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A model for delay analysis impact at planning phase of Oil and Gas pipeline projects: A case of Iraq

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Abstract

Project delay and cost overrun are major issues caused by the associated Risk Factors (RFs) in any projects including Oil and Gas Pipeline Projects (OGPPs). This problem is exacerbated by the subjective nature of the identification and quantification of delay factors t at the planning stage. To overcome above issues, this research designs a Delay Analysis Model (DAM) at planning stage of the project by introducing fuzzy logic in delay analysis; hence, systematize and objectify the quantification of the process. The paper presents a step-by-step process of identifying the RFs and quantifying the probability of project delivery. The inputs of the model are the RFs, level of impact, and the estimated maximum and minimum duration of each critical task of the project. The model is integrated with @Risk simulator to quantify the delay impact. The key output of the study is a useful delay analysis tool that help to identify and quantify the potential delay impacts and the confidence level of project deliver in time at the planning stage so that proactive measures could be taken in advance. The model was evaluated using a case study of an OGPP in Iraq. The findings suggested that a potential overall delay at all stages of the project was found around 45 days in the project.

Key Words: Oil and Gas Pipelines, Delay Analysis Model, Monte Carlo Simulation, Project Delay, @Risk simulator

Introduction

Construction delay generates long-term severe economic consequences and environmental impacts for nations, and it is one of the common problems in the construction industry in both developed and developing countries (Shah, 2016). Providing a good knowledge about the Risk Factors (RFs) and their level of impact on the projects at the planning stage could help the stakeholders to make sound decisions in response to risk management (Ruqaishi and Bashir, 2015) to keep the construction delay interruption in the projects to minimum, as much as possible (Kraidi et al., 2020a). The research gap, however, has been the lack of delay analysis tools that can reduce bias and subjectivity. To close this gap, this paper proposes a delay analysis system of risk factors using fuzzy logic theory (Chan et al., 2009), to reduce biasness of relative importance index/values of risk probability and impact on of all risk factors affecting in all critical task/activity in the construction project. The paper designs a Delay Analysis

Model (DAM), which is used to analyze and quantify the construction delay caused by the associated RFs at the planning stage of the projects in an integrated and systematic way. The DAM has been used in the Oil and Gas Pipeline Projects (OGPPs), in Iraq. The functionality of the DAM was evaluated with a case study of oil and gas pipeline project that is under construction in the south of Iraq. The paper concludes that reduction of bias and subjectivity in delay analysis creates a robust decision-making strategy for the management of delay risks

Literature Review

Fallahnejad (2013) and Sweis et al. (2019) used document analysis and a questionnaire survey to identify the main delay factors and analyze their impact on the OGPPs in Iran. Sweis et al. (2019) used a questionnaire survey to identify the root causes of the delay factors in gas pipeline projects in Iran. Ruqaishi and Bashir (2015) investigated the delay factors in the construction of oil and gas projects in Oman as a case study in the Gulf Cooperation Council (GCC) region, which involves United Arab Emirates, Saudi Arabia, Qatar, Oman, Kuwait and Bahrain. Kadry et al., (2017) examined delay risks in areas of high geopolitical environment. However, these studies did not quantify the potential delay in these projects caused by the RFs in a manner that takes care of subjectivity and bias. Moreover, the risk assessment methods used in these studies are limited to their regions of study, which means they cannot be effectively applied to analyze the impact of the delay factors in OGPPs and improve the level of safety of these projects elsewhere.

