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Causes of Construction Delay in Petrochemical Projects in KSA

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Abstract: This paper presents a study conducted to identify, assess, rank, and compare the most influencing factors causing schedule delay during construction phase of petrochemical projects in Saudi Arabia. The methodology followed in this research to achieve the main aims is a combination of comprehensive review of the literature and interviewing number of local experts, which have resulted in identifying of 23 factors. Through a web-based questionnaire survey, the identified factors were ranked. Total of 90 completed responses were gathered from 106 received responses. The completed responses gathered from 38 contractors and 52 owners. Of 90 participants, there are 32 project managers, 22 project engineers, 7 construction supervisors and the other 31 having different positions in projects departments The study has found that the most influencing factors causing schedule delay during construction in petrochemical projects in Saudi Arabia are "Poor site management and supervision by contractors"; "Conflict between main contractor and subcontractor"; "poor planning and scheduling of projects by contractor"; "Delay of material or equipment delivery"; and followed by "Delay in Handing Over Construction Site to Contractor". This paper is original in the sense that the areas of knowledge and practice covered in the identified factors were distributed and not available in one source. The factors are derived from personal interviews with selected project managers, project engineers, construction supervisors and the others from different positions in project department and from the relevant literature.

Keywords: Petrochemical projects, critical factors, Schedule delay.

1. Introduction

Petrochemicals industries are very crucial in our daily life today. It requires the investment of a huge capital annually on different construction projects. That type of construction projects are impacted mostly during construction phase, which may lead to cost overrun and/or time delay, which result in millions of dollars. Over time, petrochemicals became an essential material for many varieties of downstream products such as rubbers, plastics, PVC, clothes, kids' toy, and fertilizers, etc. Indeed, the need of petrochemical increased for the last thirty years. Nevertheless, the huge demand of petrochemicals material in whole world led for expansion of existing plants and constructing of new ones. For example, Saudi Basic Industries Corporation (SABIC) has many mega projects and expansion of existing planta. Those projects are unique in nature and usually handled by large, specialized EPC contractors, who do both design and construction. In addition to that projects, there are many other projects that do not require much specialty and considered normal and can be designed and constructed by the company own force or by local general contractors.

Petrochemical industry is similar to Oil & Gas industry. It invests enormous capital annually on different projects. Those projects pass through different phases as any typical project including initiation, planning, engineering, procurement, construction and close out. Any phase of those can be impacted by different factors, which can affect the whole project cycle. Apparently, those projects are impacted mostly during construction phase, which leads to cost overrun and/or time delay and consequently caused millions of dollars. Therefore, the goals of this research paper are to identify,

assess, rank, and compare the most influencing factors causing schedule delay during construction phase of petrochemical projects in Saudi Arabia.

2. Research problem and significance of the research.

The main objectives of the project management team during construction phase are to complete the project within its budget and on time and according to specification and quality. Hence, identifying and ranking the factors that may cause schedule delay is essential to assist the project management team to meet the above stated objectives and to avoid delay. Due to its complexity, in recent years, many of petrochemical projects completed behind the targeted date that agreed on the contract between owners and contractors. Such delay has a significant consequence to the owners as well to the contractors. The delay during construction phase is influenced by many factors that makes meeting the set date difficult task to the project management team. The literature reveals that very limited studies are reported on identifying factors affecting the project schedule during construction phase in petrochemical projects. This paper aims to identify, assess, rank, and compare the most influencing identified factors causing delay in petrochemical projects in the Eastern province in Saudi Arabia. The identification and ranking of such factors can assist owners, contractors, and project management team of this class of projects in:

- Preparing more realistic and accurate project cost and schedule.
- Completing project on time and avoiding schedule delay
- Taking the necessary steps and actions in advance to avoid such delay.
- Giving more attention to the most crucial factors.

3. Research Methodology

The research methodology used to achieve the above stated objectives involve a sequence of steps. It includes:

- Conducting a comprehensive literature review to identify the factors that cause schedule delay during construction phase of petrochemical and similar projects.
- Determining unreported factors based on interviewing with local experts who are involved in constructing petrochemical projects in Saudi Arabia.
- Combining the identified factors from the literature with that obtained from interviewing project engineers/ managers.
- Designing and developing questionnaire survey to be used for collecting feedback from experts regarding the importance of the identified factors
- Conducting pilot study with experts to assess the identified factors and to evaluate the developed questionnaire survey before send it to the targeted professionals.
- Distributing questionnaire survey to the population of 106 professionals working in this class of projects in the eastern province of Saudi Arabia.
- Analyzing the data received using the statistical analysis method to identify the level of importance for the identified factors.
- Obtaining the important index value and the rank of each factors.
- Drawing conclusion and recommendations based on the obtained results.

4. Previous studies

Delaying in construction schedule is a major concern to owners and contractors. It can lead to cost overrun and costly disputes. The literature reveals that many researches have been conducted over the years to find the causes of such delay in construction industry in general [e.g. 1 – 5]. In oil and gas construction projects, the project size is large and requires a considerable capital investment and longtime duration. This class of project comprise of three main phases; the conceptual phase; the front end engineering and design (FEED) and the engineering, procurement and construction (EPC) phase [1]. According to the survey conducted by Salama, et.al [5], the EPC is the most significant

phase that should be closely monitored and controlled to prevent time slippage and improve the overall projects performance. Accordingly, the on-time completion is a high priority for both clients and contractors [6]. Khan [7] highlighted that the main two common objectives of any construction management team are to reduce the project time and cost required in implementing a project. In addition, the literature reveals that the delay in construction project is common problem worldwide for different types of industries and it is one of the most common problems in the construction industry [8].

