Quantitative Risk Analysis for Oil and Gas Projects: A Case Study

J U D Hatmoko\(^1\) and R R Khasani\(^1\)

\(^1\)Civil Engineering Department, Engineering Faculty, Diponegoro University

jati.hatmoko@ft.undip.ac.id

Abstract. Delays have been identified as one of the significant risks in oil and gas projects. A sound risk analysis is, therefore, one of the critical factors for the success of the projects. The aim of this research was to measure the impact of delay risks on the completion time of an oil and gas project in Indonesia as a case study. Data of relevant delay risks were initially collected from literature reviews and observations on project documents and finalized through interviews with key respondents of the project. A monte-carlo based simulation software was used to simulate 28 delay risks identified and applied to the 34 project activities. This research found a probability of less than 1% for on-time project completion according to the baseline schedule (366 days). It was also projected that the project duration could be extended by 10.6% (405 days) and 14.2% (418 days) with 50% and 80% probabilities, respectively. The sensitivity analysis indicated that the most influential activity on project delays was the tubular delivery, and the risk delay with the most significant impact to project delays was the delay of long-lead item delivery. This research showed the mechanism of incorporating delay risks into relevant project activities, and the findings allow a better understanding of stakeholders to develop appropriate risk mitigation strategies.

1. Introduction

While project completion time is one of the critical indicators of a successful project, yet delays are not unusual for many types of projects in various regions [1]. Delays have been listed as among the significant risks for oil and gas projects [2]. It was found that fifty per cent of oil and gas projects in the Uni Emirate Arab, United States, Europe, and Asia suffered from delays [3][4]. Oil and gas construction projects are typically complicated, and their dynamic environment makes them even more challenging to manage. In addition, the increasing global energy demand has grown the need for reliable risk assessment models to provide appropriate and comprehensive policy planning for such projects [5]. A sound risk analysis is, therefore, one of the critical factors for the success of the projects [6].

The risks can be addressed in terms of the probabilities of occurrence, and the impacts on the project durations to determine the risk levels. Risk analysis can be carried out qualitatively as well as quantitatively [6]. The qualitative analysis is mainly based on expert judgment; hence, it can be somewhat ambiguous and probably less reliable than the quantitative analysis [7]. On the other hand, the quantitative analysis utilizes probability distribution, mathematical approach, and simulation tools.
to determine the probabilities of occurrence, and the impacts, giving more accurate and reliable results.

The aim of this research was to measure the impact of delay risks on the completion time of an oil and gas project in Indonesia as a case study by using quantitative risk analysis.

2. Delay risks on projects

Previous studies have been conducted to investigate the project delay causes of various projects in several countries, such as building construction in Ghana [8], Egypt [9], [10], Qatar [11], India [12], Nigeria [13], [14], Chile [15], Libya [16], the road construction project in Norway [17], Egypt [18], Malawi [19], Cambodia [19], Sri Lanka [20], Zambia [20], Palestine, Qatar [11], and general construction project in Iraq [21], Turkey [22], Uganda [23], Egypt [24], Zambia [25]. Orangi et al. [26] found causes for pipeline construction delays in Australia, such as change of design, design failures, miscommunication, issues relating to the customer, inadequate subsurface investigation, site management subcontractor, authorization problems, climate, production delays, cultural and heritage issue.

A research in Iran gas pipeline projects identified 43 item list of factors in and found ten critical causes of delay, such as land expropriation, purchased materials, permits for client-related materials, contractor recruitment methods, unrealistic project duration, payment to the contractors and suppliers, contract change orders (CCO), and contractors working capital [27]. Lack of communication with suppliers in the engineering and procurement stage was found to be the primary source of delay in oil and gas construction projects [2]. In addition, a quantitative analysis of around 400 pipeline projects found that country, size of the projects and climate as significant factors influencing project quality [1]. While in Indonesia, research on the risk of delays in oil and gas projects was rare. This research is expected to give a view on the causes of delays and their mitigations in oil and gas projects in Indonesia.

3. Research method

This research adopted a quantitative risk analysis approach using a monte-carlo based simulation software. This approach can deliver more accurate and reliable results in comparison to the qualitative one. In addition, this method can provide a comprehensive overview of project risk exposure [28][29].

3.1. Risk identification and the Precedence Diagram Network (PDM)

Data of relevant delay risks were initially collected from literature reviews and observations on project documents resulting in 48 identified risks. This risk list was later validated through interviews with five key expert respondents of the project, i.e. head of construction, team leader, engineer, head of project business, head of HSE, and performance analyst, resulted in 28 validated delay risks.

