Mapping Delay Risks of EPC Projects: A Case Study of A Platform and Subsea Pipeline of An Oil and Gas Project

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Abstract. More than 80% of oil and gas projects around the world experience delays, which may result in huge financial implications to the contractors and the owners. Therefore, it is important to manage delay risks factors to meet the target of project completion dates. The purpose of this study was to map delay risk factors of Engineering, Procurement, Construction (EPC) projects using a case study of a platform and subsea pipeline of an oil and gas project. Data was collected through observations and analysis of project documents, and interviews with respondents in managerial and engineer levels. A total of 28 delay risk factors was identified and quantified in terms of their probabilities and impacts. This research found 1 extreme risk (4%), 15 high risks (54%), 11 medium risks (39%) and 1 low risk (4%). The top five risk factors include, i.e. contractor's financial capability, delay in delivery of long-lead items, changes in the project scopes, delay of detailed engineering design (DED), lack of experience of contractors. These findings are beneficial for contractors and owners of oil and gas projects to understand delay risks better and to formulate risk mitigation strategies properly.

1. Introduction

Global offshore oil and gas projects have been beset with problems of delays. More than 80% of 365 projects worldwide of upstream, LNG, pipeline and refining industries with investment capital values above $1 billion have experienced schedule delays [1]. Twenty companies in the United States, Europe and Asia reported that 40% of their oil and gas projects experienced schedule delays [2]. In addition, at least 60% of projects have experienced schedule delays of more than 30% of targeted project durations [3][4]. A study on the performance of the Nigerian oil and gas projects found 37% of time overrun with a standard deviation of 41%. It was also found that the non-technical factors have more significant impacts on project performance than the technical factors [5].

Typically, the oil and gas projects use the Engineering, Procurement, Construction (EPC) contract, which means that since the front-end engineering design (FEED) to the construction stage is carried out by the same contractor. As opposed to the traditional form of contracts of Design-Bid-Build (DBB), this type of contract allows design and construction activities to be done simultaneously. This allows the completion time of EPC projects to be faster than other types of contracts [6].

The offshore oil and gas facility projects cost a significant capital investment, and the construction process is very complicated containing higher risk factors [7]. The development of offshore oil and gas production facilities consists of various technical elements involving many parties, which require proper risk management [8]. Therefore, it is very important to manage the delay risks to ensure the target of project completion dates met. This research was aimed to map delay risk factors of EPC projects. A platform and subsea pipeline of an oil and gas project in Indonesia was used as a case study.
2. Reviewing project delays risks

Previous studies reviewed project risks in terms of safety-accident, technical, construction design, politics and regulation, contractual, financial, environmental [9][9][10]. Identification of delay risk factors found that the most severe elements were poor communication between construction parties, delay in commencement, poor resource management, insufficient inspectors, rework due to poor work quality, and payments delay [11]. Investigation on delay problems of Iranian gas mega projects from multiple perspectives, i.e. customer, construction management, contractor, consultant engineering and supplier, found that significant causes of the delays were related to project procurement. ‘Financial difficulties’ was the highest importance and ‘contractors’ problems’ was the lowest significance in the gas procurement process. Three out of 10 of the most important problems related to procurement were related to infrastructure issues, including political constraints, inadequate financial support, and domestic inflation rate [12].

An investigation on construction delays of oil and gas processing facilities in Oman found the following 7 main factors, such as poor management of the site and supervision by contractors, problems with subcontractors, inadequate planning and scheduling of projects by contractors, poor management of the schedules of contractors, delay in the delivery of materials, lack of effective communication between project stakeholders, poor interaction with vendors at the stage of engineering and procurement [13]. Other study in gas pipeline projects in Iran, also found main delay factors, such as : imported materials, unrealistic duration of the project, customer - related materials, land expropriation, change orders, selection of contractors, payment to the contractor, obtaining permits, suppliers and cash flow from the contractor [14]. Table 1 shows a comprehensive list of risk factors identified from other previous research [7][18–23], which provide a good understanding of delay factors, particularly in oil and gas projects.

3. Research Method

Data was collected through observation and analysis of project documents, and interviews with 13 respondents, who work for the project in managerial and engineer levels, i.e. lead engineers (40%), staff engineers (33%), head of divisions (13%), and performance analysts (13%). Most of them (90%) had 11 to 20 years of experience, 5% had more than 20 years of experience, and the rests had worked for less than 10 years in oil and gas project.