Alinaitwe, et al [8] found that the five critical factors of delays in construction industry projects are scope variation, progress payment delay, and weak project control system, the high cost of project and political insecurity and instability. Rao [9] identified the major causes of schedule delay in construction projects from different parties including owner, contractor, designer, and external party. The author is then ranked the identified factors and found that the most significant factors causes delay from all perspectives are delay in making the payments; lack of communication between parties; late issue of instruction; poor management contractors and execution; delay in approving design document; delay due to shortage of materials and price fluctuations. Ruqaishi and Bashir [10] have identified seven major factors responsible for project delay in construction. The poor site management and supervision by contractors are found to be 1st factor. Raykar & A.N [11] were in agreement with this finding as well for construction projects in general. While others like Rao [10] ranked this as number four in his list and Mydin, et.al [12] raked it as third factor. The 2nd of critical factors as identified by Ruqaishi and Bashir [5] is problems with subcontractors, which was identified as well by Raykar & A.N [11] to be 2nd factor. The poor projects scheduling and planning by contractors is the 3rd factor (Ruqaishi & Bashir[10] and Raykar & A.N [11]. However, Khan [7] has ranked inadequate planning to be number 4th in the list. The poor management of contractors' schedules and execution has been identified to be the 4th critical factor by Ruqaishi & Bashir [10] followed by delay in delivery of materials as 5th factor, but Raykar & A.N [11] found it 4th critical factor.

Furthermore, Ruqaishi & Bashir [11] indicated that the lack of effective communication among project stakeholders is ranked as number six in top critical causes, while Rao [9] has identified this to the second critical factor and Raykar & A.N [11] classified it as 5th factor. The last and 7th factor by Ruqaishi & Bashir [11] is poor engagement with equipment suppliers in the engineering and procurement stages. Mydin, et.al [12] found that the delays caused by contractor was ranked first, then the ones by consultant factors, followed by client causes, and the least by external causes. Other factors such as scope of work, change in weather, equipment cost and usage, cash flow and decision-making policy have an impact as well (Raykar & A.N [11]. The literature clearly show that not too many studies have been reported in identifying, assessing, ranking, and comparing the most influencing factors causing schedule delay during construction phase of Petrochemical Projects. Salama, et.al [6] have stated that the most critical factors occur during EPC phase for gas and oil projects are late of material delivery; wrong and inadequate process of selecting the right contractor during the bidding stage of FEED or EPC by laying more emphasis on the bid value rather than on the contractor's competencies; ineffective communication system and shortage in experienced manpower. Khan [7] identified the top five factors causes schedule delay in gas and oil projects. Those factors are changes in scope, poor procurement process, lack of qualified labors, poor planning and scheduling, un-experienced contractor, and bad performance by the subcontractor.

5. Identifying factors causing construction delay in Petrochemical Projects

The identified factors from literature reviews are 21 factors and two more factors were identified from interviewing local experts as shown in Table 1. The factors obtained from experts are site handover delay to contractor and delay in getting work permit from government. Those factors are to be tested in this research against those projects implemented in petrochemical industry. The factors drawn from literature that causing delay in petrochemical projects along with short explanation of each factor is presented below:

146 Table 1: Summary of factors drawn from literature and local experts

Potential Factors	Resources reference number											
	1	2	3	4	5	6	7	8	9	10	11	12
1. Poor site management and supervision by contractors.	X	X	X	X		X	X	X	X	X	X	
2. Conflict between main contractor and subcontractor.		X	X			X						
3. Inadequate planning and scheduling of projects by contractor.		X			X	X	X	X				X
4. Delay of material or equipment delivery.	X	X		X	X	X						
5. Delay in Handing Over Construction Site to Contractor	Interviewing experts											
6. Shortage of Material or equipment	X								X			
7. Shortage of skilled labors by contractor				X	X				X	X		
8. Weather effects.			X			X						
9. Changes of scope/ design during construction			X		X			X	X	X	X	
10. Delay in getting work permits.	Interviewing experts											
11. lack of effective communication among the parties involved							X					
12. Inaccurate Design Drawings/ Documents by the Designer.			X		X			X		X		X
13. Lack of experience and knowledge of contractor staff.					X			X	X	X		
14. Rework due to errors during construction.			X				X					
15. Delay in progress payment by owner.	X							X			X	
16. Governmental and political related issues.										X		
17. Delay in contractor payment to sub-contractors and suppliers								X				
18. Long time for approval and decision making by owner.	X		X		X		X		X	X		
19. Unforeseen (unexpected) site conditions.				X								
20. Inappropriate construction methods.												X
21. Inflation and escalation of material prices.	X							X			X	X
22. Delays related to sub-contractors' work.					X				X			
23. Low productivity by contractor labor.					X		X	X	X			

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5.1 Poor site management and supervision by contractors

During construction, contractor wants to get the project done as efficiently and quickly as possible but if the timeline is too aggressive, it will result in more accidents, more mistakes, cut corners, and overworked, unhappy, and unproductive employees.

5,2 Conflict between main contractor and subcontractor.

Poor construction management also results due poor subcontractor selection. This leads to conflict between the two parties.

5.3 Inadequate planning and scheduling of projects by contractor.

Project planning is defined as a set of established processes used to make a decision on what tasks must be performed to achieve the projects set objectives within schedule and cost. Scheduling is setting those process and steps in timeline toward the agreed completion date.

5.4 Delay of material or equipment delivery.

This is related to long lead materials, which usually takes months to be delivered, which potentially can affect the project if the order not placed in earlier and right time.

5.5 Delay in Handing Over Construction Site to Contractor

On commencement of the main contract to construct the works, the client hands over possession of the site and contractor's work area(s) to the contractor. This handover procedure may take place at a formal handover meeting.

5.6 Shortage of Material and/or equipment

Situation where the available quantity of the required material falls short of the quantity demanded or required at a given time or price.

5.7 Shortage of skilled labors by contractor

Skilled labor in the construction industry specifically refers to labor that requires workers who have specialized training or a learned skill-set to perform the work. These workers can have varied levels of training or education. In many cases, skilled laborers are those who have received enough training to become certified in a particular trades field.

5.8 Weather effects

Meaning that bad weather conditions usually affect the construction project. For example heavy rain, sandstorm, extremely hot weather, humidity etc. may affect the labor productivity and eventually delay the project schedule.

5.9 Changes of scope/ design during construction

Design change is defined as any change to the scope of the work as defined by the contract documents following the creation of legal relations between the principal and the contractor. Often the changes are not the fault of the contractors. Design changes may occur in architectural, structural, plumbing and drainage, site works or other aspects of construction.

5.10 Delay in getting work permits.

The work permit process is a key element of controlling the work and it shall be used to confirm that work is performed in a safe and environmentally sound manner. The permission to work system utilizes a form of permission that requires review and approval prior to the commencement of work.