The oil and gas project as a case study was planned to finish in 366 days. The main stages of the project consist of the procurement and delivery of long-lead items consist of 9 activities (P1-P9), the engineering stages 10 activities (A1-A10), the procurement stages 5 activities (B1-B5), and the construction & installation stages 10 activities (C1-C6, D1-D4). Figure 1 and table 1 explain the sequence of activities carried out in this project and form the basis of the PDM network for simulation models.

3.2. The simulation model

The simulation model was developed based on the PDM network and the 28 validated delay risks of the project. The validated risk events were incorporated into the relevant project activities, as shown by a matrix of risk event and activities in table 2. The following steps were taken to carry out the monte Carlo simulation, as follows: 1) Developing the project schedule from 34 lists of project activities with a total duration of 366 days, 2) Inputting the 28 validated risk events into the risk register, 3) Compiling the qualitative risk assessment criteria with probability and impact score on the risk register, 4) Mapping risks to the project activities and determine the probability and impact value,
5) Integrating risk events into the project schedule, and 6) Running the simulation model with 10,000 iterations.

![PDM network of an oil and gas project with a 366-day duration](image)

**Figure 1.** The PDM network of an oil and gas project with a 366-day duration

| Code | Activities and durations (days) | Code | Activities and durations (days) |
|------|---------------------------------|------|---------------------------------|
| P1   | Distribution Tubular = 140d     | A9   | Cutting Plan = 58d              |
| P2   | Distribution P/L Accessories = 138d | A10  | Welding Map = 45d              |
| P3   | Distribution Pipeline = 148d    | B1   | Piping Procurement = 111d       |
| P4   | Distribution Test Separator = 98d | B2   | Mechanical Process = 100d       |
| P5   | Distribution Pig Launcher=147d  | B3   | Electrical Process = 100d       |
| P6   | Distribution Chemical Injection Pump = 101d | B4   | Instrument Process = 91d       |
| P7   | Distribution Pedestal Crane = 150d | B5   | Structural Process = 45d        |
| P8   | Distribution Wellhead Control = 169d | C1   | Jacket Fabrication = 142d       |
| P9   | Distribution Shutdown valve = 161d | C2   | Topside Fabrication = 145d      |
| A1   | Engineering Procedure = 67d     | C3   | Pile Fabrication = 101d         |
| A2   | Safety Engineering Procedure = 87d | C4   | Loadout Jacket = 25d            |
| A3   | Mechanical Work = 66d           | C5   | Loadout Topside = 25d           |
| A4   | Piping Work = 88d               | C6   | Loadout Piles = 29d             |
| A5   | Structure Work = 79d            | D1   | Pipeline Laying=10d             |
| A6   | Electrical Work = 66d           | D2   | Jacket Installation = 14d       |
| A7   | Instruments Work = 94d          | D3   | Topside Installation Hook Up = 21d |
| A8   | Shop Drawing = 68d              | D4   | Offshore Commissioning & Start Up =13d |
### Table 2. Incorporating risks to activities in the PDM network

| Activity | X01 | X02 | X03 | X04 | X05 | X06 | X07 | X08 | X09 | X10 | X11 | X12 | X13 | X14 | X15 | X16 | X17 | X18 | X19 | X20 | X21 | X22 | X23 | X24 | X25 | X26 | X27 | X28 |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| B1       | (22%) | (23%) | (15%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| B2       | (22%) | (23%) | (15%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| B3       | (22%) | (23%) | (15%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| B4       | (22%) | (23%) | (15%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| B5       | (22%) | (23%) | (15%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| C1       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| C2       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| C3       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| C4       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| C5       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| C6       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| D1       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| D2       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| D3       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |
| D4       | (16%) | (20%) | (10%) | (10%) | (8%) | (5%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) | (3%) |

Notes:
X01= Local community issues, X02= Delay in mobilising construction equipment, X03= Delay in the marine spread for installation, X04= Delay in material delivery, X05= Delay in the technical query approval process, X06= Delay in sending long lead items, X07= The unavailability of local vendors required by the contractor, X08= Low-performance equipment used in fabrication yards, X09= The low performance of marine spread, X10= Non-synchronization of fabrication with the availability of marine spread, X11= Lack of experience or performance of contractors, X12= Rework, X13= Incompetence of subcontractors, X14= Lack of supervision of site management by contractors, X15= Contractor's financial capability, X16= Low performance of the contractor engineering team, X17= Permits from the government, X18= Bad weather during construction, X19= Delay of detailed engineering design, X20= Change in sub-surface data, X21= Lack of communication between stakeholders, X22= Changes in project scope, X23= Inappropriate manpower plan, X24= Unrealistic plan, X25= Delays in inspection and testing activities by contractors, X26= Simultaneous operation between construction and operation team, X27= Completion of project readiness review, X28= Key personnel not available at the project site.