Initial risk identification from the literature review resulted in a total of 46 identified risks. These risks were consulted and validated by three senior expert respondents who had more than 20 years of working experience, to determine which risks were relevant to the project. The risk variables approved by at least two of the three senior expert respondents were kept for the next analysis. Whereas when at least two respondents considered a variable to be irrelevant, the variable was eliminated. Through this validation process, some irrelevant risk factors were omitted, and 14 additional risks were added, resulting in 28 final risk factors.

Having the risk factors validated, the respondents were asked to estimate the levels of probabilities of occurrence and impacts of the risks. The levels of risk probability were rated using a 1 to 6 scale, i.e. rare (0-10% probability), unlikely (10-30% probability), moderate (30-50% probability), likely (50-70% probability), almost certain (70-90% probability), definitely (90-100% probability). The impacts were rated based on the potential delay on the project duration using a 1 to 5 scale, i.e. insignificant (<3% of project duration), minor (3-5% of project duration), moderate (5-10% of project duration), significant (10-20% of project duration), catastrophic (>20% of project duration). To calculate the impacts, the respondents were asked to estimate the impact of the risks on the project duration based on 3 points of estimates, i.e. minimum (a), most likely (m), maximum durations (b) (Table 2). The minimum time is the most limited conceivable time in which the activity can be finished, most likely time is the time in which the activity can be finished under normal conditions, the maximum time is the longest likely time the activity may require. The expected duration for each risk impact (Te) was calculated by Eq.1 and
the percentage of the impact of delay duration by Eq.2. Risk categories, i.e. extreme, high, medium, and low, later were determined using a risk matrix showing various combinations of risk probabilities and impacts (Table 5).

\[ Expected \text{ delay duration} (T_e) = \frac{1a + 4m + 1b}{6} \]  
\[ \text{Percentage of impact} = \frac{T_e}{\text{project duration (366 days)}} \times 100\% \]

4. Results & Discussion

The 28 risk factors identified were categorized into three groups of stages, i.e. engineering [E], procurement [P], construction and installation [C] (Table 1). Four risk factors (11%) were identified in engineering stage [E], such as the low performance of the contractor engineering team, change in subsurface data, lack of communication between stakeholders, and changes of project scope. The engineering stage has ten activities with codes of A1-A10, i.e. process engineering, process safety, mechanical, piping, structure, electrical, instruments, shop drawings, cutting plan, and welding map. Eight delay risk factors (22%) were identified in the procurement stage [P], i.e. delay in material delivery, delay in sending long lead items, the unavailability of local vendors required by the regulator, lack of supervision of site management by contractors, contractor's financial capability, delay in detail engineering design, lack of communication between stakeholders, and changes of project scope. The procurement stage has 14 activities with codes of P1-P9, B1-B5. Twenty-four delay risk factors (67%) were found in the construction stage (C), such as local community issue, delay in mobilising construction equipment, delay in the marine spread for installation, etc. The construction stage had 11 activities with codes of C1-C10 and D1-D4. This finding is in line with a study by Pham and Hadikusumo [6], who found that for EPC projects the risks in construction stage were the main concern with a percentage of 44.9%, followed by the risks in the engineering stage (18.4%), and procurement stage (36.7%).

| Risk ID | Risk Factor                                      | Reference | Interview | Stage |
|--------|-------------------------------------------------|-----------|-----------|-------|
| X01    | Local community issues                          | [7]       | ●         | [C]   |
| X02    | Delay in mobilising construction equipment      | [15]      | ●         | [C]   |
| X03    | Delay in the marine spread for installation     | [16]      | ●         | [C]   |
| X04    | Delay in material delivery                      | [17]      | ●         | [P][C]|
| X05    | Delay in the technical query approval process    | [18]      | ●         | [C]   |
| X06    | Delay in sending long lead items                | [19]      | ●         | [P][C]|
| X07    | The unavailability of local vendors required by the regulator | [20] | ●         | [P]   |
| X08    | Low-performance equipment used in fabrication yards | [7]       | ●         | [C]   |
| X09    | The low performance of marine spread            | [15]      | ●         | [C]   |
| X10    | Non-synchronization of fabrication with the availability of marine spread | [16] | ●         | [C]   |
| X11    | Lack of experience or performance of contractors | [17]      | ●         | [C]   |
| X12    | Rework                                          | [18]      | ●         | [C]   |
Table 2. Calculation of expected duration (Te) of risk impacts and Linking risks to activities

