based on Significant and Almost Significant Factors

R	R ²	Adjusted R ²	Std. Error of the Estimate
0.614	0.377	0.344	3.85444

Table (24)
ANOVA Analysis for Multiple Linear Regression to Predict Duration of Delay in Days Based on Significant and Almost Significant Factors

Model	Sum of Squares	df	Mean Square	F	p-value
Regression	674.608	4	168.652	11.35	0.000
Residual	1114.253	75	14.857		
Total	1788.861	79			

Table (25) below revealed that only two critical delay factors were statistically significant predictors of duration of delay in days. These factors were scope variation ($\beta = 4.512$, $p < 0.05$) and delay in drawings preparation of the projects ($\beta = 22.272$, $p < 0.05$). Based on the results of the regression model test, the following equation was developed for the prediction of duration of delay in pipeline construction:

$$\text{Duration of delay in days} = 1.295 + 4.512 \times F_2 - 0.466 \times F_4 + 2.860 \times F_{14} + 22.272 \times F_{15} \quad \text{Equation (11)}$$

Table (25)
Coefficients' for Multiple Linear Regression to Predict Duration of Delay in Days Based on Significant and Almost Significant Factors

Delay Factors		β	<i>p</i> -value
Symbol	Description		
C	Constant	1.295	0.024
F2	Scope variation	4.512	0.001
F4	Lack of communication between client, consultant and contractor	-0.466	0.623
F14	Slow decision making within all project teams	2.860	0.056
F15	Delay in drawings preparation of the projects	22.272	0.000

Similarly, multiple linear regression model was developed to test for the extent to which the six significant delay factors could predict the cost of delay in USD. The model summary results revealed a good prediction quality of the multiple correlation coefficient ($R = 0.843$). The Adjusted R^2 coefficient showed that the four significant delay factors could account for up to 68.7% variance of the cost of delay in USD (Adj. $R^2 = 0.687$). Table (26) shows the summary of regression results. The ANOVA results shown in Table (27) below confirmed that the overall regression model was a good fit for the data. This was because a statistically significant F-statistic was achieved ($F(6, 73) = 29.880, p < 0.05$). Thus, the interpretation was that the six significant delay factors statistically significant in predicting duration of delay in days.

Table (26)
Model Summary Results for Multiple Linear Regression to Predict Cost of Delay in USD Based on Significant Factors

R	R^2	Adjusted R^2	Std. Error of the Estimate
0.843	0.711	0.687	33423.04477

Table (27)
ANOVA Analysis for Multiple Linear Regression to Predict Cost of Delay in USD Based on Significant Factors

Model	Sum of Squares	df*	Mean Square	F	p-value
Regression	200.271 x 10 ⁹	6	33.379 x 10 ⁹	29.880	0.000
Residual	81.548 x 10 ⁹	73	1.117 x 10 ⁹		
Total	281.820 x 10 ⁹	79			

The coefficients' table of the regression model, Table (28), showed that 5 of the 6 high risk delay factors were significant predictors of the cost of delay in USD. Poor site management and supervision ($\beta = 26571.714$, $p < 0.05$); inefficient and poor performance of contractors/subcontractors ($\beta = -77326.411$, $p < 0.05$); contractor's lack of planning at preconstruction ($\beta = 56808.183$, $p < 0.05$); rework due to errors, mistakes and defective works during construction ($\beta = 61517.573$, $p < 0.05$); and delay in drawings preparation of the projects ($\beta = 411771.839$, $p < 0.05$) were the statistically significant predictor variables for cost of delay in USD. The results of the multiple linear regression model test informed the development of the following equation for predicting the cost of delay in pipeline construction:

$$\text{Cost of delay in dollars} = -1326.639 + 26571.714 \times F_5 - 77326.411 \times F_6 + 56808.183 \times F_7 + 21346.484 \times F_{10} + 61517.573 \times F_{11} + 411771.839 \times F_{15}$$

Equation (12)

Table (28)
Coefficients' Table for Multiple Linear Regression to Predict Cost of Delay in USD Based on Significant Factors

Delay Factors		β	p-value
Symbol	Description		
C	Constant	-1326.639	0.838
F5	Poor site management and supervision	26571.714	0.033
F6	Inefficient and poor performance of contractors/subcontractors	-77326.411	0.000
F7	Contractor's lack of planning at preconstruction	56808.183	0.000

Delay Factors		β	p -value
Symbol	Description		
F10	Weather effect (heat, rain, wind, sand storm, etc.)	21346.484	0.080
F11	Rework due to errors, mistakes and defective works during construction	61517.573	0.000
F15	Delay in drawings preparation of the projects	411771.839	0.000

Summary of Linear Regression Results

On the basis of linear regression outcome for predicting the impact of the 17 high risk delay factors in influencing the overall project duration in days, the results indicated that the model was partially fit for prediction. This because the multiple correlation coefficient of the model ($R = 0.696$) was greater than 0.5. The linear regression analysis results also depicted that the adjusted coefficient of multiple determination ($\text{Adj. } R^2$) was 0.343. The implication was that 34.3% of the project duration variations in days were explained by the stated 17 high risk delay factors while the remaining 65.7% of the project duration variations in days were explained by other project delay factors that were not incorporated in the model. Based on ANOVA results, the F-statistics was derived as ($F(17, 62) = 3.422$) while the p -value for the model was derived as ($p = 0.0000 < 0.05$), which considered a significant relation. The implication based on ANOVA results was that the stated project duration multiple linear regression model provided good fit for the data. Therefore, all the 17 high risk delay factors seem to be statistically significant in predicting the overall project duration.

On the basis of linear regression analysis outcome for predicting the impact of the stated 17 high risk delay factors in influencing overall project cost of delay in USD, the results indicated that the multiple correlation coefficient (R) for the model was 0.753. The implication was that quality of the derived multiple linear regression model for predicting project cost

in USD was statistically significant. On the other hand, based on the adjusted coefficient of multiple determination, the multiple linear regression model for predicting project costs of delay seemed to have a greater forecasting ability compared to the multiple linear regression model for predicting the extent of project duration delays in days. On the basis of linear regression results, the adjusted coefficient of multiple determination (Adj. R^2) for the project duration cost of delays model was 0.686. The implication was that the model explained 68.6% of the variations in the project costs resulting from delay. In essence, 68.6% of the variations in project costs resulting from delays were explained by the stated 17 high risk delay factors while the remaining 31.4% of the variations in project costs resulting from delays were explained by other factors not incorporated into the prediction model. Finally, based on ANOVA results, the 17 high risk delay factors seemed to be statistically significant in predicting variations in project costs resulting from project delays. This is because, based on ANOVA analysis, the F-statistics ($F(17, 62) = 11.42$) while p -value for the model was derived as ($p = 0.000 < 0.05$).

The researcher compared the models resulted from the 17 high risk delay factors with the significant/almost significant delay factors models to evaluate these models by considering the outcome of 20 delayed projects (Appendix H). The comparison showed that the involvement of the 17 high risk factors found to be more accurate if some negative values were excluded. The values of the adjusted R^2 were almost the same for both models. This indicates that the high number of factors involvement increased the accuracy of the results considering the 17 high risk factor model. Even though not all of the 17 delay factors were significant, their contributions in the models were clearly enhancing the accuracy of the models outcomes. The validation of the chosen model with 17 high risk

delay factors would be discussed in details in the next section.

5.2 Validation of Models

To evaluate the performance of the regression models developed from the multiple linear regression tests discussed in Section 5.1, the researcher chose 20 delayed projects randomly to predict both the duration in days and the cost overrun in USD. Although the multiple linear regression results showed that some of the critical delay factors had no statistically significant predictor power for both the duration in days and the cost overrun in USD, the researcher included all 17 variables in the validation to ensure robustness in the validation exercise. Actual data obtained from company records concerning duration of delay in days and cost in USD were compared against the estimations obtained from the regression models.

Snapshot comparison of the results in tabular format (Table 29) showed that the model estimates were in the case of project 1 exactly as the actual data at all instances. For example, both the model estimate and the actual duration of delay in days was 23.10 for project 1. Similarly, both the estimated and actual cost in USD were 410,445.20. However, there were instances when the regression model's estimates differed considerably from the actual data. In the case of project 17, for example, the model estimate for duration of delay in days was 2.35 while the actual duration of delay in days was 0.06. Likewise, the estimated cost in USD for project 17 was -4,498.74 whereas the actual cost was 237.41.

The actual delays in days was calculated by dividing the actual completion hours over 24 to meet the XYZ Company target completion duration of connecting the pipelines from the wellhead to the well manifold

within a day.

On the other hand, the actual cost of delays was calculated by multiplying production loss due to delay by the average oil price at that time. For instance, Project 10 actual delay (1.33 Day) was calculated by dividing the actual duration taken to connect the well to well manifold which was 32 hours over 24 hours. For the same project, the actual cost of delay (\$10,599.28) was calculated by multiplying the production loss due to delay which was 205.25 barrels per day (bpd) by the oil price at that time, which was \$51.64.

Table (29)
Comparison of Estimated Delay and Cost Using Regression Model and Actual Project Data

Project #	Delay (Days)			Cost (USD)		
	Actual	Estimated	Error	Actual	Estimated	Error
1	23.10	23.10	0.00	410445.20	410445.20	0.00
2	0.15	-0.16	-0.31	788.10	729.17	-58.93
3	0.13	-0.16	-0.29	200.88	729.17	528.29
4	1.05	4.17	3.12	56535.55	57253.96	718.41
5	0.16	1.81	1.65	8530.84	9265.77	734.93
6	1.13	0.06	-1.07	1952.57	2875.34	922.77
7	1.00	2.73	1.73	854.69	-898.50	-1753.00
8	0.79	1.51	0.72	5666.20	7633.82	1967.60
9	0.44	0.70	0.26	864.84	3310.16	2445.30
10	1.33	0.30	-1.03	10599.28	13234.30	2635.00
11	2.03	5.26	3.23	41304.18	44052.84	2748.70
12	0.21	2.26	2.05	209.23	-2866.56	-3076.00
13	0.13	0.70	0.57	57.26	3310.16	3252.90
14	0.08	-1.02	-1.10	639.73	-2635.35	-3275.00
15	2.77	1.61	-1.16	8696.76	5102.74	-3594.00
16	2.38	2.67	0.29	100137.19	104641.17	4504.00
17	0.06	2.35	2.29	237.41	-4498.74	-4736.00
18	0.81	-0.16	-0.97	5757.83	729.17	-5029.00
19	0.25	1.81	1.56	4034.18	9265.77	5231.60
20	1.06	1.84	0.78	718.81	-4707.94	-5427.00

The negative values in the cost and delay was further investigated by undertaking additional analysis for the negative coefficients in the regression analysis equation. The following factors were having negative coefficients in the delay equation: lack of communication between client, consultant and contractor; inefficient and poor performance of contractors/subcontractors; poor managerial skills; and inadequate contractor experience. All the previous factors were expected to increase the delay in projects execution, but this is not reflected on the project time progress (Appendix I).