A study conducted by Kraidi et al., (2020a), is critical to this paper, because it details how a project planning software ASTA BIM can be used to identify activities on the critical path; and use the ASTA ASTA risk simulator to analyze the RFs that cause delays on a case study project. The ASTA risk simulator has only four methods of risk distribution (which are uniform, normal, skewed normal and skewed triangular distribution), but only one distribution method could be applied on time during the process of risk simulation, which does not reflect the reality of the RFs on the duration of the projects. This is one of the limitations of using ASTA risk simulator that quantifies the impact of the RFs on the duration of the projects. In a study done by Assaad et al. (2020), the authors used @Risk simulator to predict project performance in the construction industry. This is because @Risk simulator could enable the researchers to use most of the parametric fitted and theoretical distributions existing in the literature. For instance, normal distribution, which is defined by the mean and the standard deviation. The beta distribution, which is defined by minimum, maximum, alpha1, and alpha2; Dagum distribution, which is a continuous function defined over positive real numbers and is useful in many actuarial statistics or risk management. Kumaraswamy distribution, which is a continuous distribution used for lower and upper bounded variables, that could be used on the [0, 1] interval, and it is like the Beta distribution; but much simpler to implement in simulation studies. Pert distribution, which is a continuous function with a curved density that is a special case of the Beta General distribution and is widely used in risk analysis. Assaad et al. (2020) encouraged researchers to replicate their methodology for other types of projects, such as buildings and infrastructure. Such a methodology has been used in this paper in an infrastructure type of projects, which are OGPPs. Shebob et al. (2012) analyzed the possible minimum, the mean and the maximum duration of a construction project in Libya and the UK using Monte Carlo Simulation. However, the risk assessment methods used by Shebob et al. (2012) are limited to their regions of study, which means they cannot be effectively applied to analyze the impact of the delay factors in oil and gas projects and improve the level of safety of these projects elsewhere. The research question of this study is: what is the impact of the risk factors on the duration of OGPPs and how the study contributes to designing a DAM that expected to determine delay impact due to associated RFs in project? The DAM is integrated with @Risk simulator to quantify the delay impact caused by the associated RFs in the OGPPs considering different risk distribution methods for the same RFs and work activities at the same time, using the fuzzy logic theory to reduce bias. The adopted methodology and specification for the design and development of the DAM is described in the next sessions of this paper.

Research Methodology

This paper uses the mixed research methodology to analyze and quantify the impact of delay factors in the projects and confidence level of project delivery of an oil and gas pipeline project in a simple and systematic way. The focus is to develop a holistic and integrated a Delay Analysis Model (DAM) for the OGP projects. The study has adopted a systematic strategy with mixed research approaches to achieve reliable results from risk analysis in OGP projects. The qualitative approach of this paper refers to the literature review and the subjective and objective analysis of documents collected from the projects. Meanwhile, the quantitative approach of this paper refers to the analysis of the RFs using an industrial survey, the application fuzzy theory and the Monti Carlo algorithm using @Risk.