| Code | Activity                                      | dur. (day) | Min (day) | Most likely | Max (day) | Te (day) | Risk ID (X) |
|------|-----------------------------------------------|------------|-----------|-------------|-----------|----------|-------------|
| P1   | Delivery Tubular                             | 140        | 7         | 10          | 16        | 11        | 6           |
| P2   | Delivery P/L Accessories                     | 138        | 4         | 7           | 10        | 7         | 6           |
| P3   | Delivery Pipeline                            | 148        | 6         | 13          | 20        | 13        | 6           |
| P4   | Delivery Test Separator                      | 98         | 5         | 10          | 15        | 10        | 6           |
| P5   | Delivery Pig Launcher + Gas Scrubber         | 147        | 4         | 6           | 10        | 6         | 6           |
| P6   | Delivery Chemical Injection Pump             | 101        | 5         | 9           | 12        | 8         | 6           |
| P7   | Delivery Pedestal Crane                      | 150        | 7         | 14          | 19        | 13        | 6           |
| P8   | Delivery Wellhead Control Panel              | 169        | 4         | 8           | 11        | 8         | 6           |
| P9   | Delivery Shutdown valve & On off Valve       | 161        | 6         | 9           | 14        | 9         | 6           |
| A1   | Process Engineering                          | 67         | 7         | 10          | 14        | 10        | 16; 20; 21; 22 |
| A2   | Process Safety Engineering                   | 87         | 7         | 11          | 14        | 11        | 16; 20; 21; 22 |
| A3   | Mechanical Engineering                       | 66         | 6         | 9           | 12        | 9         | 16; 20; 21; 22 |
### Table 3. An example of calculation of means of probabilities of risks, $Te$ and the total impact

| Risk ID | No. | Activity                        | Duration (Day) | $\sum P/n$ Probability | Mean Probability | $\sum P/n$ Min | $\sum P/n$ Most Likely | $\sum P/n$ Max | Te | Total Impact |
|---------|-----|---------------------------------|----------------|-------------------------|-----------------|-----------------|------------------------|----------------|----|--------------|
| X3      | 1   | Pipeline Laying                | 10             | 34 %                    | 33 %            | 3 d             | 5 d                    | 8 d            | 5 d | 15 d         |
|         | 2   | Jacket Installation            | 14             | 34 %                    |                 | 3 d             | 5 d                    | 8 d            | 5 d |              |
|         | 3   | Topside Installation Hook Up   | 21             | 32 %                    |                 | 3 d             | 5 d                    | 8 d            | 5 d |              |

Among the risks in all the EPC stages, this research found 1 extreme risk (4%), 15 high risks (54%), 11 medium risks (39%), and 1 low risk (4%), as presented in Tables 4 and 5. The top five risk factors were in the extreme and in high categories, i.e. the contractor's financial capability (X15), delay in delivery of long-lead items (X6), changes in the project scopes (X22), delay in detail engineering design (X19), lack of experience or performance of contractors (X11), as will be discussed below.
The financial capability of contractors (X15), the top risk in the extreme category, greatly influenced the EPC project, with an estimated delay of 119 days, equals to 33% of the total project duration. This risk was linked to 16 project activities, which was the greatest number compared to the other risks. This financial capability issue is indeed very much critical to the contractors to be able to carry out the work properly, as generally, they must work with many subcontractors and suppliers [21]. These findings are also consistent with the previous study that the financial problems of the contractors were the most significant causes of delays in Jordan and Kuwaiti construction industry [22].