In the above example, D4-X1 (25%, 23, 3.6) means activity D4 has 25% of probability to be delivered late, with the extent of delays of 2 days minimum, 3 days most likely and 6 days maximum.
4. Results & Discussion

Figure 2 shows the histogram of the frequency distribution of the project completion duration after experiencing 10,000 iterations. The graph has three axes, i.e. the x-axis shows the distribution of project duration, the y-axis in the left shows the number of hits, the y-axis in the right shows the probability of the project can finish in a particular duration (days). The curve on the graph shows the cumulative frequency of the distribution. It can be estimated that the duration of project completion date to the entire phase starting from the start activity of sending long lead items to commissioning and start-up had a minimum duration of 366 days with the probability of less than 1%. The project, however, can be delayed to 405 days (i.e. 10.6% of the target duration) with a probability of 50%, and it can be delayed to 418 days (14.2% the target duration) with a probability of 80%.

![Figure 2. Distribution graph of the summary output of the Monte Carlo simulation](image)

From the simulation, it can be obtained the criticality index of activity, sensitivity index of activity, and sensitivity index of the risk event. The criticality index is the percentage where the activity is included as part of a critical path in the PDM network during the 10,000 iterations. There are activities that had a 100% criticality index, i.e. jacket installation, topside installation, commissioning, distribution tubular, load-out piles, and pile fabrication. It indicates that the activities always became part of the critical path during the simulations. The criticality index diagram can be seen in figure 3. However, the criticality index cannot be used to conclude the activities that most influence the project delays; hence, a sensitivity analysis was used for this purpose.

![Figure 3. The criticality index of activities](image)
4.1. Sensitivity analysis

The sensitivity analysis indicated the most influential activity and risk events on project delays [30]. There are two sensitivity analyses used, i.e. the activity sensitivity index and the risk sensitivity index. This index indicates which activities and risks have the most potential to influence project delays. There are six activities that have most influences on project delays, such as delivery tubular which was one of the long-lead item activities with a sensitivity index of 38%, pile package-conductor which was one part of the manufacturing activity of pile packages (28%), topside installation hook up (25%), load-out pile (20%), commissioning and start-up (18%), and jacket installation (16%). Furthermore, the top ten most influential risks to project delays were delays in distribution long-lead items with a sensitivity index of 71%, delay in detailed engineering design (26%), delays related to permit (25%), lack of contractor’s experience and performance (15%), the financial ability of contractors (9%), adverse weather conditions when carrying out work (8%), delays in mobilizing construction equipment (6%), asynchronous completion of fabrication stages with the readiness of marine spread for offshore installations (5%), the lack of competence of the subcontractor (4%), and low performance of marine spread (4%). Figure 4 shows a tornado diagram that explains the sensitivity index in project activities, while figure 5 shows a tornado diagram for the top ten risks event with the highest sensitivity index.

![Figure 4. Sensitivity index of activities](image1)

![Figure 5. Sensitivity index of risk events](image2)
4.2. Risk response strategies

A risk response plan is geared at maximizing and mitigating the potential risk that can affect the project in terms of time, cost and quality. The mitigation procedures and controls were necessary to minimize the risk probability and impact on project delay. The top ten risks that had the highest sensitivity indexes were planned for the risk mitigation process. In this study, three expert respondents were asked to provide strategies to risk mitigation and control procedures. They had positions as head of construction, coordinator of certification & permit, and lead conceptual management engineering & process improvement (MEPI) engineer. There were nine recommendations in mitigating the risks, as follows: 1) Delay in delivery long-lead item (X06) can be minimized with accelerating the tender process and purchase of requirement, using the stock of the available item in owner’s warehouse or loan from other companies, using dedicated cargo in delivery items to one destination, and tracking and updating delivery progress periodically; 2) Delay in delivery detailed engineering design (X19) can be minimized by determining substantial engineering deliverables target dates weekly monitoring to ensure DED completion time, put owner’s engineering teams and contractor to work in one office to more natural coordination and communication; 3) Permits delay from the government (X17) can be minimized by planning the applying process of work permit well in advance at least six months before the execution of work; 4) The lack of experience and performance of the contractors (X11) can be anticipated by compiling detailed evaluation criteria to evaluate the contractor's ability to get a qualified contractor, and holding a pre-bid meeting so that the contractor can better understand of the work to be performed; 5) Bad weather conditions (X18) can be minimized by scheduling the work in the other of monsoon conditions and view tide charts obtained from the reports of Meteorological, Climatological, and Geophysical Agency; 6) The lack of a contractor’s financial capacity (X15) can be minimized through in-depth evaluations and reviews by the owner's financial team, and making changes to procedures to streamline the invoice payment process; 7) Delay in mobilizing construction equipment (X02) and asynchronous completion of the fabrication phase with the availability of marine spreads for offshore installations (X10) can be anticipated by incorporating equipment mobilization plans into detailed requirements and evaluation criteria as an EPCI (engineering, procurement, construction, and installation) bidder evaluation. Afterward, conducting a pre-mobilization check and pre-job assessment to ensure equipment readiness; 8) The lack of competence of the subcontractor (X13) can be anticipated by holding meetings periodically between contractor and owner to get a commitment to the project completion date; 9) The low performance of marine spread can be anticipated by conducting pre-mobilization check and pre-job assessment to ensure marine spread readiness.