The cost factors that were found increasing the equation negative values in the cost model: lack of communication between client, consultant and contractor; inefficient and poor performance of contractors/subcontractors; poor managerial skills; inadequate contractor experience; late materials issuance; and unforeseen site conditions. All the previous factors were expected to increase the cost in projects execution, but this is not reflected on the project total cost (Appendix J). The cost of delay cannot have a negative value because it would be non-realistic to gain in term of time or money when a delay occurs in any of the construction projects.

From the comparison between actual data and regression model estimates for delay in days and cost in USD, respectively. As demonstrated in above tables, the data give the impression that the model estimates and the actual data overlap in several instances.

Table (29) data indicates that there is greater variability in the regression model estimates for delay in days as compared to the actual delay data for the 20 construction projects that were subject of the analysis.

This regression model variability insight related to the project duration prediction model was emphasized by the fact that the estimated project duration delay prediction model had a low adjusted coefficient of multiple determinations (Adjusted R^2) of 0.343.

The Table provides a comparison of the regression model estimates and actual data for project cost in USD, indicated that there was less variability between the stated two sets of data. The implication was that the linear regression model for predicting project costs resulting from project delays had a significantly forecasting and predictive ability. The significantly high predictive and forecasting ability of the stated linear regression model for project costs was emphasized by the model's high adjusted coefficient of multiple determination (Adj. R^2) of 0.686.

The estimated multi linear regression model for predicting delays in project duration had less forecasting and predictive ability compared to the estimated linear regression model for predicting project cost in USD resulting from project delays.

A paired samples t-test was performed in SPSS to determine whether the model estimates for duration of delay and cost of delay in USD were different from the actual duration of delay and cost of delay in USD. Table (30) showed that the paired samples correlations revealed strong, near-perfect correlations for actual and model estimated cost in USD ($r = 0.999$, $p < 0.05$). Similarly, model estimated and actual duration of delay in days registered near-perfect correlation ($r = 0.961$, $p < 0.05$). The paired samples test results (Table 31) showed that the mean differences of the actual and the model estimated costs were not statistically significant ($t(19) = 0.087$, $p > 0.05$). Similarly, the mean differences for the actual and the model estimated delays in days were not statistically significant ($t(19) = -1.957$,

$p > 0.05$). These results were a confirmation that the regression models developed in this study were strong enough to predict duration of delay in days and cost of delay in USD for construction projects in the oil and gas industry in Bahrain. The paired samples t-test results are summarized in Table (31) below.

Table (30)
Paired Samples Correlations to Measure the Strength of Relationship Between Estimated and Actual Data for Duration of Delay in Days and Cost of Delay in USD

		N	Correlation	Sig.
Pair 1	Actual delay in days & Estimated delay in days	20	0.961	0.000
Pair 2	Actual cost in dollars & Estimated cost in dollars	20	0.999	0.000

Table (31)
Paired Samples T-Test to Check the Differences Between Estimated and Actual Data for Duration of Delay in Days and Cost of Delay in USD

	Paired Differences		t	df	Sig. (2-tailed)
	Mean	Std. Deviation			
Pair 1 Actual duration of delay in days - Estimated duration of delay in days	-0.616	1.408	-1.957	19	0.065
Pair 2 Actual cost in USD - Estimated cost in USD	62.954	3228.514	0.087	19	0.931

On the basis of t-test paired two samples for mean, the results in Table (31) indicate that the mean actual cost in USD for the 20 projects analysed was equal to the mean estimated project costs in USD. The main

justification was that in the case of actual project cost and estimated project costs comparison, the model's t-statistics ($t = 0.087$) < t-critical values ($t_{0.05} = 0.931$).

However, the hypothesis testing results based on t-test paired two samples for mean as depicted in Table (31) indicate that the mean actual project duration in days for the 20 projects analysed was not equal to the mean estimated project duration in days. The main justification was that in the case of actual project duration in days compared to the estimated project duration in days, the absolute value of t-statistic for the model ($t = -1.957$) > t-critical values ($t_{0.05} = 0.065$).

The large differences in the standard deviation values were due to the massive variances between the projects in the oil and gas sector. The variables in each project were completely different than the other in term of cost, project size, and number of contractor involved. The pipeline projects cost varies from small amounts in thousands of USD to Millions depending on the projects scope and the criticality of the commissioning date. Furthermore, the oil price fluctuation was a major variable that could drive the actual values higher than the estimated ones. The cost of the delay could increase extremely when the oil prices inflate at different periods of the year.

5.3 Conclusion

This chapter of the research discussed the regression analysis done on the 17 most important factors or high risk delay factors in pipeline construction projects in the oil and gas industry. On the basis of linear regression outcome for predicting the impact of the 17 high risk delay factors in influencing the overall project duration in days, the results

indicated that the model was partially fit for prediction with an adjusted coefficient of multiple determination (R^2) accounted for up to 34.3% variance. On the other hand, the results of linear regression analysis for predicting the impact of the stated 17 high risk delay factors in influencing overall project cost of delay in USD indicated that the adjusted R^2 coefficient for the model was 68.6%.

The multiple linear regression results also indicated that only two critical delay factors, namely, scope variation and delay in drawings preparation of the projects were statistically significant predictors of duration of delay ($p < 0.05$). Whereas, it showed six critical delay factors those were statistically significant predictors of cost of delay. The six delay factors with p -values < 0.05 were poor site management and supervision; Inefficient and poor performance of contractors/subcontractors; Contractor's lack of planning at preconstruction; weather effect; rework due to errors, mistakes and defective works during construction; and finally delay in drawing preparation of the projects.

As a result, the estimated multiple linear regression model for predicting the costs of delay has a greater accuracy and reliability compared to the estimated multiple linear regression model for estimating duration of delay. This was due to its higher R^2 coefficient value and larger number of statistically significant predictors in comparison with duration of delay model.

Chapter Six

Discussion, Conclusion, Recommendations, and Further Research

6.1 Discussion of Results

6.2 Conclusion

6.3 Recommendations

6.4 Further Research

Chapter 6: Discussion, Conclusion, Recommendations, and Further Research

6.1 Discussion of Results

The findings of this study established that inadequate project planning, budgeting, and scheduling, scope variation, and late materials delivery were the main delay causing factor in the pipeline construction in the oil and gas industry in Bahrain. Inadequate project planning, budgeting, and scheduling ranked highest in terms of both RII and FAII. Moreover, this factor ranked high in terms of importance and moderate in terms of frequency for zoning on the risk mapping matrix. However, the findings of this study extended the knowledge by showing that planning and scheduling should go together with budgeting when it came to pipeline construction projects. As all these factors were related to the pre-construction stage that's why the study combined all three as one factor where its time line happened at the period before the construction phase.

Altogether, it was important to note that inadequate project planning, budgeting, and scheduling did not emerge as a significant predictor of duration and cost of project delays in the regression models developed for the prediction of delays in pipeline construction projects in the oil and gas industry in Bahrain. The implication of this finding was that the perceived frequency and importance of a delay factor based on expert opinion did not always mean relying on that factor to project the cost and duration of a delay. This because that the data was collected from a survey that included the opinion of different parties. However, this did not imply that a factor became less important because it could not help in predicting the duration or cost of a project. This was because a factor such as inadequate planning, budgeting, and scheduling could impact other delay factors with the

capacity to predict cost and duration of delay such as the need to alter the scope of the project and trigger inefficiency and poor performance of contractors/subcontractors.

The findings of this research showed that scope variation, as a delay causing factor, ranked highly in terms of frequency. Although scope variation did not account for significant variance in the cost of delay model, it emerged as an important predictor variable when one intended to predict duration of delay. The implication of this finding was that scoping the project accurately most likely would reduce the length of a project delay. Although scoping was not defined explicitly in this study, it often translated to increasing the scope of a project more than reducing it. In the case of pipeline construction projects in the oil and gas industry, scope variation included activities such as increasing the geographical coverage or capacity of a pipeline.

Of significant importance that most of the main delay factors were related to owners or their representatives and contractors. The regression models confirmed that owner and contractor had related critical delay factors. The owner related delay factors which affecting the delay model were scope variation and delay in drawing preparation. On the other hand, the contractor related delay factors that affecting the cost model were poor site management and supervision, inefficient and poor performance of contractors/subcontractors, contractor's lack of planning at preconstruction, and rework due to errors, mistakes and defective works during construction. However, it should be noted that delay factors related to design were also significant predictors of delay costs and delay duration in pipeline construction projects in the oil and gas industry in Bahrain in practice.

The development of a model to predict the duration of delay in days was a significant achievement for this research. The respective regression model showed that scope variations and delay in drawings preparation of the projects were the only significant predictors of duration of project delays in days. However, the two variables could only predict for up to 34.3% of duration of delay in days. This meant that up to 65.7% variance in duration of delays in pipeline construction projects could be predicted by other variables that were not included in the list of the 17 high risk delay factors. However, the model was still valid for prediction of duration of delays in pipeline construction in the oil and gas industry in Bahrain. The ascertainment received from the paired samples t-test and the regression test was adequate to render the model reliable even in future. However, notable the model was based on multiple linear regression, which meant that some of the interactions between the 17 high risk delay factors might have been overlooked.

On the other hand, the prediction model for cost of delay revealed a higher prediction power with more significant delay variables than the previous model for duration of delay. In addition, the model of cost of delay had prediction power of 68.6%, which was higher than the previous one. It was possible that the high number of significant predictor variables affected the prediction level of the model positively. However, it could also be an indication that more variables were associated with cost implications in pipeline construction delays than for duration of delay. These variables could be late material delivery, material shortage, and unrealistic contract duration imposed by client. These suggested variables were from the top 20 factors in the FAII ranking.

