

University of Bahrain

College of Engineering



**Department of
Mechanical Engineering**

**An Investigation into the Delay Factors
Affecting Maintenance and Construction Projects in
the Petrochemical Industries in Bahrain**

**A Thesis Submitted in Partial Fulfilment of the Requirements for the
M.Sc. Degree in Engineering Management**

Prepared by

Faisal Ebrahim Alali

20042387

Supervised by

Supervisor Co-Supervisor

Dr. Saad M. A. Sulieman Dr. Khalid Al-Shafei

Professor Assistant professor

May 2021

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Graduate Studies Council

Thesis Discussion Committee Decision

Student Name: Faisal Ebrahim Alali	Student ID: 20042387
Department: Mechanical Engineering	College: Engineering
Program: Master in Engineering Management	
Thesis Title: An Investigation into the Delay Factors Affecting the Maintenance and Construction Projects in the Petrochemical Industries in Bahrain	
Supervisor Name: Dr. Saad M. A. Sulieman Co Supervisor Name: Dr. Khalid Al-Shafei	Student GPA: 3.77

The Discussion Committee met on **23rd June 2021** on line on MS teams. Upon discussing the student whose details are stated above in public, the discussion committee recommends the following:

The student awarded grade **A** In the thesis subject _____

☐ Without making any changes to the thesis

☒ After making the modifications attached with this decision

Discussion Committee Members Approval:

Name	Signature
1. Prof. Saad Sulieman (Supervisor)	
2. Dr. Khalid Alshafei (Co-Supervisor)	
3. Prof. M. P. Saka (Internal Examiner)	Mehmet Polat Saka Digitally signed by Mehmet Polat Saka DN: cn=Mehmet Polat Saka, o=University of Bahrain, ou=UOB, email=mpsaka@metu.edu.tr, c=TR Date: 2021.06.23 22:38:59 +03'00'
4. Prof. Ali Ali Shash (External Examiner)	

Abstract

Delay of maintenance and construction projects in the petrochemical industries in Bahrain, which attributed by the direct cost impact on the company, is one of the major issues in petrochemical industries to tackle, especially during the challenging time of having unstable market and oil price war. The investigation addressed the delay factors and the delay consequences from two aspects; the first one is the likelihood of their occurrence, and second aspect is the severity of their impacts on the petrochemical industries in Bahrain. Initially 117 delay factors, and 29 delay consequences were identified based on analytical review of relevant literature. Then after, conducting interviews with experts from petrochemical industries, the outcomes of the literature review have been scrutinized and refined to 42 delay factors, classified under 9 different categories. For the delay consequences analysis, the research was broadened to include 14 potential delay consequences, which constituted along with the direct cost impact and which were the most relevant consequences on the petrochemical industry companies. The highest delay factors, delay consequences, and delay groups were ranked according to adjusted frequency index (FAII) as follows; for delay factors: late delivery of material or equipment, adoption of the lowest bid price system for awarding the contract, inadequate project planning, budgeting and scheduling, and late design changes initiating in the project life cycle. Also, top ranked delay consequences were concluded as: extension of works beyond the normal working hours, cost overrun, delay of other related projects, and time overrun. Risk matrix was depicted to classify the factors and consequences under different risk zones. The contractor's responses found to be perceived lower than the other respondents' categories in terms of the perception of significance level for the delay factors in petrochemical industries in Bahrain. Recommendation emphasized on the company high level objective to create a frame work to include the control of the delays in projects to be one of their organizational objectives, and to cascade from there to every department's individual objectives. Also, leadership management, and role of project leaders were recommended, with stressing of importance of early engagement of maintenance department in the project process.

Dedication

I dedicated my thesis to my beloved mother and father for their prayers, support, and leading my ambitions further up to this stage. A special dedication is extended to my wife, my source of support, for her patience, support, and giving me the hope to realize my dream. The dedication is extended to include my brothers, sisters, and all the family and close friends for their kind wishes and support throughout this important period of my life.

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List of Abbreviations

CAPEX	Capital Expenditure
FEED	Front End Engineering Design
EPC	Engineering , Procurement and Construction
RII	Relative Important Index
RNC	Reason for Non-compliance
DI	Delay Index
LPS	Last Planner System
FI	Frequency index
FAII	Adjusted Frequency Index
ANOVA	Analysis for Variance
KPI	Key Performance Indicator

Chapter 1: Introduction to the Study

- 1.1 Introduction
- 1.2 Research Problem
- 1.3 Research Questions
- 1.4 Research Objectives
- 1.5 Research Significance
- 1.6 Research Setting
- 1.7 Research Limitation
- 1.8 Research Outline

Chapter 1: Introduction to The Study

1.1 Introduction

One of the major issues that pose a concern in the maintenance and construction field is the delay in the completion of the projects. The delay has a significant impact and consequences on the organizations in terms of profitability and competitiveness in the market. Petrochemical industries are not an exceptional situation in this phenomenon. The nature and complexity of the process of such industries necessitate more stringent management to control the process and mitigate the impact and consequences of the delay to the projects.

Nowadays, Petrochemical industries are striving to maintain profitability and overcome the financial instability in the market by focusing more on the efficiency of the process and minimizing unnecessary costs. Delay impact as an over cost, penalties, losing opportunities, and losing the production is a critical factor that shall be taken into consideration by the management. Some petrochemical industries started to adopt a new strategy and planned to invest an enormous capital amount to establish new lines and produce new petrochemical products (Argaam, 2017). while other petrochemical industries strategize to explore more about the efficient utilizing of the available opportunities and recourse to reduce the cost and increase the productivity of the existing plant. One of those major opportunities is addressing the delay in maintenance and construction projects.

Projects in petrochemical are classified into a routine and turnaround projects. This research is considering the delay in the routine maintenance and construction projects that take part during the operational period of the plant. Also, the execution of construction and maintenance projects falls under the responsibility of the maintenance department in the petrochemical industries in Bahrain. This research does not however, cover the normal corrective and preventive maintenance that carried out on a daily basis or base on weekly schedule allocation, but rather, covers the major maintenance projects that have dedicated capital expenditure (CAPEX) and management approval and linked to the strategic objective of the petrochemical industries.

The maintenance projects that were sampled as a basis for this study are defined as the major maintenance projects in the petrochemical industries that involve a technical interference from the technical services team as a basis for these projects (engineering and inspection).

These projects are not the normal maintenance activities that are carried out on a daily basis. As an example of such projects, project like relining of equipment's and pipe lines, up-grading of the structures protective coating, and periodical replacement of the operational units' components. These projects are carried out according to the risk-based inspection, service life of equipment, and approved design package. The maintenance projects also include projects like the replacement of switch gear of substations, upgrading of the desalination unit water stages, refurbishment of steam boilers superheaters and burners.

Construction projects are defined as the projects set to develop a new operational unit or to enhance of the building assets inside the

petrochemical industries. These projects mostly follow a lump sum contracting methods. Recent examples of construction projects in petrochemical industries were construction of urea flare unit, construction of a new nitrogen plant to supply the additional demand of liquid nitrogen to the plants, lined up of process upstream requirement to the new Formaldehyde project, and construction and installation of ammonia venting unit. These projects found to experience a delay in various time of their project cycle, which affected the site execution and led to a various project consequence.

Any delay in completing these projects would be detrimental to the company and have a severe impact on the strategic objective and profitability of the company, especially if the completion time is affecting other operational parameters and taking into account the increased in oil and gas price and spiraling cost and construction delay which are leaving their marks on profitability and payback period (Martin, 2012).

1.2 Research Problem

History and records show that many of maintenance and construction projects in petrochemical industries have been adversely affected by the delay factors that could occurred in any phase of the project life cycle (From initiation to closing).

Based on the last five years' records from the petrochemical industries in Bahrain, these delay factors have led to many consequences that impacted the petrochemical industries in terms of direct cost and losing of potential opportunities. Thus, the economic impact of the delay in maintenance and construction projects in the petrochemical industries is problematic and significant.

1.3 Research Questions

The research shall answer the following questions:

1. What are the main delay factors in the maintenance and construction projects in petrochemical industries?
2. What are the impact and consequences of the delay in the maintenance and construction projects in the petrochemical industries?
3. How to overcome the delay in maintenance and construction projects in petrochemical industries?

1.4 Research Objectives

The following are the main objectives of the research:

1. Identify and assess the main factors that causing the delay in the maintenance and construction projects in the petrochemical industries.
2. Identify and assess the main consequences that occurred from the delay in maintenance and construction projects in the petrochemical industries.
3. Recommend a corrective action plan to overcome the delay in maintenance and construction projects in the petrochemical industries.

1.5 Research Significance

This research is addressing a tangible problem that is experienced in the petrochemical industry companies under study, that is delay in maintenance and construction projects. The outcomes of this report shall contribute to the benefit of the petrochemical industries in Bahrain and other industries that share a jointly common facilities and

work system. This is achieved by identifying the most prominent delay factors, prioritize them and recommend a corrective action plan based on the analysis of the results. Thus, lead to increase the success rates of the projects, reduce the cost and impacts of the delay, and enhance the process efficiency. Also, the findings of the reports shall establish a guideline for the interested researchers in the same field in the future, and add to the technical literature related to projects and petrochemical industries.

1.6 Research setting

Analytical literature review and theoretical frame work was part of this research, where previous related literature in field of construction, oil and gas, and petrochemical industries were reviewed, analyzed and presented.

Methods and procedures chapter focused on the methodology that was used in this research. The methods started with interviewing an expert's groups in the petrochemical field to refine the general delay list obtained from literature review. Data collection was done by using questionnaire survey in the form five points Likert scale for delay factors and delay consequences. Analysis of data was performed to find the top delay factors, and delay consequences, in accordance with FAII, and assigned them to different risk zoning. Finally, discussion of the results was presented to help the reader in understanding the results.

1.7 Research Limitation

The research has the following limitation:

- 1) Delay analysis was limited to analyze the petrochemical industries' maintenance and construction projects in Bahrain. Also, the limitation includes the type of projects that were considered in the research. The research excluded the major turnaround projects, and considered only the maintenance projects that take part during the production time of the petrochemical plant.
- 2) Another limitation was attributed to the timing period of conduction the research. All the delays factors and delay consequences were limited to the researches that were carried out in the timing period between 2008 and 2018.

1.8 Research Outline

The research consists of five chapters; where each chapter is detailed as follows:

Chapter 1: Introduction to study

This chapter covers the introduction, research problem, research questions, research objectives, research significance, research sitting, research limitation, and finally the research outline.

Chapter 2: Literature review

This chapter presents a summary of previous studies and researches conducted in the field of general construction project, petrochemical industries project, oil and gas industries, and review of analytical methods conducted on similar subject matter to aid and support the research problem and objectives.

It provides a comprehensive review of the delay factors analysis and delay consequences analysis to reach to a comprehensive list of the factors.

Chapter 3: Methods and procedures

This chapter demonstrates the methodology used in the research and includes research design, data collection methods, questionnaire survey, target population, validity of the research, reliability of the research, and lastly the data analysis techniques

Chapter 4: Results and discussion

Chapter four presents the results and discussing of the reach results. It covers the analysis of the response rate, Pearson correlation, Cronbach factor analysis, central tendency of delay factors, variance analysis between categorical groups, computation of FI, RII, and FAII factors, and illustrating the risk index matrix.

Chapter 5: Summary, conclusion and recommendation of the study

This chapter covers the conclusion of the research, and provides the final recommendations of the study.

Chapter 2: Literature Review

- 2.1 Introduction
- 2.2 Review of Related Previous Work
 - 2.2.1 Review of general construction related projects
 - 2.2.2 Review of oil and gas related projects
 - 2.2.3 Review of petrochemical related projects
 - 2.2.4 Review of analytical methods for delay factors evaluation
- 2.3 Summary of Literature Review

Chapter 2: Literature Review

2.1 Introduction

Many kinds of literature were explored to check the existing efforts and findings in the field of the construction project, project management, delay of projects, oil and gas industries, and petrochemical industries. The literature review took place by thoroughly reviewing and scrutinizing the related previous work as on section 2.2 to conclude and analyze the initial list of delay factors and delay consequences.

2.2 Review of Related Previous work

The Literature review process has been divided into four subsections, where in each subsection, the literature has compiled according to their relevancy to the delay on certain field of construction project. Also, one subsection has been dedicated to explore the existing efforts by researchers in terms of the adapted methodology to evaluate the delay factors.

2.2.1 Review of general construction related projects

As per Le-Hai et al. (2008), the planned duration and final cost at project closing are two important factors of successful projects and successful project management. This statement was concluded from their study, where a comparison was done between mega construction projects in Vietnam with various selected construction industries in Asia and Africa. The factor analysis technique was used to categorize the causes according to their frequency and severity, which yield the main factors. One of the major tasks for resolving the schedule delay

claims was the suitability of the selection of delay analysis methodology. Khoshgoftar et al. (2010) specified the successful project factors such as completion on time, within budget, within specified quality, and within client satisfaction. Since delay is regarded as a failure, then it was important for the researchers to investigate the causes of delay in Iranian construction projects. A questionnaire survey used to solicit the causes of delay for project stakeholders. Results demonstrated that finance and payments of completed work, improper planning, and site management are the common reasons for projects' delay.

Ayodele (2011) determined the cause and effect of the abandonment of projects in Nigeria in the southwest region. A structured questionnaire was distributed to the concerns who have experience in projects in at least ten years and then analyzed them by the form of RII. Results showed that the main causes for projects' abandonment were: inadequate project planning, inadequate funds, inflation, the bankruptcy of contractor, the variation of the scope, political factors, death of the client, incompetent project manager, wrong estimate, and inadequate cost control. The major consequences of the abandonment as per the study were: the disappointment of populace/users, low living standards, wastage of resources, reduction in employment opportunity, loss of revenue and difficulty in attracting foreign loans.

Abedi et al. (2011) developed a paper aimed into identifying the effects of delay that could threat project objectives in the construction field. The delay factors identified through systematic literature review and results of the study has identified six major effects of delay: time overrun, cost overrun, disputes, arbitration, total abandonment, and litigation, and showed time and cost overruns at a higher frequency.

Mohammed and Isah (2012) studied the delay in a Nigerian construction project by designing a questionnaire and distributing it to relevant clients and contractors. The study concluded that improper planning, lack of communication, design errors and shortage of supply were the top-ranked causes of delay in the Nigerian region for construction projects. The recommendation for utilizing and hiring more qualified and experienced professionals shall contribute to reduce the impact of the delay and improve the planning and coordination of construction activities in the project.

As per Mydin et al. (2014) the project delays in the construction industry are universal and not only affecting the construction industry but the overall economy of countries as well. the objective of the study was to identify and evaluate the causes and consequences of project delays in private housing projects in Malaysia, and the remedies to minimize these delays. Ten factors were analyzed to be the top ten influencing factors and the majority contributed by the contractor as the cause of delay. The consequences of delays were time overrun, cost overrun, disputes, legal action and reached up to abandonment.

Hasan et al. (2014) investigated the delay factors for road projects in Bahrain. The project analyzed the delay factors with their frequency and severity and also identified and assessed the delay's effects for the road projects. The researchers inferred that one of the major delay factors that relate to the owner is the delay in decision making process in the ministry. Amoatey et al. (2015) used a purposive sampling technique to obtain the responses for the delay causes and effects for housing construction projects in one of the Ghanaian states. As a result of the study, the following delay factors were inferred as critical factors behind the delay: delay in payment to contractor/suppliers,

inflation, price increases for the material, inadequate projects' funds from the sponsors, variation orders, and poor financial market situation. Moreover, the authors identified the most critical effects of delays as cost overrun, time overrun, litigation, lack of continuity by the owner, and arbitration.

Srdić and Šelih (2015) used an online survey tool in order to determine the current level of management techniques that are utilized in the Slovenian construction industries and concluded that delay can have different origins, can be compensable or not, and may appear concurrently or subsequently (See Figure 1). Also, research indicated that the construction companies shall use the available contemporary time management technique to a larger extent and in a more effective way in order to enhance project management efficiency.

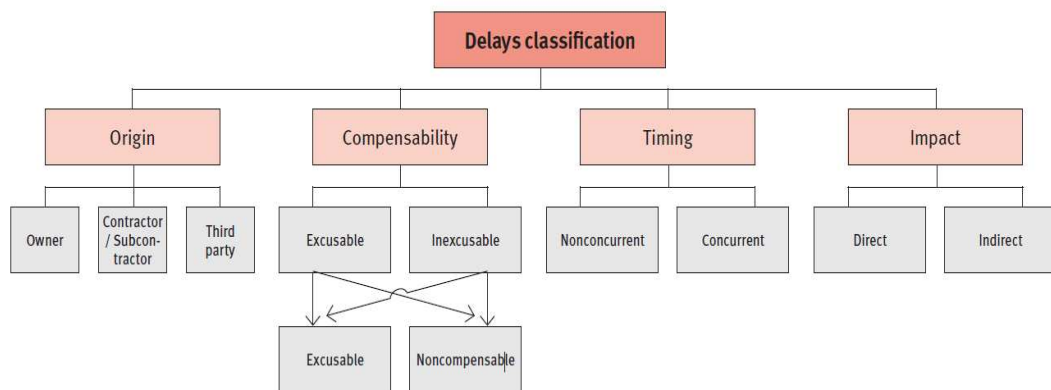


Figure 1: Delay classification (Srdić and Šelih ,2015).

Nguyen and Chileshe (2015) stated that the Vietnam industry has considerably developed since 1986 as a result of the “DOI MOI” which is defined as “all-around renovation process”, and despite all efforts and reforms attempts, a number of issues continued to harm the construction industry. Therefore, their paper aimed into identify the

issues affecting construction industry. Researchers used a mixed methodology approach by postal survey questionnaire to construction stakeholders and by conducting a semi-structured interviews. These quantitative data were analyzed by a descriptive statistical analysis which revealed top delay factors for delay in Vietnam. The revisited project failure factors could be used as a road map for revaluation and development of appropriate project management practices. Main factors were as follows: disregard of the significance of planning process, lack of experience in executing a complicated project, poor design, lack of financial capability of owner, corruption and bribery in construction, economic volatility, and high level of inflation. Kumar (2016) investigated the delays in Indian construction projects via literature review analysis and questionnaire survey as a methodology to identify the most significant factors. The author identified 103 causes of delays and categorized them into 8 different groups, from which, the most significant factors found to be inadequate contractor's work and experience, poor communication between project stakeholders, delay in material delivery and finally lack of early planning of the project.

Gunduz and AbuHassan (2016) identified the delay causes in Qatar construction projects. The methodology adopted was a systematic literature review followed by a quantitative process of developing a survey questionnaire and applying statistical analysis to the survey results to obtain the factors. RII has been used as a measure of the analysis and results led to the highest contributors factors, that were: delay in the decision-making process, poor site management and supervision, shortage of material and shortage of labors.

Rao et al. (2016) analyzed the delay factors in construction projects in Manipal town in India. The study was based on a literature review analysis and followed by a questionnaire survey, where 42 factors of six distinct categories were developed. The level of importance was computed by using the RII which revealed the highest of 0.812 for the delay in payments by the owner. Samarghandi et al. (2016) focused on the reasons for construction delays in IRAN by dividing the factors into four groups. Based on experts' review for the industrial survey, a statistical model was used to quantitatively determine the most importance delay factors in each group. For the owner related factor, it was attributed to lack of attention to inflation, where for a contractor there were two reasons: inaccurate budgeting and resource planning, and low bidding. Also, for law and regulation group, the factors were outdated standard mandatory items in cost list, and outdated items in the contract, while finally for consultant group, the reason deduced for the inaccuracy of the technical document. Moreover, the regression model used and signified that there was a significant difference between planned and actual project duration and cost which reached 5.9 months per year and 15.4% cost overrun.

Shehu et al. (2016) have evaluated the effects of construction in the Nigerian construction industry and the subsequent consequences of the delay. The paper gives prominence to the dealy issue in the construction stage through critical analysis of available literature. It revealed that the contractor is the key part in the construction and stakeholders are negatively affected by the delay. The study concluded that the effect on the nation's development, and the effect on the reputation of the contractor were the main consequences of the delay. Gebrehiwet and Luo (2017) investigated the common causes of delay

at different stages of construction and their effect, which was conducted in the Ethiopian construction project. Purposive sampling was used for the questionnaire survey and the methodology used was RII and correlation coefficient. Based on the comparison, the impacts of the delay were grouped as three categories: pre-construction stage, construction stage, and post-construction stage. These critical effects were cost overrun, time overrun, termination of the contract, arbitration, and litigation in subsequent order.

2.2.2 Review of oil and gas related projects

Salama et al. (2008) indicated that despite the similarity shared with construction projects, some factors might not be applicable to the oil and gas industry due to the distinction between the two areas. The methodology used after the literature review was interviewing experts in the oil and gas field to identify the most predominant factors and a purposive questionnaire sent via email to 100 practitioners working in oil and gas projects in Abudhabi. Data analysis showed a strong correlation between the Front End Engineering Design (FEED) phase and the delay at the end of the Engineering , Procurement and Construction (EPC) project, which shall give an early warning and call for immediate remedial action. Moreover, and in view of consequences and due to increased oil prices, the return on investment and payback period is relative must be shorter than before which gives more focus and pressure on timely completion of projects.

Research on oil and gas construction projects in Oman showed a high degree of agreement between project stakeholders, contractors, clients, and consultants for the causes of projects' delay (Ruqaishi and Bashir, 2015). According to the study, seven factors were identified as the major causes of the projects' delay, among them the unique factor

identified for the oil and gas industry was the poor interaction with vendors in engineering and procurement stage. Koirala et al. (2017) studied the impact on delay in the construction of large scale hydropower projects during the pre-implementation phase of the project. The study which is based on case study analysis of the West Seti hydropower project (in the far-western development area of Nepal) attempted to highlight the impact caused by large scale project trapped in long pre-implementation phase, and explain the factors that intensify the impact on affected communities like political context, the flow of information, and lack of meaningful participation of local people during the planning phase. A study has been made to investigate the effect of the delay on the involved stakeholders on EPC contracts on oil and gas industries and the extent of the effect and its consequences through systematic literature review analysis.

The main consequences for the delay in the construction phase in oil and gas projects, according to Suppramaniam and Ismail (2018) are abandonment, arbitration, cost overrun, disputes, litigation, and time overrun. A survey done by Seddeeq et al. (2019) revealed the major causes of time and cost overrun in Saudi Arabia oil and gas construction industry. The research shows that the change in design and scope by the owner during the construction stage is the main reason for time overrun while underestimating the cost to the benefit is the main reason for cost overrun. In pipeline construction projects in oil and gas industry in Bahrain, the delay factors with their associated risk were identified by (Mohammed and Suliman, 2019). Delay factors were identified with their impacts and illustrated using risk mapping matrix for classification of delay factors under different zoning.

2.2.3 Review of petrochemical related projects

The delay in Iranian petrochemical industries constructions projects was studied by (Naimi et al., 2008). The study reveals that the delay in delivering the material, shortage of material, lack of competent and skilled manpower, inflation and unrealistic planning during the bidding stage are the main contributors to the delay. 91% of the projects were found to be delayed which is quite huge number with an average of 63% of delay from the planned duration. Moreover, the researcher concludes that despite of the delay and major disputes, only few cases were raised up to the level of liquidated damages or other sort of penalty, which is attributed to the prevailed culture in Iran as per the researchers. Pham and Hadikusumo (2014) said the petrochemical plays a significant role in economic development in Vietnam. Many projects in the past ten years have been developed using the EPC project delivery system for faster completion, however, many of them suffered from schedule delays. Therefore, in order to resolve the problem, a qualitative research methodology developed by using a case study from selected EPC projects with the objective of defining the current business models used in Vitnmian petrochemical industries and exploring the root causes of delays. By interviewing the management officers in three understudies cases, it was concluded that local and foreign EPC contractors shared similar business practices that ease the process of identification of the root causes of delay in each case separately.

A study made for petrochemical projects in Saudi Arabia shows the most influencing factors contributed to the schedule delay during the construction of petrochemical projects in Saudi Arabia by (Alhajri and Alshibani, 2018). These factors were as following: poor site

management, poor supervision by contractor, conflict arises between the main contractor and subcontractor, poor planning and scheduling of projects by contractor, delays in material delivery, and delay in handing over the construction site to contractor.

2.2.4 Review of analytical methods for delay factors evaluation

A paper done by Yang and Kao (2009) analyzed and reviewed 18 delay analysis methods and compared in detail three processes based on dynamic analysis. These processes are namely snapshot analysis, window analysis, and isolated delay type method. The difference between these dynamic methods is in terms of capabilities, required documents, timing and analysis process which were discussed in detail in order to aid the delay's analyst to choose the most appropriate method for their case. The study concluded with identifying six suggestions for developing the ideal delay analysis method, that consist of the availability of as planned schedule, availability of plan for dealing with different delay types, clear liability distribution, consideration of multiple critical paths and critical paths change, defining total float in clear position, and incorporating the system into popular commercial scheduling software.

Pourrostam and Ismail (2011) quoted that delays can only be minimized when the causes are identified. Thus, the paper aimed into finding the most effective methods for minimizing delays in construction projects. A systematic literature review for the related fields has been conducted for projects from the last decade and highlighted from the consultant and contractor perspective based on

the Relative Important Index (RII). The most effective methods to minimize the delay were: adequate funding, competent project manager, awarding bid system, complete design at the right time, resources availability, clarity of objective, and use experienced subcontractors. Tariq (2013) suggested a six sigma methodology as a management framework tool for handling undesired effects associated with delays in construction projects. The author defined the risk framework based on a critical review of previous research carried in different industries. The effectiveness of this method has been compared and validated through empirical analysis based on real-life case studies. Findings concluded that the risk management framework defined in project management lacks compatibility with handling real-time projects. By combining several methodologies, it has been possible from the author's point of view to devise a framework that proved to be beneficial and compatible with six sigma methodology. González et al. (2013) focused on using quantitative evaluation for the delay impact to overcome the limitation in systematic way of relating the causes of delay to their impacts in the literature. The paper used a methodology to examine qualitative delay causes and quantitative time performance dimensions of the delay issues, at which it proposed two indicators. The first one is the Reason for Non-compliance (RNC) as an indicator to categorize scheduling failures, and secondly the Delay Index (DI) as a time performance indicator that describes the impact of delay on project activities. The paper examines two building projects and found that planning and subcontractors are the primary RNCs that having the biggest impact on on-time performance. The data are obtained through the monitoring the project performance on weekly basis, and analyzing the actual progressive and cumulative progress at the beginning of the week for

each activity, and compare it to the scheduled or planned progress at the end of the week and also to the actual progress at the end of the week. The slacks activities were assigned to the origin causes, and finally, the delay index was measured by the below formula for each activity:

$$DI = \frac{WS_i - Re_{i+1}}{WS_i - Re_i}$$

Where: Re_i is the actual weekly progress at starting of the week i , and WS_i is the planned progress by activity for the week i .