Table 4. The Calculation of risk probabilities and impact

| Risk ID | Mean Probability | Total Impact | Impact (% of duration) | Risk Probability | Risk Impact | Risk Category |
|---------|------------------|--------------|------------------------|------------------|-------------|---------------|
| X15     | 32 %             | 119 d        | 33%                    | 3                | 5           | Extreme       |
| X6      | 26 %             | 158 d        | 43%                    | 2                | 5           | High          |
| X22     | 16 %             | 113 d        | 31%                    | 2                | 5           | High          |
| X19     | 29 %             | 167 d        | 46%                    | 2                | 5           | High          |
| X11     | 27 %             | 79 d         | 22%                    | 2                | 5           | High          |
| X16     | 14 %             | 77 d         | 21%                    | 2                | 5           | High          |
| X21     | 15 %             | 56 d         | 15%                    | 2                | 5           | High          |
| X4      | 27 %             | 107 d        | 29%                    | 2                | 4           | High          |
| X2      | 27 %             | 98 d         | 27%                    | 2                | 4           | High          |
| X13     | 30 %             | 49 d         | 13%                    | 3                | 4           | High          |
| X14     | 13 %             | 42 d         | 11%                    | 2                | 4           | High          |
| X17     | 29 %             | 32 d         | 9%                     | 2                | 4           | High          |
| X25     | 22 %             | 32 d         | 9%                     | 2                | 4           | High          |
| X12     | 31 %             | 41 d         | 11%                    | 3                | 3           | High          |
| X18     | 35 %             | 27 d         | 7%                     | 3                | 3           | High          |
| X27     | 30 %             | 46 d         | 13%                    | 3                | 3           | High          |
| X1      | 25 %             | 37 d         | 10%                    | 2                | 3           | Medium        |
| X5      | 25 %             | 34 d         | 9%                     | 2                | 3           | Medium        |
| X8      | 28 %             | 21 d         | 6%                     | 2                | 3           | Medium        |
| X10     | 24 %             | 22 d         | 6%                     | 2                | 3           | Medium        |
| X20     | 17 %             | 30 d         | 8%                     | 2                | 3           | Medium        |
| X23     | 25 %             | 15 d         | 4%                     | 2                | 3           | Medium        |
| X28     | 14 %             | 20 d         | 5%                     | 2                | 3           | Medium        |
| X3      | 33 %             | 13 d         | 4%                     | 3                | 2           | Medium        |
| X26     | 37 %             | 45 d         | 12%                    | 3                | 2           | Medium        |
| X24     | 32 %             | 13 d         | 4%                     | 3                | 2           | Medium        |
| X7      | 10 %             | 30 d         | 8%                     | 1                | 4           | Medium        |
| X9      | 25 %             | 16 d         | 4%                     | 2                | 2           | Low           |

Delay in the delivery of long-lead items (X6) was the second highest risk level, with 26% probability of occurrence and catastrophic impact with a total estimated delay of 158 days (43% of project duration). This delay was linked to impact 13 activities of the project, one of which was the Delivery Wellhead Control Panel (P8). It had the most extended duration of 169 days, with an expected duration time of
delay (Te) of 8 days. Long-lead items (LLI) refer to equipment, products and systems, which need a long time to procure, hence they play a significant role in determining the on-time completion of a project. One of the LLI materials in oil and gas construction is tubular steel, which is the primary material for jacket construction. The long lead time can be caused by poor communication with material suppliers particularly in the engineering and procurement stages[23]. This means that the procurement process may begin early to anticipate the long-time delivery of the materials to the project [24]. If the material is delivered too late, this is likely to affect the entire project completion time. Accelerating cycle time for long-lead-time equipment can lead to up to 30% delivery-schedule reduction [2]. The LLI usually need approximately 5-12 months to procure, therefore, it is generally done directly by the owner.

Table 5. The risk matrix

| Probability of Occurrence | Impact | Insignificant (3-5%) | Minor (5-10%) | Moderate (10-20%) | Significant (20-50%) | Catastrophic (>50%) |
|---------------------------|--------|---------------------|--------------|------------------|----------------------|-------------------|
| Definitely (90-100%)      |        | M                   | H            | E                | E                    | E                 |
| Almost Certain (70-90%)   |        | M                   | H            | E                | E                    | E                 |
| Likely (50-70%)           |        | M                   | H            | H                | E                    | E                 |
| Unlikely (30-50%)         |        | L                   | M            | X12,X18,X27     | H                    | E                 |
| Rare (0-10%)              |        | L                   | L            | X9               | X12,X18,X27          | H                 |

Changes in work scope (X22) had 16% probability of occurrence and catastrophic impact with a total estimate delay of 113 days, or 31% of the project duration, and could affect 19 activities. The maturity of design, changes in supporting data, owner requests can be the main causes of changes in the scope of work. Changes in work scope have been found as one of the frequent causes of delays [3], as this delay risk can occur in all EPC stages. Frequent change orders issued by owners were the most significant causes of construction delays [7][22].

The delay of detailed engineering design (X19) had 29% probability of occurrence and catastrophic impact with a total estimate delay of 167 days, or 46% of the project duration, and could affect 12 activities. As this delay is the first stage of the three stages of an EPC project, certain project activities cannot commence and finish on time as the result. The complexity of the design may even exacerbate the situation. Delays related to the engineering design were found as the risk with the greatest negative impact on the project performance[25].