The fact that the estimated linear regression model for project duration delays had a significantly low predictive ability ($\text{Adj. } R^2 = 34.3\%$) implies that additional effort and measures needed to be exerted in order to find other alternative factors to enhance the stated model. To increase the model's predictive ability, the study would have to explore other project delay factors that had a significant impact on overall project duration delays. For instance, various studies have found that project procurement issues, project complexities and inadequate financial resources, which were not incorporated in this study, were also likely to have a significant effect on the overall project duration delays in construction projects. Therefore, future studies on estimating prediction models in pipeline construction should seek to incorporate the stated three project delay factors and other alternative factors in order to enhance the model's predictive ability.

Finally, this study found that the estimated linear regression model for predicting the project costs of delays has a greater accuracy and reliability compared to the estimated linear regression model for estimating project duration delays. This was because; the estimated linear regression model for predicting project cost of delays had a significantly higher adjusted coefficient of multiple determination ($\text{Adj. } R^2$) of 68.6% compared to the adjusted coefficient of multiple determination ($\text{Adj. } R^2$) of 34.3% for the project duration delays prediction model.

Based on the two regression models for duration of delay in days as described in Chapter 5 (Section 5.1, Page 97 and 98) and the cost of delays in Chapter 5 (Section 5.1, Page 100 and 101), Figure (7) below contains the significant predictor variables.

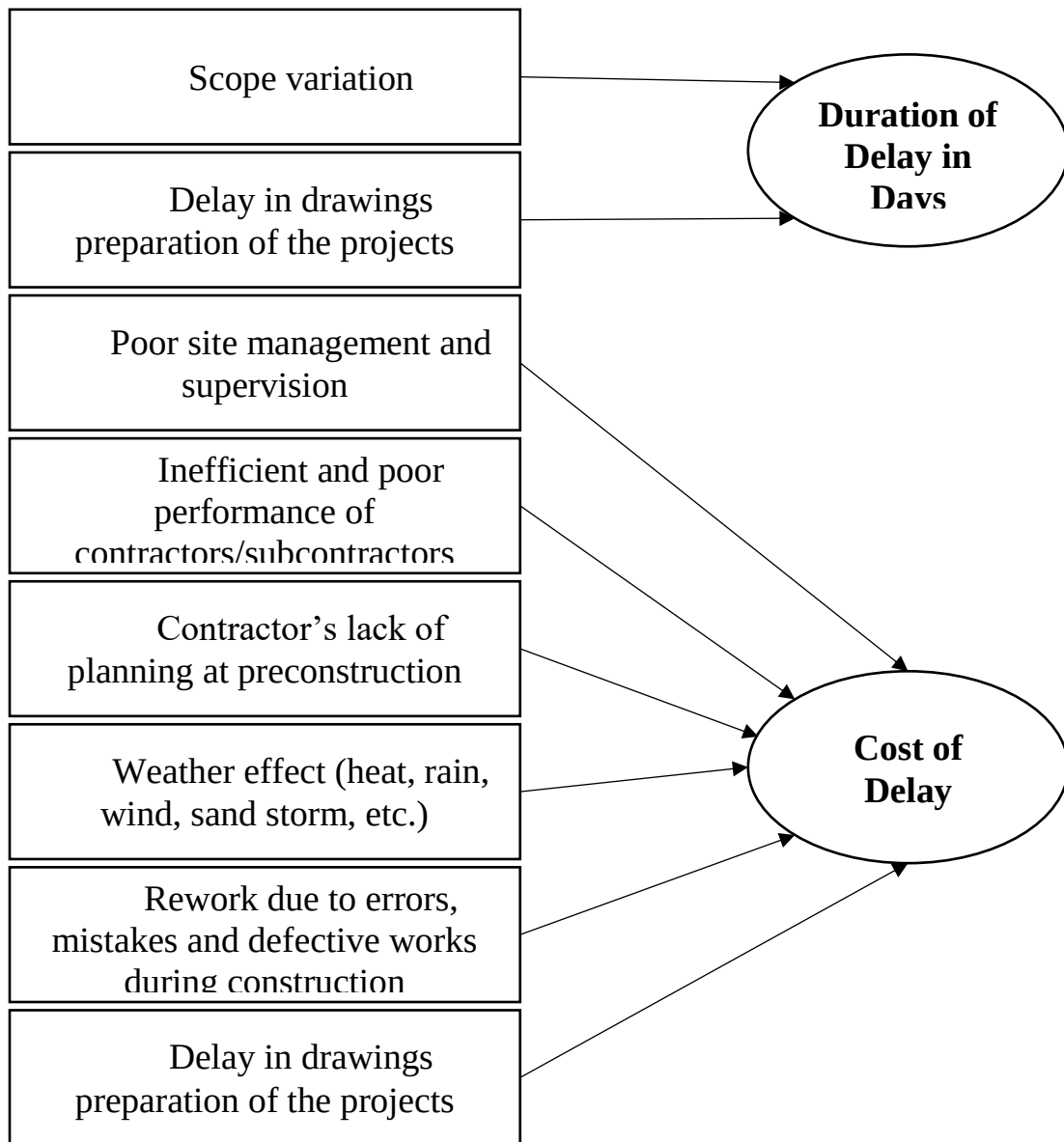


Figure (7)
Validated Prediction Model for Delay in Pipeline Construction Projects in Oil and Gas Industry as Developed in This Research

6.2 Conclusion

Based on the data collected, analysed and the findings presented in this study, the researcher concluded that various factors could be used to predict delays in pipeline construction projects. The FAII rankings for owner related factors and contractor related factors were higher compared to other factors. These findings, therefore, show that these factors are the primary factors to be considered in prediction of delays in pipeline construction projects. Besides the two primary factors, the findings also showed that design-related delays significantly predict the project overruns costs which are as a result of project duration delays.

The study showed that inadequate project planning, budgeting, and scheduling, project scope variations and late delivery of materials were the top ranked delay factors affecting project duration in pipeline construction projects within the oil and gas industry in Bahrain. Based on FAII and risk assessment mapping matrix, the main project delay factor that ranked highest in terms of its importance and frequency was inadequate project planning, budgeting and project scheduling. However, based on results of linear regression model, the stated project delay factor; inadequate project planning, budgeting and project scheduling was found to have minimal predictive power in influencing overall project duration delays and the associated project cost overruns. Nonetheless, the study concluded and acknowledged that the stated project delay factor could still provide a significant indirect impact to overall project duration delays and project cost overruns in pipeline construction projects within the oil and gas industry in Bahrain.

On the basis of the FAII rankings, the study also showed that project scope variation tended to have high rank in their importance to predicting project duration delays. Specifically, the study found that project scope variation had a significant direct effect in causing project duration delays in pipeline construction projects that were undertaken within the oil and gas industry. However, importance and impact of the project scope variation in predicting overall project cost of delays was found to be significantly minimal as compared to its effect in causing project duration delays.

In addition, the study acknowledged that based on the outcome from linear regression analysis, project scope variation and delays in drawings preparation for the project have a significant effect in predicting project duration delays in the pipeline construction projects. However, the predictive ability of these two project delay factors was not strong since they explained only 34.3% of the variations in project duration delays.

On the basis of results from the multiple linear regression analysis, the study concluded that the project cost of delays prediction model had a greater predictive and forecasting ability compared to the project duration delays prediction model, which has less predictive ability. This because the adjusted coefficient of multiple determination ($\text{Adj. } R^2$) of 34.3% for the project duration delays prediction model was significantly less compared to the adjusted coefficient of multiple determination ($\text{Adj. } R^2$) of 68.6% related to the project cost of delays prediction model. The study acknowledged that the stated 17 critical project delay factors had a significantly greater effect in influencing the overall project costs of delays rather than the project duration delays. However, only six of these factors showed statistically significant results with respect to the model.

Therefore, the study suggested that 11 out of the 17 critical project delay factors would need to be replaced with other statistically significant factors in order to increase the predictive ability of the model.

The predictive power of the project cost of delays linear regression model was emphasized by the statistical results from t-test paired two samples for mean, which indicated that the mean of actual project cost of delays and the mean of estimated projected cost of delays seemed to be equal. However, the results from t-test paired two samples for mean indicated that the mean of actual project duration delays in days seemed to be statistically different and low compared to the mean of estimated project duration delays in days.

Finally, based on a comparative analysis of the actual project data and the linear regression coefficient estimates for each of the 20 projects, the study showed that the variability of actual project costs to estimated costs based on linear regression model for project cost delays was significantly low. However, the variability of actual project duration in days compared to the estimated project duration in days based on linear regression model outcome was found to be significantly large.

6.3 Recommendations

The findings of this research and the research process itself inspired various procedural recommendations towards addressing the challenge of delays in pipeline construction projects in the oil and gas industry in Bahrain. These are:

1. Inadequate Project Planning, Budgeting, and Scheduling

- Considering that the Government of Bahrain is the owner of projects concerning the construction of pipelines in the oil and gas industry, it is imperative that it incorporates planning, scheduling, and budgeting training for Bahraini nationals. In addition, there is need for integration of top-level expertise from other oil and gas countries to help in knowledge transfer and transfusion of management and administration skills especially those concerning planning, budgeting, and scheduling for pipeline construction projects. Finally, government and contractors need to ensure that they allocate enough time for planning purposes to also ensure that the project scope is as consistent as possible throughout the entire project phase.

- There is a need for regular monitoring and mitigation of contractor and owner related factors especially those with high risk impact and frequency, such as inadequate project planning, budgeting and scheduling; scope variations; late materials delivery; insufficient contractor's manpower (or resources); and lack of communication between client, consultant and contractor. This requires the development of project data about the root triggers of the critical delay factors. This will help in the development of a knowledge base about the triggers, critical delay factors, and solutions towards mitigating them. The principal outcome of addressing these challenges will be the reduction of the cost impact and duration of delays in pipeline construction in the oil and gas industry in Bahrain.

2. Scope Variation

Scope variation is defined as new requirements added after the project initiation. These changes are not properly reviewed regularly. The problem lies in the project team expectation to deliver those changes within the

same resources and time as the original scope.