AlSehaimi et al. (2013) studies and evaluated the effectiveness of the implementation of the lean construction approach called the Last Planner System (LPS) in Saudi Arabia construction industry in order to improve construction planning practice and enhance the site management. Two large state-owned projects were selected for the aim of project evaluation through a research methodology that included interviews, observations, and questionnaires surveys. The major benefits of implementing the LPS were covering many aspects of project management, including: improve the construction planning, enhance the site management, and improve communication and coordination among project parties. The paper also deduced the barrier against realizing the full potential of LPS, like the involvement of many subcontractors in projects, people's commitment, and attitude to time. Identifying the constraints of the activities are highly important for the scheduling of construction projects as per (Nguyen and Chua., 2014). The more elaboration in criticality, the better schedule management can be achieved. The researchers presented a method to classify and identify the criticality of schedule management according to four major classes: project-critical constraints, activity-critical

constraints, sequence-critical constraints and non-critical. One of the major contributors to projects delay is the rework, where it has been investigated in detail by (Hwang and Yang, 2014) . The researcher studied and assessed the rework impact on the schedule performance by developing a questionnaire followed by face to face interviews with six industry experts to get an in-depth understanding of the findings. Findings revealed that rework is a leading factor affecting schedule performance and the root causes are namely: design changes, poor design, and poor site management by the contractor, that negatively affect the schedule.

Mahamid and Al-Ghonamy (2015) made a study aimed into identifying the risk matrix for delay causes in construction projects in Saudi Arabia, but from the consultants point of view. 51 questionnaire surveys undertaken by consultants working on construction projects in the Northern province of Saudi Arabia to quantify the causes identified through systematic literature review. The study concluded top delay causes in Saudi Arabia as a bid award system for lowest price, changes in material types and specification during construction, contract management, duration of the contract, market fluctuation, frequent changes, improper planning and lack of adequate manpower. The following risk index between severity and frequency was utilized as per Figure 2 .

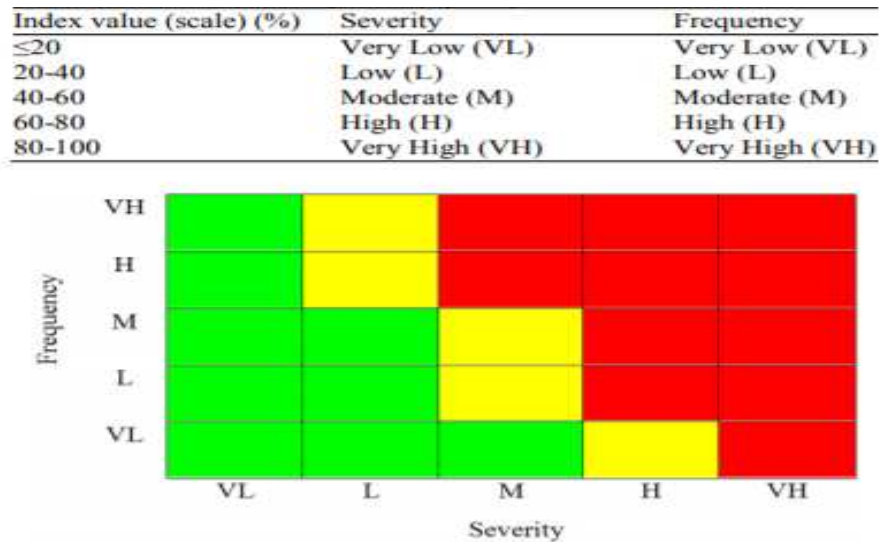


Figure 2: Risk matrix used by (Mahamid and Al-Ghonamy, 2015).

2.3 Summary of Literature Review

Delay in projects is a universal phenomenon, which is not only affecting the construction industries, but the overall economy of the countries as well (Mydin et al., 2014). In the previous section, a systematic literature review analysis has been conducted in order to identify the most critical delay factors and delay consequences by combining the results from various relevant sources. This was purely based on cross-referencing and critical judging, which does not require, at this stage, any primary and complex data collection methods.

The systematic literature review has been found to be extremely beneficial in terms of identifying the delay factors, exploring new research methodologies that suit the set objectives, get in-depth details about recommendations in other organizations and industries, and understanding the most prominent consequences of the delay.

The content of literature was analyzed conceptually by focusing on specific keywords in the literature, identify the factors and tabulating

them with their reference. The lack of studies pertaining to the delay in petrochemical industries especially in this region was obvious. Although construction projects share some similar characteristics, but the difference in working environment and nature of work will induce a different classification for the delay factors under distinguished level of consequences. This will be taken into the consideration while setting the research methodology in the next chapter.

Table 1 shows the delay factors based on the systematic review of the literature with their reference. Moreover, it is worth mentioning that the delay factors list was enhanced by the addition of new factors that are pertaining to petrochemical industries from researcher point of view.

Note: The number precedes the below author names has been used in the Table 1 to refer to the source of the delay factor. The References are sorted in timely manner according to the timing of the research publication as the following:

- 1) Naimi et al (2008).
- 2) Hasan et al (2014).
- 3) Quraish and Bashir (2015).
- 4) Kumar (2016).
- 5) Alhaji and Alessiani (2018).
- 6) Siddiq et al. (2019).
- 7) Mohammed and Suliman (2019).

Table 1: Delay factors obtained from literature review process

SN.	Delay Factor	Literature Reference
A	Design and Engineering related factors	
1	Late design change	1
2	Poor design / Design error	1,6,7
3	Incomplete and unclear drawing and project document	1,5
4	Delay in Preparation and approval and issuance of drawings and documents	1,2,3,4,7
5	Poor qualification and Inadequate design team experience	2,4,7
6	Reengineering of different units caused by poor basic design package, and structural modifications after starting the project	2,3,6
7	Poor interaction with vendors in the engineering stage	3
8	Weak and insufficient technical studies for the project	6
9	Major changes of design during construction by consultant, and delay in approving major changes	2,3,6
10	Engineer reluctance for change and their inflexibilities	4
11	Insufficient data collection and survey before design	3,4,6
12	Mistakes and discrepancies made in design documents leads to frequent revisions of drawings/designs	4
13	Unclear and inadequate details in drawings and also slow response on doubts arising from the drawings	4
14	Using poor /old engineering design software	4
15	Complexity of project conception & designing	4
16	Improper selection of project location	1,7
17	Misunderstanding of owner requirements by design engineer	4
B	Management related factor	
18	Bureaucracy in organization	1,4
19	Owner influence (unrealistic project duration imposed by owner)	1,3,7

Table 1(continued): Delay factors obtained from literature review process

SN.	Delay Factor	Literature Reference
20	Owner interference, Changes, and scope variation	1,2,3,4,5,6,7
21	Slow decision making and approval by the owner organization	1,2,3,4,5,6,7
22	Client cash flow and payment problem, and Delay in project financing and progressive payments	1,2,3,4,5,7
23	Unavailability or late approval of project budget	2,7
24	Adoption of fast-track project delivery strategy	6
25	Adoption of the lowest bid price system	2,6
C	Contract related factors	
26	Poor definition of interfaces causing scope creep	3
27	Mistakes and discrepancies in contract document and drawing	2,3,6
28	Inadequate project duration defined in original contract	3
29	Poor definition of payment milestones/distribution	3,6
30	Improper selection of the type of contract for the project	4
31	Complications in the tendering process	3
32	Aggressive competition at tender stage	4,5
33	Short bid preparation time leads to improper bidding by contractor	5
34	Inadequate delay penalties/poor incentives for early completion	3,4,5
38	Damage of sorted material while they are needed urgently due to improper storage of materials	4
39	lack of adequate space for storing materials in site	4
40	Procuring undesired or unwanted material instead	4
41	Escalation of material prices	1,4,5
42	Late material issuance	7
43	Poor procurement programming of materials (Late procurement of materials/late ordering)	4,6,7

Table 1 (Continued): Delay factors obtained from literature review process (Continue)

SN.	Delay Factor	Literature Reference
44	Problem with equipment transportation and delivering to the site.	4
45	Sudden increase in quantity needed	4
E	Project team related factors	
46	Incompetent project team and lack of experience in construction	1,6,7 and modified by researcher
47	Inappropriate overall organization structure for the projects	3
48	poor contract and schedule management by project team	1,3,6(modified by researcher)
49	Inadequate project planning, budgeting and scheduling	1,6,7
50	Poor technical experience	1(modified by researcher)
51	Poor site supervision	1,2,4,7
52	Poorly defined or vague scope of work	3,6
53	Delay in performing inspection and testing	2,3,4
54	Inadequate quality assurance/control	3,6
55	Lack of ownership in the project, And conflict between owners of project	3,4,6
56	Delay in handing over the construction site to contractor	5
F	Site and work execution related factors	
57	Unsafe practice at site (Poor safety conditions)	2,4,7
58	Lack of site utilities or services, or unavailability/poor temporary facility of utilities in site (such as water, electricity, telephone, etc.)	7
59	Accident during construction	2,7
60	Security and slow site clearance (checking process for quality, safety and other purposes)	4 (Modified by researcher)

Table 1(Continued): Delay factors obtained from literature review process

SN.	Delay Factor	Literature Reference
61	Difficulties / Delay in obtaining work permits	1,2,5(Modified by researcher)
62	Unclear or undefined positions of services networks in drawings	2
63	Unforeseen site condition	1,3,5,6,7
64	Weather effect (heat, rain, wind, sand storm, etc.	1,2,3,5,6,7
65	Summer restriction on time of work	2
66	Environmental protection pressure by stakeholders	7
67	Delay in Way-leave approval from utilities agencies	2 (modified by researcher)
G	work force related factors	
68	Shortage of manpower	1,3,4,6
69	Unexpected low manpower productivity	1,3,4,5,6
70	Lack of skilled manpower	1,6,7
71	Personal conflicts among labors	4
72	Workers Safety & health problems when working in hazardous conditions and their absenteeism	4
73	Nationality and language of vendors and workers	4 (modified by researcher)
74	Lack of motivation	4
H	Project tools and equipment related factors	
75	Equipment failure or breakdown	1,3,4
76	Unavailability or shortage of heavy material when needed	2,4,5,6,7
77	Low level of equipment-operator's skill	4
78	Low productivity and efficiency of equipment	4
79	Wrong kind of equipment selection	4
80	Lack of hi-tech, advanced and special equipment	4

Table 1(Continued): Delay factors obtained from literature review process

SN.	Delay Factor	Literature Reference
81	Complication of hiring and transporting to the site	4
82	Limited mechanization due to cheap labor cost in the locality	4
I	Contractor related factors	
83	Poor understanding of scope of work during bidding stage	3,6
84	Negligence of site visits before/during the bidding process	6
85	Under bidding	6
86	Negotiations and obtaining method of contracts	4
87	Poor estimation of project time and material quantities required before contracting	4
88	Inadequate scheduling / planning / estimation by contractor	1,2,3,4,5,7
89	Inappropriate Construction methods	1,2,3,4,5,7
90	Inadequate contractor experience	1,2,3,4,5,6,7
91	Poor supervision & managerial skills	4
92	Delay in fabrication activities	7
93	In-efficient and poor performance of contractors/subcontractors	7
94	Poor site management and supervision	1,2,3, 5,7
95	Delay or problems caused by subcontractors (Conflict with subcontractor), or delay in contractor payment to subcontractor and supplier	1,3,4,5,6
96	Rework due to errors, mistakes and defective works during construction	1,2,3,4,5,6,7
97	Poor communication / conflict between contractor and project parties	1,2,4
98	Difficulties in project financing by contractor	1,2,3,4,6,7

Table 1(Continued): Delay factors obtained from literature review process

SN.	Delay Factor	Literature Reference
99	Insufficient contractor's manpower (or resources)	7
100	Shortage of skilled labors by contractor	2,5
101	Slow mobilization & demobilization of labor	4
J	All parties related factors	
102	Personality clash between two or more members from different parties	6
103	Lack of communication between parties involved	1,2,3,4,5,6,7
104	Lack of periodic meeting among the management, site personnel and the contractors and also weekly project evaluation meetings	4
K	Legal related factors	
105	Changes in laws and regulations	2,3,7
106	Insufficient laws on projects	7
107	Inefficiency of legal process	7
108	Unfamiliarity with government regulations and laws	3,5
L	External related factors	
109	Economic and financial condition of the market	1,3,6,7
110	Dispute with residents /neighbors around site	2,3,7
111	Lack of coordination among public agencies concerned	7
112	Damage to work by third party	7
113	Corruption and bribery	7
114	Political situation and security	2
115	Fraudulent practices and kickbacks	4
116	Corruption & hostile political conditions and also strikes called by political parties	4
117	Effects of social and cultural factors	4

The second outcome from the analysis of literatures was the delay consequences, which revealed 23 consequences that consist the most prominent consequences in maintenance and projects fields. Moreover, the list of delay consequences will further be refined, by offering it for scrutinizing and reviewing process by petrochemical experts, as per the methodology set in chapter 3. The delay consequences were summarized in Table 2 with their references that were sorted out in timely manner.

- 8) Mohammed and Isah (2012)
- 9) Hasan et al. (2014)
- 10) Kumar (2016)
- 11) Suppramaniam and Ismail (2018)

Table 2: Delay consequences obtained from literature review process

SN.	Delay Consequence	Literature Reference
1	Abandonment of project	9,10,11
2	Time overrun	8,9,10,11
3	Disputes	8,9,10,11
4	Idling resources	11
5	Lack of continuity by client	11
6	Penalties	8,9,10,11
7	Arbitration or Litigation between the participants of the project	9,10,11
8	Bankruptcy	11
9	Cost overrun	8,9,10,11
10	Declination of reputation	8,10
11	Distrust with contractor	10,11
12	Delay in the progress payment due to distrust	10,11
13	Loss of profit and revenue	10,11

Table 2 (Continued): Delay consequences obtained from literature review process

SN.	Delay Consequence	Literature Reference
14	Loss of market value of the contractor	11
15	Negative social impact	11
16	Non-productivity loss for the owner	11
17	Poor quality of work due to hurry	11
18	Reduction in profit for the contractor	10,11
19	Termination of contract	9
20	Loss of Interest by the Stakeholder – has been merged with continuity	8
21	Blacklist by Authorities or company	8
22	Delay of other projects related to the main one	9
23	Disruption of traffic movement	9

Finally, as the aim of this research was to assess the delay phenomenon in petrochemical industries in Bahrain, and to do so, with a very minimal literature in such filed and in this specific demographic region. Yet high number of delay factors have been deduced in this process, but this was due to a direct cross referencing from a mixture of construction industries, as the construction industries have their common characteristics in many aspects. To resolve this issue, these factors will be further examined by offering them to Petrochemical industries' experts to identify the most relevant delay factors in petrochemical industries and filter the initial delay list. Therefore, a top-down approach was adapted in this research to prove and construct validity of results, and to justify the research design and strategy. This top-down approach implies the usage of comprehensive factors as a basis for decision making.

Furthermore, as an exploratory research nature was decided to explore the delay phenomena, this exploratory research nature implies inductive research approach which require quantitative methods to obtain and ranked the most prominent factors.

According to the analysis of the available methodologies, it was found that weighted average was an efficient and proven technique that was widely used to obtain to the inferential statistical analysis and reach to acceptable conclusion. This research, however, did not only adapt the simple weighted average, but also carried out further analysis to analyze the criticality of these delay factors and consequences base on the risk matrix to assign them to different risk zones.

Chapter 3: Methods and Procedures

- 3.1 Research Design
- 3.2 Data Collection
 - 3.2.1 Data collection from literature review
 - 3.2.2 Focus group interview
- 3.3 Design of the Questionnaire Survey
 - 3.3.1 Likert scale
 - 3.3.2 Likert scale analysis
- 3.4 Target Population
- 3.5 Validity of the Results
 - 3.5.1 Construct validity
 - 3.5.2 Internal validity
 - 3.5.3 External validity
- 3.6 Reliability of the Results
- 3.7 Data Analysis Techniques
 - 3.7.1 Adjusted frequency index
 - 3.7.2 Risk mapping index

Chapter 3: Methods and Procedures

3.1 Research Design

This study aims to use a descriptive research design that will identify and prioritize delay factors affecting the maintenance and construction projects in petrochemical industries in Bahrain, and their associated impact and consequences, in order to recommend a corrective action plan for the maintenance department on the basis of literature review and focused group interview.

The research design and methodology took parts as per Figure 3.

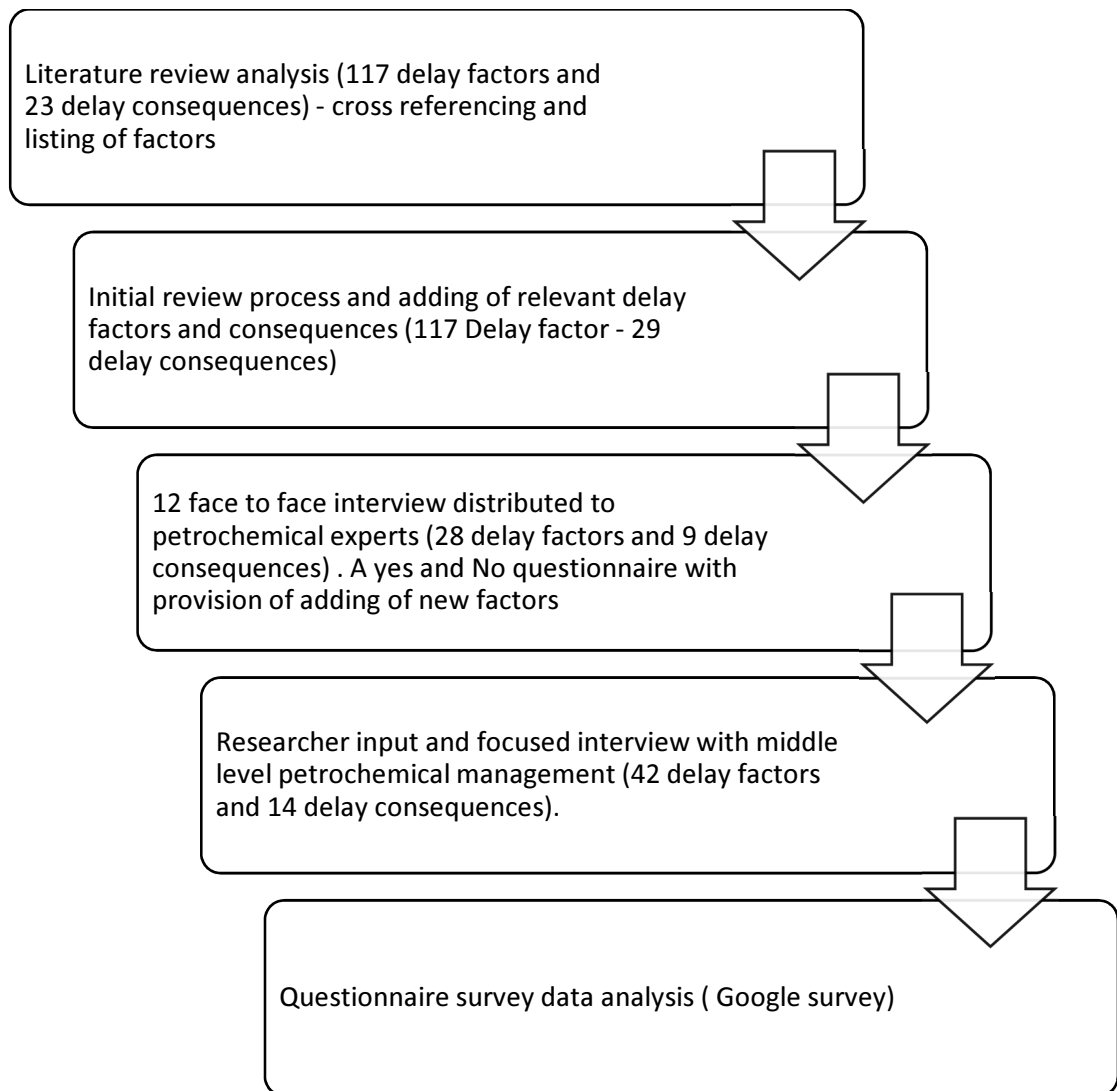


Figure 3: Research design and methodology flow chart

3.2 Data Collection

1. The first source of data was obtained from the petrochemical industries in Bahrain, from the projects records, and planning system. Also, from the outcomes of the comprehensive review of the related literature.
2. Secondly, data was collected through mix approaches: Semi-qualitative approach (Interview), and quantitative approach (Questionnaire).

3.2.1 Data collection from literature review

Conducted an extensive literature review to identify and analyze the delay factors into groups.

1. Initially 117 factors were identified and classified under 12 groups in accordance with the processes of the petrochemical industries in Bahrain. This way of grouping assumed to have more linkage and compatibility with the working method in the petrochemical industries. Also, contractor related factors remain as one of the main delay group in the study (Please refer to Table 1).
2. Similarly, from the systematic review of literatures, 23 delay consequence were identified.
3. Initial review by the researcher, where a 6 number of delay consequences were added to the original list due to their relevancy to the working condition in the petrochemical industries. These delay consequences were not traced during the literature review process according to the researcher knowledge and best effort. Therefore, the delay consequences were increased to 29.
4. The number of delay factors and delay consequences will be further refined according to the outcomes from the focus group interview with Petrochemical experts as per 3.2.2

3.2.2 Focus group interview

1. Interview with 12 experts specialized in the field of maintenance and construction in petrochemical industries. This group was selected among an engineers and supervisors (as a minimum working level), having more than 10 years of

experience in the field of maintenance and construction projects in the petrochemical industries, in order to evaluate the level of agreement with the identified delay factors and consequences, identify new factors that are applicable to petrochemical industries in Bahrain “if any “, and shortlist the initial list (Appendix A). This process followed by application of Pareto rule “Pareto rule, found by Vilfredo Pareto and specified that 80% of consequences produced from 20% of the causes, asserting an equal relation between inputs and output” (Pareto principle, 2019). Therefore, any delay factors and consequences get 8 or more acceptances out of 12 respondents, will be qualified out of this process and thus, re-classification of delay factors groups (Appendix B).

2. For delay factors, 28 factors were qualified out of initial 117 factors = 23.9% of the factors. From 12 groups for delay factors, 4 groups’ factors found with no high relevancy to petrochemical industries, namely; Projects’ tools and equipment related factors, all parties related factors, legal related factors and external related factors which remark the unique nature of petrochemical industries and highly dependence on the internal procedures and regulation into their processes.
3. For the delay consequences, 9 out of 29 consequences with 31% of total consequences were qualified.
4. Another look was giving to the eliminated factors in order to capture all relevant data for the next stage analysis. The factors that get 7 out of 12 agreements from the interview results were considered for final evaluation for more comprehensive outcomes. The delay factors were increased to 42 factors

classified under 9 related groups, and delay consequences to 14 consequences.

3.3 Design of the Questionnaire Survey

To get feedback about the frequency and severity of the delay factors and the main consequences of delay, a Likert scale questionnaire was designed and developed. The data collection and compilation of responses were via online mean (Google survey), and personally by hand to hand to the selected category of questionnaire's sample.

An extensive discussion conducted with middle level management from different working discipline in petrochemical industries in Bahrain to have their final input and opinion while going through the questionnaire. As a result, minor adjustment has been made, and delay factors were finalized to 42 factors. (Questionnaire is attached in appendix -C)

3.3.1 Likert scale

A Likert scale questionnaire, using scale 1-5, was designed for the delay factors (Frequency of occurrence and severity level) and also for the delay consequences (Frequency of occurrence and impact level on the organization).

3.3.2 Likert scale analysis

As per Boone and Boone (2012) research, where they elaborated about differences between Likert-type and Likert scale data and provide their recommendation for descriptive statistics to be used during analysis.

Likert-type item is defined as any one of the single questions that may be used in the research instrument and when there is no attempt for researcher to combine the responses from the items into composite scale. However, the “Likert scale is composed of series of four or more Likert type items that are combined into single composite score or variable during the data analysis process” (Boone and Boone, 2012). These combined items analysis used to provide quantitative measures of character or personality traits. Thus, Likert scale data are analyzed at interval measurement scale and created by calculating composite score (sum or mean) for the Likert-scale items.

Table 3: Comparison between Likert-type data and Likert scale data

Measure	Likert-type data	Likert scale data
Central tendency	Median or mode	Mean
Variability	Frequencies	Standard deviation
Association	Kendall tau B or C	Perason’s r
Other statistics	Chi-square	Anova, t-test , regression

Table 3 shows the suggested data analysis procedures for Likert-type and Likert scale data.

3.4 Target Population

The target population was from the petrochemical industries employees who are dealing with or involving in projects as a main sample for this research from technical background and from supervisory level or engineers as a minimum working level. Also, the petrochemical responses were supported with secondary responses from two categories:

- 1) Contractors working in petrochemical industries projects, and having a minimum working level as a site supervisor or project manager.
- 2) Technical personnel (Supervisor level and more) from oil and gas organizations that share some jointly owned assets and facilities with petrochemical industries, and also being affected as a one of the main stakeholders by petrochemical industries projects.

3.5 Validity of the Results

The below stated conditions to be fulfilled to assess the validity of the research, as per statsdirect.com:

3.5.1 Construct validity

The simplest type of validity assessment, which is concerned with the extent to which the research measures what it claims to measure. Top-down approach is intended to be used in this research to prove and construct validity, and to prove the selected methodology of the research.

3.5.2 Internal validity

This validity is fulfilled when the research demonstrated a closer internal relation between variables and their total sum of Likert scale items, which was computed statistically by using Pearson correlation test.

In terms of questionnaire, the term criterion validity was used to express the extent to which items in questionnaire are actually measures the factors and consequences ranks that its intended to measure.

Thus, it will be used to emphasize the initial assumption of the existing relation between Likert scale items and single composite variable of delay factors and delay consequences.

3.5.3 External validity

External validity is concerned if the findings could be generalized to other relevant settings or groups, whether the existing choice of the sample was justified, and whether the findings from your selected sample could be generalize to all the population. It answered the following queries about sample representative, selection of proper people, and the existence of mixture in sample group. This step was analyzed and addressed thoroughly in the chapter 4.

3.6 Reliability of the Research

Reliability of the delay factors and delay consequences was evaluated using SPSS software by obtaining Cronbach factor for both the frequency of occurrence and severity level for each delay factor and delay consequence.

Also, the following was considered while distributing and analyzing the questionnaire to ensure the reliability of the results (Laerd dissertation, n.d.).

Participant error: Is any factor that can adversely affect the way in which participants performs. Hence, the appropriate timing for interview or questionnaire was selected, and made the maximum efforts to ensure the respondents were not harrying to the extent that could affect the response quality.

Participant bias: Any factor that would produce false response: Like interviewing in open offices in the middle area, where the respondent could be afraid that his answers could be over heard by others.

Researcher error: Any factor that could altered the researcher interpretation, like interview. The interview was set in a way not to be conducted in one day to avoid tiredness and loss the ability of obtaining the best answers from each interviewee

Last and most common was researcher bias: This was defined as any factor that could induced a biasness in the recording of responses. So, to maximum practicable extent, the research focused in making the analysis in objective way and avoiding the human tendency towards being subjective.