The purpose of the system is to verify that work between different teams working in proximity to each other is identified.

5.11 Lack of effective communication among the parties involved.

Effective Communication involves the giving and receiving of information, signals, or messages by talk, gestures and writing and it is one of the core competencies that all information professionals should possess.

5.12 Inaccurate Design Drawings/ Documents by the Designer.

The wrong design drawing/ document such wrong dimensions, specification etc. can lead to rework the engineering, fabrication if involved and execution as well, which leads to time and cost overrun.

5.13 Lack of experience and knowledge of contractor staff.

Having less experience staff in construction work is risky that may lead to rework, bad quality, and schedule delay.

5.14 Rework due to errors during construction.

Errors are defined as unintended deviations from correct and acceptable practices and lead to project cost and schedule overruns, which are both unnecessary and avoidable.

5.15 Delay in progress payment by owner.

This refers to the delay in releasing the progress payment where the payment claim is made when each stage is completed.

5.16 Governmental and political related issues.

This involves new regulations and standards that were not available during or before the signing of contract, which impose certain requirement to be complied with and eventually affect cost or schedule.

5.17 Delay in contractor payment to sub-contractors and suppliers.

Delaying the payment between main contractor and subcontractor can breach the contract between both parties and likely to harm the project itself.

5.18 Long time for approval and decision making by owner.

Delaying the approval of some important document or keeping the decision pending without clear path for long time has definitely impact on the project schedule.

5.19 Unforeseen (unexpected) site conditions.

Unforeseen site conditions typically arise in two situations: (1) the conditions encountered at the site differ materially from those indicated in the contract, or (2) the conditions encountered at the site differ materially from those normally encountered.

5.20 Inappropriate construction methods.

Sometime, there are several ways of doing one thing and there is only one right way to get it done. Using different method than the right will consume the time with uselessly and can lead to health and safety incident or ending up with bad quality product.

5.21 Inflation and escalation of material prices.

Inflation is an economic term that indicates the increase in price of goods and services over time. Where escalation refers to rise in the price of specific commodities, goods, or services due to a combination of inflation, supply/demand, and other effects such as environmental and engineering changes.

5.22 Delays related to sub-contractor's work.

The main contractor is obligated as per the contract to complete on time regardless of sub-contractor performance. Sometime, main contractor is impacted due to the performance of a sub-contractor. Main contractor is responsible to coordinate between sub-contractor if more than one and ensure no clutches or delays because of their performance.

5.23 Low productivity by contractor labor.

Labor productivity is concerned with the amount (volume) of output that is obtained from each employee. It is a key measure of business efficiency, particularly for firms in which the production process is labor-intensive.

6. Assessment of factors causing delay in petrochemical projects

The identified 23 factors were ranked through a web-based questionnaire survey. 90 responses were gathered from the full population of the 106-professional working in petrochemical projects in the Eastern Province of Saudi Arabia. This section presents an assessment of the perceived level of importance of each of the 23 factors causing schedule delay of petrochemical projects.

6.1 Characteristics of the respondents

The scope of this study was focused on obtaining responses from the project staff such as project engineer, manager, supervisor etc. working in petrochemical projects. In the 90 responses received, there are 32 project managers, 22 project engineers, 7 construction supervisors and the other 31 having different positions in project department. All responses were classified according to their experiences in petrochemical projects and arranged in four groups, which are 0 to 5 years, 5 to 10, 10 to 15 and more than 15 years as shown in Figure 1. A percentage of 44.4% of responses are from people having project experience for more than 10 years. On the other hand, a percentage of 21.1% of participants having 5 years' experience or less.

The questionnaire used for gathering the information has mainly the following four sections;

- The purpose
- Personal information of the respondent
- Evaluation of the factors causing schedule delay during construction stage.

A brief guide and the purpose of the questionnaire described in the first section, which is the purpose of the questionnaire. In the second section, personal information of the respondent is required, which in this case project managers, project engineers, or construction supervisors. In third section, the respondent is requested to provide general information about their total experience, company and specific experience for petrochemical projects.

Last but not the least section is the fourth one, which is the main section, and most important one. This section is named "factor impacting construction phase". In this section of the questionnaire, respondents are provided with a list of all 23 factors that may influence the schedule of a project. The respondents were asked to rate the factors in terms of importance and the frequency (probability) of an occurrence of that factor. The ratings used along with their corresponding weight were "very high" important" with five points, "high" with four points, "Moderate" with three points, "Low" with two point and "very low" with one points.

The questionnaire survey was conducted in the Eastern Province of Saudi Arabia. This is mainly due to two reasons. The first is the ease of access by the researchers who is currently located in that region. The second is the ability to answer questions raised by the respondents participating in the study due to the interview method of collecting the required data. 90 respondents were gathered in this study to rate importance of those factors and the frequency (probability) of an occurrence of the identified factor.

6.2 Relative Importance Index (RII)

The gathered responses were assessed, tabulated, and the relative importance index (RII) method was used to determine the relative importance of the identified factors. This deterministic method is chosen for the following reasons:

- It is easy to be understood and used by all levels of respondents regardless of their level of education
- The questionnaire survey involves large number of factors, which makes the application of RII effective. the following equation is used to determine the relative importance index (RII)

$$RII = \frac{\Sigma S}{W(N)} \quad (1)$$

Where,
S = Scale of each factor based on the participant judgment (1 to 5).
W = This is highest weight, equal 5
N = Number of participant
RII is varying from 1 to 0, where a higher value means that the factor is more important.

6.3 Frequency Adjusted Importance Index (FAII)

This method reflects the impact and the frequency in the equation resulted from survey. The Frequency index (FI) and Relative importance index (RII) shall be calculated. In order to calculate FI, the following equation shall be applied:

$$FI\% = \frac{\Sigma S}{W(N)} \; X \; 100 \quad (2)$$

Where,
S = Scale of each factor based on the participant judgment (1 to 5).
W = This is highest weight, equal 5
N = Number of participant

After calculating the FI% and the RII, then frequency adjusted importance index shall be identified using the following equation:

$$FAII = RII \; X \; FI\% \quad (3)$$

6.4 Spearman's Rank Correlation.

One of the analysis useful tools and can help in achieving the desired accuracy level is Spearman's Rank Correlation Factor. It does not require the distribution to be normal, which gives this tool the privilege over other tools. In this report, the Spearman's' rank equation is applied in order to check the relationship between two different categories, for example, the correlation between the RII and FAII for received responses. Furthermore, the correlation between Owner & Contractor

perspectives for ranking of delay factors. The value of r falls in the range between +1 and −1, where +1 indicates an agreement and while −1 indicates a disagreement.

$$r = 1 - \left[\frac{6\sum d^2}{n^3 - n}\right] \quad (4)$$

r = Spearman rank correlation coefficient.
d = difference between two ranking by different groups/ methods
n = is the number of delay factors.