Five vital ways should be considered in order to keep control of the project:

- *Document the Requirements*

The most important aspect to avoid scope variation on any project is to document the requirements. All the project stakeholders and users should be asked about their exact work requirements and expectations. Those requirements and expectations should be documented. In case of conflict of interest among stakeholders, someone should be assigned to arbitrate and make a final decision. All requirements should be prioritized and captured in a document that can be shared online with all concern parties.

- *Set up Change Control Processes*

A change control process is mainly the management and control of possible changes in the project process. If a change is suggested, then it should be reviewed and approved or rejected by a designated party to incorporate it into the project plan if it is approved. A formal team meeting is not mandatory unless the changes are significant and need a thorough review.

- *Create a Clear Project Schedule*

A project schedule results from knowing what the project will deliver; it should express all the requirements and the way they will be achieved, in the form of tasks and activities. Therefore, the requirements are used to create a detailed task list. After project schedule preparation, a contingency plan should be addressed to avoid any future delays.

- *Verify the Scope with the Stakeholders*

The project requirements and schedule should be properly understood and discussed by the stakeholders to insure that all the expected elements are represented in the task list. It is advised to schedule some time with each stakeholders to discuss exactly what the project is going to deliver, how the changes are managed, and what to be approved to avoid unexpected disappointments. However, it is useful to remind them with the impact of new changes in terms of time and payment.

- *Engage the Project Team*

The project team should be aware about the change control process and how it will affect them. However, any new project changes by the stakeholders must be approved through a formal process. This process should be explained and documented by the project team.

In conclusion, scope variation is a major problem on projects, especially when the impact of changes on resources, budget and schedule are not fully understood by the stakeholders and the project team. If the initial project scope was clear and changes were carefully managed during the lifecycle of the project, then it will not be a major issue. In order to avoid scope variation and manage continues changing requirements of the project, an online software tool would be helpful for adding new changes and review them in real time.

3. Late Materials Delivery

- *Supplier Performance Measurement and Evaluation*

The supplier performance measurement should be conducted through an appropriate system which will provide a general view about the suppliers' evaluation and selection. The system should depend on real facts

rather than assumptions of the suppliers' delivery performance. After implementing the performance measurement system, the resulting recommendations should be addressed to the initial key suppliers in order to improve their delivery performance.

- *Projects and Supply Chain Department Cooperation and Feedback*

The communication between the projects and the supply chain department should be enhanced in order to achieve a better delivery performance. This can be done by providing delivery performance feedback through regular meetings to discuss the status of materials delivery and delivery time changes. Moreover, both entities should cooperate with each other towards reaching the organization's mission and vision.

- *Contractors Penalties*

Penalties must be paid by the suppliers if the materials are not delivered on time and as per contract agreement. If there are no economical consequences, there will not be any improvement in delivery precision.

- *Suppliers Selection*

The suppliers' selection should be based on many important criteria, such as reputation of the supplier, the quality of service, the suppliers' commitment, and punctuality. By focusing on lower cost suppliers, the projects can be jeopardized and the consequences can be disastrous.

4. Insufficient Contractor's Manpower (or Resources)

- *Advance Notice of Future Projects*

The owner company is responsible for proving as accurate as possible forecast plan to avoid any unexpected project delays. A three months look

ahead notice is advised to be given to the contractors in order to manage their resources properly. The reason behind choosing a three months' notice is to facilitate and help the contractor during projects planning stage. Furthermore, clear scope of works, and prepared pre-construction documents and drawings are very important to allow the contractors allocating their resources in a good manner.

- *Contractor Capabilities*

The owner company should not overload the contractors with a large number of projects in a limited time frame. On the other hand, the contractor should not accept optimum number of projects that he could not handle. There are number of factors that should be considered by the contractor before determining the acceptable number of projects, such as number of workers, availability of machinery, financial resources, management capability, and the types of work.

- *Projects Subcontracting/Delegation*

When the contractor fail to meet owner expectation and encounters the difficulty of executing all projects undertaken in parallel, and ultimately, none of the projects can be completed within the stipulated period. In this case, the contractor should delegate some of the projects to subcontractors who are capable to execute and deliver those projects on time and required quality.

5. Lack of communication between client, consultant and contractor

- *Active Communication*

Being present is one of the most essential part of effective communication that a project manager should possess. This can be

achieved by being readily available with a clear understanding of the team capabilities, roles, challenges, and achievements. Indirect communications (e.g. emails and voicemail) are better preferred in order to avoid passive communication between all involved parties.

- *Active Listening*

Comprehend what the person is saying before taking an action to avoid any kind of misunderstanding. Lack of proper listening can lead to valuable opportunities losses, especially when people come with new ideas or recommendations. This can be achieved for example by being totally present, paying attention to body language, and proper eye contact.

- *Communication Plan*

A general communication plan should be created to meet the expectation of an efficient communication between concerned parties. Several points should be put into consideration when creating the communication plan, such as ways of communication (e.g. reports, meeting, etc.), frequency of communication (e.g. weekly, monthly, quarterly, etc.), and communication parties.

- *Appropriate Meeting Plan*

A meeting can be a double-edged sword. As effective as meetings can be in simplifying communication, they can also be a massive time consumer. Consequently, the meetings should be planned in advance in terms of discussed subjects, people involved and meeting duration.

- *Electronic/Online Applications*

Due to the busy nature of the oil and gas pipeline construction projects, it would be difficult to continuously follow up with the team

members' progress and assigned tasks. Hence, it is advisable to use project management applications (e.g. Basecamp and Asana) which will clarify the team members' responsibilities and facilitate the communication for a more efficient workflow. Moreover, file sharing apps will prevent file loss, increase workflow, and save valuable time by making the files accessible to each project members' digital device. Finally, an online communication tools (e.g. Skype) will facilitate the discussion among the concerned parties in a more personalized way than e-mails, especially when face-to-face communication is not possible among teams.

Finally, regarding the prediction models, the significant model predictor variables can be mitigated by having additional measures at the preconstruction phase .This can be achieved by making a precise scope tender documents to avoid variations during the actual construction. In addition, the designer should be asked for clear time line for the design drawing to avoid submitting the drawing late. Furthermore, select efficient contractor with high performance through Bahrain tender board where a rigorous selection criteria is implemented for the selection process. The contractor should be selected based on previous projects performance were they can be tested on delivering the projects milestone on time using the right mandatory skills. Moreover, the weather condition effect can be mitigated as a delay variable by reducing the field construction activities and selecting the right equipment's that perform the required task in such bad weather condition.

6.4 Further Research

From the research, it is evident that there is need for further research on delays in pipeline construction in the oil and gas industry. Further research in future is needed to cover the following:

- 1) The model developed within this study needs to be enhanced through introduction and testing of additional factors to replace the current ones which show insignificant effect on delay duration and cost.
- 2) Although the prediction models developed in this research for duration of delays and cost impact were tested and validated using actual project data, further research is needed to test the model using data from different companies in the same field in Bahrain. Moreover, further research is needed in other countries and pipeline industry sectors to investigate the applicability of the prediction models. Structural Equation Modelling (SEM) tools such as Analysis of Moment Structures (AMOS) can be used to identify any underlying relationships between the delay factors and factors that might have affected the final outcome of the regression tests.
- 3) In the creation and validation of the delay and cost models, the researcher along with two experts studied the binary analysis. More accurate results can be obtained from future studies if more experts are involved through an online survey to do the analysis applying the binary regression model. Each project factors can be studied by the experts which will result in a more accurate regression model outcome. Due to the limited time the researcher focused only applying the binary analysis on two

experts.

- 4) Different methods can be used other than the regression analysis such as Fuzzy Theory and Neural Theory to obtain a better models that can predict both time and cost. The binary method can be improved by mixing the binary variables and the magnitudes/real numbers variables to improve the regression model outcome which will lead to more accurate results.

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Appendix A: Summary of 42 Delay Factors Classified into Seven Categories

Appendix A: Summary of 42 Delay Factors Classified into Seven Categories

No.	Delay Factors	Literature Sources
1. Owner-related delay factors		
1	Decision-making delays	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
2	Work suspension	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Ibrahim, 2013; Gidado and Ghulam, 2012; Sweis et al., 2008; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
3	Document approval and revision delays	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Ibrahim, 2013; Gidado and Ghulam, 2012; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
4	Construction site delivery to contractor	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Sweis et al., 2008; Assaf and Al-Hejji, 2006
5	Payment and financing delays	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, and Tindiwensi, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
6	Project changes	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi,

No.	Delay Factors	Literature Sources
		Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al-Momani, 2000; Al Jurf and Beheiry, 2012
7	Project bidding and award type	Marzouk and El-Rasa, 2014; Aziz, 2013; Gidado and Ghulam, 2012; Assaf and Al-Hejji, 2006;
8	Unrealistic enforcement of contract duration	Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
9	Owner or agency's inexperience in construction projects	Gunduz, Nielsen, and Ozdemir, 2014; Aziz, 2013; Toor and Ogunlana, 2008
10	Owner delays in handing over completed work approval or process	Doloi et al., 2012
2. Consultant-related delays		
1	Inexperience	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Gidado and Ghulam, 2012; Sweis et al., 2008; Toor and Ogunlana, 2008; Assaf and Al-Hejji, 2006
2	Approval delays for drawings, submittals etc.	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al-Momani, 2000; Al Jurf and

No.	Delay Factors	Literature Sources
		Beheiry, 2012
3	Discrepancies or errors in specifications and/or documents the consultant provides	Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
4	Poor coordination and communication with other parties	Marzouk and El-Rasa, 2014; Aziz, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
5	Inspection delays	Gunduz, Nielsen, and Ozdemir, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Ibrahim, 2013; Doloi et al., 2012;Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010;Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
3. Contractor-related delays		
1	Contractor challenges in financing projects	Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Al-Kharashi and Skitmore, 2009; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
2	Poor site supervision and management	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012;Khoshgoftar, Abu

No.	Delay Factors	Literature Sources
		Bakar, and Osman, 2010; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006;
3	Deficient project scheduling and planning	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, and Tindiwensi, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
4	Rework during construction because of errors	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, and Tindiwensi, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012;
5	Sub-contractor-induced delays	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
6	Contractor inexperience and under-qualification	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
7	Poor coordination and communication with others	Gunduz, Nielsen, and Ozdemir, 2014; Aziz, 2013; Alinaitwe, Apolot, and Tindiwensi, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh,