The findings of this research related to delay risks in the oil and gas project complement and reinforce the findings of the following research in oil and gas projects in other regions. A study in Victoria-based pipeline projects found that climate conditions, permissions or authorizations, delays in procurement, and subcontractor issues as the root causes of the project delays [26]. The issuance of permits and contractor's financial involved significant delays in Iran's gas pipeline projects [27]. In Oman, seven main factors were identified responsible for construction delays for oil and gas processing facilities, two of which were issues with subcontractors, delays in the distribution of materials [2]. A study in Australia suggested that essential risk factors causing project delays, including delays in procurement of materials, delays in the deployment of resources, lack of experience and skills of contractors, delays in commissioning and start-up [31]. This study complements the previous research by developing the risk mitigation strategy in oil and gas projects in order to mitigate the impact on project delays.

5. Conclusion

Delays have been described as among the significant risks in oil and gas projects. The aim of this research was to measure the impact of delay risks on the completion time of an oil and gas project in Indonesia as a case study. This research found a probability of less than 1% for on-time project completion according to the baseline schedule (366 days). The results of the Monte Carlo simulation
show that the project duration could be delayed to 405 days (10.6% of the target duration) and 418 days (14.2% the target duration) with probabilities of 50% and 80%, respectively. The sensitivity analysis found the top six activities that most influence on project delays, i.e.: (1) delivery tubular, (2) pile package-conductor, (3) topside installation hook up, (4) load-out pile, (5) commissioning and start-up, and (6) jacket installation. The top ten most influential risks to project delays found include: (1) delays in distribution long lead items, (2) delays in detailed engineering design, (3) delays related to permit, (4) lack of contractor’s experience and performance, (5) the financial ability of contractors, (6) adverse weather conditions, (7) delays in mobilizing construction equipment, (8) asynchronous completion of fabrication stages with offshore installations, (9) the lack of competence of the subcontractor, (10) low performance of marine spread. This research showed the mechanism of incorporating delay risks into relevant project activities and proposed some mitigation strategies to minimize the risk probability and impact on the project completion time, which will allow a better understanding of stakeholders to develop appropriate risk mitigation strategies for typical oil and gas projects. In order to extend the generalization of these findings, further research can be done by adding more case studies.

Acknowledgements

This research was financially supported by The Faculty of Engineering, Diponegoro University, Indonesia through Strategic Research Grant 2019. The authors appreciate Hardy Gunanda and Imam Hadrazi Baihaki for assisting the survey and data collection process of this research.