7. Discussion of the results

The data for this report were collected from a survey developed through www.esurevycreator.com. It is an online survey service used in creating, sharing the survey, and finally recording responses. The survey was shared by emails. Total response was 106, but the completed was 90 only. For this analysis the completed responses, which 90 were used.

7.1 Respondent Profile.

Survey was distributed to 106 and 90 responses were received; 38 from contractor side and 52 from owner side as shown in Figure 1. From 90 participants, there are 32 project managers, 22 project engineers, 7 construction supervisors and the other 31 having different positions in project department. All responses were classified according to their experiences in petrochemical projects and arranged in four groups, which are 0 to 5 years, 5 to 10, 10 to 15 and more than 15 years as shown in Figure 2. A percentage of 44.4% of responses are from people having project experience for more than 10 years. On the other hand, a percentage of 21.1% of participants having 5 years' experience or less.

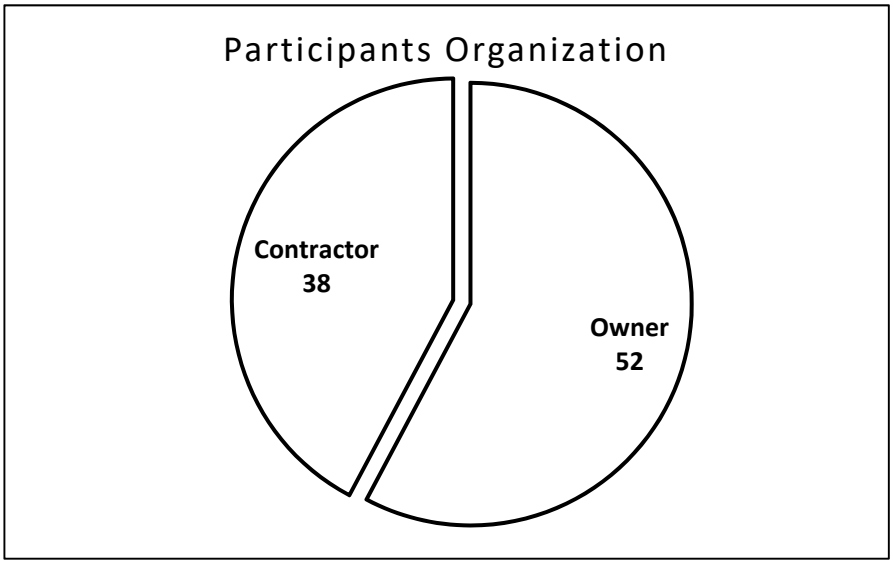

Figure 1: Participants Organization

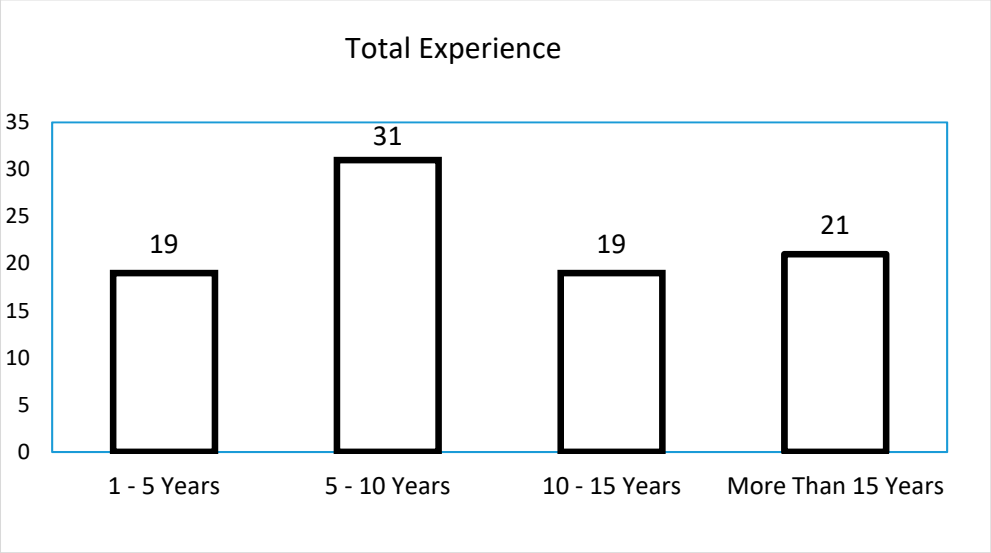

Figure 2: Respondent's total experience.

7.2 Influencing factors

All the respondents rated each individual delay factors in terms of impact level and frequency level using a scale of five points. In the survey, it was requested to evaluate the impact level of the construction projects delay and the frequency of that factor, which is how often the factor can happen in construction projects. Table 2 shows the original data of the survey, which presents the impact level (importance) and Table 3 presents the original data of the frequency values rated by the participants.