No.	Delay Factors	Literature Sources
		2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
8	Unsafe on-site practices and conditions	Doloi et al., 2012; Sweis et al., 2008; Toor and Ogunlana, 2008; Al Jurf and Beheiry, 2012
4. Material-related delays		
1	Shortage	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Ibrahim, 2013;Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
2	Material delivery	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Sweis et al., 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006;Al-Momani, 2000;Al Jurf and Beheiry, 2012
3	Changes in specifications and types of materials during construction	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Gidado and Ghulam, 2012; Sweis et al., 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006
4	Price escalations and inflation	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Sweis et al., 2008; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
5. Labor-related delays		
1	Labor shortage	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Ibrahim, 2013; Gidado and Ghulam,

No.	Delay Factors	Literature Sources
		2012; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012; Shehzad, 2015
2	Unqualified labor force	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Al-Kharashi and Skitmore, 2009; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006
3	Low labor productivity	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
6. Construction site delays		
1	Equipment failure or shortage	Gunduz, Nielsen, and Ozdemir, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
2	Unfavorable and unexpected site conditions	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Toor and Ogunlana, 2008; Assaf and Al-Hejji, 2006; Al-Momani, 2000
3	Job site constraints (e.g. poor access and congestion)	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Ibrahim, 2013; Doloi et al., 2012; Gidado and Ghulam, 2012; Toor and Ogunlana,

No.	Delay Factors	Literature Sources
		2008; Assaf and Al-Hejji, 2006
4	Absence of site utilities including electricity and water	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Gidado and Ghulam, 2012; Toor and Ogunlana, 2008; Assaf and Al-Hejji, 2006
5	Construction accidents	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Doloï et al., 2012; Gidado and Ghulam, 2012; Assaf and Al-Hejji, 2006; Al Jurf and Beheiry, 2012
6	Problems associated with neighboring facilities or structure such as cultural and social ones	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Ibrahim, 2013;Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Assaf and Al-Hejji, 2006
7. External delay factors		
1	Weather-related	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Ibrahim, 2013; Doloï et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Toor and Ogunlana, 2008; Faridi and El-Sayegh, 2006; Assaf and Al-Hejji, 2006; Al-Momani, 2000;Al Jurf and Beheiry, 2012
2	Change in laws and regulations	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Doloï et al., 2012; Gidado and Ghulam, 2012; Khoshgoftar, Abu Bakar, and Osman, 2010; Sweis et al., 2008; Assaf and Al-Hejji, 2006
3	Delays in final certification and inspection by third parties	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Aziz, 2013; Assaf and Al-Hejji, 2006
4	Global financial crisis	Gunduz, Nielsen, and Ozdemir, 2014; Aziz, 2013; Gidado and Ghulam, 2012;

No.	Delay Factors	Literature Sources
		Toor and Ogunlana, 2008;Al-Momani, 2000
5	Force majeure	Gunduz, Nielsen, and Ozdemir, 2014; Marzouk and El-Rasa, 2014; Gardezi, Manarvi, and Gardezi, 2014; Aziz, 2013; Alinaitwe, Apolot, andTindiwensi, 2013; Ibrahim, 2013; Gidado and Ghulam, 2012; Toor and Ogunlana, 2008; Assaf and Al-Hejji, 2006

Appendix B: General Interview Protocol for Focus Group Interview

FACTORS LEADING TO DELAY IN PIPELINE CONSTRUCTION PROJECTS IN OIL AND GAS INDUSTRY					
Sr.	Factors	Non Applicable	May Be Applicable	Highly Applicable	Other Related Area
Management-Administrative Related					
1	Slow decision in building project team				
2	Poor managerial skills				
3	Inadequate project planning, budgeting and scheduling				
4	Inappropriate overall organizational structure				
5	Unsuitable management structure of contractor				
6	Slow decision making within all project teams				
7	Lack of communication – client & contractor				
8	Lack of communication – consultant & contractor				
9	Lack of communication – client & consultant				
10	Slow information flow between project teams				
11	Unsuitable leadership of contractor's manager				
12	Unrealistic contract duration imposed by client				
13	Disputes, conflict, and strikes				
14	Non-availability of transportation				
15	Inadequate staff				
16	Inadequate working facilities				
17	Improper incentive policy				
18	Incompetence of project team				
19	Late internal approval process from the owner				
20	Inadequate project organization structure				
21	Improper project feasibility study				
22	Poor relation and dispute with partners				
23	Lack of experience of owner (or owner representative) in construction projects				
24	Delay by owner in handing over process or approval of completed work				
25	Lake of experience of consultants				
26	Poor communication and coordination with other parties				
27	Lack of operators during the Pre Start-up Safety Review (PSSR)				
28	No approval by other parties to continue working during the weekend (i.e. Riffa Views)				
29	No overtime approval by the management				
30	Dependency on other departments to complete the project (e.g. Maintenance, WO Depts.)				
31	Late request by the owner/Production				
Design Related					
32	Inaccurate basic process data				
33	Delay in design information				
34	Design development delay				
35	Decisions during development stage				
36	Mistakes and discrepancies in design documents				

FACTORS LEADING TO DELAY IN PIPELINE CONSTRUCTION PROJECTS IN OIL AND GAS INDUSTRY					
Sr.	Factors	Non Applicable	May Be Applicable	Highly Applicable	Other Related Area
37	Inadequate design team experience				
38	Scope variations				
39	Long wait for approval of drawings/documents				
40	Changes in specifications & datasheets				
41	Incomplete documents				
42	Transmittal delays				
43	Long wait for vendor data				
44	Improper selection of project location				
45	Poor design				
46	Design changes				
47	Delay in revising and approving documents (design, shop drawings, submittals. etc.)				
48	Delay in approval of submittals, design drawings, shop drawings, and sample materials, etc.				
49	Mistakes or discrepancies in documents or specifications issued by consultants				
50	Modification required by other parties (i.e. Operation, QA/QC, Design Engineer, etc.)				
51	Oil leakage due to using of different joints technology				
52	Delay due to enhancement of joint technologies to avoid oil leakage in future wells handing over				
53	Delay in drawings preparation of the projects				
54	Design changes during construction				
55	Incorrect decision to re-use/utilize idle flowline (i.e. non-active well)				
Contract Related					
56	Lengthy contract awarding process				
57	Frequent tender modification				
58	Poor participation from bidders				
59	Granting bid extensions to bidders				
60	Bid evaluation process				
61	Delay in obtaining management approvals				
62	Inadequate tendering				
63	Delay in signing contract				
64	Ambiguous conditions of contract				
65	Work conditions deferring from contract				
66	Inadequate type of contract				
67	Inadequate tendering price				
68	Type of project bidding and award				
69	Unrealistic enforced contract duration				
Materials Related					
70	Poor quality of procured materials				
71	Late material delivery				
72	Materials shortage				
73	Changes in material types and specifications during construction				

FACTORS LEADING TO DELAY IN PIPELINE CONSTRUCTION PROJECTS IN OIL AND GAS INDUSTRY					
Sr.	Factors	Non Applicable	May Be Applicable	Highly Applicable	Other Related Area
74	Inflation and escalation of material prices				
75	Unavailability/shortage of equipment				
76	Late materials issuance for the projects				
Construction Related					
77	Poor site management and supervision				
78	Project construction complexity				
79	Inadequate control over site resource allocation				
80	Inadequate contractor experience				
81	Shortage of skilled labour				
82	Contractor's lack of planning at preconstruction				
83	Poor procurement programming of materials				
84	Poor subcontractor performance				
85	Delay in fabrication				
86	Construction mistakes & defective Works				
87	Lack of coordination on-site				
88	Shortage of new technologies				
89	Lack of knowledge and experience on construction				
90	Ineffectiveness and lack of supervision of consultants				
91	Inefficient and poor performance of contractors				
92	Inadequate coordination among contractors				
93	Deference practice among foreign contractors and domestic contractors				
94	Lack of coordination among contractors and sub-contractors				
95	Constructibility				
96	Suspension of work				
97	Delay in delivering construction site to contractor				
98	Changes to the project by owner				
99	Delay in inspection				
100	Rework due to errors during construction				
101	Delays related to subcontractors work				
102	Poor qualification of contractors' staff				
103	Inappropriate construction methods				
104	Unsafe practice at site (Poor safety conditions on site)				
105	Shortage of labours				
106	Unqualified workforce				
107	Low productivity of labours				
108	Shortage of equipment and/or equipment failure				
109	Unforeseen site conditions (Unexpected subsurface conditions e.g. soil, high water table, etc.)				
110	Restriction at job site (Poor site access, traffic congestion)				
111	Lack of site utilities or services such as (water, electricity, etc.)				

FACTORS LEADING TO DELAY IN PIPELINE CONSTRUCTION PROJECTS IN OIL AND GAS INDUSTRY					
Sr.	Factors	Non Applicable	May Be Applicable	Highly Applicable	Other Related Area
112	Accident during construction				
113	Rework major project handing over activities (i.e. hydro-test failure, Radiography Test result failure)				
114	Oil Leak during project handing over activities				
115	HSE did not allow SIMOPS to be done for project hand over, due to the existence of W/O Rig				
116	Delay due to Permit To Work (PTW) issuance				
117	Insufficient operators to complete PTW, LOTO and PSSR requirements				
118	QA/QC requirement during the PSSR (i.e. Item A in the Punch List)				
119	Modification resulted from contractor's mistakesModification resulted from contractor's mistakes				
120	Insufficient contractor's manpower (or resources)				
Financial / Economical Related					
121	Financial processes				
122	Financial difficulties				
123	Budget allocation				
124	Improper CAPEX rephrasing				
125	Invoices payment delays				
126	Economic problems				
127	Increase of resettlement cost				
128	Exchange rate changes				
129	Financial problems with consultants				
130	Increase of labor cost				
131	Increase of material cost				
132	Economic and financial crisis				
133	Increase of equipment cost				
134	Inflation rate fluctuation				
135	Interest rate fluctuation				
136	Low credibility of lenders				
137	Late approval by lender				
138	Increase of tax rate				
139	Lender interference				
140	Inflexible and complex rules and regulations of lender				
141	Lack of lender co-operation				
142	Delay of financing and payments by owner				
143	Difficulties in financing the project by contractor				
144	Global financial crisis				
145	Unavailability or late approval of project budget				
Statutory Laws & Regulations Related					
146	Changes in laws & regulations				
147	Safety procedures & rules				
148	International regulations				