3.7 Data Analysis Techniques

The collected data was organized and analyzed using statistical software like MINITAB and SPSS. Descriptive and inferential statistical analysis was carried out to find the relation between different factors and the delay, mainly by using adjusted frequency index (FAII), measuring the central tendency of the delay factors, developing the delay matrix index, and classifying the delay factors and delay consequences. Understanding the impacts of delay will aid to develop the most adequate control measure and corrective action and establish a guideline for the maintenance department not only to quantify the impacts of delay as possible for future projects, but also to understand the most important frequent consequences on the company, projects, and contractors.

To calculate the average of the factors, the below equations was used in Excel to obtain the result.

$$\text{Frequency mean} = \sum_{i=1}^5 \left(\frac{n_{ij} * i}{N} \right), \text{ for } j=1,2,3,\dots,42 \quad (1)$$

$$\text{Importance mean} = \sum_{i=1}^5 \left(\frac{n'_{ij} * i}{N} \right), \text{ for } j=1,2,3,\dots,42 \quad (2)$$

Where n_{ij} = number of respondents who gives frequency score i ($i=1,2,\dots,5$) to factor j , n'_{ji} = number of respondents who gives severity score i ($i=1,2,\dots,5$) to factor j , and N = total number of respondents =63.

Moreover, analysis of variance (ANOVA) test will be conducted to ascertain if there was any significant difference between the participants categorizes (organization) in the perception of the delay, and to decide whether the data could be aggregated or if it should be considered in individual group in the statistical calculation, before proceeding with final data analysis.

3.7.1 Adjusted frequency index

Adjusted frequency index was used to rank the delay factors, delay consequences and delay groups based on their frequency of occurrence and severity level (importance).

In order to compute the FAII, it was required to calculate both frequency index of factor j ($FI_{(j)}$) and relative importance index ($RII_{(j)}$) based on the responses obtained from the survey, according to below equations:

$$FI(j) = \frac{\sum_{i=1}^A n_{ij} * i}{A * N} \quad (3)$$

And;

$$RII(j) = \frac{\sum_{i=1}^A n'_{ij} * i}{A * N} \quad (4)$$

Where FI =the frequency index, and RII = relative importance index for factor j, and j (j=1,2, 3,..42); whereas A is the highest possible score in the Likert scale and= 5.

Finally, FAII was computed based on both (FI_(j)) and (RII_(j)) from the analysis of the data obtained from the survey and results of Equation (3) and (4). FAII was calculated as per Equation 5, which was used in the analysis in order to rank the delay factors, delay consequences, and delay factors' groups:

$$FAII(j) = RII(j) * FI(j) \quad (5)$$

3.7.2 Risk mapping index

The final analysis was to classify the delay factors by using the risk-based criteria for each factor (Frequency of occurrence, versus the severity level)

Similarly, the risk mapping was deployed for the delay consequences in the term of (consequences of occurrence) versus the impact on the organization which represent the importance of the delay consequence.

The Figure 4 below was the final outcome of the risk mapping with the following details:

		FREQUENCY OF OCCURRENCE (LIKELIHOOD)				
		Very low	Low	Medium	High	Very High
SEVERITY LEVEL	Very High	Low/Med	Medium	Med/High	High	High
	High	Low	Low/Med	Medium	Med/High	High
	Medium	Low	Low/Med	Medium	Med/High	Med/High
	Low	Low	Low/Med	Low/Med	Medium	Med/High
	Very Low	Low	Low	Low/Med	Medium	Medium

Figure. 4: Risk matrix

Where, Table 4 shows the risk zones according to their scale and color coding in the risk matrix:

Table 4: Risk zones color coding

Scale**	Zone	Colour coding	X- Axis*	Y- Axis*
1.0-1.8	1		Low	Low
1.81-2.60	2		Low /Medium	Low/Medium
2.61-3.40	3		Medium	Medium
3.41-4.2	4		Medium / High	Medium/High
4.21-5.0	5		High	High

Notes:

* The X and Y axis was for diagonal line of the risk matrix. The actual representation was as per the Table 4.

**Scale was obtained by subtracting highest possible answer 5 from lowest possible answer 1 and divide the total by 5.

$$\frac{5-1}{5} = 0.8 \text{ for each interval.}$$

Chapter 4: Results and Discussion

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Chapter 4: Results and Discussion

4.1 Introduction

This chapter demonstrates and illustrates the analysis used to obtain the results and discuss them thoroughly and in depth. The analysis sequence follows the flow chart in Figure 5.

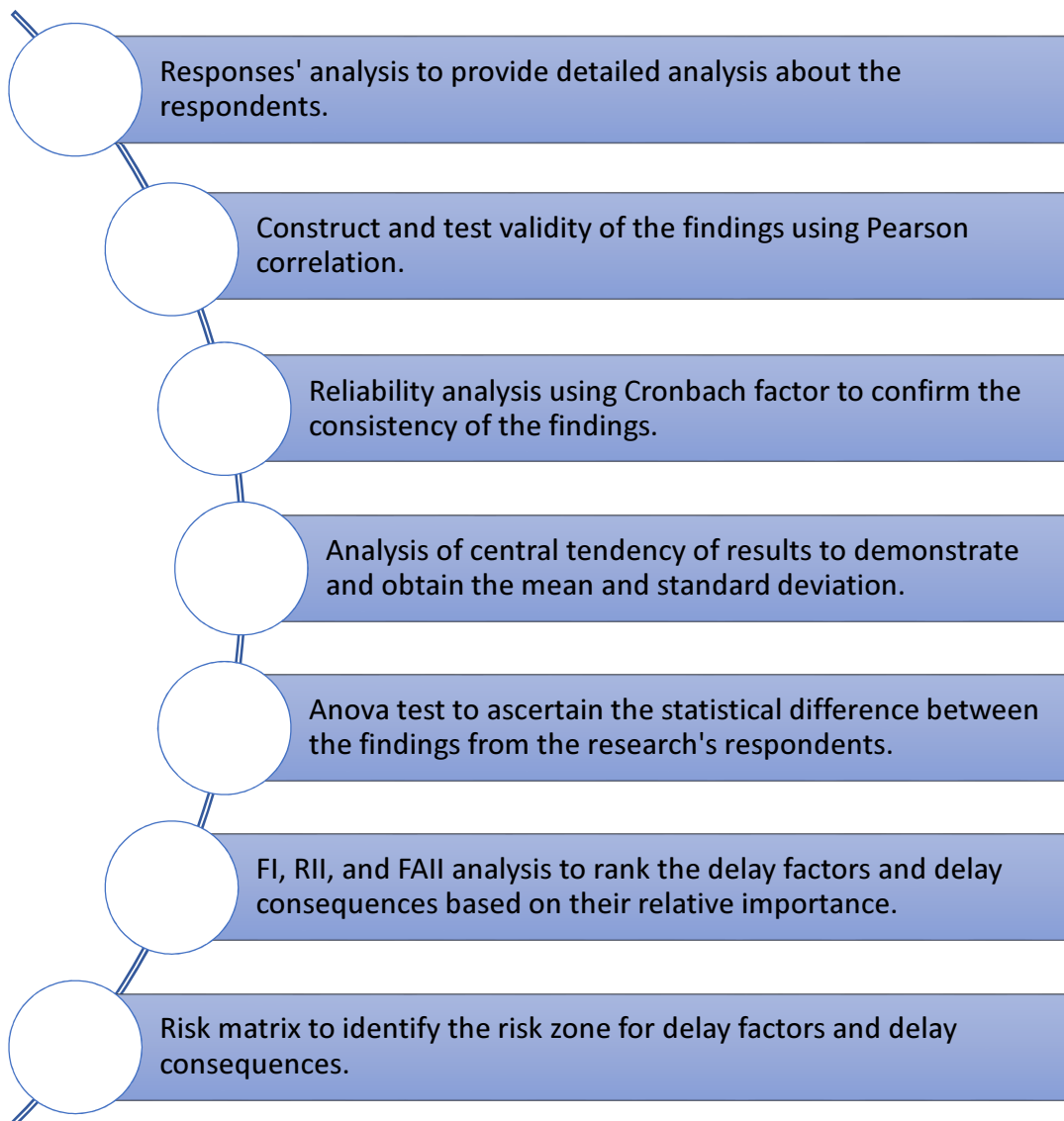


Figure 5: Statistical analysis flow chart

4.2 Responses Analysis

Questionnaire was distributed via google form web-link, and through hard copies to selective samples in petrochemical industries, oil and gas companies that shares similar work system, and contractors working in projects in petrochemical industries.

The overall responses were 63 responses with no missing data due to distribution the questionnaires to precise selective group, and making all the questions as a mandatory in the google web questionnaire based.

The number of sample size in petrochemical industries population was computed based on the equations (6) and (7) respectively.

$$n = \frac{m}{1 + \left(\frac{m-1}{N}\right)} \quad (6)$$

Where n = sample size of limited population; m = unlimited sample size of population; and N is the size available of population.

m was computed based on the equation (7)

$$m = \frac{Z^2 P (1-P)}{e^2} \quad (7)$$

Where Z=1.96 for confidence level = 95%; P= population proportion = 0.5 as a conservative value for unknown proportion, e= estimate margin of error = 12.6% for non-probability sampling for industrial standard at 95% confidence level (What is margin of error, n.d.).

Thus, by substituting in equation (7), for unlimited population sample size, $m = \frac{(1.96^2 \times 0.5 \times (1-0.5))}{0.126^2} = 60$

By substituting valve m =60 in Equation 6 to obtain the representative sample size for the finite population for petrochemical industries

company under study= $n = \frac{60}{1 + (\frac{60-1}{68})} = 32$, that satisfied 95% confidence of interval.

The overall response rate was 58.33% of total distributed questionnaires, which was above the average response rate for studies that utilized data gathered from organizational respondents 35.6% (Baruch and Brooks C, 2008).

Table 5: Population and response rate

	Petrochemical	Oil & gas	Contractor
Target population	68	20	20
Responses	39	13	11
Response %	57.35%	65.0%	55.0%

The highest frequency of the respondents was from the targeted Petrochemical company with 61.9% of total responses, followed by contractors with 17.5%, and finally people working in different oil and gas companies as 20.6%.

Table 6: Industry of the respondents

Industry	Frequency	Percent	Valid Percent	Cumulative Percent
PETROCHEMICAL	39	61.9	61.9	61.9
CONTRACTOR	11	17.5	17.5	79.4
OIL & GAS	13	20.6	20.6	100.0
Total	63	100.0	100.0	-

The respondents were personnel from the mentioned above companies and industries, which highly support the outcomes of the report. The highest participants were having more than 15 years of experience 46%, followed by people having 11-15 years' experience 27%. So,

73% of respondents were having more than 10 years which shall enlighten the outcomes of the research.

Note: The minimum requirement to be selected to enter to this questionnaire was to have a minim 3 years of experience to allow the credibility and practicality of knowing the difficulties of projects process and their impacts.

Table 7: Years of experience of the respondents

Years of experience	Frequency	Percent	Valid Percent	Cumulative Percent
3-5 years	4	6.3	6.3	6.3
6-10 years	13	20.6	20.6	27.0
11-15 years	17	27.0	27.0	54.0
Above 15 years	29	46.0	46.0	100.0
Total	63	100.0	100.0	-

As initially aimed, the main focus was on maintenance and projects categories which consists 39.7% and 25.5 % respectively from over all participants. This is followed by technical services department personnel with 17.5 %, and operation personnel with 11.1% of total respondents.

Note: The others are referred to quality auditors whom are carrying out the compliance audit of the systems, and have experience in quality processes and current situation of the petrochemical industries on the basis of quality assurance audits and recommendations.

Table 8: Working field of the respondents

Working field	Frequency	Percent	Valid Percent	Cumulative Percent
Maintenance	25	39.7	39.7	39.7
Technical services	11	17.5	17.5	57.1
Operation	7	11.1	11.1	68.3
Purchasing and Material	2	3.2	3.2	71.4
Projects	16	25.4	25.4	96.8
Other	2	3.2	3.2	100.0
Total	63	100.0	100.0	-

4.3 Construct and Test Validity Using Pearson Correlation

Pearson correlation test is used to assess the validity of the data when correlated with the overall composed sum for delay factors. This has to be done twice, once for the frequency of occurrence and second, for the severity level. And similarly, for delay consequences (For frequency of occurrence, and impact level of the consequence).

4.3.1 Validity of delay factors

Majority of components of Likert scale data showed a very high correlation with the overall results of sum of the factors in terms of frequency and severity. For instance, the value obtained for “delay in preparation documents” was 0.634 which is significant at 0.01 level and at 99% confidence interval.

The only one exception of all correlation (84 correlations) was the severity of the “late design change” which found with lower value of correlation and equal 0.217 with P-value =0.088, while the frequency

Pearson value was 0.526 as per below table and achieving the significant correlation level at 0.01 level.

Here to mention that, if P-value was less than the significance level, then sample contains sufficient evidence to reject the null hypothesis and conclude that the correlation coefficient does not equal zero. In other word, the sample data support the notion that relationship exist in population. The correlation coefficient donated by r is measured statistically, where zero indicates no linear relation and one is the highest correlation positively or negatively (DM STAT-1, n.d.).

Pearson is geometrically function of the angle between two vectors, and calculated as per Table 9 obtained from SPSS.

Table 9: Pearson correlation for delay factors

SN	Delay factor	Analysis	Pearson correlation for delay factor frequency	Pearson correlation for delay factor severity
1	Late design changes	Pearson Correlation	.526**	0.217
		Sig. (2-tailed)	0.000	0.088
		N	63	63
2	Incomplete documents	Pearson Correlation	.480**	.413**
		Sig. (2-tailed)	0.000	0.001
		N	63	63
3	Delay in preparation of documents	Pearson Correlation	.634**	.500**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
4	Mistakes in design	Pearson Correlation	.630**	.519**
		Sig. (2-tailed)	0.000	0.000
		N	63	63

Table 9 (Continued): Pearson correlation for delay factors

SN	Delay factor	Analysis	Pearson correlation for delay factor frequency	Pearson correlation for delay factor severity
5	Bureaucracy in organization	Pearson Correlation	.405**	.483**
		Sig. (2-tailed)	0.001	0.000
		N	63	63
6	Unrealistic project duration	Pearson Correlation	.579**	.317*
		Sig. (2-tailed)	0.000	0.011
		N	63	63
7	Variation	Pearson Correlation	.642**	.420**
		Sig. (2-tailed)	0.000	0.001
		N	63	63
8	Slow decision making	Pearson Correlation	.698**	.586**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
9	Fast-track project delivery strategy	Pearson Correlation	.329**	.281*
		Sig. (2-tailed)	0.009	0.026
		N	63	63
10	lowest bid price system	Pearson Correlation	.409**	.481**
		Sig. (2-tailed)	0.001	0.000
		N	63	63
11	Poor definition of interfaces	Pearson Correlation	.655**	.636**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
12	Inadequate project duration	Pearson Correlation	.595**	.592**
		Sig. (2-tailed)	0.000	0.000
		N	63	63

Table 9 (Continued): Pearson correlation for delay factors

SN	Delay factor	Analysis	Pearson correlation for delay factor frequency	Pearson correlation for delay factors severity
13	Complicated tender procedures	Pearson Correlation	.522**	.653**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
14	Late delivery of material or equipment	Pearson Correlation	.639**	.646**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
15	Material shortage or scarcity	Pearson Correlation	.579**	.675**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
16	Poor procurement programming	Pearson Correlation	.656**	.737**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
17	Problem with equipment transportation	Pearson Correlation	.525**	.545**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
18	Poor contract management	Pearson Correlation	.725**	.774**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
19	Inadequate project planning	Pearson Correlation	.668**	.765**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
20	Delay in inspection and testing	Pearson Correlation	.649**	.637**
		Sig. (2-tailed)	0.000	0.000
		N	63	63

Table 9 (Continued): Pearson correlation for delay factors

SN	Delay factor	Analysis	Pearson correlation for delay factor frequency	Pearson correlation for delay factor severity
21	Inadequate quality assurance and quality control	Pearson Correlation	.550**	.583**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
22	Lack of ownership	Pearson Correlation	.519**	.574**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
23	Delay in handing over site to the contractor	Pearson Correlation	.592**	.596**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
24	Accidents	Pearson Correlation	.487**	.488**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
25	Security and slow site clearance	Pearson Correlation	.447**	.537**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
26	work permits	Pearson Correlation	.547**	.504**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
27	Weather effect	Pearson Correlation	.361**	.371**
		Sig. (2-tailed)	0.004	0.003
		N	63	63
28	Summer restriction	Pearson Correlation	.430**	.452**
		Sig. (2-tailed)	0.000	0.000
		N	63	63

Table 9 (Continue): Pearson correlation for delay factors

SN	Delay factor	Analysis	Pearson correlation for delay factor frequency	Pearson correlation for delay factor severity
29	Way-leave approval	Pearson Correlation	.518**	.483**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
30	Shortage of manpower	Pearson Correlation	.620**	.646**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
31	Manpower productivity	Pearson Correlation	.448**	.553**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
32	Poor understanding of scope by contractor	Pearson Correlation	.679**	.651**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
33	Poor estimation of time by contractor	Pearson Correlation	.648**	.558**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
34	Poor project planning by contractor	Pearson Correlation	.657**	.648**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
35	Inadequate contractor experience	Pearson Correlation	.502**	.603**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
36	Subcontractors	Pearson Correlation	.349**	.593**
		Sig. (2-tailed)	0.005	0.000
		N	63	63

Table 9 (Continued): Pearson correlation for delay factors

SN	Delay factor	Analysis	Pearson correlation for Delay factor frequency	Pearson correlation for delay factor severity
37	Rework	Pearson Correlation	.448**	.493**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
38	Poor communication between contractor and project parties	Pearson Correlation	.461**	.692**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
39	Insufficient contractor's manpower	Pearson Correlation	.705**	.779**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
40	Shortage of skilled labors by contractor	Pearson Correlation	.681**	.660**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
41	Lack of communication between parties involved	Pearson Correlation	.644**	.706**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
42	Lack of periodical meetings	Pearson Correlation	.594**	.561**
		Sig. (2-tailed)	0.000	0.000
		N	63	63

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

4.3.2 Validity of delay consequences

All of the delay consequences' frequency and impact found to have a high association with composed sum value of delay

consequences, with correlation values that were significant at 0.01 level, as per Table 10.

Highest Pearson coefficients r was found to be equal to 0.780 “Declination of reputation and confidence in project team” for the delay consequence impact calculation.

Lowest correlation obtained was for the delay consequence impact for the item “extension of works beyond the normal working hours to cope with new schedule” and equal $r = 0.391$ with $p\text{-value}=0.002$ which was still significant at 0.01 level.

Detail of the Pearson results are as per Table 10 below.

Table 10: Pearson correlation for delay consequences

SN	Delay consequence	Analysis	Pearson correlation for delay consequence frequency	Pearson correlation for delay consequence impact level
1	Time overrun	Pearson Correlation	.672**	.549**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
2	Disputes	Pearson Correlation	.679**	.583**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
3	Idling of resources	Pearson Correlation	.607**	.638**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
4	Lack of continuity by the management.	Pearson Correlation	.726**	.642**
		Sig. (2-tailed)	0.000	0.000
		N	63	63

Table 10 (Continued): Pearson correlation for delay consequences

SN	Delay factors	Analysis	Pearson correlation for delay consequence frequency	Pearson correlation for delay consequence impact level
5	Cost overrun	Pearson Correlation	.679**	.635**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
6	Declination of reputation of project team	Pearson Correlation	.715**	.780**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
7	Distrust with the contractor	Pearson Correlation	.569**	.580**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
8	Blacklisting the contractor	Pearson Correlation	.646**	.671**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
9	Delay of other related projects	Pearson Correlation	.769**	.708**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
10	Extension of works beyond normal working hours	Pearson Correlation	.573**	.391**
		Sig. (2-tailed)	0.000	0.002
		N	63	63
11	Importing the utilities and material from outside	Pearson Correlation	.603**	.685**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
12	Change the form of delivery of material	Pearson Correlation	.522**	.471**
		Sig. (2-tailed)	0.000	0.000
		N	63	63

Table10 (Continued): Pearson correlation for delay consequences

SN	Delay factors	Analysis	Pearson correlation for delay consequence frequency	Pearson correlation for delay consequence impact level
13	Compromise the quality of work	Pearson Correlation	.671**	.640**
		Sig. (2-tailed)	0.000	0.000
		N	63	63
14	Not achieving production target	Pearson Correlation	.491**	.680**
		Sig. (2-tailed)	0.000	0.000
		N	63	63

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

4.4 Reliability Analysis

Reliability refers to whether the data collection techniques and analytic procedures would reproduce consistent findings if they were repeated on another occasion or if they were replicated by another person.

Reliability of the delay factors and delay consequences were evaluated through SPSS software by obtaining Cronbach factor.

4.4.1 Reliability analysis for delay factors

The Reliability test for delay factors will be carried out twice:

- 1) For delay factors frequency of occurrence:

The results indicate a very high internal consistency with 0.945 Cronbach Alpha value.

Table 11: Reliability test for delay factors frequency

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.945	0.946	42

The high internal consistency was supported with finding that, there was no significant effect of the deletion process of any of the standardized delay factors, and the lowest Cronbach factor obtained was 0.943. The detail of this process was computed by using SPSS program as tabulated in Table 12.

Table 12: Analysis of Cronbach's alpha for delay factors frequency

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
1	Late design changes	108.349	484.328	0.496	0.944
2	Incomplete documents	108.476	484.963	0.446	0.944
3	Delay in preparation of documents	108.285	477.756	0.607	0.943
4	Mistakes in design	108.968	480.676	0.606	0.943
5	Bureaucracy in organization	108.667	486.355	0.363	0.945
6	Unrealistic project duration	108.587	480.440	0.549	0.944

Table 12 (Continued): Analysis of Cronbach's alpha for delay factors frequency

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
7	Variation	108.397	477.082	0.614	0.943
8	Slow decision making	108.603	472.275	0.672	0.943
9	Fast-track project delivery strategy	108.412	492.924	0.293	0.945
10	lowest bid price system	107.794	486.586	0.368	0.945
11	Poor definition of interfaces	108.746	475.289	0.627	0.943
12	Inadequate project duration	108.794	477.618	0.563	0.944
13	Complicated tender procedures	108.175	481.308	0.486	0.944
14	Late delivery of material or equipment	108.508	483.544	0.618	0.943
15	Material shortage or scarcity	108.984	479.532	0.547	0.944

Table 12 (Continued): Analysis of Cronbach's alpha for delay factors frequency

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
16	Poor procurement programming	108.841	477.652	0.630	0.943
17	Problem with equipment transportation	109.191	485.221	0.496	0.944
18	Poor contract management	108.714	473.562	0.703	0.943
19	Inadequate project planning	108.556	473.735	0.640	0.943
20	Delay in inspection and testing	108.936	479.383	0.624	0.943
21	Inadequate quality assurance and quality control	109.159	485.265	0.524	0.944
22	Lack of ownership	108.952	481.594	0.483	0.944
23	Delay in handing over site to the contractor	109.063	483.512	0.567	0.944
24	Accidents	109.524	490.479	0.463	0.944

Table 12 (Continued): Analysis of Cronbach's alpha for delay factors frequency

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
25	Security and slow site clearance	108.619	482.433	0.403	0.945
26	work permits	108.809	483.576	0.518	0.944
27	Weather effect	108.905	491.410	0.326	0.945
28	Summer restriction	108.048	484.724	0.388	0.945
29	Way-leave approval	108.397	480.114	0.480	0.944
30	Shortage of manpower	108.698	481.472	0.595	0.943
31	Manpower productivity	109.095	488.410	0.416	0.945
32	Poor understanding of scope by contractor	108.698	478.633	0.657	0.943
33	Poor estimation of time by contractor	108.667	480.065	0.624	0.943
34	Poor project planning by contractor	108.825	478.082	0.632	0.943
35	Inadequate contractor experience	109.254	485.870	0.472	0.944

Table 12 (Continued): Analysis of Cronbach's alpha for delay factors frequency

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
36	Subcontractors	108.809	491.189	0.312	0.945
37	Rework	108.952	489.724	0.419	0.945
38	Poor communication between contractor and project parties	108.968	487.451	0.429	0.944
39	Insufficient contractor's manpower	108.761	477.281	0.683	0.943
40	Shortage of skilled labors by contractor	108.857	475.608	0.656	0.943
41	Lack of communication between parties involved	108.714	478.982	0.619	0.943
42	Lack of periodical meetings	108.857	478.705	0.563	0.944

2) For delay factors severity level:

For delay factors severity level, same method has been deployed with internal consistency measured in terms of Cronbach Alpha factor and equal to 0.947.

Table 13: Reliability test for delay factors severity level

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.947	0.947	42

This high Cronbach value indicated that all items of delay factors were in high association and were eligible for further evaluation.

Any deletion of any factors, the Cronbach Alpha factors found to have no significance deference and maximum Cronbach Alpha reached to 0.948.

Table 14: Analysis of Cronbach's alpha for delay factors severity

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
1	Late design changes	128.682	579.962	0.183	0.948
2	Incomplete documents	128.825	568.953	0.378	0.947
3	Delay in preparation of documents	128.778	562.047	0.464	0.946
4	Mistakes in design	128.524	564.479	0.488	0.946
5	Bureaucracy in organization	129.048	562.885	0.446	0.947

Table 14 (Continued): Analysis of Cronbach's alpha for delay factors severity

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
6	Unrealistic project duration	128.794	574.392	0.281	0.947
7	Variation	128.667	568.355	0.384	0.947
8	Slow decision making	129.016	559.113	0.556	0.946
9	Fast-track project delivery strategy	128.889	576.520	0.246	0.948
10	lowest bid price system	128.825	563.695	0.445	0.947
11	Poor definition of interfaces	128.809	557.447	0.610	0.945
12	Inadequate project duration	128.682	556.027	0.559	0.946
13	Complicated tender procedures	128.794	557.876	0.628	0.945
14	Late delivery of material or equipment	127.825	559.501	0.623	0.945

Table 14 (Continued): Analysis of Cronbach's alpha for delay factors severity

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
15	Material shortage or scarcity	128.349	555.650	0.651	0.945
16	Poor procurement programming	128.524	555.253	0.718	0.945
17	Problem with equipment transportation	128.841	561.136	0.513	0.946
18	Poor contract management	128.794	549.812	0.756	0.944
19	Inadequate project planning	128.619	553.207	0.747	0.945
20	Delay in inspection and testing	128.921	557.784	0.611	0.945
21	Inadequate quality assurance and quality control	128.809	558.899	0.552	0.946
22	Lack of ownership	128.936	560.673	0.545	0.946

Table 14 (Continued): Analysis of Cronbach's alpha for delay factors severity

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
23	Delay in handing over site to the contractor	128.936	560.899	0.569	0.946
24	Accidents	128.587	561.279	0.449	0.947
25	Security and slow site clearance	129.349	561.392	0.505	0.946
26	work permits	129.254	565.580	0.473	0.946
27	Weather effect	129.222	570.595	0.333	0.947
28	Summer restriction	129.174	568.082	0.419	0.947
29	Way-leave approval	129.016	565.435	0.450	0.946
30	Shortage of manpower	128.635	561.461	0.624	0.945
31	Manpower productivity	128.984	563.564	0.525	0.946
32	Poor understanding of scope by contractor	128.746	556.547	0.626	0.945
33	Poor estimation of time by contractor	128.619	563.756	0.531	0.946

Table 14 (Continued): Analysis of Cronbach's alpha for delay factors severity

SN	Delay factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
34	Poor project planning by contractor	128.698	557.279	0.622	0.945
35	Inadequate contractor experience	128.619	554.724	0.570	0.946
36	Subcontractors	128.968	558.128	0.563	0.946
37	Rework	128.476	561.705	0.455	0.946
38	Poor communication between contractor and project parties	128.889	551.358	0.667	0.945
39	Insufficient contractor's manpower	128.76	550.281	0.762	0.944
40	Shortage of skilled labors by contractor	128.984	556.209	0.635	0.945
41	Lack of communication between parties involved	128.889	554.971	0.684	0.945
42	Lack of periodical meetings	129.286	563.175	0.533	0.946

4.4.2 Reliability analysis of delay consequences

The reliability analysis was done also for delay consequences frequency of occurrence, and for the impact of the delay consequences.