Table 2: Raw Data for Relative Importance Index (RII)

S/n	Potential Delay Factor	Impact Level					
		1	2	3	4	5	Total Response
1	Poor site management and supervision by contractors.	1	4	16	37	32	90
2	Conflict between main contractor and subcontractor.	3	13	27	25	22	90
3	Poor Planning and Scheduling of Projects by Contractor.	1	7	18	32	32	90
4	Delay of material or equipment delivery.	1	4	12	28	45	90
5	Delay in Handing Over Construction Site to Contractor	1	6	31	30	22	90
6	Shortage of skilled labors by contractor	2	7	20	48	13	90
7	Weather effects.	1	15	38	28	08	90
8	Changes of scope/ design during construction	0	13	19	31	27	90
9	Delay in getting work permits.	1	6	23	39	21	90
10	lack of effective communication among the parties involved	1	15	25	43	6	90
11	Inaccurate Design Drawings/ Documents by the Designer.	0	9	23	36	22	90
12	Lack of experience and knowledge of contractor staff.	2	2	29	40	17	90
13	Rework due to errors during construction.	2	16	30	31	11	90
14	Delay in progress payment by owner.	6	18	26	24	16	90

15	Governmental and political related issues.	14	22	25	18	11	90
16	Delay in contractor payment to sub-contractors and suppliers	6	13	38	20	13	90
17	Long time for approval and decision making by owner.	2	2	27	33	26	90
18	Shortage of Materials or Equipment	3	7	29	38	13	90
19	Unforeseen (unexpected) site conditions.	2	15	35	29	9	90
20	Wrong construction methods.	3	17	28	31	11	90
21	Inflation and escalation of material prices.	4	12	45	22	7	90
22	Delays related to sub-contractors' work.	3	9	29	42	7	90
23	Low productivity by contractor labor.	4	8	24	44	10	90

Table 3: Raw Data for Frequency Index (FI)

S/n	Potential Delay Factor	Frequency Level					
		1	2	3	4	5	Total Response
1	Poor site management and supervision by contractors.	3	19	43	21	4	90
2	Conflict between main contractor and subcontractor.	11	29	38	8	4	90
3	Poor Planning and Scheduling of Projects by Contractor.	7	24	33	17	9	90
4	Delay of material or equipment delivery.	4	17	40	20	9	90
5	Delay in Handing Over Construction Site to Contractor	3	35	37	10	5	90
6	Shortage of skilled labors by contractor	12	14	34	25	5	90
7	Weather effects.	20	23	38	7	2	90
8	Changes of scope/ design during construction	4	27	39	16	4	90
9	Delay in getting work permits.	3	17	32	22	16	90
10	lack of effective communication among the parties involved	5	29	32	22	2	90
11	Inaccurate Design Drawings/ Documents by the Designer.	11	22	37	18	2	90
12	Lack of experience and knowledge of contractor staff.	9	31	29	18	3	90
13	Rework due to errors during construction.	8	35	29	14	4	90
14	Delay in progress payment by owner.	25	30	25	6	4	90
15	Governmental and political related issues.	37	29	15	6	3	90
16	Delay in contractor payment to sub-contractors and suppliers	14	28	38	5	5	90
17	Long time for approval and decision making by owner.	6	21	37	19	7	90
18	Shortage of Materials or Equipment	18	24	37	10	1	90
19	Unforeseen (unexpected) site conditions.	22	32	29	6	1	90
20	Wrong construction methods.	26	32	26	5	1	90
21	Inflation and escalation of material prices.	24	32	29	4	1	90
22	Delays related to sub-contractors' work.	7	29	41	11	2	90
23	Low productivity by contractor labor.	10	24	42	11	3	90

7.3 RII Ranking

The gathered data were analyzed to develop the Relative Importance Index (RII) and Frequency Adjusted Importance Index (FAII). If the number is high, that means high importance level of the cause factor and vice versa. Table 4 illustrated both RII values and the ranks of those potential delay factors rated using five scales for the impact level.

The Relative importance index (RII) equation was used to generate these values. Then, the generated values were ranked from highest to lowest to identify the top five factors having the highest RII value. The below list shows the top potential factors listed in order from the highest to lowest between the top five:

1. Delay of material or equipment delivery.
2. Poor site management and supervision by contractors.
3. Poor Planning and Scheduling of Projects by Contractor.
4. Long time for approval and decision making by owner.
5. Delay in getting work permits.

Table 4: Relative Importance Index (RII)

s/n	Potential Delay Factor	RII	Ranking
1	Delay of material or equipment delivery.	0.849	1
2	Poor site management and supervision by contractors.	0.811	2
3	Poor Planning and Scheduling of Projects by Contractor.	0.793	3
4	Long time for approval and decision making by owner.	0.776	4
5	Delay in getting work permits.	0.762	5
6	Changes of scope/ design during construction	0.76	6
7	Inaccurate Design Drawings/ Documents by the Designer.	0.758	7
8	Lack of experience and knowledge of contractor staff.	0.751	8
9	Delay in Handing Over Construction Site to Contractor	0.747	9
10	Shortage of skilled labors by contractor	0.74	10
11	Shortage of Materials or Equipment	0.713	11
12	Conflict between main contractor and subcontractor.	0.711	12
13	Low productivity by contractor labor.	0.707	13
14	Delays related to sub-contractors' work.	0.691	14
15	lack of effective communication among the parties involved	0.684	15
16	Rework due to errors during construction.	0.673	16
17	Wrong construction methods.	0.667	17
18	Unforeseen (unexpected) site conditions.	0.662	18
19	Weather effects.	0.66	19
20	Delay in progress payment by owner.	0.658	20
21	Delay in contractor payment to sub-contractors and suppliers	0.647	21
22	Inflation and escalation of material prices.	0.636	22
23	Governmental and political related issues.	0.578	23

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7.4 *FAII Ranking*

Frequency of potential delay factors is shown in Table 5. These values were developed after applying the Frequency Index (FI) Equation. Table 6 shows the Frequency Adjusted Importance Index (FAII), which is simply combination between RII and FI. FAII values were generated by using Equation 3. Then, the generated values were ranked from highest to lowest to identify the top five factors having the highest FAII value. The following list shows, the top potential factors listed from the highest to lowest between the top five:

1. Delay of material or equipment delivery.
2. Delay in getting work permits.
3. Poor site management and supervision by contractors.
4. Poor Planning and Scheduling of Projects by Contractor.
5. Long time for approval and decision making by owner.