FACTORS LEADING TO DELAY IN PIPELINE CONSTRUCTION PROJECTS IN OIL AND GAS INDUSTRY					
Sr.	Factors	Non Applicable	May Be Applicable	Highly Applicable	Other Related Area
149	Company codes & standards				
150	Bahrain laws & regulations				
151	Bureaucratic government system and long project approval procedure				
152	Insufficient laws on projects				
153	Inefficiency of legal process				
154	Changes of policies				
155	Difference of standards and codes in Joint Venture (JV)				
156	Government interference				
157	Lack of cooperation from government				
158	Poor relation with government departments				
159	Changes in government regulations and laws				
160	Delay or Long way leave approval process by other parties				
External Factors Related					
161	Fire				
162	Dispute with residents around site				
163	Corruption and bribery				
164	Unusual weather				
165	Lack of coordination among public agencies concerned				
166	Environmental protection pressure of other groups				
167	Damage to work by third party				
168	Problem with nearby structure or facilities (Disturbance to public activities, effect of social and cultural factors)				
169	Weather effect (heat, rain, wind, sand storm, etc.)				
170	Delay in performing final inspection and certification by a third party				
171	Force Majeure (earthquake, etc.)				
172	Restricted access - No gate pass/access approval from third party (i.e. BDF)				
173	Unplanned Workover rig movement (i.e. reschedule of rig movement)				

RESULTS OF SURVEY INTERVIEW			
HIGHLY APPLICABLE FACTORS FOR 8 EXPERTS RESPONDENTS	HIGHLY APPLICABLE	NO. OF FACTORS	CUMULATIVE NO.
71, 72, 105	8	3	3
7, 76, 91	7	3	6
3, 11, 15, 18, 79, 80, 81, 82, 83, 87, 104, 107, 112, 120, 145	6	15	21
2, 9, 12, 37, 38, 45, 75, 77, 84, 85, 86, 94, 100, 106, 108, 119, 160, 161, 164, 169	5	20	41
4, 5, 8, 10, 14, 22, 23, 26, 32, 34, 36, 39, 53, 54, 61, 92, 95, 97, 98, 101, 103, 109, 110, 113, 116, 132, 162, 171	4	28	69
1, 6, 13, 24, 33, 41, 44, 46, 47, 48, 49, 56, 60, 62, 69, 70, 73, 78, 89, 96, 102, 111, 115, 117, 123, 126, 137, 143, 144, 150, 154, 167, 168, 173	3	34	103
16, 19, 20, 31, 35, 40, 43, 51, 63, 64, 65, 66, 90, 99, 114, 118, 122, 124, 129, 133, 142, 146, 147, 149, 151, 153, 156, 157, 158, 159, 163, 170, 172	2	33	136
17, 21, 25, 27, 30, 52, 55, 57, 58, 67, 68, 93, 121, 130, 131, 134, 135, 136, 138, 141, 148, 152, 155, 165, 166	1	25	161
28, 29, 42, 50, 59, 74, 88, 125, 127, 128, 139, 140	0	12	173

**Appendix C: Final List of 47 Delay Causing
Factors in Pipeline Construction Projects in Oil
and Gas Industry Compiled Based on Results of
the Focus Group Interviews**

Appendix C: Final List of 47 Delay Causing Factors in Pipeline Construction Projects Based on the Focus Group Results

FACTORS LEADING TO DELAY	
Sr.	Factors
Management-Administrative Related	
1	Poor managerial skills
2	Inadequate project planning, budgeting and scheduling
3	Slow decision making within all project teams
4	Lack of communication between client, consultant and contractor
5	Unrealistic contract duration imposed by client
6	Incompetence of project team
7	Lack of experience of owner (or owner representative) in construction projects
Design Related	
8	Inadequate design team experience
9	Scope variations
10	Long wait for approval of drawings/documents
11	Improper selection of project location
12	Poor design
13	Delay in revising and approving documents (design, shop drawings, submittals, etc.)
14	Delay in drawings preparation of the projects
Materials Related	
15	Late materials delivery
16	Late materials issuance
17	Materials shortage
18	Poor procurement programming of materials
19	Unavailability/shortage of equipment
Construction Related	
20	Poor site management and supervision
21	Inadequate contractor experience
22	Contractor's lack of planning at preconstruction
23	Delay in fabrication
24	Inefficient and poor performance of contractors/subcontractors
25	Rework due to errors, mistakes and defective works during

FACTORS LEADING TO DELAY	
Sr.	Factors
	construction
26	Inappropriate construction methods
27	Unsafe practice at site (Poor safety conditions on site)
28	Unqualified workforce
29	Unforeseen site conditions
30	Lack of site utilities or services
31	Accident during construction
32	Insufficient contractor's manpower (or resources)
Financial / Economical Related	
33	Economic and financial crisis
34	Delay of financing and payments by owner
35	Difficulties in financing the project by contractor
36	Unavailability or late approval of project budget
Statutory Laws and Regulations Related	
37	Changes in laws and regulations
38	Insufficient laws on projects
39	Inefficiency of legal process
40	Government interference and approvals
41	Delay or long way leave approval process by other parties
External Factors Related	
42	Dispute with residents around site
43	Corruption and bribery
44	Lack of coordination among public agencies concerned
45	Environmental protection pressure by stakeholders
46	Damage to work by third party
47	Weather effect (heat, rain, wind, sand storm, etc.)

Appendix D: Questionnaire

University of Bahrain
College of Engineering
Engineering Management Master Program

Factors Leading to Delay in Pipeline Construction Projects in Oil and Gas Industry
(Questionnaire)



Dear Sir/Madam,

My name is Reyadh Mahmood Mohammed, a graduate student of University of Bahrain. I am conducting a research about "Factors Leading to Delay in Pipeline Construction Projects in Oil and Gas Industry", which I have chosen as a topic to conduct research on it for my Master's Thesis.

The objectives of the research is to identify the main factors causing delays in pipeline construction projects, identify the impact of delays and to develop prediction model of delay in pipeline construction projects. I kindly invite you to be part of this research and request you to assist in completing the brief questionnaire. I would kindly request your participation, and cooperation in providing the required information in the questionnaire, as well as to thank you for your valuable time and efforts.

The information provided will only be used for research on an academic platform.

Yours Sincerely,

Reyadh Mahmood Mohammed
Graduate Student,
University of Bahrain
Email: reyadh.mahmood80@gmail.com
Supervisor: Professor Saaed Suliman

Demographic Data

Please check which most accurately describes:

All information, including all results and personal information from participating individuals will be kept strictly confidential and be used only for research purposes by University of Bahrain ONLY.

1. Current Projects location

- ☐ Bahrain
- ☐ Other GCC (Saudi Arabia, Kuwait, Oman, UAE)

Other locations (please specify)

2. Organization type

- ☐ Owner
- ☐ Contractor
- ☐ Consultant
- ☐ Designer/ Architect
- ☐ Subcontractor
- ☐ Supplier

Other (please specify)

3. Job Designation

- ☐ Associate Engineer
- ☐ Project / Construction Manager
- ☐ Project Engineer
- ☐ Site Supervisor
- ☐ Design Engineer

Other (please specify)

4. Industry type

- ☐ Superstructure
- ☐ Infrastructure
- ☐ Oil & Gas
- ☐ Industrial

Other (please specify)

5. Total experience in pipeline construction in years

- ☐ 0 - 5
- ☐ 6 - 10
- ☐ 11 - 15
- ☐ 16+

Other (please specify)

6. Your highest education

- ☐ Phd / Doctorate
- ☐ Masters
- ☐ Bachelors
- ☐ Diploma

Other (please specify)

7. Size of your company

- ☐ Large (>250 employees)
- ☐ Medium (50 < employees < 250)
- ☐ Small (10 < employees < 50)
- ☐ Micro (< 10 employees)

[illegible]

[illegible]

Appendix E: Binary Analysis for 80 Delayed Projects in XYZ Company using Factor Analysis Method

8 Categories Resulted from Factor Analysis

CATEGORY 1

Statutory laws and regulations Group

CATEGORY 2

Contractor-related delays Group

CATEGORY 3

Owner-related delays Group

CATEGORY 4

Labor-related delays Group

CATEGORY 5

Pre-construction related delays Group

CATEGORY 6

Management related delays Group

CATEGORY 7

Contract related delays Group

CATEGORY 8

Lack of site utilities or services Group

Appendix E: Binary Analysis for 80 Delayed Projects in XYZ Company using Factor Analysis Method