1) Delay consequences frequency of occurrence

Table 15: Reliably test of delay consequences frequency of occurrence

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.886	.888	14

Although the Cronbach factor was less than the figure obtained for the delay factors frequency, but it still considered as a high value at 88.6% of consistency.

This value was reflected on the internal consistency of all items, as the reliability remained almost constant despite deletion of any standard item as per Table 16.

Table 16: Analysis of Cronbach's alpha for delay consequences frequency of occurrence

SN	Delay Consequence	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
1	Time overrun	31.873	58.145	.600	.877
2	Disputes	32.333	58.000	.607	.876
3	Idling of resources	32.175	59.469	.528	.880

Table 16 (Continued): Analysis of Cronbach's alpha for delay consequences frequency of occurrence

SN	Delay Consequence	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
4	Lack of continuity by the management	32.746	58.709	.673	.874
5	Cost overrun	32.032	57.676	.605	.876
6	Declination of reputation of project team	32.651	58.876	.661	.875
7	Distrust with the contractor.	32.540	59.575	.479	.883
8	Blacklisting contractor	32.873	59.500	.580	.878
9	Delay of other related projects	32.270	56.813	.715	.871
10	Extension of works beyond normal working hours	31.429	58.959	.477	.883
11	Importing the utilities and material from outside	32.635	59.590	.525	.880

Table 16 (Continued): Analysis of Cronbach's alpha for delay consequences frequency of occurrence

SN	Delay Consequence	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
12	Change the form of delivery of material	32.4921	61.641	.447	.883
13	Compromising the quality of work	32.6032	57.727	.595	.877
14	Not achieving production target	32.9048	61.442	.403	.885

2) Delay consequence impact level

There was no significant difference in the analysis of the frequency of delay consequences, as the Cronbach remained at higher side at 0.876 as per Table 17.

Table 17: Reliability test for delay consequences impact

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.876	.876	14

The effect of deletion of any of the delay consequence on the total Cronbach factor was calculated and showed no significance effect on

the results. All the results after deleting of any factors were ranging from 0.859 to 0.878 as per Table 18 calculation.

Table 18: Analysis of Cronbach's alpha for delay consequences impact

SN	Delay Consequence	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
1	Time overrun	39.619	78.691	.477	.871
2	Disputes	40.063	76.964	.504	.870
3	Idling of resources	40.429	76.668	.572	.867
4	Lack of continuity by the management	40.079	74.107	.556	.867
5	Cost overrun	39.603	74.630	.551	.868
6	Declination of reputation of project team	39.952	72.820	.729	.859
7	Distrust with the contractor.	40.238	76.475	.495	.870
8	Blacklisting contractor	40.063	73.770	.593	.865
9	Delay of other related projects	39.413	74.698	.647	.863

Table 18 (Continued): Analysis of Cronbach's alpha for delay consequences impact

SN	Delay Consequence	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
10	Extension of works beyond normal working hours	39.937	81.222	.303	.878
11	Importing the utilities and material from outside	39.921	74.848	.619	.864
12	Change the form of delivery of material	40.095	78.926	.377	.876
13	Compromising the quality of work	39.397	74.405	.556	.867
14	Not achieving production target	39.365	72.719	.597	.865

4.5 Analysis of the Central Tendency of the Results

The central tendency was evaluated by obtaining the mean of the frequency as per equation (1), mean of importance as per equation (2) in the methodology, and the standard deviation for the variability between each factor. It was an essential step to ascertain the highest ranked factor, and evaluate the dispersion for each factor. The central

tendency analysis was conducted for delay factor, delay consequences and delay groups.

4.5.1 Central tendency analysis for delay factors

Mean and standard variation for each delay factor were calculated in terms of the frequency of occurrence and the severity level as follows:

Table 19: Central tendency analysis for delay factors

Delay factor		Frequency of occurrence		Severity level	
SN	Description	Mean	Std. Dev.	Mean	Std. Dev.
Design and Engineering related factors					
1	Late design changes initiating in the project life cycle	3.032	0.915	3.270	0.846
2	Incomplete/unclear drawing and project documents	2.905	0.979	3.127	1.008
3	Delay in preparation, approval and issuance of drawings and documents	3.095	0.995	3.175	1.129
4	Mistakes and discrepancies made in design documents	2.413	0.891	3.429	0.979
Management related factors					
5	Bureaucracy in the organization	2.714	1.099	2.905	1.132
6	Owner influence (Unrealistic project duration imposed by owner)	2.794	0.986	3.159	0.954
7	Owner interference (Changes, and scope variation)	2.984	1.008	3.286	1.023
8	Slow decision making and approval by the owner organization	2.778	1.084	2.937	1.061
9	Adoption of fast-track project delivery strategy	2.968	0.879	3.064	0.914

Table 19 (Continued): Central tendency analysis for delay factors

Delay factor		Frequency of occurrence		Severity level	
SN	Description	Mean	Std. Dev.	Mean	Std. Dev.
10	Adoption of the lowest bid price system for awarding the contract	3.587	1.072	3.127	1.100
Contract related factors					
11	Poor definition of interfaces causing scope creep	2.635	1.052	3.143	1.030
12	Inadequate project duration defined in the original contract	2.587	1.072	3.270	1.167
13	Complicated and long tendering procedures to award the contract	3.206	1.065	3.159	0.987
Material and equipment related factors					
14	Late delivery of material or equipment.	2.873	0.772	4.127	0.942
15	Material shortage or scarcity	2.397	1.025	3.603	1.025
16	Poor procurement programming of materials (Late order or wrong sequence of order)	2.540	0.964	3.429	0.946
17	Problem with equipment transportation and delivery to the site	2.191	0.877	3.111	1.064
Project management related factors					
18	Poor contract and schedule management by the project team	2.667	1.000	3.159	1.050
19	Inadequate project planning, budgeting, and scheduling	2.825	1.086	3.333	0.967
20	Delay in performing inspection and testing	2.444	0.912	3.032	1.016
21	Inadequate quality assurance and quality control	2.222	0.832	3.143	1.075
22	Lack of ownership in the project, and conflict between owners of the project	2.429	1.058	3.016	1.024

Table 19 (Continued): Central tendency analysis for delay factors

Delay factor		Frequency of occurrence		Severity level	
SN	Description	Mean	Std. Dev.	Mean	Std. Dev.
23	Delay in handing over the construction site to the contractor	2.318	0.839	3.016	0.975
Site and work execution related factors					
24	Accidents during the construction.	1.857	0.692	3.365	1.195
25	Security and slow site clearance (checking process for quality, safety and other purposes)	2.762	1.201	2.603	1.071
26	Difficulties and delay in obtaining work permits	2.571	0.911	2.698	0.961
27	Weather effect: (heat, rain, wind, sand storm, etc.)	2.476	0.895	2.730	1.035
28	Summer restriction on time of work	3.333	1.122	2.778	0.958
29	Delay in Way-leave approval from authorities	2.984	1.129	2.937	1.014
Manpower related factors					
30	Shortage of manpower.	2.683	0.877	3.318	0.877
31	Unexpected low manpower productivity	2.286	0.869	2.968	0.950
Contractor related factors					
32	Poor understanding of the scope of work during the bidding stage	2.683	0.895	3.206	1.034
33	Poor estimation of project time, material quantity requirement before contracting	2.714	0.888	3.333	0.933
34	Inadequate project planning, budgeting, and scheduling by the contractor	2.556	0.947	3.254	1.016
35	Inadequate contractor experience	2.127	0.889	3.333	1.191

Table 19 (Continued): Central tendency analysis for delay factors

Delay factor		Frequency of occurrence		Severity level	
SN	Description	Mean	Std. Dev.	Mean	Std. Dev.
Contractor related factors (Continue)					
36	Delay or problems caused by subcontractors	2.571	0.946	2.984	1.085
37	Rework due to errors, mistakes and defective works during construction	2.429	0.797	3.476	1.162
38	Poor communication and conflict between contractor and project parties	2.413	0.891	3.064	1.134
39	Insufficient contractor's manpower (or resources)	2.619	0.906	3.191	1.030
40	Shortage of skilled labors by the contractor	2.524	0.998	2.968	1.031
Common factors					
41	Lack of communication between parties involved	2.667	0.933	3.064	0.998
42	Lack of periodic meetings among the management, site personnel, and contractors	2.524	1.030	2.667	0.950

1) Analysis of delay factors' frequency of occurrence

The average of the all-delay factors frequency of occurrence was equal to 2.652. The highest mean was for delay factor 10 [Adoption of lowest bid price system] with 3.587, and lowest was delay factor 24 [Accident during construction] with 1.856.

The maximum standard variation was 1.201 for delay factor 25 [security and slow clearance], and with majority of standard deviation

values found to be below one, which was another indicator of the internal consistency of the results.

The central tendency of delay factors frequency of occurrence was summarized as Table 20.

Table 20: Summary of statistical analysis of delay factors frequency of occurrence

	Mean	Minimum	Maximum	Skewness	N of Items
Item Means	2.652	1.856	3.587	0.42	42

The below box plot in Figure 6 shows the outliers point at value equal to 3.587, which was the highest delay factor in terms of frequency of occurrence in petrochemical industries in Bahrain. This peak point was related to delay factor 10 [Adoption of the lowest bid price system for awarding the contract].

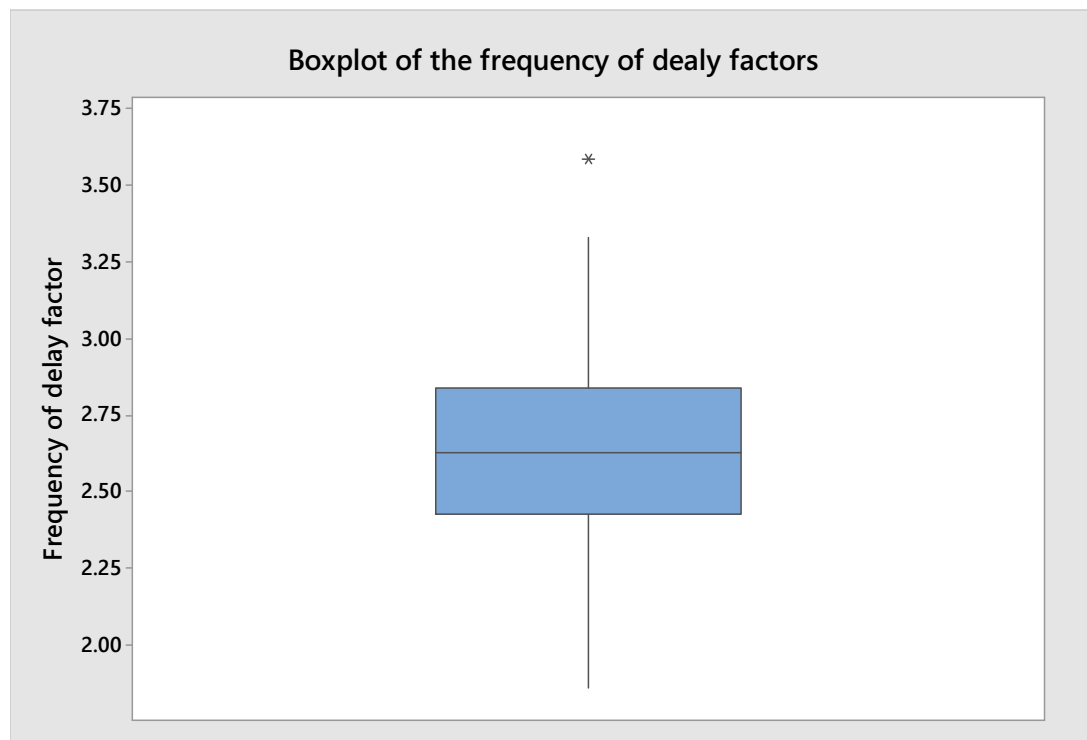


Figure 6: Boxplot of delay factors frequency of occurrence

Also, a graphical representation for the summary report for delay factors frequency of occurrence was plotted on histogram with statistical analysis which showed very low standard deviation level of 0.33 and P-value=0.53.

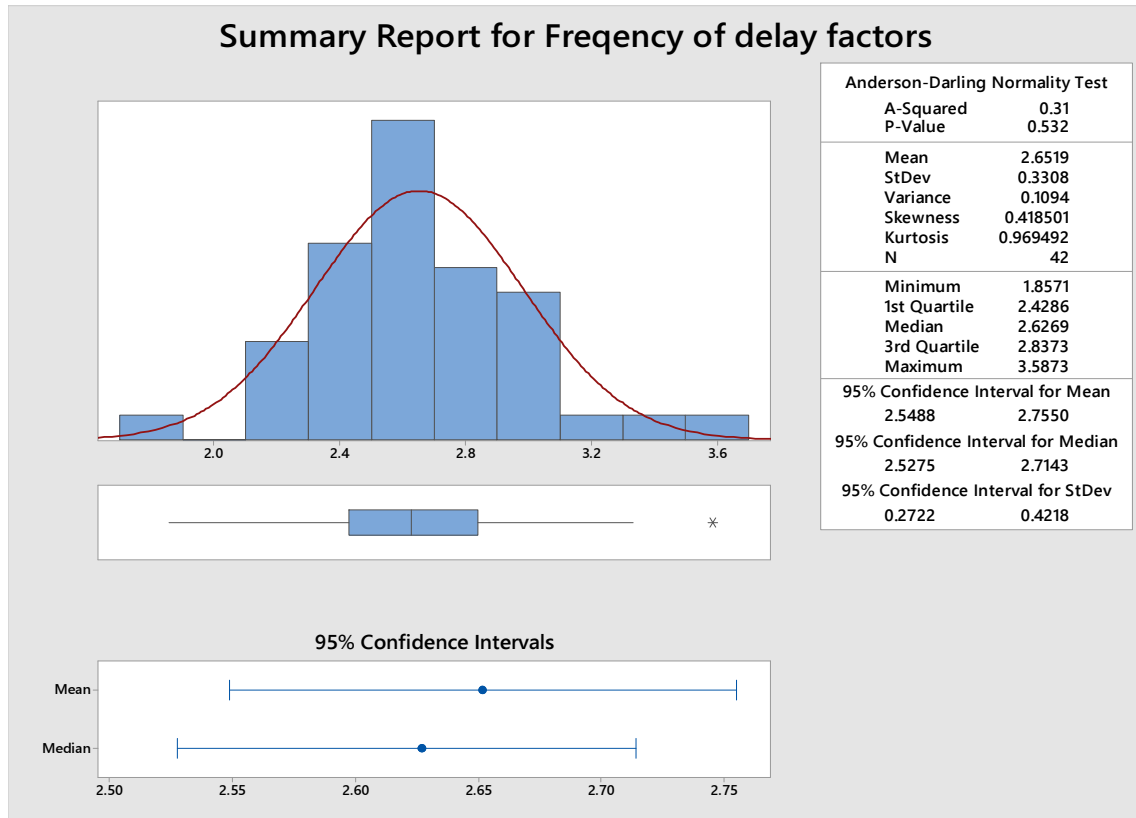


Figure 7: Summary report and histogram of delay factors frequency of occurrence

2) Analysis of delay factors' severity level

Similarly, the analysis for the severity level of delay factors was carried out, with average value of 3.142 for all the delay factors, with highest standard deviation of 1.195 for item 24 [Accidents during the construction].

As a direct comparison, the severity of delay factors got higher average weight, when compared to the frequency of occurrence of delay factors This difference was computed based on overall average

results as following: Average of delay factors on the occurrence scale – Average of delay factors severity level = $3.142 - 2.652 = 0.49$. This 0.49 degree on the 5-degree Likert scale was equivalent to $0.49/5 = 9.8\%$ difference from the total.

Also, the highest weightage was 4.127 for delay factor 14 [The late delivery of material and equipment], which was shown as an outlier point in box plot Figure 8 and marked in Table 21 as maximum value.

Table 21: Statistical summary of delay factors severity level

	Mean	Minimum	Maximum	Skewness	N of Items
Item Means	3.142	2.603	4.127	0.85	42

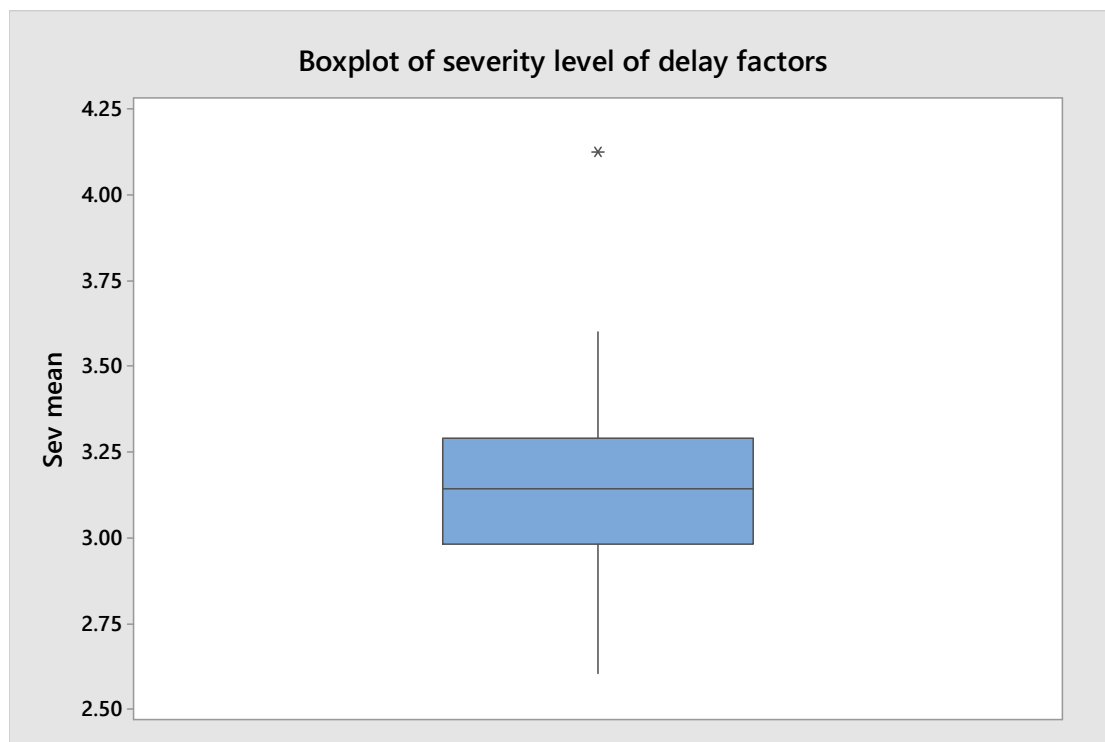


Figure 8: Box plot of delay factors severity level

Moreover, it was noticed the skewness was increased toward left and mean of the factors was shifted to point slightly beyond the middle point as shown in the below histogram – Figure 9.

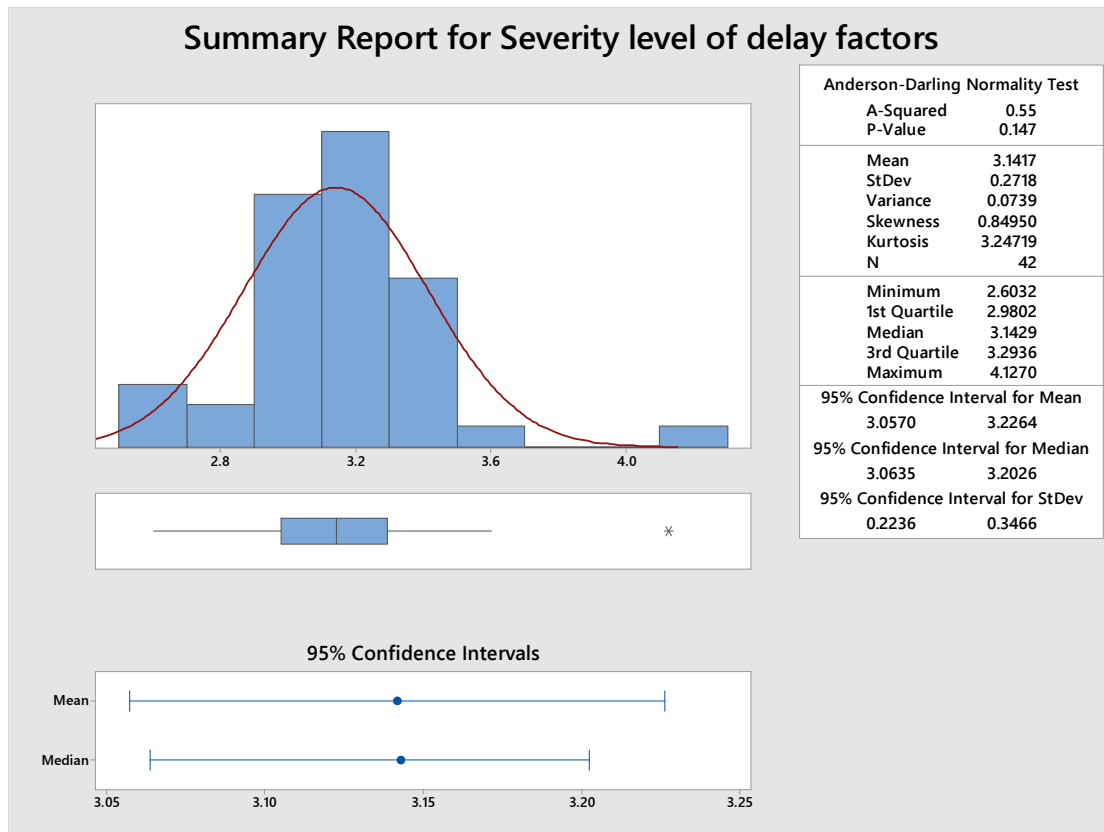


Figure 9: Summary report and histogram of delay factors severity level

4.5.2 Central tendency analysis for the delay consequences

Table 22 summarized the mean and standard deviation calculations for the delay consequences in terms of frequency of occurrence and impact level.

Table 22: Delay consequences central tendency analysis

Delay consequence		Frequency of occurrence		Impact level	
SN	Delay Consequence	Mean	Std. Deviation	Mean	Std. Deviation
1	Time overrun	3.016	0.959	3.318	0.895
2	Disputes between project parties	2.556	0.963	2.873	1.024
3	Idling of resources	2.714	0.923	2.508	0.948

Table 22 (Continued): Delay consequences central tendency analysis

Delay consequence		Frequency of occurrence		Impact level	
SN	Delay Consequence	Mean	Std. Deviation	Mean	Std. Deviation
4	Lack of continuity by the management	2.143	0.820	2.857	1.203
5	Cost overrun	2.857	0.998	3.333	1.164
6	Declination of reputation and confidence in the project team	2.238	0.817	2.984	1.055
7	Distrust with the contractor	2.349	0.986	2.698	1.087
8	Blacklisting the contractor by the owner	2.016	0.852	2.873	1.171
9	Delay of other projects related to the main and critical-path project	2.619	0.941	3.524	1.014
10	Extension of works beyond the normal working hours to cope with the new schedule	3.460	1.060	3.000	0.916
11	Importing the utilities and material that the company is not able to produce during the delay period of the project and outage of the unit	2.254	0.915	3.016	1.039
12	Change the form of delivery of material from Sea to air freight	2.397	0.794	2.841	1.050
13	Compromising the quality of work under pressure	2.286	1.007	3.540	1.175
14	Not achieving the production target	1.984	0.889	3.571	1.254

1) Analysis of delay consequence frequency of occurrence

The frequency of occurrence for the overall delay consequences was found with mean value at 2.49, with maximum value at 3.46 for delay consequence 10 [Extension of works beyond the normal working hours] which was the most frequently occurred delay consequence. The minimum delay consequence to occur was found with value equal to 1.984 for the delay consequence 14 [Not achieving the production target]. This analysis was summarized in Table 23.

Table 23: Statistical summary of delay consequences frequency of occurrence

	Mean	Minimum	Maximum	Range	Maximum / Minimum	ST. Deviation	N of Items
Item Means	2.492	1.984	3.460	1.476	1.476	.413	14

The box plot was appeared with no outliers, and with peak value reached to 3.460 and third quartile at 3.749 level.

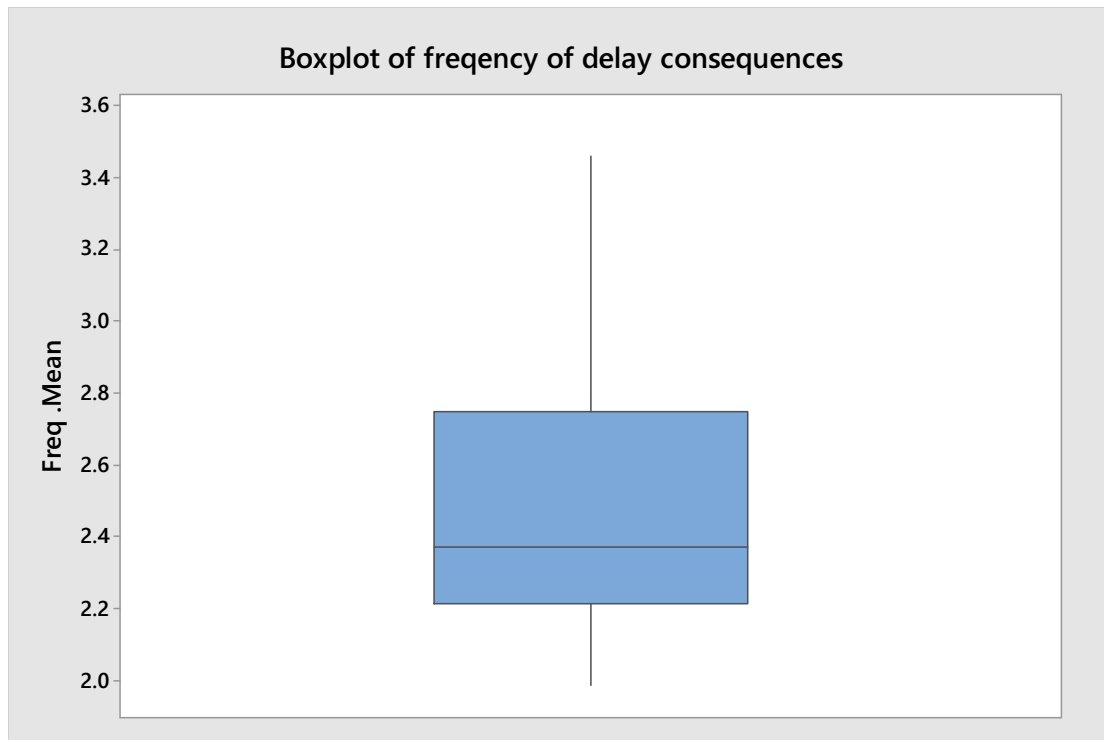


Figure 10: Box plot of delay consequences frequency of occurrence

The above box plot in Figure 10 shows that the body of the box which ranged from first quartile and third quartile was between 2.2 and 2.75 which indicted a very close proximity for the consequences rating.