Table 5: Frequency Index (FI) Ranking

s/n	Potential Delay Factor	FI%	Ranking
1	Delay in getting work permits.	66.89%	1
2	Delay of material or equipment delivery.	62.89%	2
3	Poor site management and supervision by contractors.	60.89%	3
4	Long time for approval and decision making by owner.	60.00%	4
5	Poor Planning and Scheduling of Projects by Contractor.	59.33%	5.5
6	Shortage of skilled labors by contractor	59.33%	5.5
7	Changes of scope/ design during construction	57.56%	7
8	lack of effective communication among the parties involved	57.11%	8
9	Delay in Handing Over Construction Site to Contractor	55.33%	9
10	Inaccurate Design Drawings/ Documents by the Designer.	55.11%	10
11	Lack of experience and knowledge of contractor staff.	54.44%	11
12	Low productivity by contractor labor.	54.00%	12
13	Delays related to sub-contractors' work.	53.78%	13
14	Rework due to errors during construction.	53.56%	14
15	Conflict between main contractor and subcontractor.	52.22%	15
16	Delay in contractor payment to sub-contractors and suppliers	50.89%	16
17	Shortage of Materials or Equipment	49.33%	17
18	Weather effects.	48.44%	18
19	Delay in progress payment by owner.	45.33%	19
20	Unforeseen (unexpected) site conditions.	44.89%	20
21	Inflation and escalation of material prices.	43.56%	21
22	Wrong construction methods.	42.89%	22
23	Governmental and political related issues.	39.78%	23

411 *Table 6: Frequency Adjusted Importance Index (FAII) Ranking*

S/n	Potential Delay Factors	FAII	Ranking
1	Poor site management and supervision by contractors.	49.4%	3
2	Conflict between main contractor and subcontractor.	37.1%	14
3	Poor Planning and Scheduling of Projects by Contractor.	47.1%	4
4	Delay of material or equipment delivery.	53.4%	1
5	Delay in Handing Over Construction Site to Contractor	41.3%	9
6	Shortage of skilled labors by contractor	43.9%	6
7	Weather effects.	32.0%	18
8	Changes of scope/ design during construction	43.7%	7
9	Delay in getting work permits.	51.0%	2
10	lack of effective communication among the parties involved	39.1%	11
11	Inaccurate Design Drawings/ Documents by the Designer.	41.8%	8
12	Lack of experience and knowledge of contractor staff.	40.9%	10
13	Rework due to errors during construction.	36.1%	15
14	Delay in progress payment by owner.	29.8%	19
15	Governmental and political related issues.	23.0%	23
16	Delay in contractor payment to sub-contractors and suppliers	32.9%	17
17	Long time for approval and decision making by owner.	46.5%	5
18	Shortage of Materials or Equipment	35.2%	16
19	Unforeseen (unexpected) site conditions.	29.7%	20
20	Wrong construction methods.	28.6%	21
21	Inflation and escalation of material prices.	27.7%	22
22	Delays related to sub-contractors' work.	37.2%	13
23	Low productivity by contractor labor.	38.2%	12

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413 **7.5** *Spearman's rank correlation factor.*

414 In order to decide which ranking method to be used between RII & FAII, Spearman's rank
415 correlation factor (r) shall be followed. This method is generally used to show the discrepancies and
416 differences between different ranking methods, where value equals +1 indicates agreement and -1
417 indicates disagreement. If value 0 is obtained, then means no relationship does exist. Table 7 shows
418 that r to be almost equal to 0, which means no relationship between the RII and FAII. FAII was
419 adapted as it takes into consideration impact level as well as frequency level.

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429 *Table 7: Spearman's rank correlation factor between RII and FAII*

S/n	Potential Delay Factor	RII Rank	FAII Rank	d	d^2
1	Poor site management and supervision by contractors.	2	3	1	1
2	Conflict between main contractor and subcontractor.	12	14	2	4
3	Poor Planning and Scheduling of Projects by Contractor.	3	4	1	1
4	Delay of material or equipment delivery.	1	1	0	0
5	Delay in Handing Over Construction Site to Contractor	9	9	0	0
6	Shortage of skilled labors by contractor	10	6	-4	16
7	Weather effects.	19	18	-1	1
8	Changes of scope/ design during construction	6	7	1	1
9	Delay in getting work permits.	5	2	-3	9
10	lack of effective communication among the parties involved	15	11	-4	16
11	Inaccurate Design Drawings/ Documents by the Designer.	7	8	1	1
12	Lack of experience and knowledge of contractor staff.	8	10	2	4
13	Rework due to errors during construction.	16	15	-1	1
14	Delay in progress payment by owner.	20	19	-1	1
15	Governmental and political related issues.	23	23	0	0
16	Delay in contractor payment to sub-contractors and suppliers	21	17	-4	16
17	Long time for approval and decision making by owner.	4	5	1	1
18	Shortage of Materials or Equipment	11	16	5	25
19	Unforeseen (unexpected) site conditions.	18	20	2	4
20	Wrong construction methods.	17	21	4	16
21	Inflation and escalation of material prices.	22	22	0	0
22	Delays related to sub-contractors' work.	14	13	-1	1
23	Low productivity by contractor labor.	13	12	-1	1
Total					120
r					0.06

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431 In addition, this correlation factor is used to check the difference between Owner and contractor
432 perspectives. From Table 8, it is clearly shown that there are differences between owner ranking and
433 contractor ranking, some high and some low, but in general, the overall ranking correlation found to
434 be 0.4, which indicates somehow an agreement between both perspectives.

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Table 8: Spearman's rank correlation factor between Owner and Contractor

S/n	Potential Delay Factor	Owner		Contractor			
		FAII	RANK	FAII	Rank	d	d^2
1	Poor site management and supervision by contractors.	54.49%	2	42.26%	6	-4	16
2	Conflict between main contractor and subcontractor.	41.47%	9	30.27%	20	-11	121
3	Poor Planning and Scheduling of Projects by Contractor.	49.92%	3	42.01%	7	-4	16
4	Delay of material or equipment delivery.	57.29%	1	47.07%	4	-3	9
5	Delay in Handing Over Construction Site to Contractor	40.26%	11	41.46%	8	3	9
6	Shortage of skilled labors by contractor	49.45%	4	36.77%	11	-7	49
7	Weather effects.	29.40%	18	35.83%	13	5	25
8	Changes of scope/ design during construction	44.06%	7	43.01%	5	2	4
9	Delay in getting work permits.	45.95%	5	57.70%	1	4	16
10	lack of effective communication among the parties involved	40.09%	12	37.32%	10	2	4
11	Inaccurate Design Drawings/ Documents by the Designer.	37.87%	13	47.40%	3	10	100
12	Lack of experience and knowledge of contractor staff.	41.47%	9	35.72%	14	-5	25
13	Rework due to errors during construction.	37.17%	14	34.52%	15	-1	1
14	Delay in progress payment by owner.	23.81%	22	39.08%	9	13	169
15	Governmental and political related issues.	23.83%	21	22.14%	23	-2	4
16	Delay in contractor payment to sub-contractors and suppliers	36.04%	15	28.27%	21	-6	36
17	Long time for approval and decision making by owner.	45.32%	6	48.48%	2	4	16
18	Shortage of Materials or Equipment	34.08%	16	36.39%	12	4	16
19	Unforeseen (unexpected) site conditions.	29.61%	17	30.07%	20	-3	9
20	Wrong construction methods.	29.14%	19	28.21%	22	-3	9
21	Inflation and escalation of material prices.	25.05%	20	32.08%	16	4	16
22	Delays related to sub-contractors' work.	41.25%	10	31.53%	18	-8	64
23	Low productivity by contractor labor.	42.90%	8	31.73%	17	-9	81
Total							815
R							0.4