Delay risk due to lack of experience or performance of contractors (X11), had 27% probability of occurrence and catastrophic impact with a total estimate delay of 79 days, or 21% of the project duration, and could affect 10 activities. The implementation of the three stages of an EPC project by a single entity, requires the contractor to have a comprehensive understanding and sufficient capability to run the whole process of engineering, procurement, and construction. Although the contractor can collaborate with other partners, it will need a very good interaction among the parties. This delay was also identified as one of the major risks in oil and gas projects in the Gulf Cooperation Council Countries [23], which could eventually lead to other risks.

Project delay is indeed considered as a common problem in the global construction industry, including in oil and gas projects[23]. As every project is unique, however, the top delay risk factors may vary
depending on the types of the project, procurement models, locations, materials, construction methods, site conditions, etc. This may explain why various results may be obtained from previous studies, such as [4][17][23]. In addition, although this research was done within the context of the case study of a platform and subsea pipeline of an oil and gas project, the results are likely to be relevant and applicable to other oil and gas projects.

5. Conclusion
The purpose of this study was to map risk factors that affect the delay in the EPC projects, using a platform and subsea pipeline of an oil and gas project in Indonesia as the case study. A total of 28 potential risk factors was identified and categorized into three groups of stages, i.e. engineering [E] (11%), procurement [P] (22%), construction and installation [C] (67%). This research also found 1 extreme risk (4%), 15 high risks (54%), 11 medium risks (39%), and 1 low risk (4%), with the top five risk factors, i.e. the contractor's financial capability, delay in delivery of long-lead items, changes in the project scopes, delay in detail engineering design, lack of experience or performance of contractors. These findings provide new valuable information to understand delay risks of an oil and gas project, particularly in the platform and subsea pipelines context, which later will be useful to formulate proper risk mitigation strategies. To gain more comprehensive understandings on these risks, further research can be done by simulating these delay risks in the project, and carry out a sensitivity analysis. Furthermore, as the results from one case study may be still limited for generalization, investigation on a greater number of projects may provide more evidence and comprehensive results.

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References
[1] Ernst, Young 2014 Global Limited (London: EYGM)
[2] McKenna M G, Wilczynski H and VanderShee D 2006 Capital Project Execution In The Oil And Gas Industry: Increased Challenges, Increased Opportunities (Virginia: Booz Allen Hamilton Inc).
[3] Merrow Edward W 2012 Oil Gas Facil 1 38–42.
[4] Rui Z et al 2018 Energy 158 666–80.
[5] Patil S et al 2018 Energy 158 666–80.
[6] Pham L H, and Hadikusumo H 2014 Int J Energy Sect Manag 8 3–26.
[7] Basak M, Coffey V and Perrons R K 2018 SPE Asia Pacific Oil and Gas Conference and Exhibition.
[8] Zou P X W, Zhang G and Wang J 2007 Int J Proj Manag 25 601–14.
[9] Wiguna I P A and Scott S 2006 Constr Manag Econ 24 1125–35.
[10] Enshassi A, Mohamed S and Mosa J A 2008 Engineering 13 29–44.
[11] Mahamid I 2011 Eng Constr Archit Manag 18 609–17.
[12] Vafaiee M, Owlia M S and Vahdat M A 2010 Int. Conf Ind Eng Oper Manag.
[13] Ruqiashi M and Bashir H A 2015 J Manag Eng 31 11-6.
[14] Fallahnejad M H 2013 Int J Proj Manag 31 136–46.
[15] Chaher Z C and Soomro A R 2016 Int J Sci Res Publ 6 703–9.
[16] Sohrabnejad A and Rahimi M 2015 J Constr Eng 2015 1–10.
[17] El-Shenawy M, Nour M and Sanad A E M 2014 Int’l J Scientific Res 2 317.
[18] Rahman M M and Kumaraswamy M M 2002 Eng Constr Archit Manag 9 45–54.
[19] Gündüz M, Nielsen Y and Özdemir M 2013 J Manag Eng 29 133–9.
[20] Li Q F, Zhang P and Fu Y C 2013 Res J Appl Sci Eng Technol 6 1523–30.
[21] Wenzhe Tang et al 2007 133 944–956 [cited on December]
[22] Basak M Coffey V and Perrons R K 2017 IEEE Int Conf Ind Eng Eng Manag 2017 730–4 [cited December 2018]
[23] Ruqaishi M and Bashir H A 2015 *J Manag Eng* **31** 05014017 [cited on May 2015]
[24] Mroz D, Shykinov N, De Vos M and Schwarz G 2013 *IFAC-Papers OnLine* **28** 124–9.
[25] Kuo Y-C and Lu S-T 2013 *Int J Proj Manag* **31** 602–14.