Project #	Actual Delay (Days)	Cost of Delay (USD)	CATEGORY 1	CATEGORY 2	CATEGORY 3	CATEGORY 4	CATEGORY 5	CATEGORY 6	CATEGORY 7	CATEGORY 8
5	2.00	12,340.71	0	1	0	1	0	1	0	0
6	0.67	25,783.95	0	1	0	1	0	1	0	0
7	3.00	15,435.55	0	1	0	1	0	1	0	0
8	1.96	43,498.46	0	1	1	0	0	0	0	0
9	0.23	10,687.79	1	1	0	0	0	1	0	0
10	0.88	4,227.23	1	1	0	0	0	1	0	0
11	0.42	59,878.27	0	1	0	0	0	0	0	0
12	1.46	35,539.78	0	1	0	0	0	0	0	0
13	0.09	159.45	0	1	1	1	0	1	0	0
14	1.67	31,990.41	0	1	1	0	0	1	0	0
16	3.42	66,186.15	0	1	1	1	0	1	0	0
17	1.81	22,884.90	0	1	1	0	0	1	0	0
18	3.67	48,198.13	0	1	1	1	0	1	0	0
19	2.63	253,404.11	0	1	1	0	0	1	0	0
20	2.13	5,102.83	0	1	1	1	0	1	0	0
23	1.67	0.00	0	1	0	0	0	0	0	0
24	0.08	212.27	0	1	0	1	0	0	0	0
26	7.15	34,853.31	0	1	1	0	1	1	0	0
28	0.65	0.00	1	1	1	0	0	1	0	0
33	23.10	410,445.20	0	0	1	0	1	1	0	0
38	13.71	12,394.11	0	0	1	0	1	1	0	0
41	1.30	2,132.16	0	1	1	0	0	1	0	0
42	5.03	0.00	0	1	1	0	0	1	0	0
43	0.42	2,927.68	0	1	1	0	0	1	0	0
44	4.65	37,527.00	0	1	1	0	1	1	0	0
46	0.60	500.77	0	1	1	0	1	1	0	0
49	0.10	5,312.36	0	0	1	0	1	1	0	0
50	1.17	14,950.26	0	0	1	0	1	0	0	0
51	0.90	0.00	0	0	1	0	1	1	0	0
53	9.13	0.00	0	1	1	0	1	1	0	0
55	1.05	56,535.55	0	1	1	0	1	1	0	0
56	2.28	5,843.00	0	1	1	1	1	1	0	0
57	0.46	10,583.20	0	1	1	0	0	1	0	0
60	0.14	0.00	1	1	1	0	1	1	0	0
61	0.21	209.23	0	0	1	0	1	1	0	0
62	2.03	41,304.18	0	1	1	1	0	1	0	0
73	15.38	13,013.82	0	0	1	0	1	1	0	0
89	0.16	8,530.84	0	1	1	0	0	1	0	0
90	2.31	1,454.60	0	0	1	0	0	1	0	0
91	1.06	718.81	0	0	1	0	1	1	0	0
92	30.33	227,010.96	0	1	1	0	0	1	0	0
93	1.08	0.00	0	1	1	0	0	1	0	0
94	1.00	854.69	0	0	1	0	1	1	0	0
97	0.25	4,034.18	0	1	1	0	0	1	0	0
98	0.27	520.86	0	1	1	0	0	1	0	0
100	0.25	338.25	0	1	1	1	0	1	0	0
101	0.40	129.14	0	1	1	0	0	1	0	0
102	2.42	15,012.92	0	0	1	0	1	1	0	0
103	1.13	14,644.80	0	1	1	0	1	1	0	0
104	1.08	2,806.82	1	0	1	0	1	1	0	0
107	0.35	22.86	0	1	1	0	0	1	0	0
108	0.79	5,666.20	0	1	0	0	0	1	0	0
109	0.06	237.41	0	1	1	0	0	1	0	0
110	0.13	57.26	0	1	0	1	0	1	0	0
112	0.10	717.53	0	1	0	0	0	0	0	0
113	2.38	100,137.19	0	1	1	0	0	1	0	0
114	0.08	316.30	0	1	1	0	1	1	0	0
115	0.38	822.43	0	1	1	0	0	1	0	0
116	0.19	4,337.95	0	1	0	1	0	0	0	0
117	0.44	864.84	0	1	0	1	0	1	0	0
118	0.31	3,261.07	0	1	0	0	0	0	0	0
119	0.04	375.70	0	1	1	0	0	1	0	0
120	0.31	749.91	0	1	1	0	0	1	0	0
121	0.31	903.70	0	1	0	0	0	0	0	0
122	3.00	18,336.33	0	1	0	1	0	1	0	0
123	1.33	10,599.28	0	1	0	0	0	0	0	0
124	0.81	5,757.83	0	1	0	1	0	1	0	0
125	0.15	901.97	1	1	1	0	0	1	0	0
126	0.15	788.10	0	1	0	1	0	1	0	0
127	0.13	197.14	0	1	1	0	0	1	0	0
128	0.08	316.34	0	1	1	0	0	1	0	0
129	1.56	401.82	0	0	1	0	0	1	0	0
132	0.94	7,682.58	0	1	1	0	0	1	0	0
133	0.08	639.73	0	1	1	0	0	1	0	0
134	2.77	8,696.76	0	1	1	1	0	1	0	0
135	1.13	1,952.57	0	1	1	0	0	1	0	0
136	0.75	7,235.93	0	1	1	0	0	1	0	0
145	3.13	5,573.89	1	1	0	1	0	1	0	0
150	0.13	200.88	0	1	0	1	0	1	0	0
151	0.25	197.14	0	1	0	0	0	0	0	0

Appendix F: Statistic Results of Factor Analysis Models

Appendix F: Statistic Results of Factor Analysis Models

➤ Delay in days

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.313	0.098	0.024	4.70074

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	175.786	6	29.298	1.326	0.257
	Residual	1613.075	73	22.097		
	Total	1788.861	79			

➤ Cost of Delay in Dollars

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.178	0.032	- 0.048	61,138.39762

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.953 x 10 ⁹	6	1.492 x 10 ⁹	0.399	0.877
	Residual	272.867 x 10 ⁹	73	3.738 x 10 ⁹		
	Total	281.820 x 10 ⁹	79			

**Appendix G: Binary Analysis for 80
Delayed Projects in XYZ Company using
Risk Mapping Matrix Method**

19 High Risk Delay Factors Resulted from XYZ Company Risk Mapping Matrix

F1	Inadequate project planning, budgeting and scheduling	F10	Poor managerial skills
F2	Scope variation	F11	Delay or long way leave approval process by other parties
F3	Late materials delivery	F12	Weather effect (heat, rain, wind, sand storm, etc.)
F4	Insufficient contractor's manpower (or resources)	F13	Rework due to errors, mistakes and defective works during construction
F5	Lack of communication between client, consultant & contractor	F14	Inadequate contractor experience
F6	Poor site management and supervision	F15	Incompetence of project team
F7	Inefficient and poor performance of contractors/subcontractors	F16	Slow decision making within all project teams
F8	Materials shortage	F17	Delay in drawings preparation of the projects
F9	Contractor's lack of planning at preconstruction	F18	Late materials issuance
		F19	Unforeseen site conditions

Appendix G: Binary Analysis for 80 Delayed Projects in XYZ Company using Risk Mapping Matrix Method

Project #	Actual Delay (Days)	Cost of Delay (USD)	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19
5	2.00	12,340.71	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	1
6	0.67	25,783.95	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	1
7	3.00	15,435.55	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	1
8	1.96	43,498.46	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1
9	0.23	10,687.79	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
10	0.88	4,227.23	1	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	0	1
11	0.42	59,878.27	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
12	1.46	35,539.78	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
13	0.09	159.45	0	1	0	0	0	1	1	0	0	1	0	0	1	1	1	0	0	0	1
14	1.67	31,990.41	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1
16	3.42	66,186.15	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1
17	1.81	22,884.90	1	1	0	0	1	1	0	0	1	0	0	0	0	1	1	0	0	0	0
18	3.67	48,198.13	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1
19	2.63	253,404.11	1	0	0	0	1	1	0	0	1	0	1	0	0	0	1	0	0	0	0
20	2.13	5,102.83	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1
23	1.67	0.00	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
24	0.08	212.27	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
26	7.15	34,853.31	1	0	0	0	1	1	0	0	1	0	1	0	0	0	1	0	0	0	0
28	0.65	0.00	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1
33	23.10	410,445.20	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0
38	13.71	12,394.11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
41	1.30	2,132.16	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1
42	5.03	0.00	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1
43	0.42	2,927.68	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1
44	4.65	37,527.00	1	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1
46	0.60	500.77	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
49	0.10	5,312.36	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
50	1.17	14,950.26	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
51	0.90	0.00	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
53	9.13	0.00	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1
55	1.05	56,535.55	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1
56	2.28	5,843.00	1	0	0	0	1	1	1	0	1	0	0	0	0	1	1	0	0	0	1
57	0.46	10,583.20	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1
60	0.14	0.00	1	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	0	0
61	0.21	209.23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
62	2.03	41,304.18	1	1	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	1
73	15.38	13,013.82	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0

Project #	Actual Delay (Days)	Cost of Delay (USD)	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19
89	0.16	8,530.84	1	0	0	0	0	1	1	0	1	0	0	0	0	1	1	0	0	0	0
90	2.31	1,454.60	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
91	1.06	718.81	1	0	1	0	1	0	0	1	0	1	0	0	0	0	1	1	0	1	0
92	30.33	227,010.96	1	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	1
93	1.08	0.00	1	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1
94	1.00	854.69	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0
97	0.25	4,034.18	1	0	0	0	0	1	1	0	1	0	0	0	0	1	1	0	0	0	0
98	0.27	520.86	1	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0
100	0.25	338.25	1	0	0	1	0	1	1	0	1	1	0	0	0	1	1	0	0	0	0
101	0.40	129.14	1	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0	0	0	0
102	2.42	15,012.92	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0
103	1.13	14,644.80	1	0	0	0	0	1	1	0	1	1	0	0	0	1	1	0	0	0	0
104	1.08	2,806.82	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0
107	0.35	22.86	1	0	0	0	0	1	1	0	1	1	0	0	0	1	1	0	0	0	0
108	0.79	5,666.20	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1
109	0.06	237.41	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
110	0.13	57.26	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	1
112	0.10	717.53	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
113	2.38	100,137.19	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1
114	0.08	316.30	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1
115	0.38	822.43	1	1	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	0	1
116	0.19	4,337.95	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	1
117	0.44	864.84	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	1
118	0.31	3,261.07	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
119	0.04	375.70	1	0	0	0	0	1	1	0	1	1	0	0	0	1	1	0	0	0	0
120	0.31	749.91	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	1
121	0.31	903.70	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
122	3.00	18,336.33	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	1
123	1.33	10,599.28	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
124	0.81	5,757.83	0	0	0	0	0	1	1	0	0	1	0	0	1	1	1	0	0	0	1
125	0.15	901.97	1	0	0	1	0	1	1	0	1	1	0	0	0	1	1	0	0	0	0
126	0.15	788.10	0	0	0	0	0	1	1	0	0	1	0	0	1	1	1	0	0	0	1
127	0.13	197.14	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	1
128	0.08	316.34	1	0	0	0	1	1	1	0	0	1	0	0	1	1	1	0	0	0	1
129	1.56	401.82	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0
132	0.94	7,682.58	1	0	0	1	1	1	1	0	1	1	0	0	0	1	1	0	0	0	0
133	0.08	639.73	1	0	0	0	1	1	1	0	1	1	0	0	0	1	1	0	0	0	1
134	2.77	8,696.76	1	0	0	1	0	1	1	0	1	1	0	0	0	1	1	0	0	0	1
135	1.13	1,952.57	1	0	1	0	0	1	1	1	1	1	0	0	0	1	1	0	0	1	0
136	0.75	7,235.93	1	0	0	0	1	1	1	0	1	1	0	0	0	1	1	0	0	0	1
145	3.13	5,573.89	0	0	0	0	0	1	1	0	1	1	0	0	0	1	1	0	0	0	0