7.6 Contribution of the Experts to the Results

After a review of past literature, a list of 23 delay factors was produced and presented in a questionnaire survey. The survey was distributed to various experts in the field of construction industry. Then, 90 respondents evaluated the twenty-three (23) delay factors based on importance (the delay impact on construction project) and frequency (How often the factor is implemented or considered). The gathered data of 90 complete responses were analyzed using different ranking methods such as Relative Importance Index (RII), Frequency Index (FI), and Frequency adjusted Importance Index (FAII). In terms of importance, we used equation. 1 to find RII and found the top important factors are Delay of material or equipment delivery, Poor site management and

supervision by contractors, Poor Planning and Scheduling of Projects by Contractor, Long time for approval and decision making by owner and Delay in getting work permits.

On the other hand, using Equation. 2 to find the top 5 frequent factors (FI), which found to be Delay in getting work permits, Delay of material or equipment delivery, Poor site management and supervision by contractors, Long time for approval and decision making by owner, Poor Planning and Scheduling of Projects by Contractor and Shortage of skilled labors. Ultimately, the best way is to find the top 5 in terms of importance and frequency, is to use Equation. 3 which is Frequency Adjusted Importance Index (FAII). Therefore, the top five as per FAII found to be Delay of material or equipment delivery, Delay in getting work permits, Poor site management, and supervision by contractors, Poor Planning and Scheduling of Projects by Contractor, Long time for approval and decision-making by owner.

Therefore, common FAII ranking was adapted in this case for this discussion. From table 7, it can be concluded that the factor, which is considered most significant, is Delay of material or equipment delivery (53.4%). In fact, this a fixed risk for all project regardless of the type and magnitude. If the required material is related to an activity within the critical path, then this will affect the whole project schedule and cost as the assigned resources will be idly standby waiting for the materials. The second critical factor based on the survey is Delay in getting work permits (51.0%). This factor was not highlighted during the literature review but found to be the second critical in the list. In fact, this is more applicable for petrochemical companies, where the permits are issued on daily basis and different work permits for different type of activities such as hot work, cold work, confined space entry etc. Indeed, delaying the issuance of work permit has a negative impact on the project completion time, especially for those activities in the critical path. Usually the work permits for project are delayed due to Maintenance activities as the same person issues permits for both. Poor site management and supervision by contractors (49.4%) was seen to be the third critical factor. This is true, as the poor management is always a risk for any project. Poor management can affect project schedule by not managing the critical activities and assign the required resources on time, reporting the progress and taking the corrective action timely. Furthermore, project cost can be also impacted if not managing the cash flow and utilizing the resources effectively in order to avoid idle time. On the other hand, the good project management can have positive impact on both cost and schedule.

The fourth critical factor found to be Poor Planning and Scheduling of Projects by Contractor (47.1%). Indeed, failure in planning is just a planning for failure. Poor planning and scheduling is a result of under-estimation the of activity duration, ignoring the productivity factor, over confidence etc. Subsequently, the overall project cost and schedule is affected. Long time for approval and decision making by owner (46.5%) found to be the fifth critical factor. In reality, delaying owner decisions or making changes to the project can easily hinder construction project to finish on time. Many extensions of time and variation orders claims are raised by both consultants and contractors based on owner decisions. On the other hand, the top least critical factors found to be Governmental and political related issues (23%), Inflation and escalation of material prices (27.7%), Wrong construction methods (28.6%), Unforeseen (unexpected) site conditions (29.7%) and Delay in progress payment by owner (29.8%).

8. Recommendation

8.1 Owner

Out of five critical factors, two found to be caused by owner, which are Delay in getting work permits and Long time for approval and decision making by owner. Delaying the work permit found to be the second highest overall. In fact, it is critical in construction project in petrochemical plant like SABIC as the permit is issued on daily basis and by different people depending on the shift arrangement. In addition, the priority always goes to maintenance activity when it comes for permit issuance. Therefore, based on best practice and previous experience, it is strongly recommended to assign a dedicated work permit issuer for this project. The best time for such assignment is during

construction kick off meeting to have full alignment for the work permit requirement prior starting of the construction activity. The second factor by owner is Long time for approval and decision-making, which found to be the least critical among the top five. Thus, owner needs to provide assured decisions with correct information when it is required, in order to avoid any decisions that may potentially delay the work. Indeed, based on the nature and the complexity of the project, Project team shall be assigned according to their Key Technical Competency (KTC) and seniority. Furthermore, if certain expertise is unique and required, and then a consultant or third party shall be hired at early start prior even the design stage.

Regarding the other factors, which caused mainly by contractor, but still owner can support in avoiding those factors. Delay of material or equipment delivery found to be highest critical factor among top five. In fact, contractor causes this, but owner still can support in avoiding by ensuring the purchase order (PO) issuance for all long lead items and keep monitoring for the delivery status on monthly or weekly basis as required. Another example, where the factor is mainly contractor cause by owner can support is Poor site management and supervision by contractors. In fact, owner shall request a CV for all project management and conduct an interview to ensure they have the required skills and fit for this project. For poor planning and scheduling, the owner shall thoroughly review the project schedule and challenge all unrealistic duration whether positive or negative.