The histogram and graphical representation shown in Figure 11 indicate the normality of the data at P-value=0.391 and standard deviation = 0.412. The Data were skewed to left, which indicate a low probability of occurrence of delay consequence in the petrochemical industries in Bahrain.

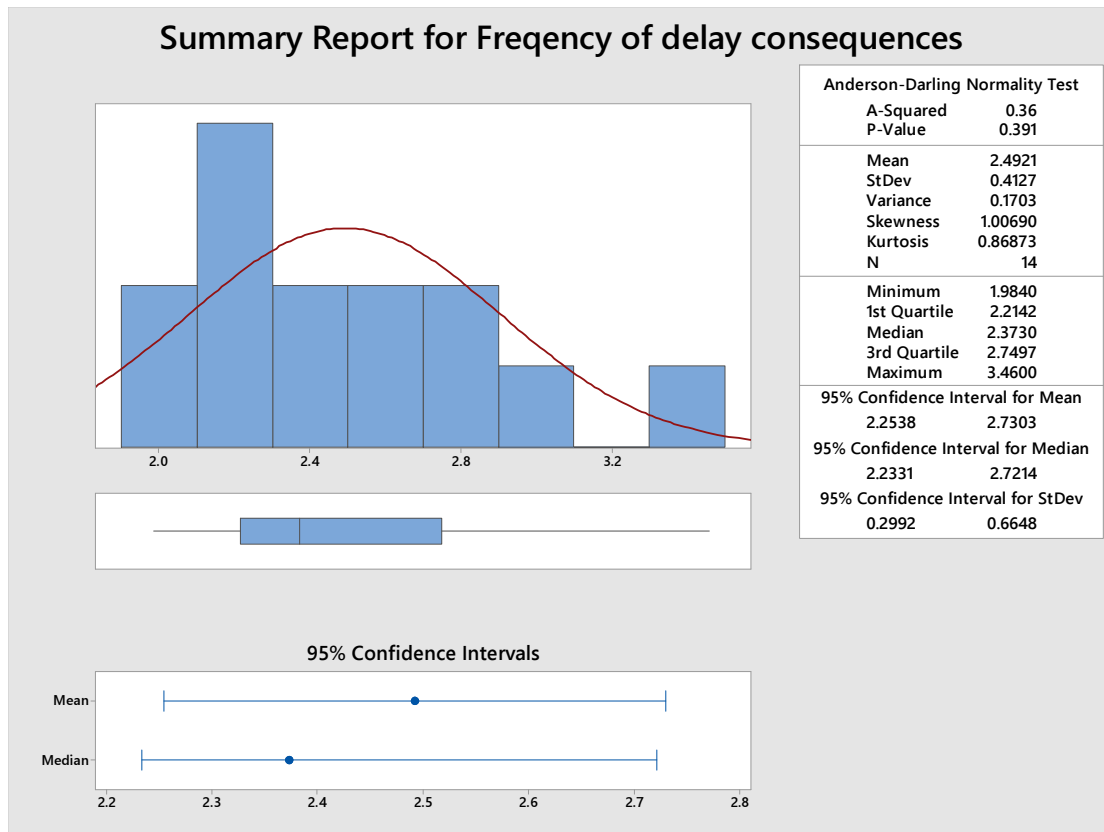


Figure 11: Summary report and histogram of delay consequences frequency of occurrence

2) Analysis of delay consequences impact level:

The statistical Summary for the impact level of delay consequences was computed as per Table 24.

Table 24: Statistical summary of delay consequences impact level

	Mean	Minimum	Maximum	Range	Maximum / Minimum	ST. Deviation	N of Items
Item Means	3.067	2.508	3.571	1.063	1.424	.334	14

Overall mean value was increased when compared to the overall mean of the frequency of occurrence and found to equal to 3.067. Minimum value was also increased from 1.98 in frequency of occurrence of delay consequence to 2.508 for delay consequence 3 [Idling of

resources], and maximum value remained relatively at same level and equal to 3.571 for delay consequence 14 [Not achieving the production target].

Below box plot in Figure 12 indicated that the median for the Likert scale analysis at 2.99 which approximately hitting the mean point = 3.067.

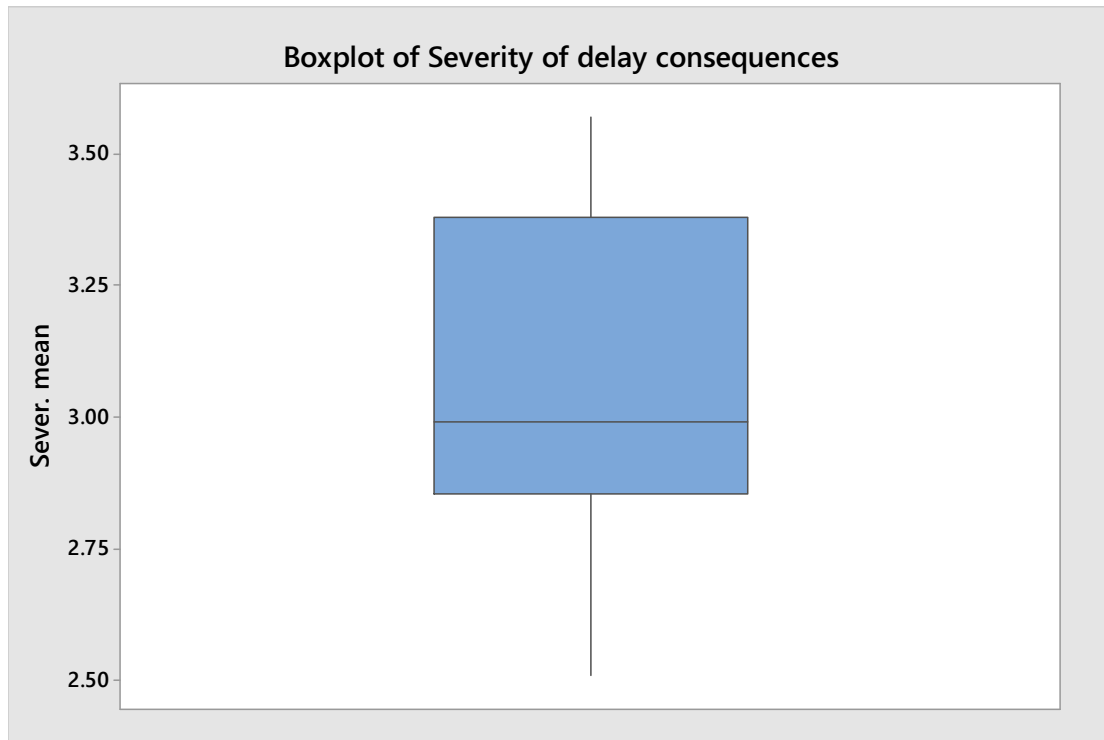


Figure 12: boxplot of delay consequences impact level

All the Points were scattered toward left and right, but not centrally distributed as per histogram representation in Figure 13. Therefore, ANOVA test was carried out in section 4.5 in this report, for participants' groups to test the variance in the perception of the impact level of delay consequences between the respondents' groups.

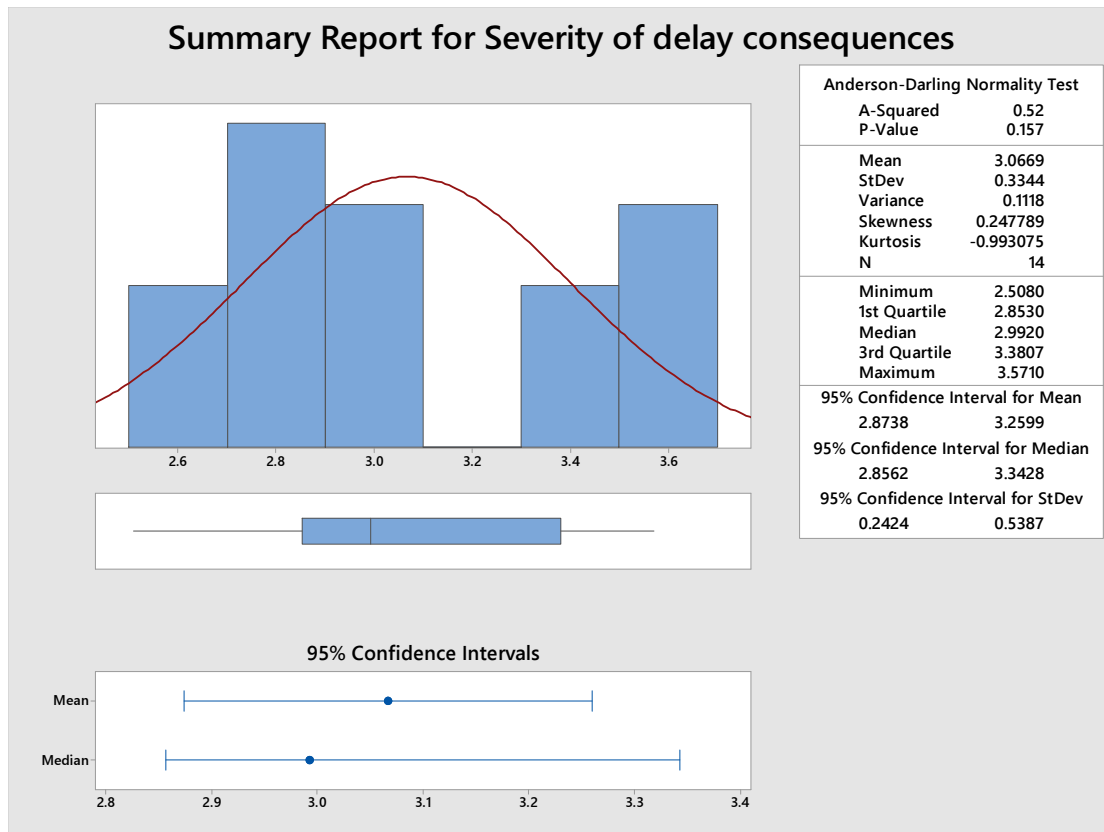


Figure 13: Summary report and histogram of delay consequences impact level

4.5.3 Central tendency analysis for delay factors groups

Analysis of mean value for each individual delay group was conducted as per Table 25 to find the most critical delay groups in terms of overall weightage. Analysis for the delay groups was carried out twice, once for the frequency of occurrence of its delay factors, and secondly for their severity level.

Table 25: statistical analysis of delay factors' groups

SN	Delay group	Total Delay factors	Delay factors frequency of occurrence			Delay factors severity level		
			Mean	Min	Max	Mean	Min	Max
1	Design related factors	4	2.861	2.413	3.095	3.250	3.127	3.429

Table 25 (Continued): statistical analysis of delay factors' groups

SN	Delay group	Total Delay factors	Delay factors frequency of occurrence			Delay factors severity level		
			Mean	Min	Max	Mean	Min	Max
2	Management related factors	6	2.971	2.714	3.587	3.079	2.905	3.286
3	Contract related factors	3	2.809	2.587	3.206	3.190	3.143	3.270
4	Material and equipment related factors	4	2.500	2.191	2.873	3.567	3.111	4.127
5	Project management related factors	6	2.484	2.222	2.825	3.226	3.016	3.333
6	Site related factors	6	2.664	1.857	3.333	2.852	2.603	3.365
7	Manpower related factors	2	2.484	2.286	2.683	3.143	2.968	3.317
8	Contractor related factors	9	2.515	2.127	2.714	3.201	2.9683	3.476
9	Common factors	2	2.595	2.524	2.667	2.865	2.667	3.063

Maximum mean value for frequency of occurrence for overall delay groups, was found for the delay group 2 [management related group] with mean = 2.971, with maximum individual value for delay factor 10 [Adoption of the lowest bid price system for awarding the contract] and equal to 3.587.

From severity level point of view, delay group 4 [material and equipment group] has secured the highest ranking, with mean value at

3.567, and contained the most severe delay factor number 14 [late delivery of material or equipment].

Moreover, the FI, RII and FAII were computed for the delay groups, as per equations, 3,4, and 5 in the methodology. The results were as per Table 26.

Table 26: FI, RII, and FAII analysis of delay factors groups

SN	Delay group	Total factors	FI	Rank	RII	Rank	FAII	Rank
1	Design related factors	4	0.572	2	0.650	2	0.372	1
2	Management related factors	6	0.594	1	0.616	7	0.366	2
3	Contract related factors	3	0.562	3	0.638	5	0.358	3
4	Material and equipment related factors	4	0.500	7	0.713	1	0.357	4
5	Project management related factors	6	0.497	8	0.645	3	0.321	6
6	Site related factors	6	0.533	4	0.570	9	0.304	8
7	Manpower related factors	2	0.497	9	0.629	6	0.312	7
8	Contractor related factors	9	0.503	6	0.640	4	0.322	5
9	Common factors	2	0.519	5	0.573	8	0.297	9

The most significant delay group after combining both the frequency of occurrence and severity level in terms of FAII, was found to be delay group number 1 [Design related factors] with FAII= 0.372,

followed by delay group number 2 [management related factors], with FAII= 0.366, then delay group 3 [contract related factors], and delay group 4 [material and equipment related factors], with FAII= 0.358 and 0.357 respectively. Remaining delay groups found to be below 0.350.

While evaluating the RII, the highest delay group was found to be delay group 2 [material and equipment related factors] of 71.3%, followed by group 1[design related factors] which appeared again in highest ranked delay groups with RII=0.65, and then delay group 5 [project management related factors] of 64.5%.

FI analysis result for the top three delay groups remained as same as FAII analysis, but with different sequencing, where delay group 2 [management related factors] scored the highest= 57.2%, followed by delay group 1 [design related factors] = 59.4%, and the third was the delay group 3 [contract related factors] with FI= 56.2%. These delay groups were the only groups that got more the 50% score in the FI analysis.

4.6 Analysis of Variance between the Participants' Industries

The study's data collection was through a Likert's scale questionnaire survey, and the main participants in this study were from the following industries: petrochemical industries, oil and gas, and contractor. Hence, ANOVA test was selected to test and identify if there were any significant differences between the participants from different industries before proceeding with further analysis and conclusion.

The composed total value for each participant from the above industries was used to carry out the comparison, and to obtain the quantitative analysis for the participants' industries.

Participants industries were summarized as per Table 5 in section 4.1, and were shown as the following number of respondents:

- 1) Petrochemical industries = 39
- 2) Oil and gas = 13
- 3) Contractor = 11

Hence, it was envisaged that possibly any participant could score in total any value between minimum value $[42 \times 1 = 42]$ and maximum $[42 \times 5 = 210]$, from the summation of 42 delay factors, that obtained from 63 participants, classified under three distinguished industries, who have responded to the questionnaire survey of 5 points Likert scale.

Similarly, any participant could score any value between minimum value $[14 \times 1 = 14]$ and maximum $[14 \times 5 = 70]$, for the ANOVA analysis for 14 delay consequences analyzed from the 63 participants in the three industries.

Based on the individual participants grading of the delay factors and delay consequences, individual box plots were plotted to aid the conclusion of the differences between the participants' industries. The ANOVA test was done for the following:

1) ANOVA test for delay factors

This test was analyzing the two aspects of delay factors; frequency of occurrence, and severity level.

The Figure 14 shows the ANOVA analysis for the summation of frequency of occurrence of delay factors for each individual participant under the three industries.

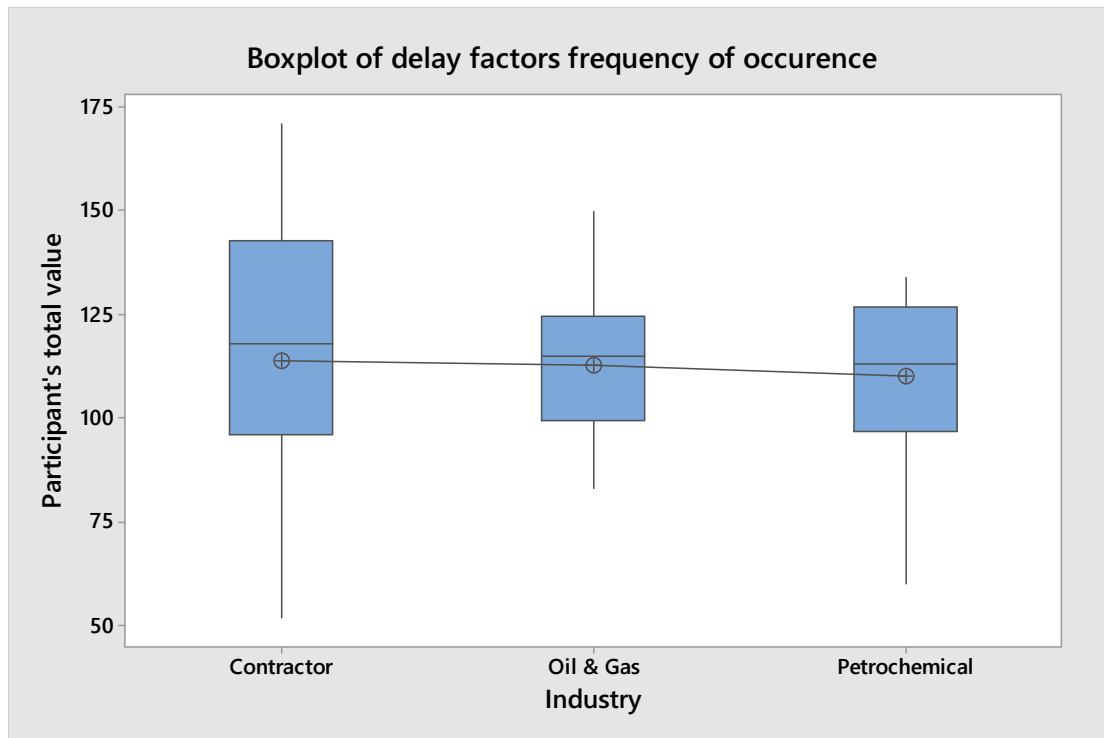


Figure 14: ANOVA for the frequency of occurrence of delay factors Vs. Industry

The test found to be not significant, as P-value was more than Alpha= 0.05. Therefore, the decision was not to reject the nil hypothesis, as there was no evidence on the existence of a significant difference between the three categories (Industries), and therefore, all means were considered as statistically equal. This was detailed in Table 27, obtained from Minitab software analysis.

Table 27: ANOVA analysis for the delay factors frequency Vs. Industry

Method	
Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	$\alpha = 0.05$
Equal variances were assumed for the analysis.	
Factor Information	

Factor	Levels	Values
Industry	3	Contractor, Oil & Gas, Petrochemical

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Industry	2	167.6	83.79	0.16	0.851
Error	60	31151.3	519.19		
Total	62	31318.9			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
22.7857	0.54%	0.00%	0.00%

Means

Industry	N	Mean	StDev	95% CI
Contractor	11	114.0	36.1	(100.3, 127.7)
Oil & Gas	13	112.92	17.89	(100.28, 125.56)
Petrochemical	39	110.13	19.41	(102.83, 117.43)

Pooled StDev = 22.7857

Also, for severity level of delay factors, same ANOVA was carried out and box plot in Figure 15 shows the summation of the total responses for each individual participant with maximum value of 210 and minimum value= 42.

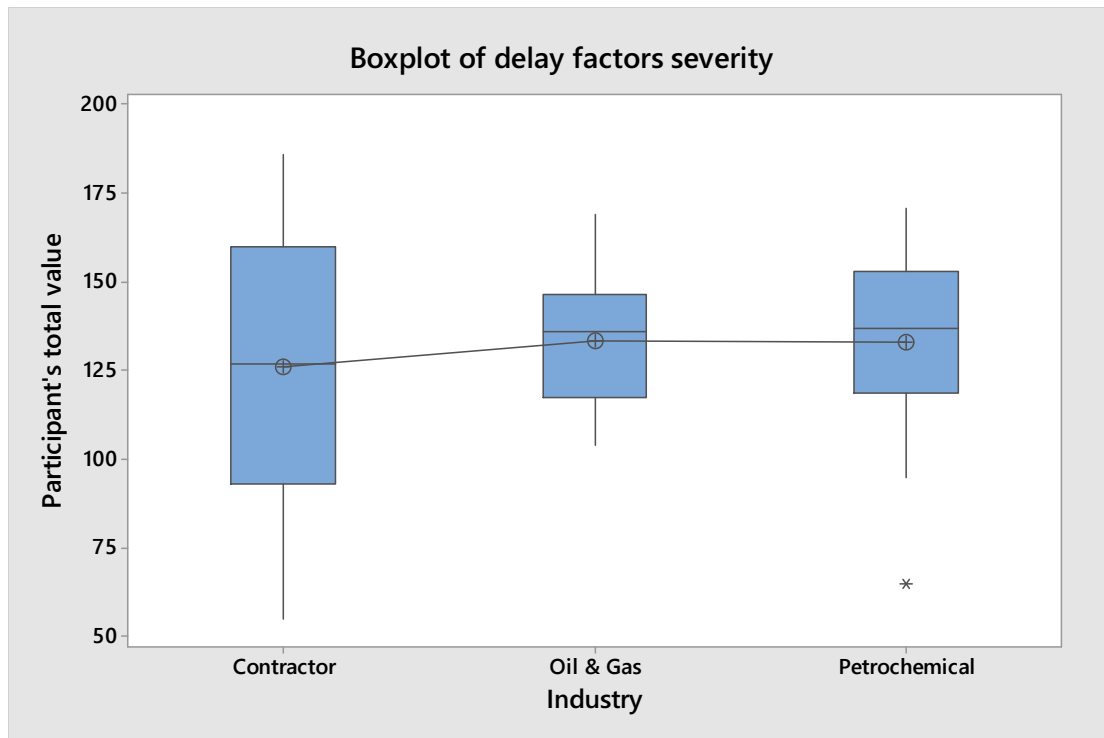


Figure 15: ANOVA between the delay factors severity level and the industry

Table 28 shows the detailed analysis of the ANOVA test for the delay factors severity against the participants' industries.

Table 28: ANOVA analysis for the delay factors severity Vs. industry

Null hypothesis	All means are equal				
Alternative hypothesis	At least one mean is different				
Significance level	$\alpha = 0.05$				
Equal variances were assumed for the analysis.					
Factor Information					
Factor	Levels	Values			
Industry	3	Contractor, Oil & Gas, Petrochemical			
Analysis of Variance					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Industry	2	434.9	217.5	0.36	0.698
Error	60	36029.9	600.5		
Total	62	36464.9			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
24.5051	1.19%	0.00%	0.00%

Means

Industry	N	Mean	StDev	95% CI
Contractor	11	126.3	37.4	(111.5, 141.1)
Oil & Gas	13	133.69	19.13	(120.10, 147.29)
Petrochemical	39	132.97	21.54	(125.13, 140.82)

Pooled StDev = 24.5051

The test had revealed no significant difference between the mean of each participants' industries in terms of the severity level of the delay factors, and therefore, all three industries were considered as hypothetically equal.

2) ANOVA test for delay consequences

Questionnaire results were used for the 14 delay consequences, where the total number for each individual respondent against these 14 delay consequences were calculated, with maximum value of 70 (14x5), and minimum value = 14 (14x1).

The two criteria for delay consequences were adapted were; the frequency of occurrence of such consequence and its impact level.

For the frequency of occurrence for delay consequence, the following box plot in Figure 16 was resulted.

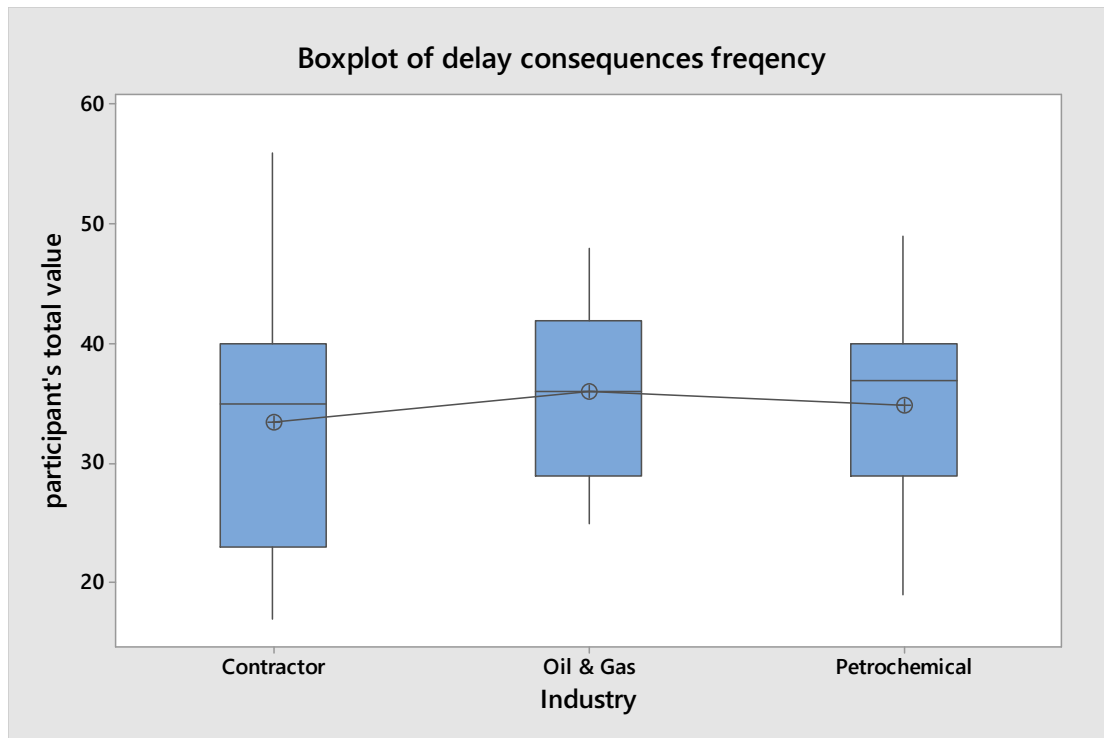


Figure 16: ANOVA between the delay consequences frequency and the industry

As per the below analysis, The P value > 0.05 . Hence, H_0 assumption was not rejected, which indicated that all industries' means were equal.