Project #	Actual Delay (Days)	Cost of Delay (USD)	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19
150	0.13	200.88	0	0	0	0	0	1	1	0	0	1	0	0	1	1	1	0	0	0	1
151	0.25	197.14	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1

**Appendix H: Evaluation of Models Resulted
From 17 High Risk Delay Factors and
Significant/Almost Significant Delay
Factors for 20 Delayed Projects**

**Appendix H: Evaluation of Models Resulted From17
High Risk Delay Factors and Significant/Almost Significant
Delay Factors for 20 Delayed Projects**

Project No.	Delay (Days)			Cost (USD)		
	Actual	Estimated (17)	Estimated (4)	Actual	Estimated (17)	Estimated (6)
1	23.10	23.10	23.10	410445.20	410445.20	410445.20
2	0.15	-0.16	1.30	788.10	729.17	9436.24
3	0.13	-0.16	1.30	200.88	729.17	9436.24
4	1.05	4.17	1.30	56535.55	57253.96	20019.85
5	0.16	1.81	1.30	8530.84	9265.77	4726.85
6	1.13	0.06	1.30	1952.57	2875.34	4726.85
7	1.00	2.73	3.69	854.69	-898.50	-1326.64
8	0.79	1.51	1.30	5666.20	7633.82	25245.08
9	0.44	0.70	1.30	864.84	3310.16	9436.24
10	1.33	0.30	1.30	10599.28	13234.30	20019.85
11	2.03	5.26	5.81	41304.18	44052.84	60190.93
12	0.21	2.26	1.30	209.23	-2866.56	-1326.64
13	0.13	0.70	1.30	57.26	3310.16	9436.24
14	0.08	-1.02	0.83	639.73	-2635.35	4726.85
15	2.77	1.61	1.30	8696.76	5102.74	4726.85
16	2.38	2.67	0.83	100137.19	104641.17	87590.90
17	0.06	2.35	1.30	237.41	-4498.74	-1326.64
18	0.81	-0.16	1.30	5757.83	729.17	9436.24
19	0.25	1.81	1.30	4034.18	9265.77	4726.85
20	1.06	1.84	3.69	718.81	-4707.94	-1326.64

Appendix I: Analysis of Negative Signs in Delay Model Data

Appendix I: Analysis of Negative Signs in Delay Model Data

Projects	Actual Delay	Estimated Delay	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17
	Beta		2.343	3.708	0.566	-2.058	2.366	-1.737	1.754	-0.858	0.134	1.687	2.892	-2.830	1.387	3.388	22.900	-0.892	0.089
69	0.15	-0.162	0	0	0	0	1	1	0	1	0	0	1	1	1	0	0	0	1
79	0.13	-0.162	0	0	0	0	1	1	0	1	0	0	1	1	1	0	0	0	1
74	0.08	-1.015	1	0	0	1	1	1	1	1	0	0	0	1	1	0	0	0	1
67	0.81	-0.162	0	0	0	0	1	1	0	1	0	0	1	1	1	0	0	0	1

F1	Inadequate project planning, budgeting and scheduling
F2	Scope variation
F3	Insufficient contractor's manpower (or resources)
F4	Lack of communication between client, consultant and contractor
F5	Poor site management and supervision
F6	Inefficient and poor performance of contractors/subcontractors
F7	Contractor's lack of planning at preconstruction
F8	Poor managerial skills
F9	Delay or long way leave approval process by other parties
F10	Weather effect (heat, rain, wind, sand storm, etc.)
F11	Rework due to errors, mistakes and defective works during construction
F12	Inadequate contractor experience
F13	Incompetence of project team
F14	Slow decision making within all project teams
F15	Delay in drawings preparation of the projects
F16	Late materials issuance
F17	Unforeseen site conditions

Note: The Black Bolded Factors are significant with p-values < 0.05
Wheres the **Orange Bolded** factors are almost significant with p-valus approximately < 0.05

Estimated Delay Equation:

$$\text{Duration of delay in days} = -1.471 + (2.343 \times F_1) + (3.708 \times F_2) + (0.566 \times F_3) - (2.058 \times F_4) + (2.366 \times F_5) - (1.737 \times F_6) + (1.754 \times F_7) - (0.858 \times F_8) + (0.134 \times F_9) + (1.687 \times F_{10}) + (2.892 \times F_{11}) - (2.830 \times F_{12}) + (1.387 \times F_{13}) + (3.388 \times F_{14}) + (22.900 \times F_{15}) - (0.892 \times F_{16}) + (0.089 \times F_{17})$$

Appendix J: Analysis of Negative Signs in Cost Model Data

Appendix J: Analysis of Negative Signs in Cost Model Data

Projects	Actual Cost	Estimated Cost	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17
	Beta	-26184.500	18040.552	11158.961	50.141	-7687.950	32754.106	-46878.255	56317.855	-2580.991	20701.724	41050.981	70034.984	-30061.376	5277.391	12236.998	420999.707	-3809.442	-1632.185
43	854.69	-898.500	1	0	0	1	0	0	0	1	0	0	0	0	1	1	0	0	0
35	209.23	-2866.557	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
74	639.73	-2635.353	1	0	0	1	1	1	1	1	0	0	0	1	1	0	0	0	1
53	237.41	-4498.742	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
40	718.81	-4707.942	1	0	0	1	0	0	0	1	0	0	0	0	1	1	0	1	0

F1	Inadequate project planning, budgeting and scheduling
F2	Scope variation
F3	Insufficient contractor's manpower (or resources)
F4	Lack of communication between client, consultant and contractor
F5	Poor site management and supervision
F6	Inefficient and poor performance of contractors/subcontractors
F7	Contractor's lack of planning at preconstruction
F8	Poor managerial skills
F9	Delay or long way leave approval process by other parties
F10	Weather effect (heat, rain, wind, sand storm, etc.)
F11	Rework due to errors, mistakes and defective works during construction
F12	Inadequate contractor experience
F13	Incompetence of project team
F14	Slow decision making within all project teams
F15	Delay in drawings preparation of the projects
F16	Late materials issuance
F17	Unforeseen site conditions

Note: The Bolded Factors are significant with p-values < 0.05

Estimated Cost Equation:

$$\begin{aligned}
 \text{Cost of delay in dollars} = & -26184.500 + (18040.552 \times F1) + (11158.961 \times F2) + (50.141 \times F3) \\
 & - (7687.950 \times F4) + (32754.106 \times F5) - (46878.255 \times F6) + (56317.855 \times F7) \\
 & - (2580.991 \times F8) + (20701.724 \times F9) + (41050.981 \times F10) + (70034.984 \times F11) \\
 & - (30061.376 \times F12) + (5277.391 \times F13) + (12236.998 \times F14) + (420999.707 \times F15) \\
 & - (3809.442 \times F16) - (1632.185 \times F17)
 \end{aligned}$$

جامعة البحرين

قسم الهندسة الميكانيكية

كلية الهندسة



نماذج التنبؤ للتأخير في مشاريع بناء خطوط الأنابيب في صناعة النفط والغاز

أطروحة مقدمة كجزء من متطلبات الحصول على درجة الماجستير في الإدارة الهندسية

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مملكة البحرين

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ملخص الدراسة

كان الهدف من هذا البحث هو تطوير نموذج للتنبؤ بالتأخير في إنشاء خطوط الأنابيب في صناعة النفط والغاز في البحرين. تم تطوير طريقة البحث عن طريق تصميم فلسفي براغماتي. استخدمت طرق بحثية بتصميم مختلف مدعومة بمجموعة مناقشات مركزة مع الخبراء ($N = 8$) في إنشاء خط الأنابيب لتطوير قائمة من 47 عامل تأخير كانت الأكثر قابلية للتطبيق على مشكلة البحث. أنشأ إستبيان على شبكة الإنترنت ($N = 93$) لجمع البيانات الكمية على أهمية وتواتر حدوث عوامل التأخير. قيمت أهمية عوامل التأخير باستخدام مؤشر الأهمية النسبية (RII) بينما أجري ترتيب تكرار حدوثهم باستخدام مؤشر الأهمية المعدلة للتردد (FAII). نفذ إجراء الانحدار الخطي المتعدد في SPSS لتوضيح التنبؤ لكل من مدة التأخير بالأيام وتكلفة التأخير بالدولار الأمريكي. كما استخدم الانحدار الخطي المتعدد بواسطة بيانات مؤشر الأداء الرئيسي (KPI) الحقيقي لإحدى الشركات في مجال النفط والغاز للتحقق من صحة نماذج التنبؤ.

أوضحت نتائج هذه الدراسة أن التخطيط غير الملائم للمشروع والميزانية والجدولة وتغيرات مخطط المشروع والتأخر في تسليم المواد، جميع هذه العوامل كانت أسباب التأخير الرئيسية التي تسببت في تأخير مشاريع إنشاء خطوط الأنابيب في صناعة النفط والغاز في البحرين. الجدير بالذكر أن معظم عوامل التأخير الرئيسية كانت تتعلق بالمالكين أو ممثليهم والمقاولين.

أوضح نموذج الانحدار الخاص أن الاختلاف في مخطط المشروع والتأخير في إعداد الرسومات للمشاريع هي أهم المؤشرات للتأخير في المشاريع. مع ملاحظة إن تلك المتغيرات أدت إلى ما يقارب 34 ٪ من مدة التأخير. من ناحية أخرى، كشف نموذج التنبؤ لتكلفة التأخير عن قوة تنبؤية أعلى بمتغيرات تأخير أكثر. يبين نموذج التكلفة أن ضعف إدارة الموقع والإشراف وعدم قدرة المقاول بالقيام بالمهام المطلوبة وضعف التخطيط عند المقاولين قبل عملية الإنشاء وحالة الطقس المتغيرة وإعادة العمل المترتب عن الأخطاء والعيوب أثناء عملية الإنشاء وكذلك التأخير في إعداد الرسومات للمشاريع كانت أهم المؤشرات لزيادة تكلفة المشاريع. مع ملاحظة إن تلك المتغيرات أدت إلى ما يقارب 69 ٪ من الزيادة في تكلفة المشاريع الناجمة عن التأخير.