8.2 Contractor

Majority of the projects delay factors are caused by the contractor. In this report, three out of five critical factors caused by contractors. The highest critical factor in the top five is caused by contractor; is Delay of material or equipment delivery. This is critical and always a risky in each project. It is recommended that contractor shall start the placement of all purchase orders of long lead items after contract is signed. Also, special tracking mechanism and monitoring like SPI (Schedule Performance Index) for that the long lead items. The second potential delay factor caused by contactor was Poor site management and supervision. It is fact that the improper site management is really a potential risk in each project and can cause a chronic issue. Thus, contractor is responsible of hiring qualified people and having the enough experience to handle the project. In addition, providing required training is also essential to keep them updated with latest tools and techniques used in construction management.

Poor planning and scheduling found to be the third potential delay caused by contractor and ranked number four among common top five critical factors. In reality, planning refers to the planning of different stages and activities such mobilization planning, construction planning (sequence of activities), risk planning, commissioning planning, start-up planning etc. scheduling is time factor of these planning items. Contractor shall pay attention to the factors affecting planning and scheduling such as un-expected events and the production rate of used resources during the development of schedule baseline. In addition, very close monitoring shall be done for the project baseline to check for any variation, and then corrective action shall be taken in order to meet the timeline. The corrective action can be through activities crashing (project accelerating) or changing some sequence of certain activities.

9. Conclusion

Petrochemicals became essential material in our daily life. Petrochemicals industry is similar to any other Oil & Gas industry. It invests very huge capital annually on different projects in nature; expansion, revamp, legal, safety etc. Those projects are impacted mostly during construction phase, which leads to either cost overrun or time delay or both and cause millions of Saudi Riyals. The potential factors causing cost overrun or schedule delay were identified from literature reviews and people having experience in this class of projects. Then, survey was designed, developed, and distributed among owner and contractors' employees to check the relevance of those factors on those Projects.

All completed responses; 90 were analyzed using Relative Importance Index (RII), Frequency Index (FI) and Frequency Adjusted Importance Index (FAII). The adapted ranking was FAII as it

552 combines both importance and frequency measures. Based on FAII, it was found that the top five
553 critical factors are Delay of material or equipment delivery (1st), Delay in getting work permits (2nd),
554 Poor site management and supervision by contractors (3rd), Poor Planning and Scheduling of Projects
555 by Contractor (4th), Long time for approval and decision making by owner (5th). On the other hand,
556 the least five effective factors are governmental and political related issues (23rd), Inflation and
557 escalation of material prices (22nd), Wrong construction methods (21st), Unforeseen (unexpected) site
558 conditions (20th) and Delay in progress payment by owner (19th).
559 Eventfully, several recommendations were generated for both owners and contractors. For
560 example, from owner side to dedicated work permit issuer, involvement of experience people in
561 project to help in making decision, etc. From contractor side is to provide monitoring and control tool
562 like SPI for material delivery, to hire qualified and experience people for site management etc.
563 Ultimately, the objective of this report is already met by assessing the potential factor and providing
564 the required recommendations to help in avoiding those factors from happening.
565

566 **References**

567 1. Srdić, A., Šelih, J. Delays in Construction Projects: Causes and Mitigation. *Organization, technology, &*
568 *management in construction* **2015**, *7(3)*, DOI:10.5592/otmcj.2015.3.5
569 2. Gunduz, M., AbuHassan, M. 'Causes of Construction Delays in Qatar Construction Projects', *Journal of Civil,*
570 *Environmental, Structural, Construction and Architectural Engineering* **2016**, *10(4)*, 531 - 536
571 3. Samarghandi, H., Tabatabaei, S., Taabayan, P., Hashemi,. A ., and Willoughby, K. Studying the reasons for
572 delay and cost overrun in construction projects: The case of Iran. *Journal of Construction in Developing*
573 *Countries* **2016**, *21(1)*, 51–84, DOI: 10.21315/jcdc2016.21.1.4
574 4. Doloi, H., Sawhney, A., and Iyer., K, Rentala, S. Analysing factors affecting delays in Indian construction
575 projects, *International Journal of Project Management* **2012**, *Volume 30,* DOI:
576 http://dx.doi.org/10.1016/j.ijproman.2011.10.004.
577 5. Tan Phat Nguyen Nicholas Chileshe. Revisiting the construction project failure factors in Vietnam, *Built*
578 *Environment Project and Asset Management* **2015**, *Vol. 5 Iss 4,* 398 – 416, DOI:
579 http://dx.doi.org/10.1108/BEPAM-10-2013-0042.
580 6. Salama, M, El Hamid, M A and Keogh, B. Investigating the causes of delay within oil and gas Projects in
581 the U.A.E. In: Dainty, A (Ed) Procs 24th Annual ARCOM Conference, 1-3 September 2008, Cardiff, UK,
582 Association of Researchers in Construction Management, 819-827.
583 7. Khan, S.. An Analysis on Critical Causes of Delays in Oil & Gas Construction Projects, Paper Presented at
584 Project Management National Conference: Architecting Project Management for Redefining India, India,
585 2015, September 10-12, The Lalit Ashok, Bengaluru: A PMI Team India Event.
586 8. Alinaitwe, H., Apolot, R. and Tindiwensi, D. Investigation into the Causes of Delays and Cost Overruns in
587 Uganda's Public Sector Construction Projects. *Journal of Construction in Developing Countries* **2013,** *18*, 33-47
588 9. Rao, B. P. Delay Analysis of Construction Projects. *Journal of IT and Economic Development* **2016**, *7(1),* 15-24.
589 *10.* Ruqaishi, M., & Bashir, H. A. Causes of Delay in Construction Projects in the Oil and Gas Industry in the
590 Gulf Cooperation Council Countries: A Case Study. *Journal of Management in Engineering* **2013**.
591 *11.* Raykar, P., & A.N, G. Analyzing the Critical Factors Influencing the Time Overrun and Cost Overrun in
592 Construction Project. *International Journal of Engineering Research* **2016**, *5(1),* 21-25.
593 *12.* Mydin, M. O., Sani, N. M., Taib, M., & Alias, N. M. Imperative Causes of Delays in Construction Projects
594 from Developers' Outlook. *EDP Sciences* **2014**. DOI: 10.1051