Table 29: ANOVA analysis for the delay consequences frequency Vs. Industry

Method		
Null hypothesis	All means are equal	
Alternative hypothesis	At least one mean is different	
Significance level	$\alpha = 0.05$	
Equal variances were assumed for the analysis.		
Factor Information		
Factor	Levels	Values
Industry	3	Contractor, Oil & Gas, Petrochemical
Analysis of Variance		

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Industry	2	38.73	19.36	0.28	0.758
Error	60	4167.50	69.46		
Total	62	4206.22			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
8.33416	0.92%	0.00%	0.00%

Means

Industry	N	Mean	StDev	95% CI
Contractor	11	33.45	11.72	(28.43, 38.48)
Oil & Gas	13	36.00	7.27	(31.38, 40.62)
Petrochemical	39	34.92	7.54	(32.25, 37.59)

Pooled StDev = 8.33416

The final ANOVA carried out for impact level of delay consequences with below box plot, which shows contractors respondents are varying from the other industries with more spreading towards the lowest possible value.

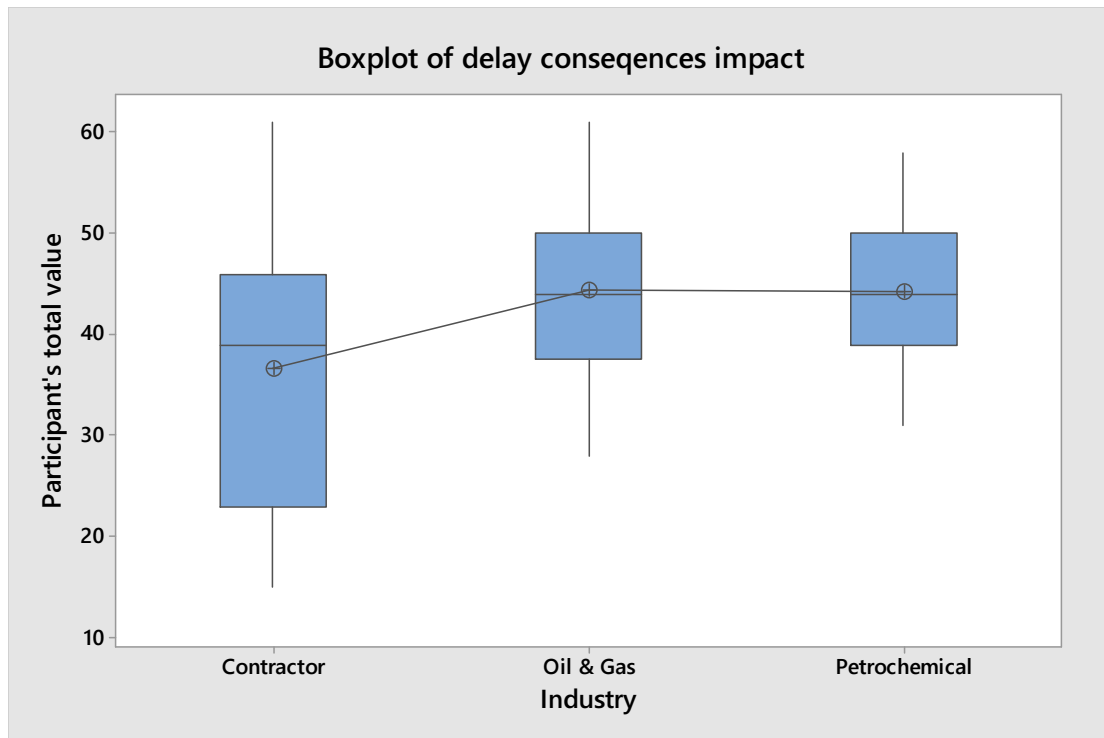


Figure 17: ANOVA between the delay consequences impact and the industry

Here, the analysis was ended up with rejecting the null hypothesis, as the obtained P-value = 0.045 less than Alpha = 0.05. Hence, at least one participants' industry mean value was different than others. It could be figured out from Figure 17 also, that the contractor analysis for delay consequences severity level was at least different than the participants in petrochemical and oil and gas industries which remained hypothetically equal.

Table 30: ANOVA analysis for the delay consequences frequency Vs. Industry

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	$\alpha = 0.05$
Equal variances were assumed for the analysis.	
Factor Information	

Factor	Levels	Values
Industry	3	Contractor, Oil & Gas, Petrochemical

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Industry	2	529.2	264.60	3.26	0.045
Error	60	4868.5	81.14		
Total	62	5397.7			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
9.00791	9.80%	6.80%	0.00%

Means

Industry	N	Mean	StDev	95% CI
Contractor	11	36.64	13.92	(31.20, 42.07)
Oil & Gas	13	44.38	8.71	(39.39, 49.38)
Petrochemical	39	44.23	7.29	(41.35, 47.12)

Pooled StDev = 9.00791

Conclusion:

Based on the ANOVA analysis for the delay factors versus the different industries, it was concluded that the responses from petrochemical industries could be taken into consideration solely. However, and in order to give an attention to other potentially high ranked delay factor that may resulted from the other industries, the overall combined results for all respondents were also analyzed, in order to ensure the inclusion of all significant delay factors in the risk matrix, and in order to ensure not to miss by chance any potential significant delay factor.

Also, it was concluded from the ANOVA analysis of delay consequences, that the impact level of delay consequence shown by

the participants from different industries was perceived differently. Therefore, the analysis of delay consequences was conducted by taking into consideration the petrochemical industry, as the main industry in this investigation, to conclude the most significant delay consequences by computing the FAII. Moreover, delay matrix for delay consequences was developed for contractor's industry, along with the main industry of petrochemical respondents, in order to analyze the genuine differences between the industries in a qualitative and quantitative manner.

4.7 FI, RII, and FAII Analysis for Delay Factors and Delay Consequences

The Table 31 was developed for the delay factors affecting the maintenance and construction projects in petrochemical industries, to compare two industries, the petrochemical industries as concluded from the analysis of ANOVA, and the overall responses from all industries in order to include any critical delay factors that could result from this analysis to the final conclusion.

The calculation of FI, RII, FAII took the mean value analysis from Appendix D, and Table 19, and substituted them in Equations (3), (4), and (5). For instance, for delay factor number 1 [late design changes initiating in the project life cycle], the following calculations were conducted for petrochemical industries respondents,

$$FI(j) = \frac{\sum_{i=1}^A n_{ij} * i}{A * N} = 2.97/5 = 0.594, RII(j) = \frac{\sum_{i=1}^A n'_{ij} * i}{A * N} = 3.38/5 = 0.676,$$

and therefore, $FAII(j) = RII(j) * FI(j) = 0.594 \times 0.676 = 0.402$, for J = delay factor number 1.

Table 31: FI, RII, and FAII analysis for delay factors

SN	Delay factor	Analysis	Petrochemical industries	Rank	All industries	Rank
1	Late design changes	FI	0.594	9	0.606	5
		RII	0.676	11	0.654	12
		FAII	0.402	4	0.396	4
2	Incomplete documents	FI	0.570	11	0.580	9
		RII	0.642	18	0.626	24
		FAII	0.366	10	0.363	10
3	Delay in preparation of documents	FI	0.600	8	0.620	4
		RII	0.626	23	0.634	17
		FAII	0.376	8	0.393	5
4	Mistakes in design	FI	0.476	31	0.482	34
		RII	0.698	6	0.686	5
		FAII	0.332	21	0.331	24
5	Bureaucracy in organization	FI	0.570	12	0.542	15
		RII	0.584	35	0.580	37
		FAII	0.333	20	0.314	27
6	Unrealistic project duration	FI	0.534	19	0.558	12
		RII	0.616	26	0.632	19
		FAII	0.329	24	0.353	13
7	Variation	FI	0.600	7	0.596	6
		RII	0.642	17	0.658	11
		FAII	0.385	6	0.392	6
8	Slow decision making	FI	0.528	20	0.556	13
		RII	0.584	36	0.588	36
		FAII	0.308	30	0.329	26
9	Fast-track project delivery strategy	FI	0.580	10	0.594	8
		RII	0.600	29	0.612	26
		FAII	0.348	14	0.363	9

Table 31 (Continued): FI, RII, and FAII analysis for delay factors

SN	Delay factor	Analysis	Petrochemical industries	Rank	All industries	Rank
10	lowest bid price system	FI	0.724	1	0.718	1
		RII	0.606	28	0.626	23
		FAII	0.439	2	0.449	2
11	Poor definition of interfaces	FI	0.508	24	0.526	21
		RII	0.590	34	0.628	21
		FAII	0.300	32	0.330	32
12	Inadequate project duration	FI	0.508	23	0.518	23
		RII	0.662	13	0.654	13
		FAII	0.336	19	0.339	18
13	Complicated tender procedures	FI	0.636	3	0.642	3
		RII	0.610	27	0.632	18
		FAII	0.388	5	0.406	3
14	Late delivery of material or equipment	FI	0.534	18	0.574	10
		RII	0.852	1	0.826	1
		FAII	0.455	1	0.474	1
15	Material shortage or scarcity	FI	0.430	38	0.480	36
		RII	0.728	3	0.720	2
		FAII	0.313	29	0.345	16
16	Poor procurement programming	FI	0.476	32	0.508	27
		RII	0.698	7	0.686	4
		FAII	0.476	22	0.348	15
17	Problem with equipment transportation	FI	0.400	41	0.438	40
		RII	0.642	19	0.622	25
		FAII	0.257	37	0.272	38
18	Poor contract management	FI	0.544	15	0.534	19
		RII	0.636	20	0.632	20
		FAII	0.346	17	0.337	20
19	Inadequate project planning	FI	0.606	6	0.566	11
		RII	0.682	10	0.666	7
		FAII	0.413	3	0.377	7

Table 31 (Continued): FI, RII, and FAII analysis for delay factors

SN	Delay factor	Analysis	Petrochemical industries	Rank	All industries	Rank
20	Delay in inspection and testing	FI	0.502	26	0.488	31
		RII	0.636	21	0.606	29
		FAII	0.319	25	0.296	30
21	Inadequate quality assurance and quality control	FI	0.426	39	0.444	39
		RII	0.652	15	0.628	22
		FAII	0.278	36	0.279	36
22	Lack of ownership	FI	0.502	27	0.486	32
		RII	0.630	22	0.604	30
		FAII	0.316	27	0.293	32
23	Delay in handing over site to the contractor	FI	0.446	36	0.464	37
		RII	0.564	37	0.604	31
		FAII	0.252	39	0.280	35
24	Accidents	FI	0.344	42	0.336	42
		RII	0.698	8	0.674	6
		FAII	0.240	42	0.226	42
25	Security and slow site clearance	FI	0.620	5	0.552	14
		RII	0.508	42	0.520	42
		FAII	0.315	28	0.287	33
26	work permits	FI	0.472	34	0.514	24
		RII	0.512	41	0.540	40
		FAII	0.242	41	0.278	37
27	Weather effect	FI	0.472	33	0.496	30
		RII	0.518	40	0.546	39
		FAII	0.244	40	0.271	40
28	Summer restriction	FI	0.672	2	0.667	2
		RII	0.582	39	0.556	38
		FAII	0.355	12	0.371	8
29	Way-leave approval	FI	0.626	4	0.596	7
		RII	0.544	38	0.588	35
		FAII	0.347	15	0.350	14

Table 31 (Continued): FI, RII, and FAII analysis for delay factors

SN	Delay factor	Analysis	Petrochemical industries	Rank	All industries	Rank
30	Shortage of manpower	FI	0.524	22	0.536	17
		RII	0.662	12	0.664	10
		FAII	0.347	16	0.356	12
31	Manpower productivity	FI	0.426	40	0.458	38
		RII	0.594	32	0.594	34
		FAII	0.253	38	0.272	39
32	Poor understanding of scope by contractor	FI	0.538	17	0.536	18
		RII	0.656	14	0.642	15
		FAII	0.353	13	0.344	17
33	Poor estimation of time by contractor	FI	0.544	14	0.542	16
		RII	0.688	9	0.667	8
		FAII	0.374	9	0.361	11
34	Poor project planning by contractor	FI	0.524	21	0.512	26
		RII	0.698	5	0.650	14
		FAII	0.365	11	0.333	22
35	Inadequate contractor experience	FI	0.436	37	0.426	41
		RII	0.702	4	0.667	9
		FAII	0.306	31	0.284	34
36	Subcontractors	FI	0.488	30	0.514	25
		RII	0.600	30	0.596	32
		FAII	0.293	34	0.306	28
37	Rework	FI	0.502	25	0.486	33
		RII	0.754	2	0.696	3
		FAII	0.379	7	0.338	19
38	Poor communication between contractor and project parties	FI	0.456	35	0.482	35
		RII	0.620	25	0.612	28
		FAII	0.283	35	0.295	31

Table 31 (Continued): FI, RII, and FAII analysis for delay factors

SN	Delay factor	Analysis	Petrochemical industries	Rank	All industries	Rank
39	Insufficient contractor's manpower	FI	0.492	29	0.524	22
		RII	0.646	16	0.638	16
		FAII	0.318	26	0.334	21
40	Shortage of skilled labors by contractor	FI	0.498	28	0.504	28
		RII	0.594	31	0.594	33
		FAII	0.296	33	0.299	29
41	Lack of communication between parties involved	FI	0.544	16	0.534	20
		RII	0.620	24	0.612	27
		FAII	0.337	18	0.327	25
42	Lack of periodical meetings	FI	0.558	13	0.504	29
		RII	0.590	33	0.534	41
		FAII	0.329	23	0.269	41

Any delay factor with FAII score that is more than “0.36” is considered as a one of main delay factors. This interpretation because that “FAII=0.36” is reflecting the following criteria; frequency of occurrence equal to [At least sometimes = 3], and impact level equal to [At least moderate=3] in the five-points Likert scale.

The score of 3 in the Likert scale is equivalent to (3/5 points = 0.6) in the FI and RII indices, and FAII would be at least equal to $0.6 \times 0.6 = 0.36$, according to Equation (5).

Therefore, any delay factor with FAII that is higher than 0.36 is considered as one of main delay factors that is satisfying both condition of frequency and severity.

It was noticed that the delay factors satisfying the condition of FAII more than 0.36, were the first 12th ranked in petrochemical analysis, and they were in common between both industries in Table 31, with an exception of three factors. These three factors were as following:

- 1) Delay factor 37 [Rework due to errors, mistakes, and defective works during construction] which shown an FAII of 0.38 in petrochemical industries, but was left in the 19th rank in all industries assessment.
- 2) Delay factor 34 [Poor project planning by contractor] was in the 11th ranking in petrochemical industries, while obtaining only 0.33 in all industries calculation.
- 3) Also, delay factor 28 [summer restriction of working time] which was in 12th rank in the petrochemical industries, with FAII of 0.35, and it was included with the top delay factors, with FAII=0.37 in all industries analysis, thus meeting the acceptance criteria.

FI, RII, and FAII analysis for delay consequences:

As the ANOVA test has shown a significant difference between participant's groups, therefore the petrochemical industries responses were considered as a main participant in research, with comparison with contractor industries that resulted the significant difference in ANOVA test.

The finding was as per Table 32, which was obtained by computing the mean value from (Appendix D) and substituting the values in Equations (3), (4), and (5).

Table 32: Analysis of FI, RII, and FAII analysis for delay consequences

SN	Delay Consequence	Analysis	Petrochemical industries	Rank	Contractor	Rank
1	Time overrun	FI	0.610	2	0.564	3
		RII	0.672	5	0.672	1
		FAII	0.410	2	0.379	3

Table 32 (Continued): FI, RII, and FAII analysis for delay consequences

2	Disputes	FI	0.492	6	0.510	4
		RII	0.558	12	0.546	5
		FAII	0.275	8	0.278	4
3	Idling of resources	FI	0.554	4	0.490	5
		RII	0.482	14	0.510	8
		FAII	0.267	11	0.250	6
4	Lack of continuity by the management	FI	0.426	12	0.418	11
		RII	0.580	10	0.436	11
		FAII	0.247	12	0.182	11
5	Cost overrun	FI	0.570	3	0.600	2
		RII	0.688	4	0.654	2
		FAII	0.392	3	0.392	2
6	Declination of reputation of project team	FI	0.430	11	0.454	8
		RII	0.620	7	0.528	6
		FAII	0.267	10	0.240	8
7	Distrust with the contractor	FI	0.452	10	0.472	6
		RII	0.524	13	0.528	7
		FAII	0.237	14	0.249	7
8	Blacklisting the contractor	FI	0.416	13	0.364	14
		RII	0.580	11	0.436	12
		FAII	0.241	13	0.159	14
9	Delay of other related projects	FI	0.534	5	0.472	7
		RII	0.728	3	0.564	4
		FAII	0.389	4	0.266	5
10	Extension of works beyond normal working hours	FI	0.728	1	0.636	1
		RII	0.600	8	0.636	23
		FAII	0.437	1	0.404	1
11	Importing the utilities and material from outside	FI	0.462	8	0.454	9
		RII	0.594	9	0.490	9
		FAII	0.274	9	0.222	9

Table 32 (Continued): FI, RII, and FAII analysis for delay consequences

SN	Delay consequence	Analysis	Petrochemical industries	Rank	Contractor	Rank
12	Change the form of delivery of material	FI	0.492	7	0.400	12
		RII	0.626	6	0.418	13
		FAII	0.308	6	0.167	12
13	Compromise the quality of work	FI	0.456	9	0.400	13
		RII	0.784	2	0.418	14
		FAII	0.358	5	0.167	13
14	Not achieving production target	FI	0.364	14	0.454	10
		RII	0.810	1	0.490	10
		FAII	0.295	7	0.222	10

The analysis of delay consequences from the petrochemical industries revealed that delay consequence 10 [Extension of time beyond working hours] has secured a very high rank in terms of FI of 73%, followed by delay consequence 2 [time over run] at FI= 61%, and then cost overrun, delay consequence 5, at FI = 57%. Also, [Delay of other related projects] as a delay consequence 9, scored an FI of 53%.

The impact of the delay consequences was also analyzed in terms of RII index. Highest impact was associated with delay consequence 14 [Not achieving the production target] which was one of the strategic goals of the petrochemical industries company under study, and got 81%, followed by delay consequence 13 of [having compromised quality of work] at RII=78%, and then [delays of other projects related to the main project] with RII=73% (delay consequence 9).

4.8 Risk Matrix Index

1) Risk matrix for delay factors (Frequency of occurrence VS. severity level)

The risk matrix shown in Figure 18 includes the delay factors obtained from the analysis of the FAII analysis of delay factors, and classified under different risk zones according to their frequency of occurrence and severity level.

		FREQUENCY OF OCCURRENCE (LIKELIHOOD)				
		Very Low 1-1.8	Low 1.81-2.6	Medium 2.61-3.4	High 3.41-4.2	Very High 4.21-5
SEVERITY LEVEL	Very High 4.21-5.0	Low/Med	Medium	14	High	High
	High 3.41-4.2	24	4,15,16 35	19,33,34,37	Med/High	High
	Medium 2.61-3.4	Low	11,12,17 20,21,22 23,31,36 38,39,40	1,2,3,5,6 7,8,9,13,18 28,29,30,32 41,42	10	Med/High
	Low 1.81-2.6	Low	26,27	25	Medium	Med/High
	Very Low 1-1.8	Low	Low	Low/Med	Medium	Medium

Figure 18: Risk matrix for delay factors

The above risk matrix depicted the risk region for the delay factors, and highlighted the 12 critical delay factors in red color. In such, two delay factors found to be in the orange zone (Med/high risk), namely delay factor 14 [late delivery of material and equipment] and delay factor 10 [adoption of lowest bid price system]. The other 10 critical

delay factors were found to be laid in the yellow zone (medium risk). The critical delay factors in yellow zone were differentiated on other factors by attaining high FAII score that was greater than 0.36.

2) Risk matrix for delay consequences (Frequency of occurrence VS. impact level)

Risk matrix was also depicted for the delay consequences for petrochemical industries and contractor, in order to address the differences between them in qualitative manner.

The first risk matrix for delay consequences was developed for petrochemical industries as per Figure 19.

		FREQUENCY OF OCCURRENCE (LIKELIHOOD)				
		Very Low 1-1.8	Low 1.81-2.6	Medium 2.61-3.4	High 3.41-4.2	Very High 4.21-5
Impact level	Very High 4.21-5.0					
	High 3.41-4.2		13,14	5,9		
	Medium 2.61-3.4		2,4,6 7,8,11 12	1	10	
	Low 1.81-2.6			3		
	Very Low 1-1.8					

Figure 19: Risk matrix for delay consequences (Petrochemical)

The above risk matrix shows one delay consequence in the orange zone (Med to high risk), that is delay consequence 10 [Extension of works beyond working hours], and three factors in yellow zone (Medium risk).

The second risk matrix for delay consequence was developed for contractor industry, and the following risk matrix was developed.

		FREQUENCY OF OCCURRENCE (LIKELIHOOD)				
		Very Low 1-1.8	Low 1.81-2.6	Medium 2.61-3.4	High 3.41-4.2	Very High 4.21-5
Impact level	Very High 4.21-5.0					
	High 3.41-4.2					
	Medium 2.61-3.4		2,3,4 6,7,9	1,5,10		
	Low 1.81-2.6		8,11,12 13,14			
	Very Low 1-1.8					

Figure 20 : Risk matrix for delay consequences (Contractor responses)

The main difference was that there was no delay consequence in the orange zone (medium/high risk) for contractor, with only three delay consequences laid in the yellow risk zone, as shown in Figure 20.

The other observation was that most of the delay consequences from contractor industry obtained less FAII score in comparison with petrochemical industries respondents. This could be attributed to the complexity and nature of the petrochemical industries, where the majority of the consequences could affect the petrochemical industry company more than what it can do with the contractor.

4.9 Main Delay Factors and Delay Consequences

- Twelve delay factors in petrochemical industries in Bahrain were found to be significant according to FAII ranking, and risk zone. These factors were ranked in ascending order from the highest significance as per Table 33.

Table 33: Main delay factors in Petrochemical industries in Bahrain

Rank	Delay factor	Description	FAII	Risk zone	Color coding
1	14	Late delivery of material or equipment	0.455	4	Orange
2	10	Adoption of the lowest bid price system for awarding the contract	0.439	4	Orange
3	19	Inadequate project planning, budgeting, and scheduling	0.413	3	Yellow
4	1	Late design changes initiating in the project life cycle	0.402	3	Yellow
5	13	Complicated and long tendering procedures to award the contract	0.388	3	Yellow
6	7	Changes, and scope variation by the petrochemical industries	0.385	3	Yellow
7	37	Rework due to errors, mistakes and defective works during construction	0.379	3	Yellow
8	3	Delay in preparation, approval and issuance of drawings and documents	0.376	3	Yellow
9	33	Poor estimation of project time, and material quantity requirement before contracting	0.374	3	Yellow

Table 33 (Continued): Main delay factors in Petrochemical industries in Bahrain

Rank	Delay factor	Description	FAII	Risk zone	Color coding
10	2	Incomplete drawing and project documents	0.366	3	Yellow
11	34	Poor project planning by contractor	0.365	3	Yellow
12	28	Summer restriction on time of work	0.355 *	3	Yellow

*Delay factors 28 obtained FAII= 0.371 in overall industries, and thus considered as one of main delay factors.

The highest-ranking delay factor is the factor#14 [Late delivery of equipment]. This significance is associated with the impact of the undelivered material on time on the project status.

Basically, this factor will lead to a project extension, and increase the cost of the project especially when it decided to expedite the delivery and working methods. Moreover, a dispute with contractor might arise due to stoppage of his work.

Another significance delay factor that falls in the orange risk zone is delay factor#10 [Adoption of the lowest bid price system for awarding the contract]. This type of bidding system is attributed by the two envelop evaluation system, where the technical evaluation is carried first, and then followed with the commercial evaluation of the qualified offers. This factor is significance due to its high frequency level and due to its lengthy process. In mainly affect the critical projects that have a very limited time to start the execution phase in order to cater the petrochemical industries important requirement like

the plan of major maintenance turnaround. This also related to delay factor#13.

Other factors are relevant to design issue, issuance of project documents and their accuracy, and the implication of changes and variation on the project progress. These factors are also linked with the rework that caused by inaccurate documents or a variation in the requirement.

Proper planning by the project team and contractor and accurate estimation of time and material would substantially enhance the project progress efficiency by ensuring the application of best project management techniques throughout the project.

- Four delay consequences were qualified as the main delay consequences in the petrochemical industries in Bahrain. These delay consequences were listed as per Table 34.

Table 34: Main delay consequences in petrochemical industries in Bahrain

Rank	Delay consequence	Description	FAI	Risk zone	Color code
1	10	Extension of works beyond the normal working hours	0.437	4	Orange
2	1	Time overrun	0.410	3	Yellow
3	5	Cost overrun	0.392	3	Yellow
4	9	Delay of other related projects	0.389	3	Yellow

Delay consequence#10 [Time extension beyond normal hours] found to be the highest ranked delay consequence. Although, it might be thought at to have a softer impact, but this is not actual case in

petrochemical industries. The interpretation of this phenomena is due to the fact that majority of maintenance and construction projects in petrochemical industries are planned to be carried out within the normal working hours. However, in case of any delay or changes originated in any critical project, then the new schedule and requirement have to be met. Eventually, extending of project timing become a necessary action to cope with project requirement and in as an attempt to reduce the delay of the project.

The impact of this consequence [Time extension beyond normal hours] is not associated only with only additional working hours, but it implicitly includes many other delay consequences. These consequences might emerge as a dispute between project parties [Delay consequence#2], or increase in the cost overrun of the project [Delay consequence#5], or maybe compromise the quality of the work due to haste and overload of the workers [Delay consequence#13]. All the said consequences can be linked with the project time extension, and especially when other projects have to be started immediately [Delay consequence# 9].

Chapter 5: Summary, Conclusion and Recommendation of the Study

- 5.1 Summary
- 5.2 Findings
- 5.3 Conclusion
- 5.4 Recommendations to Overcome the Top Delay Factors
- 5.5 Recommendations for Petrochemical Industries in Bahrain
- 5.6 Recommendations for Future Studies

Chapter 5: Summary, Conclusion and Recommendation of the Study

5.1 Summary

The delay of the maintenance and construction projects in petrochemical industries is a problematic issue and lead to a serious impact on the petrochemical industries especially during hard situation of unstable market price.

This research covers the available gaps in the petrochemical industries in Bahrain in the field of maintenance and construction projects, and interprets and ranks the delay factors and consequences in a systematic way in order recommend a corrective action plan against the significant factors that affect the petrochemical industries. The methodology started with the analytical review of literature and conclusion of relevant factors through a series of focused interviews with the experts from the industries, and then designing of a questionnaire to quantitatively analyze the results.