References

[1] Ruiz Z et al 2018 A comprehensive investigation on the performance of oil and gas development in Nigeria: Technical and non-technical analyses Energy 158 666–680
[2] Ruqaishi M and Bashir H A 2015 Causes of delay in construction projects in the oil and gas industry in the gulf cooperation council countries: A case study J. Manag. Eng. 31 (3)
[3] Faridi A S and El-Sayegh S M 2006 Significant factors causing delay in the UAE construction industry Constr. Manag. Econ 24 (11) 1167–1176
[4] McKenna M G, Wilczynski H, and VanderSchee D 2006 Capital Project Execution in the Oil and Gas Industry Booz Allen Hamilton Inc
[5] Dedasht G, Zin R M, Ferwati M S, Abdullahi M M, Keyvanfar A, and McCaffer R 2017 DEMATEL–ANP risk assessment in oil and gas construction projects Sustain 9 (8) 1–24
[6] PMI A 2017 guide to the project management body of knowledge (PMBOK guide) 6. VER, Proj. Manag. Inst.
[7] Patterson F D and Neailey K 2002 A risk register database system to aid the management of project risk Int. J. Proj. Manag. 20 (5) 365–374
[8] Fugar F D and Agyakwah-Baah A B 1970 Delays in Building Construction Projects in Ghana Constr. Econ. Build. 10 (1–2) 103–116
[9] Alaghbargi W, Mohd Razali A K, Azizah S, and Ernawati 2007 The significant factors causing delay of building construction projects in Malaysia Eng. Constr. Archit. Manag. 14 (2) 192–206
[10] Authors F 2014 Factors contributing to project time and hence cost overrun in the Malaysian construction industry
[11] Senouci A, Ismail A, and Eldin N 2016 Time Delay and Cost Overrun in Qatari Public Construction Projects Procedia Eng. 164 (June) 368–375
[12] Shanmuganathan N and Baskar G 2015 Ranking of delay factors causes time and cost overruns in construction projects in Tamil Nadu Int. J. Appl. Eng. Res. 10 (24) 4444–44453
[13] Aibinu A A and Jagbore G O 2002 The effects of construction delays on project delivery in Nigerian construction industry Int. J. Proj. Manag. 20 (8) 593–599
[14] Aibinu A A and Odeyinka H A 2006 Construction delays and their causative factors in Nigeria J. Constr. Eng. Manag. 132 (7) 667–677
[15] González P, González V, Molenaar K, and Orozco F 2014 Analysis of causes of delay and time performance in construction projects J. Constr. Eng. Manag. 140 (1)
[16] Shebob A, Dawood N, Shah R K, and Xu Q 2012 Comparative study of delay factors in Libyan and the UK construction industry Eng. Constr. Archit. Manag. 19 (6) 688–712
[17] Mahamid I 2011 Risk matrix for factors affecting time delay in road construction projects: owners’ perspective Eng. Constr. Archit. Manag. 18 (6) 609–617
[18] Aziz R F and Abdel-Hakam A A 2016 Exploring delay causes of road construction projects in Egypt Alexandria Eng. J. 55 (2) 1515–1539
[19] Kamanga M J and Steyn W J V D M 2013 Causes of delay in road construction projects in Malawi J. South African Inst. Civ. Eng. 19 (6) 688–712
[20] Ali naitwe H, Apolot R, and Tindiwensi D 2013 Investigation into the causes of delays and cost overruns in Uganda’s public sector construction projects J. Constr. Dev. Ctries. 18 (2) 33–47
[21] Bekr G A 2015 Causes of delay in public construction projects in Iraq Jordan J. Civ. Eng. 9 (2) 149–162
[22] Kazaz A, Ulubeyli S and Tuncbilekli N A 2012 Causes of Delays in Construction Projects in Turkey J. Civ. Eng. Manag. 18 (3) 426–435
[23] Alnaitwe H, Apolot R, and Tindiwensi D 2013 Investigation into the causes of delays and cost overruns in Uganda’s public sector construction projects J. Constr. Dev. Ctries. 18 (2) 33–47
[24] Marzouk M M and El-rasas T I 2014 Analyzing delay causes in Egyptian construction projects J. Adv. Res. 5 (1) 49–55
[25] Kaliba C, Muya M, and Mumba K 2009 Cost escalation and schedule delays in road construction projects in Zambia Int. J. Proj. Manag. 27 (5) 522–531
[26] Orangi A, Palaneeswaran E, and Wilson J 2011 Exploring delays in Victoria-based Australian pipeline projects Procedia Eng. 14 874–881
[27] Fallahnejad M H 2013 Delay causes in Iran gas pipeline projects Int. J. Proj. Manag. 31 (1) 136–146
[28] Italy A et al 2009 Risk Quantification and Risk Management in Renewable Energy Projects Risk Quantification and Risk Management in Renewable Energy Projects 2 Risk Quantification and Risk Management in Renewable Energy Projects
[29] Ayodeji C O A, Emmanuel Oke and M M Raphiri 2015 Major Construction Risk Factors Considered by General Contractors in Qatar Eur. J. Mark. 24 (5) 41–49
[30] Grimsey D and Lewis M K 2002 Evaluating the risks of public private partnerships for infrastructure projects Int. J. Proj. Manag. 20 (2) 107–118
[31] Basak M, Coffey V, and Perrons R K 2018 Risk Factors Affecting Delays in Upstream Natural Gas Mega-Projects: An Australian Perspective, in SPE Asia Pacific Oil and Gas Conference and Exhibition