The highest delay factors, delay consequences, and delay groups were ranked according to their FAII. The study has considered the significance of delay factors and delay consequences from two aspects. The first one was the frequency of their occurrence, and the second one was their severity level.

5.2 Findings

The following findings were concluded as an outcome of this study:

- 1) The Lowest delay consequences was found for delay consequence #8 [Black listing the contractor] and equal only 0.166 when analyzing

the responses from contractor industries only (More conservative side). This low FAII for blacklisting contractors which was obtained from the contractor responses solely signifies the stringent system in place for pre-qualifying the contractors for various fields and projects in petrochemical industries.

2) The frequency of occurrence of delay factors has found to have a less significance with at least 10% level when compare with its severity level. This could be attributed to the system of work that is designed and implemented by petrochemical industries to control the maintenance and construction projects. However, and due to high severity level, more stringent controls shall be emphasized in the processes in order to control and mitigate the delay consequences.

3) The lowest delay consequences frequency found for delay consequence# 14 [Not achieving the production target] and equal to 1.82. This indicates “Never to rare” occurrence. Whereas, the same delay consequence found to have a very high impact level with RII=81%. This is another indicator of the control system placed by petrochemical industries to achieve the organizational objective of the set production target.

4) The lowest delay consequence impact level in terms of RII was delay consequence 3 [Idling of resources].

5) The highest FI was for delay factor 10 [Adoption of lowest bid price system] with 72.4%, and lowest was delay factor 24 [Accident during construction] with FI=34.4%.

6) The highest RII for delay factor was 85.2% for delay factor#14 [The late delivery of material and equipment], and lowest RII was for delay factor#25 [security and slow site clearance].

8) Out of the 12 main delay factors identified in this study, 3 factors found to be related to contractor against 9 delay factors found to be related to petrochemical industries. Among these 9 delay factors, only 2 were related to the top management, while the other 7 delay factors were under responsibility of the project team in petrochemical industries.

5.3 Conclusion

The study revealed the highest delay factors and delay consequences in petrochemical industries in Bahrain. Also, it ranks the delay groups according to their FAII index. The study explored 12 delay factors as a significant delay factors, out of which 2 of them fall in the orange risk zones and other 10 in the yellow risk zone. Also, there was no delay factors laid in the red zone.

These delay factors were from highest to lowest significance as follows; late delivery of material or equipment, adoption of the lowest bid price system for awarding the contract, inadequate project planning, budgeting, and scheduling, late design changes initiating in the project life cycle, rework due to defective work and mistakes, and delay in approval, issuance of drawing and document. Also, Poor estimation of project time, and material quantity requirement before contracting, Incomplete drawing and project documents, Poor project planning by contractor, and finally due to summer restriction on time of work.

Also, the top ranked delay consequences were concluded as follows: extension of works beyond the normal working hours, cost overrun, delay of other related projects, and time overrun. The first delay consequences fall in the orange zones while the other three among the

significance consequences were in the yellow zones. All other consequences were classified as in the green zone which was attributed to their low frequency of occurrence though some of their significance was high.

The impact of [Time extension beyond normal hours] is not associated only with the working time itself, but it implicitly includes many other delay consequences that inhere within the time extension. These consequences might be for instance human factors like disputes between project parties (Delay consequence#2), increase the cost overrun (Delay consequence#5), and compromise the quality of the work due to haste and overload of the workers (Delay consequence#13). All the said consequences can be linked with the project time extension, and especially when other projects have to be started immediately (Delay consequence# 9).

It was concluded from the highest-ranking delay groups, that these groups were directly related to the petrochemical industries' systems and internal procedures. Also, it was noticed that contractor related factors and work site related factors found in late ranking unlike the majority of the findings from other industries' research. Also, it was concluded from the analysis that the contractor respondents have a different perception for the impact level of the delay consequence when compared to the participants from the petrochemical industries. This is a very important concluded point which shall be focused by the petrochemical industries to communicate the project importance well and in advance to the potential contractors during the bidding stage, especially if they were new contractor to this filed.

5.4 Recommendations to Overcome the Top Delay Factors

Here are the recommended actions plan based on the concluded main delay factors in Petrochemical industries in Bahrain.

1) Delay factor #14 [Adoption of lowest bid price system]

The system in place in petrochemical industries in Bahrain for awarding the contract is the lowest price system based on the two enveloped evaluations, where technical evaluation is carried out first to filter the conforming offers, and then awarding the lowest price bidder provided that it's conformed to the company requirement that was evaluated in first stage. The attributes of other offers in this method are discarded which can lead to lose of potential competitive advantage. This method, does not allow value decision on which some bidders attributes may be better than other which might be needed, like the high experience, for contractors to complete the projects in shortest time available to avoid any further delays (clever buying, n.d.)

For this reason, the petrochemical industries shall classify the types of the bidding systems based on some criteria like importance and complexity of projects, value of the contract, and significant risk of the project. In this case, alternative bidding methods are more recommended, like weighted attributes method.

2) Delay factor #10 [Late delivery of material and equipment]

This is a repetitive cause in petrochemical industries (Naimi, Elhag, and Fenn, 2008). Therefore, it is recommended to enhance the follow up protocols with vendors and suppliers in order to

ensure the timely availability of material and solve any emerged issue.

3) Delay factor#19 [Inadequate project planning, budgeting and scheduling]

Early interference of execution team in the project planning and assessment would be highly beneficial to accurately and unbiasedly estimate the project requirement.

4) Delay factor #1 [Late design changes initiating in the project life cycle]

Normally, the late changes are initiated from the projects' requestors. Therefore, understanding the real requirement of end-users, and conducting various meetings during the design stage between the engineers and other relevant technical teams are recommended to avoid last minute changes to the projects.

5) Delay factor#13 [Complicated and long tendering procedures]

The system of awarding the contract shall be reviewed, and maximum time frame for tendering process to be clearly set for critical maintenance and construction projects. The tendering period to be included in the overall project duration, and has to be agreed initially to count the earliest start date of the project back-to-back.

6) Delay factor#7 [Changes, and variation by the petrochemical industries]

Usually, management decision is beyond the control of the execution team. However, understanding the top management requirement, and application of leader ship skills by project leader

will aid to mitigate and alleviate the consequences. Therefore, a role of competent project leader is crucial to do the coordination between the top-level management and project team.

7) Delay factor# 37 [Rework due to errors, mistakes and defective works during construction]

This is directly related to execution team and the appointed contractor. The more emphasize on the quality control and quality assurance during the tendering evaluation stage, the more control on the quality outcomes of the projects.

8) Delay factor#3 [Delay in preparation, approval and issuance of drawings and documents]

It is recommended that the project has to be rigorously followed throughout all the stages by an assigned project leader who should be capable, empowered, and supported by high level to move the projects forward to be completed on time and within the budget. The project leader shall work to establish the system to prioritize the projects base on their importance and impact

9) Delay factor#33 [Poor estimation of project time, material quantity requirement before contracting]

The earliest to discover the above delay factor, the less severe consequences to occur. The regular meetings and shared opinions about project requirement can alarm the project leader of any shortcoming or misunderstanding of any party in order to take a corrective action at the earliest.

10) Delay factor#2 [Incomplete drawings and project documents]

This delay factor could be resulted from the delay in preparation project documents (Delay factor#3), which can lead to variation and disputes between projects parties. The packages of main projects are recommended be completed and verified before sending the project documents to execution team for implementation.

11) Delay factor#34 [Poor project planning by contracting]

This delay factor is directly related to contractor. The process to control this potential delay factor by petrochemical industries is started from the mandatory kick of meeting, to re-emphasis on the awareness of the contractor on the project criticality.

12) Delay factor#28 [Summer restriction on time of work]

As practicably possible, critical maintenance and construction projects shall be planned in such way that it is not falling within the peak summer period. This has to be highlighted as a general guideline to be followed by the project schedulers. It is not only the regulation that banned working from 12:00 to 16:00 daily in July and August, but rather, it is to do with the productivity of the workers, and the project's quality requirement that emphasizes on certain ambient temperature as a quality check.

5.5 Recommendations for Petrochemical Industries in Bahrain

Below are the high-level recommendations for the top management in petrochemical industries to evaluate their practicality and feasibility for incorporating them in the company standard procedures.

- Add the delay as a key performance indicator (KPI) in the organization objective, and cascade it to all the departments' objectives for their planning and adherence to the integrated KPI. Currently, some of the departments in petrochemical industries company have their own target for the delay and timely completion, but it was not serving the purpose of controlling the delay, as the safety margin kept adding from department to department allowing the objective to be fulfilled without addressing delay issue.
- The petrochemical industries shall develop criteria to define and rank the maintenance and construction projects based on their importance and complexity. High tanked projects shall follow different route for bidding procedures, and get the priority by technical service department to complete the projects' documents on timely manner.
- Adapt weighted average attributes bidding method with clear criterion for the technical evaluation instead of current practice of having the lowest price bidding system through two envelopes evaluation. This method has to be envisaged specially for important and complex projects, and where the risk of the project is considered significant.

5.6 Recommendations for Future Studies

Below are the recommendations for the future study consideration in the field of delay in maintenance and construction projects in petrochemical industries in Bahrain.

- Conduct a pair wise comparison analysis between main delay factors and delay consequences, and assign the delay factors with consequences to ascertain any direct relation between them.

- Interpenetration for delay formula based on the main delay factors identified herewith in this research and by using of linear regression analysis. These delay factors have to be applied and validated on the future maintenance and construction projects in Petrochemical industries company.
- Application of statistical approaches like six sigma methodologies on selected major projects that phased with delay, which will statistically analyze the delay in terms of delay impacts, cost impacts, and identify the causes.
- Since the outbreak of COVID-19 dieses in 2020, it is suggested to consider the COVID-19 effect and impacts on projects' performance for future studies.

References

- Abedi, M., Fathi, M. S., & Mohammad, M. F. (2011). Effects of construction delays on construction project objectives. *In proceedings of The First Iranian Students Scientific Conference*. Malaysia (Vol.9,PP.1-8)
- Alhajri, A. R., & Alshibani, A. (2018, June 25). Critical Factors behind Construction Delay in Petrochemical Projects in Saudi Arabia. *Energies 11*(7), P.1652.
- AlSehaimi, A. O., Fazenda, P. T., & Koskela, L. (2013). Improving construction management practice in Saudi arabia with the last planner system: a case study . *Engineering, Construction and Architectural Management*, 21(1), 51-64.
- Amoatey, C. T., Adaku, E., & Famiyeh, S. (2015). Analysing delay causes and effects in Ghanaian state housing construction projects. *International Journal of Managing Projects in Business*, 8(1), 198-214.
- Argaam. (2017, 7 10). Retrieved from Argaam: <https://www.argaam.com/en/article/articledetail/id/494558>
- Ayodele, E. O. (2011). Abandonment of construction projects in Nigeria: causes and effects. *Journal of Emerging Trends in Economics and Management Sciences*, 2(2), 142-145.
- Baruch, Y., & Brooks C, H. (2008). Survey response rate levels and trends in organizational research. *Human relations*, 61(8), 1139-1160.

- Boone, H., & Boone, D. (2012). Analyzing likert data. *Journal of extension*, 1-5.
- clever buying*. (n.d.). Retrieved from www.cleaverbuying.com:
<https://www.cleverbuying.com/what-evaluation-method-should-i-use>
- DM STAT-1*. (n.d.). Retrieved from dmstat1.com:
www.dmstat1.com/res/TheCorrelationCoefficientDefined.html
- Gebrehiwet, T., & Luo, H. (2017). Analysis of delay impact on construction project based on RII and correlation coefficient: Empirical study. *Creative Construction Conference, 196*, pp. 366-374. Primosten, Croati.
- González, P., González, V., Molenaar, K., & Orozco, F. (2013). Analysis of causes of delay and time performance in construction projects. *Journal of Construction Engineering and Management*, 140(1).
- Gunduz, M., & AbuHassan, M. H. (2016). Causes of construction delays in Qatar construction projects. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, 10(4), 516-521.
- Hasan, R., Suliman, S. M., & Malki, Y. A. (2014, FEB). An Investigation into the Delays in Road Projects in Bahrain. *International Journal of Research in Engineering and Science (IJRES)*, 2(2), 38-47.
- Validity. (n.d.). Retrieved from statsdirect.com
<http://www.statsdirect.com/help/Default.htm#basics/validity.htm>
- Hwang, B. G., & Yang, S. (2014). Rework and schedule performance: A profile of incidence, impact, causes and solutions. *Engineering, Construction and Architectural Management*, 21(2), 190-205.

- Khoshgoftar, M., Bakar, A. H., & Osman, O. (2010). Causes of delays in Iranian construction projects. *International Journal of Construction Management*, 10(2), 53-69.
- Koirala, S., Hill, D., & Morgan, R. (2017). Impacts of the delay in construction of a large scale hydropower project on potential displacees. *Impact Assessment and Project Appraisal*, 35(1), 106-116.
- Kumar, D. (2016). Causes and Effects of Delays in Indian Construction Projects. *International Research Journal of Engineering and Technology*, 3(4), 1831-1837.
- Laerd dissertation. (n.d.). Retrieved from dissertation.aerd.com: <http://dissertation.laerd.com/reliability-in-research-p2.php>
- Le-Hoai, L., Dai Lee, Y., & Lee, J. Y. (2008). Delay and cost overruns in Vietnam large construction projects: A comparison with other selected countries. *KSCE journal of civil engineering*, 6(12), 367-377.
- Mahamid, I., & Al-Ghonamy, A. &. (2015). Risk Matrix for Delay Causes in Construction Projects in Saudi Arabia. *Research Journal of Applied Sciences, Engineering and Technology*, 9(8), 665-670.
- Martin, M. (2012, 9 28). Saudi Kayan chases profit. *MEED : Middle east economic digest*, 56(39), 34-35.
- Mhlanga, M. Z., Munapo, E., & Mavetera, N. (2016, July 14). Investigating causes of delays and cost escalation in project execution during turnarounds. *Investment Management and Financial Innovations*, 13(2-2), 334-338.

- Mohammed, K. A., & Isah, A. D. (2012). Causes of delay in Nigeria construction industry. *Interdisciplinary journal of contemporary research in business*, 4(2), 785-794.
- Mohammed, R. M., & Suliman, S. M. (2019). Delay in Pipeline Construction Projects in the Oil and Gas Industry: Part 1 (Risk Mapping of Delay Factors). *International Journal of Construction Engineering and Management*, Vol. 8 No. 1, 24-35.
- Mydin, M. O., Sani, N. M., Taib, M., & Alias, N. M. (2014). Imperative causes of delays in construction projects from developers' outlook. In MATEC Web of Conferences. In *MATEC Web of Conferences*. 10, p. 06005. Penang: EDP Sciences.
- Naimi, M., Elhag, T., & Fenn, P. (2008). Delay and its consequences in construction of Iranian petrochemical plants. *International conference on multi-national construction projects, "Securing high Performance through Cultural awareness and Dispute Avoidance*. SHANGHAI.
- Nguyen, Q. T., & Chua., D. K. (2014, January). Criticality of Schedule Constraints – Classification and Identification for Project Management. *Journal of Engineering, Project, and Production Management*, 4.1, 17–25.
- Nguyen, T. P., & Chileshe, N. (2015). Revisiting the construction project failure factors in Vietnam. *Built Environment Project and Asset Management*, 5(4), 398-416.
- Pareto principle*. (2019, August 29). Retrieved from Investodia.com: <https://www.investopedia.com/terms/p/paretoprinciple.asp>

- Pham, L. H., & Hadikusumo, H. (2014). Schedule delays in engineering, procurement, and construction petrochemical projects in Vietnam: A qualitative research study. *International Journal of Energy Sector Management*, 8(1), 3-26.
- Pourrostan, T., & Ismail, A. (2011). Study of Methods for Minimizing Construction Delays: Evidences from a Developing Country. *Advanced Materials Research*, 201-2013, 2939-2942.
- Rao, B. P., Shekar, S. C., Jaiswal, N., Jain, A., & Saxena, A. D. (2016). Delay analysis of construction projects. *Journal of Information Technology and Economic Development*, 7(1), 15-24.
- Ruqaishi, M., & Bashir, H. (2015). Causes of delay in construction projects in the oil and gas industry in the gulf cooperation council countries . A case study. *Journal of management in Engineering*, 31(3).
- Salama, M., El Hamid, M. A., & Keogh, B. (2008). Investigating the causes of delay within oil and gas projects in the UAE. *In Proc. 24th Annual ARCOM Conference* (pp. 1-3). Cardiff, United Kingdom: School of Management and Languages, Heriot-Watt University.
- Samarghandi, H., Mousavi, S., Taabayan, P., Mir Hashemi, A., & Willoughby, K. (2016). Studying the Reasons for Delay and Cost Overrun in Construction Projects: The Case of Iran. *Journal of Construction in Developing Countries*, 21(1), 51-84. doi:10.21315/jcdc2016.21.1.4
- Seddeeq, A. B., Assaf, S. A., Abdallah, A., & Hassanain, M. A. (2019). Time and Cost Overrun in the Saudi Arabian Oil and Gas Construction Industry. *BUILDINGs*, 9(2), 41-60.

- Shehu, A. A., Masrom, A. N., & Mohammed, M. (2016). The Effects Of Construction Delays on The Contractor's Reputation In Nigeria-The Perception Of Professionals. *Journal of Multidisciplinary Engineering Science and Technology (JMEST)*, 3(3).
- Srdić, A., & Šelih, J. (2015). Delays in construction projects: causes and mitigation. *Organization, technology & management in construction: an international journal*, 7(3), 1383-1389. doi:10.5592/otmcj.2015.3.5
- Suppramaniam, U. K., & Ismail, S. (2018). Effects of Delay in Construction Phase of Oil and Gas Projects in Malaysia. *Journal of Advanced Research in Business and Management Studies*, 13(1), 31-38.
- Tariq, M. U. (2013). A six sigma based risk management framework for handling undesired effects associated with delays in project completion. *International Journal of Lean Six Sigma*, 4(3), 265-279. doi:doi:http://dx.doi.org.proxygw.wrlc.org/10.1108/IJLSS-05-2
- What is margin of error.* (n.d.). Retrieved from questionpro.com: <https://www.questionpro.com/blog/margin-of-error/>
- Wikepdia.* (2020, July 12). Retrieved from wikipedia.org: https://en.wikipedia.org/wiki/Pareto_principle
- Yang, J. B., & Kao, C. K. (2009). Review of delay analysis methods: A process-based comparison. *The Open Construction and Building Technology Journal*, 3(1), 81-89.

Appendices

Appendix (A)	Focus Group Interview with a Preliminary Survey
Appendix (B)	Interview Results
Appendix (C)	Research Questionnaire Survey
Appendix (D)	Petrochemical industries and contractor average weightage analysis

Appendix A

Focus group interview with preliminary survey

[An investigation into the delay factors affecting the maintenance and construction projects in the Petrochemical industries in Bahrain]

Name

Department

(optional
)

Position

Date

This is a preliminary survey seeks the opinion of expertise in field of maintenance and construction projects in petrochemical industries in Bahrain, in order to identify the most relevant and critical Delay factors and their consequences

A Yes and no check list is prepared to evaluate the extent of the agreement to the identified factors and relevancy to petrochemical industries

The survey consists of two parts

Part I: Delay factor

Which of the following delay factors are related to petrochemical industries in your opinion? Also please feel free to add any new factors as found applicable

No	Delay factor	Yes	No
	Design & Engineering related factors Technical service department (Owner)		
1	Late design change	☐	☐
2	Poor design / Design error	☐	☐
3	Incomplete and unclear drawing and project document	☐	☐

No	Delay factor	Yes	No
4	Delay in Preparation and approval and issuance of drawings and documents	☐	☐
5	Poor qualification and Inadequate design team experience	☐	☐
6	Reengineering of different units caused by poor basic design package structural modifications after starting the project	☐	☐
7	Poor interaction with vendors in the engineering stage	☐	☐
8	Weak and insufficient technical studies for the project	☐	☐
9	Major changes of design during construction by consultant And delay in approving major changes	☐	☐
10	Engineer reluctance for change and their inflexibilities	☐	☐
11	Insufficient data collection and survey before design	☐	☐
12	Mistakes and discrepancies made in design documents leads to frequent revisions of drawings/designs	☐	☐
13	Unclear and inadequate details in drawings and also slow response on doubts arising from the drawings	☐	☐
14	Using poor /old engineering design software	☐	☐
15	Complexity of project conception & designing	☐	☐
16	Improper selection of project location	☐	☐
17	Misunderstanding of owner requirements by design engineer	☐	☐
	Management related factors Owner		
18	Bureaucracy in organization	☐	☐
19	Owner influence (unrealistic project duration imposed by owner)	☐	☐
20	Owner interference, Changes, and scope variation	☐	☐
21	Slow decision making and approval by the owner organization	☐	☐
22	Client cash flow and payment problem, and Delay in project financing and progressive payments	☐	☐

No	Delay factor	Yes	No
23	Unavailability or late approval of project budget	☐	☐
24	Adoption of fast-track project delivery strategy	☐	☐
25	Adoption of the lowest bid price system	☐	☐
	Contract related factors Engineering, Purchasing and Maintenance departments (Owner)		
26	Poor definition of interfaces causing scope creep	☐	☐
27	Mistakes and discrepancies in contract document and drawing	☐	☐
28	Inadequate project duration defined in original contract	☐	☐
29	Poor definition of payment milestones/distribution	☐	☐
30	Improper selection of the type of contract for the project	☐	☐
31	Complications in the tendering process	☐	☐
32	Aggressive competition at tender stage	☐	☐
33	Short bid preparation time leads to improper bidding by contractor	☐	☐
34	Inadequate delay penalties/poor incentives for early completion	☐	☐
	Material and plant's equipment related factors Material and purchasing department and Maintenance department (Owner)		
35	Late delivery of material or plant	☐	☐
36	Material shortage / scarcity	☐	☐
37	Change in material type during construction due to poor quality of procured material	☐	☐
38	Damage of sorted material while they are needed urgently due to improper storage of materials	☐	☐
39	lack of adequate space for storing materials in site	☐	☐
40	Procuring undesired or unwanted material instead	☐	☐
41	Escalation of material prices	☐	☐
42	Late material issuance	☐	☐
43	Poor procurement programming of materials (Late procurement of materials/late ordering)	☐	☐
44	Problem with equipment transportation and delivering to the site	☐	☐
45	Sudden increase in quantity needed	☐	☐

No	Delay factor	Yes	No
	Project team related factors Maintenance and Operation department (Owner)		
46	Incompetent project team and lack of experience in construction	☐	☐
47	Inappropriate overall organization structure for the projects	☐	☐
48	poor contract and schedule management by project team	☐	☐
49	Inadequate project planning, budgeting and scheduling	☐	☐
50	Poor technical experience	☐	☐
51	Poor site supervision	☐	☐
52	Poorly defined or vague scope of work	☐	☐
53	Delay in performing inspection and testing	☐	☐
54	Inadequate quality assurance/control	☐	☐
55	Lack of ownership in the project, And conflict between owners of project	☐	☐
56	Delay in handing over the construction site to contractor	☐	☐
	Site and work execution related factors Owner & contractor		
57	Unsafe practice at site (Poor safety conditions)	☐	☐
58	Lack of site utilities or services Unavailability/poor temporary facility of utilities in site (such as water, electricity, telephone, etc.)	☐	☐
59	Accident during construction	☐	☐
60	Security and slow site clearance (checking process for quality, safety and other purposes)	☐	☐
61	Difficulties / Delay in obtaining work permits	☐	☐
62	Unclear or undefined positions of services networks in drawings	☐	☐
63	Unforeseen site condition	☐	☐
64	Weather effect (heat, rain, wind, sand storm, etc.	☐	☐
65	Summer restriction on time of work	☐	☐
66	Environmental protection pressure by stakeholders	☐	☐
67	Delay in Way-leave approval from utilities agencies	☐	☐
	work force related factors –		

No	Delay factor	Yes	No
	Maintenance and operation department including direct hired contract manpower (Owner)		
68	Shortage of manpower	☐	☐
69	Unexpected low manpower productivity	☐	☐
70	Lack of skilled manpower	☐	☐
71	Personal conflicts among labors	☐	☐
72	Workers Safety & health problems when working in hazardous conditions and their absenteeism	☐	☐
73	Nationality and language of vendors and workers	☐	☐
74	Lack of motivation	☐	☐
	Project's tools and equipment's related factors Maintenance department (Owner)		
75	Equipment failure or breakdown	☐	☐
76	Unavailability or Shortage of heavy equipment when needed	☐	☐
77	Low level of equipment-operator's skill	☐	☐
78	Low productivity and efficiency of equipment	☐	☐
79	Wrong kind of equipment selection	☐	☐
80	Lack of hi-tech, advanced and special equipment	☐	☐
81	Complication of hiring and transporting to the site	☐	☐
82	Limited mechanization due to cheap labor cost in the locality	☐	☐
	Contractor related factors		
83	Poor understanding of scope of work during bidding stage	☐	☐
84	Negligence of site visits before/during the bidding process	☐	☐
85	Under bidding	☐	☐
86	Negotiations and obtaining method of contracts	☐	☐
87	Poor estimation of project time and material quantities required before contracting	☐	☐
88	Inadequate scheduling / planning / estimation by contractor	☐	☐
89	Inappropriate Construction methods	☐	☐
90	Inadequate contractor experience	☐	☐

No	Delay factor	Yes	No
91	Poor supervision & managerial skills	☐	☐
92	Delay in fabrication activities	☐	☐
93	In-efficient and poor performance of contractors/subcontractors	☐	☐
94	Poor site management and supervision	☐	☐
95	Delay or problems caused by subcontractors	☐	☐
	Conflict with subcontractor		
	Delay in contractor payment to subcontractor and supplier		
96	Rework due to errors, mistakes and defective works during construction	☐	☐
97	Poor communication / conflict between contractor and project parties	☐	☐
98	Difficulties in project financing by contractor	☐	☐
99	Insufficient contractor's manpower (or resources)	☐	☐
100	Shortage of skilled labors by contractor	☐	☐
101	Slow mobilization & demobilization of labor	☐	☐
	All parties related factors Owner and contractor		
102	Personality clash between two or more members from different parties	☐	☐
103	Lack of communication between parties involved	☐	☐
104	Lack of periodic meeting among the management, site personnel and the contractors and also weekly project evaluation meetings	☐	☐
	Legal related factors		
105	Changes in laws and regulations	☐	☐
106	Insufficient laws on projects	☐	☐
107	Inefficiency of legal process	☐	☐
108	Unfamiliarity with government regulations and laws	☐	☐
	External related factors		
109	Economic and financial condition of the market	☐	☐
110	Dispute with residents /neighbors around site	☐	☐
111	Lack of coordination among public agencies concerned	☐	☐
112	Damage to work by third party	☐	☐

No	Delay factor	Yes	No
113	Corruption and bribery	☐	☐
114	Political situation and security	☐	☐
115	Fraudulent practices and kickbacks	☐	☐
116	Corruption & hostile political conditions and also strikes called by political parties	☐	☐
117	Effects of social and cultural factors	☐	☐

Part 2: Delay consequences

Which of the following delay consequences are related to petrochemical industries in your opinion? Also please feel free to add any new factors as found applicable

No	Delay consequences	Yes	No
1	Abandonment of project	☐	☐
2	Time overrun	☐	☐
3	Disputes	☐	☐
4	Idling resources	☐	☐
5	Lack of continuity by client	☐	☐
6	Penalties	☐	☐
7	Arbitration or Litigation between the participants of the project	☐	☐
8	Bankruptcy	☐	☐
9	Cost overrun	☐	☐
10	Declination of reputation	☐	☐
11	Distrust with contractor	☐	☐
12	Delay in the progress payment due to distrust	☐	☐
13	Loss of profit and revenue	☐	☐
14	Loss of market value of the contractor	☐	☐
15	Negative social impact	☐	☐
16	Non-productivity loss for the owner	☐	☐

No	Delay consequences	Yes	No
17	Poor quality of work due to hurry	☐	☐
18	Reduction in profit for the contractor	☐	☐
19	Termination of contract	☐	☐
20	Loss of Interest by the Stakeholder	☐	☐
21	Blacklist by Authorities or company	☐	☐
22	Delay of other projects related to the main one	☐	☐
23	Disruption of traffic movement	☐	☐
24	The work extended to hours beyond the normal working hours to cope with new schedule	☐	☐
25	Importing the products that company is not able to produce during the outage or delay in startup	☐	☐
26	Change the form of delivery of material from ship to air freighted	☐	☐
27	Compromised quality of work under pressure	☐	☐
28	Image disruption and customer dissatisfaction for direct customer who is waiting to ship the product and subsequent penalty for delay.	☐	☐
29	Not achieving production target	☐	☐

Appendix B

Interview results

SN	Delay factor	Number of agreements
	Design & Engineering related factors Technical service department (Owner)	
1	Late design change	8
2	Poor design / Design error	6
3	Incomplete and unclear drawing and project document	8
4	Delay in Preparation and approval and issuance of drawings and documents	8
5	Poor qualification and Inadequate design team experience	4
6	Reengineering of different units caused by poor basic design package structural modifications after starting the project	5
7	Poor interaction with vendors in the engineering stage	5
8	Weak and insufficient technical studies for the project	3
9	Major changes of design during construction by consultant And delay in approving major changes	7
10	Engineer reluctance for change and their inflexibilities	4
11	Insufficient data collection and survey before design	4
12	Mistakes and discrepancies made in design documents leads to frequent revisions of drawings/designs	7
13	Unclear and inadequate details in drawings and also slow response on doubts arising from the drawings	8
14	Using poor /old engineering design software	3
15	Complexity of project conception & designing	3
16	Improper selection of project location	2

SN	Delay factor	Number of agreements
17	Misunderstanding of owner requirements by design engineer	4
	Management related factors Owner	
18	Bureaucracy in organization	7
19	Owner influence (unrealistic project duration imposed by owner)	8
20	Owner interference, Changes, and scope variation	9
21	Slow decision making and approval by the owner organization	9
22	Client cash flow and payment problem, and Delay in project financing and progressive payments	3
23	Unavailability or late approval of project budget	6
24	Adoption of fast-track project delivery strategy	7
25	Adoption of the lowest bid price system	8
	Contract related factors Engineering, Purchasing and Maintenance departments (Owner)	
26	Poor definition of interfaces causing scope creep	7
27	Mistakes and discrepancies in contract document and drawing	6
28	Inadequate project duration defined in original contract	7
29	Poor definition of payment milestones/distribution	4
30	Improper selection of the type of contract for the project	4
31	Complications in the tendering process	9
32	Aggressive competition at tender stage	5
33	Short bid preparation time leads to improper bidding by contractor	6
34	Inadequate delay penalties/poor incentives for early completion	5
	Material and plant's equipment related factors Material and purchasing department and Maintenance department (Owner)	
35	Late delivery of material or plant	10
36	Material shortage / scarcity	9
37	Change in material type during construction due to poor	5

SN	Delay factor	Number of agreements
	quality of procured material	
38	Damage of sorted material while they are needed urgently due to improper storage of materials	4
39	lack of adequate space for storing materials in site	4
40	Procuring undesired or unwanted material instead	5
41	Escalation of material prices	6
42	Late material issuance	6
43	Poor procurement programming of materials (Late procurement of materials/late ordering)	8
44	Problem with equipment transportation and delivering to the site	7
45	Sudden increase in quantity needed	5
	Project team related factors Maintenance and Operation department (Owner)	
46	Incompetent project team and lack of experience in construction	6
47	Inappropriate overall organization structure for the projects	6
48	poor contract and schedule management by project team	8
49	Inadequate project planning, budgeting and scheduling	8
50	Poor technical experience	5
51	Poor site supervision	6
52	Poorly defined or vague scope of work	6
53	Delay in performing inspection and testing	7
54	Inadequate quality assurance/control	7
55	Lack of ownership in the project, And conflict between owners of project	8
56	Delay in handing over the construction site to contractor	9
	Site and work execution related factors Owner & contractor	
57	Unsafe practice at site (Poor safety conditions)	5
58	Lack of site utilities or services Unavailability/poor temporary facility of utilities in site (such as water, electricity, telephone, etc.)	6
59	Accident during construction	8

SN	Delay factor	Number of agreements
60	Security and slow site clearance (checking process for quality, safety and other purposes)	9
61	Difficulties / Delay in obtaining work permits	8
62	Unclear or undefined positions of services networks in drawings	6
63	Unforeseen site condition	6
64	Weather effect (heat, rain, wind, sand storm, etc.	7
65	Summer restriction on time of work	10
66	Environmental protection pressure by stakeholders	6
67	Delay in Way-leave approval from utilities agencies	10
	work force related factors – Maintenance and operation department including direct hired contract manpower (Owner)	
68	Shortage of manpower	8
69	Unexpected low manpower productivity	7
70	Lack of skilled manpower	6
71	Personal conflicts among labors	3
72	Workers Safety & health problems when working in hazardous conditions and their absenteeism	5
73	Nationality and language of vendors and workers	3
74	Lack of motivation	6
	Project's tools and equipment's related factors Maintenance department (Owner)	
75	Equipment failure or breakdown	5
76	Unavailability or Shortage of heavy equipment when needed	6
77	Low level of equipment-operator's skill	6
78	Low productivity and efficiency of equipment	5
79	Wrong kind of equipment selection	4
80	Lack of hi-tech, advanced and special equipment	2
81	Complication of hiring and transporting to the site	3

SN	Delay factor	Number of agreements
82	Limited mechanization due to cheap labor cost in the locality	3
	Contractor related factors	
83	Poor understanding of scope of work during bidding stage	7
84	Negligence of site visits before/during the bidding process	5
85	Under bidding	6
86	Negotiations and obtaining method of contracts	3
87	Poor estimation of project time and material quantities required before contracting	8
88	Inadequate scheduling / planning / estimation by contractor	9
89	Inappropriate Construction methods	6
90	Inadequate contractor experience	8
91	Poor supervision & managerial skills	6
92	Delay in fabrication activities	6
93	In-efficient and poor performance of contractors/subcontractors	6
94	Poor site management and supervision	4
95	Delay or problems caused by subcontractors Conflict with subcontractor Delay in contractor payment to subcontractor and supplier	7
96	Rework due to errors, mistakes and defective works during construction	9
97	Poor communication / conflict between contractor and project parties	8
98	Difficulties in project financing by contractor	4
99	Insufficient contractor's manpower (or resources)	9
100	Shortage of skilled labors by contractor	8
101	Slow mobilization & demobilization of labor	5
	All parties related factors Owner and contractor	
102	Personality clash between two or more members from different parties	5

SN	Delay factor	Number of agreements
103	Lack of communication between parties involved	7
104	Lack of periodic meeting among the management, site personnel and the contractors and also weekly project evaluation meetings	7
	Legal related factors	
105	Changes in laws and regulations	4
106	Insufficient laws on projects	3
107	Inefficiency of legal process	3
108	Unfamiliarity with government regulations and laws	4
	External related factors	
109	Economic and financial condition of the market	5
110	Dispute with residents /neighbors around site	6
111	Lack of coordination among public agencies concerned	4
112	Damage to work by third party	3
113	Corruption and bribery	2
114	Political situation and security	5
115	Fraudulent practices and kickbacks	4
116	Corruption & hostile political conditions and also strikes called by political parties	3
117	Effects of social and cultural factors	1

Delay consequences:

SN	Delay consequences	Number of agreements
1	Abandonment of project	2
2	Time overrun	9
3	Disputes	7
4	Idling resources	8
5	Lack of continuity by client	8
6	Penalties	5
7	Arbitration or Litigation between the participants of the project	5
8	Bankruptcy	5

SN	Delay consequences	Number of agreements
9	Cost overrun	8
10	Declination of reputation	8
11	Distrust with contractor	7
12	Delay in the progress payment due to distrust	6
13	Loss of profit and revenue	6
14	Loss of market value of the contractor	6
15	Negative social impact	4
16	Non-productivity loss for the owner	5
17	Poor quality of work due to hurry – Duplicated with 27	8
18	Reduction in profit for the contractor –removed as it related directly to contractor	8
19	Termination of contract	6
20	Loss of Interest by the Stakeholder	6
21	Blacklist by Authorities or company	7
22	Delay of other projects related to the main one	7
23	Disruption of traffic movement	6
24	The work extended to hours beyond the normal working hours to cope with new schedule	8
25	Importing the products that company is not able to produce during the outage or delay in startup	8
26	Change the form of delivery of material from ship to air freighted	7
27	Compromised quality of work under pressure	7
28	Image disruption and customer dissatisfaction for direct customer who is waiting to ship the product and subsequent penalty for delay.	6
29	Not achieving production target	7

Appendix C

Research Questionnaire Survey

An Investigation into the Delay Factors Affecting the Maintenance and Construction Projects in the Petrochemical Industries in Bahrain

The following questionnaire survey is part of Master thesis requirement in engineering management, conducted under the title "An Investigation into the Delay Factors Affecting the Maintenance and Construction Projects in the Petrochemical Industries in Bahrain"

The survey is designed to target technical employees from the petrochemical industries, contractors working in petrochemical industries, and also engineers and project managers from related oil and gas industries that share a similar working system.

The questionnaire consists of three parts. Part one is the general information and background of the respondents. Part two is a list of delay factors under nine different related groups, and part three is about the delay consequences.

In order to rank the delay factors and their consequences, a risk matrix will be utilized with two dimensions which will be obtained from the questionnaire outcome. The first dimension is the frequency of occurrence and the second one is the severity level. You are kindly requested to rank these factors on a Likert scale (1-5) for each question in parts two and three.

The questionnaire will take approximately 20 to 30 minutes to complete. If you have any questions about the survey, please contact me on my phone at +973 39883636 or my email f_ebr@hotmail.com.

As part of my research, a brief follow-up interview might be conducted , which could be done over the phone or in person. It will be highly appreciated if the respondent chooses to provide his name and contact number or email. All personal information will be kept confidential and will not be shared.

* Required

Part 1

General information and back ground of the respondents

1. Name

This information is only for record keeping and will be kept confidential. This is an optional request.

2. Job title *

All information will be kept confidential. This information will help the researcher to better analyze the outcome of the survey.

3. Industry *

Mark only one oval.

☐ Petrochemical

☐ Contractor

☐ Oil & Gas

☐ Other: _____

4. Working field *

Mark only one oval.

☐ Maintenance

☐ Technical services

☐ Operation

☐ Purchasing and Material

☐ Projects

☐ Other: _____

5. Years of experience *

Mark only one oval.

- ☐ 3-5 years
- ☐ 6-10 years
- ☐ 11-15 years
- ☐ Above 15 years

Part 2: Delay factors analysis

Delay factors are categorized under nine different related groups. For each delay factor, there are two questions. Question one for the frequency of occurrence, and question two for the severity level.

Group 1: Design and Engineering related factors

This section presents delay factors typically originating in the engineering section.

The Likert scale rate shall be as follows:
Frequency of occurrence: Never (1), Rare (2), Sometimes (3), Often (4), and Always (5).
Severity level :Very low (1), Low(2), Moderate(3), High(4), and Very high(5).

6. Late design changes initiating in the project life cycle. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

7. Incomplete/unclear drawing and project documents. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

8. Delay in preparation, approval and issuance of drawings and documents. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

9. Mistakes and discrepancies made in design documents. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

Group 2: Management
related factors

This section presents delay factors typically originating from management decisions and working culture.

The likert scale rate shall be as follows:

Frequency of occurrence: Never (1), Rare (2), Sometimes (3), Often (4), and Always (5).

Severity level :Very low (1), Low(2), Moderate(3), High(4), and Very high(5).

10. Bureaucracy in the organization. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

11. Owner influence (Unrealistic project duration imposed by owner). *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

12. Owner interference(Changes, and scope variation). *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

13. Slow decision making and approval by the owner organization. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

14. Adoption of fast-track project delivery strategy. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

15. Adoption of the lowest bid price system for awarding the contract. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

Group 3: Contract
related factors

This section presents delay factors typically originating from a contractual point of view.

The Likert scale rate shall be as follows:

Frequency of occurrence: Never (1), Rare (2), Sometimes (3), Often (4), and Always (5).

Severity level :Very low (1), Low(2), Moderate(3), High(4), and Very high(5).

16. Poor definition of interfaces causing scope creep. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

17. Inadequate project duration defined in the original contract. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

18. Complicated and long tendering procedures to award the contract. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

Group 4: Material and equipment related factors

This section presents delay factors typically originating from aspects related to the material and the equipment.

The Likert scale rate shall be as follows:

Frequency of occurrence :Never (1), Rare (2), Sometimes (3), Often (4), and Always (5).

Severity level :Very low (1), Low(2), Moderate(3), High(4), and Very high(5).

19. Late delivery of material or equipment. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

20. Material shortage or scarcity. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

21. Poor procurement programming of materials (Late order or wrong sequence of order). *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

22. Problem with equipment transportation and delivery to the site. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

Group 5: Project
management related factors

This section presents delay factors typically originating from the project management aspects.

The Likert scale rate shall be as follows:

Frequency of occurrence: Never (1), Rare (2), Sometimes (3), Often (4), and Always (5).

Severity level :Very low (1), Low(2), Moderate(3), High(4), and Very high(5).

23. Poor contract and schedule management by the project team. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

24. Inadequate project planning, budgeting, and scheduling. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

25. Delay in performing inspection and testing. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

26. Inadequate quality assurance and quality control. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

27. Lack of ownership in the project, and conflict between owners of the project. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

28. Delay in handing over the construction site to the contractor. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

Group 6: Site and work execution related factors

This section presents delay factors typically originating from the site and work execution related issues.

The Likert scale rate shall be as follows:

Frequency of occurrence: Never (1), Rare (2), Sometimes (3), Often (4), and Always (5).

Severity level :Very low (1), Low(2), Moderate(3), High(4), and Very high(5).

29. Accidents during the construction. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

30. Security and slow site clearance (checking process for quality, safety and other purposes). *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

31. Difficulties and delay in obtaining work permits. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

32. Weather effect: (heat, rain, wind, sand storm, etc.). *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

33. Summer restriction on time of work. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

34. Delay in Way-leave approval from authorities. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

Group 7: Manpower
related factors

This section presents delay factors typically originating from manpower involved in project execution.

The Likert scale rate shall be as follows:

Frequency of occurrence: Never (1), Rare (2), Sometimes (3), Often (4), and Always (5).

Severity level :Very low (1), Low(2), Moderate(3), High(4), and Very high(5).

35. Shortage of manpower. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

36. Unexpected low manpower productivity *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

Group 8: Contractor
related factors.

This section presents delay factors typically originating from the contractors.

The Likert scale rate shall be as follows:

Frequency of occurrence: Never (1), Rare (2), Sometimes (3), Often (4), and Always (5).

Severity level :Very low (1), Low(2), Moderate(3), High(4), and Very high(5).

37. Poor understanding of the scope of work during the bidding stage. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

38. Poor estimation of project time, material quantity requirement before contracting. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

39. Inadequate project planning, budgeting, and scheduling by the contractor. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

40. Inadequate contractor experience. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

41. Delay or problems caused by subcontractors. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

42. Rework due to errors, mistakes and defective works during construction. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

43. Poor communication & conflict between contractor and project parties. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

44. Insufficient contractor's manpower (or resources). *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

45. Shortage of skilled labors by the contractor. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

Group 9: Common factors - All parties.

This section presents delay factors that are commonly experienced amongst all parties involved in the project life cycle.

The Likert scale rate shall be as follows:

Frequency of occurrence: Never (1), Rare (2), Sometimes (3), Often (4), and Always (5).

Severity level :Very low (1), Low(2), Moderate(3), High(4), and Very high(5).

46. Lack of communication between parties involved. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

47. Lack of periodic meetings among the management, site personnel, and contractors. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Severity level	☐	☐	☐	☐	☐

Part 3: Delay
consequences
analysis

This section includes a list of the delay consequences in maintenance and construction projects in the petrochemical industries in Bahrain.
Please evaluate the consequences of the delay based on the frequency of occurrence and the impact level of the delay consequence.
Frequency of occurrence shall be categorized as follows: Never (1), Rare (2), Sometimes (3), Often (4), and always (5).
And impact level shall be categorized as Very low (1), Low (2), Moderate (3), High (4), and Very high (5).

48. Time overrun. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

49. Disputes between project parties. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

50. Idling resources. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

51. Lack of continuity by the management. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

52. Cost overrun. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

53. Declination of reputation and confidence in the project team. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

54. Distrust with the contractor. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

55. Blacklisting the contractor by the owner. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

56. Delay of other projects related to the main and critical-path project. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

57. Extension of works beyond the normal working hours to cope with the new schedule. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

58. Importing the utilities and material that the company is not able to produce during the delay period of the project and outage of the unit. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

59. Change the form of delivery of material from ship to air freight. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

60. Compromising the quality of work under pressure. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

61. Not achieving the production target. *

Mark only one oval per row.

	1	2	3	4	5
Frequency of occurrence	☐	☐	☐	☐	☐
Impact level	☐	☐	☐	☐	☐

Appendix D

- 1) Delay factors average weight calculation for petrochemical industries for frequency of occurrence and severity level as per Equation (1) and (2).
- 2) Delay consequences average weight calculation for petrochemical industries and contractor, for frequency of occurrence and impact level as per Equations (1) & (2).

- 1) Delay factors average weight calculation for petrochemical industries for frequency of occurrence and severity level as per Equation (1) and (2).

SN	Delay description	Mean Frequency of occurrence	Mean Severity level
1	Late design changes initiating in the project life cycle	2.97	3.38
2	Incomplete/unclear drawing and project documents	2.85	3.21
3	Delay in preparation, approval and issuance of drawings and documents	3.00	3.13
4	Mistakes and discrepancies made in design documents	2.38	3.49
5	Bureaucracy in the organization.	2.85	2.92
6	Owner influence (Unrealistic project duration imposed by owner)	2.67	3.08
7	Owner interference (Changes, and scope variation)	3.00	3.21
8	Slow decision making and approval by the owner organization	2.64	2.92
9	Adoption of fast-track project delivery strategy	2.90	3.00
10	Adoption of the lowest bid price system for awarding the contract	3.62	3.03
11	Poor definition of interfaces causing scope creep	2.54	2.95
12	Inadequate project duration defined in the original contract	2.54	3.31
13	Complicated and long tendering procedures to award the contract	3.18	3.05
14	Late delivery of material or equipment	2.67	4.26

SN	Delay description	Mean Frequency of occurrence	Mean Severity level
15	Material shortage or scarcity	2.15	3.64
16	Poor procurement programming of materials (Late order or wrong sequence of order)	2.38	3.49
17	Problem with equipment transportation and delivery to the site	2.00	3.21
18	Poor contract and schedule management by the project team	2.72	3.18
19	Inadequate project planning, budgeting, and scheduling	3.03	3.41
20	Delay in performing inspection and testing	2.51	3.18
21	Inadequate quality assurance and quality control	2.13	3.26
22	Lack of ownership in the project, and conflict between owners of the project	2.51	3.15
23	Delay in handing over the construction site to the contractor	2.23	2.82
24	Accidents during the construction.	1.72	3.49
25	Security and slow site clearance (checking process for quality, safety and other purposes)	3.10	2.54
26	Difficulties and delay in obtaining work permits	2.36	2.56
27	Weather effect: (heat, rain, wind, sand storm, etc.)	2.36	2.59
28	Summer restriction on time of work	3.36	2.64
29	Delay in Way-leave approval from authorities	3.13	2.77

SN	Delay description	Mean Frequency of occurrence	Mean Severity level
30	Shortage of manpower.	2.62	3.31
31	Unexpected low manpower productivity	2.13	2.97
32	Poor understanding of the scope of work during the bidding stage	2.69	3.28
33	Poor estimation of project time, material quantity requirement before contracting	2.72	3.44
34	Inadequate project planning, budgeting, and scheduling by the contractor	2.62	3.49
35	Inadequate contractor experience	2.18	3.51
36	Delay or problems caused by subcontractors	2.44	3.00
37	Rework due to errors, mistakes and defective works during construction	2.51	3.77
38	Poor communication & conflict between contractor and project parties	2.28	3.10
39	Insufficient contractor's manpower (or resources)	2.46	3.23
40	Shortage of skilled labors by the contractor	2.49	2.97
41	Lack of communication between parties involved	2.72	3.10
42	Lack of periodic meetings among the management, site personnel, and contractors	2.79	2.95

- 2) Delay consequences average weight calculation for petrochemical industries and contractor, for frequency occurrence and impact level as per Equations (1) & (2).

SN	Delay Consequence	Petrochemical industries		Contractor	
		Mean Frequency of occurrence	Mean Severity level	Mean Frequency of occurrence	Mean Severity level
1	Time overrun	3.05	3.36	2.82	3.36
2	Disputes between project parties	2.46	2.79	2.55	2.73
3	Idling of resources	2.77	2.41	2.45	2.55
4	Lack of continuity by the management	2.13	2.90	2.09	2.18
5	Cost overrun	2.85	3.44	3.00	3.27
6	Declination of reputation and confidence in the project team	2.15	3.10	2.27	2.64
7	Distrust with the contractor	2.26	2.62	2.36	2.64
8	Blacklisting the contractor by the owner	2.08	2.90	1.82	2.18
9	Delay of other projects related to the main and critical-path project	2.67	3.64	2.36	2.82
10	Extension of works beyond the normal working hours to cope with the new schedule	3.64	3.00	3.18	3.18
11	Importing the utilities and material that the company is not able to produce during the	2.31	2.97	2.27	2.45

SN	Delay Consequence	Petrochemical industries		Contractor	
		Mean Frequency of occurrence	Mean Severity level	Mean Frequency of occurrence	Mean Severity level
	delay period of the project and outage of the unit				
12	Change the form of delivery of material from Sea to air freight	2.46	3.13	2.00	2.09
13	Compromising the quality of work under pressure	2.28	3.92	2.00	2.09
14	Not achieving the production target	1.82	4.05	2.27	2.45

ملخص

التأخير في مشاريع الصيانة والتشييد التابعة لصناعة البتروكيماويات في البحرين ، والتي لها تأثير مباشر بارتفاع التكلفة على الشركة، هي واحدة من التحديات المهمة التي يجب على الشركات البتروكيماوية مواجهتها وحلها خصوصا في هذه الفترات المضطربة التي تتميز بعدم استقرار اسعار المنتجات البتروكيماوية واضطراب اسعار النفط والغاز. التحقيق في هذا التأخير اخذ في اعتبار الدراسة كل من عوامل التأخير، وعواقب التأخير من خلال منظورين اثنين، أولهما احتمالية وقوع عامل التأخير او عاقبة التأخير ، والثاني النتائج المترتبة من خلال وقوع هذه العوامل. بدايةً ، تم تحديد 117 عامل تأخير، و 29 أثر للتأخير من خلال تحليل عميق للمصادر والدراسات المتوفرة التي لها علاقة بموضوع الدراسة. هذه العوامل تم تنقيحها من خلال عرضها واجراء مقابلات مع مختصين وخبراء في مجال مشاريع صناعة البتروكيماويات ، وبالتالي الوصول إلى القائمة النهائية والتي تضمنت 42 عامل للتأخير مصنفيين ضمن 9 مجموعات مختلفة. عواقب التأخير لم تتضمن فقط تكلفة هذه المشاريع، بل الدراسة شملت منظورا أكبر يشمل 14 عنصراً محتملاً للدراسة النهائية، والتي تم الوصول إليها بعد دراسة المصادر المتوفرة واخذ رأي المعنيين في صناعة البتروكيماويات في البحرين. بناءً على تحليل النتائج باستخدام معامل التأخير المعدل، تم تحديد أهم عوامل التأخير تأثيراً في قطاع البتروكيماويات بالبحرين وهي التأخر في وصول المواد والاجهزة، اعتماد العطاء الأقل سعراً كمنهجية أساسية في ارساء المناقصات، عدم إتمام تخطيط المشاريع بصورة كافية، و حدوث تغيرات في التصميم اثناء فترات مختلفة من المشروع. و في ما يتعلق بتأثير ومقبات التأخير، أشارت النتائج إلى زيادة أوقات العمل في المشاريع في فترات التشييد والصيانة ومالها من تأثيرات سلبية، ارتفاع التكلفة على الشركة، وتأخر مشاريع مهمة لها ارتباط بالمشروع الاساسي. مصفوفة الخطر أيضا تم تحليلها ورسمها لتقسيم عوامل وعواقب التأخير إلى أقسام مختلفة تبعاً لدرجات الخطر. التحليل لمصفوفة الخطر أظهر أن الردود التحليلية للمقاولين في قطاع البتروكيماويات في البحرين قد حصل على نتائج أقل للخطر المترتب على التأخير وهذا يرجع للفرق بين طبيعية المسؤولية بين المقاول وبقية الاطراف التي تتحمل ذات العواقب ولكن بتأثير أكبر. التوصيات شملت التركيز على إضافة بنود التأخير لتصبح ركيزة في اهداف الشركة الرئيسية، ومنها نزولا الى اهداف كل الدوائر الوظيفية. أيضاً توصية أهمية دور إدارة المشاريع ودور مدير المشروع كرابط مهم خلال تنفيذ المشروع، مع التركيز على ضرورة إدماج قسم الصيانة بشكل خاص في مراحل المشروع بصورة مبكرة لتدارك أي تأخير والتخطيط للحد من عواقبه.



بحث عوامل التأخير المؤثرة على مشاريع الصيانة والتشييد في صناعة البتروكيماويات في البحرين

بحث لاستكمال متطلبات الحصول على درجة (الماجستير) في برنامج الإدارة الهندسية

اعداد

فيصل إبراهيم العلي

20042387

إشراف

المشرف المشارك

د. خالد الشافعي

أستاذ مساعد

جامعة البحرين

المشرف

أ.د سعد سليمان

أستاذ

جامعة البحرين

مملكة البحرين

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