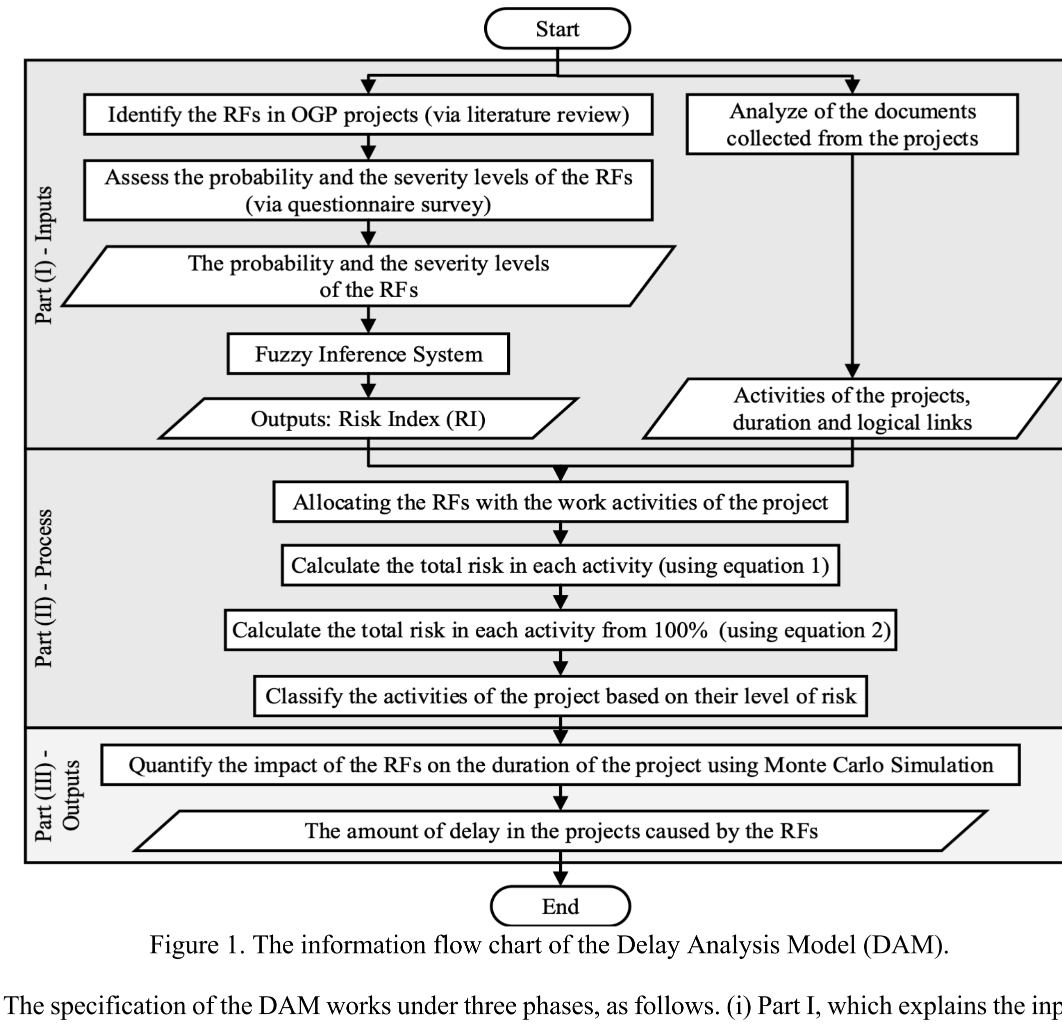

Figure 1. The information flow chart of the Delay Analysis Model (DAM).

The specification of the DAM works under three phases, as follows. (i) Part I, which explains the inputs of the model and how to find them; (i) Part II, which explains the process part of the model and illustrators how to link the RFs to the activities of the projects and calculate the risk level in each critical activity (already identified using project planning software). And (iii) part III, which explains the outputs of the model. Figure 1 presents the information flow diagram of the Delay Analysis Model (DAM) designed and developed in the study

Step 1: Identify the potential RFs in OGPPs: This step involves investigating the published studies that identified and analyzed the risk factors, which may affect the duration of OGPPs worldwide. This part of the DAM explains the process of identifying and assessing the RFs in OGP projects in Iraq. Firstly, the RFs were identified via an extensive literature review about the risks in OGP projects worldwide in order to overcome the problem of data scarcity about the RFs in OGP projects in Iraq (Kraidi et al., 2017). Based on the findings of the literature review, a questionnaire survey was designed and conducted with construction professionals to identify the probability and severity levels of the RFs within OGP projects in Iraq (Kraidi et al., 2019b) and analyze the RFs regards their degree of probability and impact on OGP projects. The outputs of this step are the probability and severity level of potential RFs with Risk Index (RI) values in the projects. See Table1 for details of RFs with respective RI.

Table 1:
The results of identifying and assessing the RFs in OGPPs in Iraq.

List of Risk Factors (RFs)	The findings of the survey (Kraidi et al. 2019b).		Result (Kraidi et al., 2019c, 2018).
RFs (Kraidi et al., 2017 and 2019a).	Probability	Severity	Risk Index (RI)
Sabotage	3.995	4.490	3.99
Corruption	3.717	4.192	3.87
Insecure areas	3.712	4.106	3.76
Low public legal & moral awareness	3.692	3.859	3.80
Thieves	3.687	4.081	3.75
Corrosion & lack of protection against it	3.687	3.990	3.72
Improper safety regulations	3.667	3.949	3.70
Exposed pipelines	3.667	3.682	3.70
Shortage of IT services	3.657	3.652	3.68
Improper inspection & maintenance	3.646	3.924	3.69
Lack of proper training	3.631	3.773	3.71
Weak ability to identify the threats	3.631	3.899	3.67
The pipeline is easy to access	3.626	3.646	0.57
Limited warning signs	3.621	3.571	3.56
Little research on this topic	3.606	3.697	3.55
Lawlessness	3.566	3.682	3.54
Lack of risk registration	3.530	3.697	3.60
Stakeholders' attention	3.495	3.143	3.51
Conflicts over land ownership	3.449	3.611	3.68
Public's poverty & education level	3.333	3.409	3.49
Design, construction & material defects	3.323	3.848	3.64
Threats to staff	3.227	3.399	3.35
Inadequate risk management	3.101	3.505	3.48
Operational errors	2.980	3.611	3.30
Leakage of sensitive information	2.747	3.505	3.38
Geological risks	2.652	3.182	3.17
Natural disasters & weather conditions	2.465	3.066	3.10
Vehicle accidents	2.237	2.712	2.80
Hacker attacks on operating or control	1.894	2.970	3.03
Animal accidents	3.995	4.490	1.95

Step 2: Risk assessment: The RFs were assessed regarding their degree of impact on the projects based on the results of a questionnaire survey and the application of the fuzzy theory for determining the risk index by considering the biasness of the stakeholder's judgement on probability and consequence level. This study has carried out an industrial survey to determine probability and severity of each RFs. The RFs that identified based on the findings of the literature review (see step 1 above) were conducted in a questionnaire survey to identify the probability and severity levels based on the perceptions of the stakeholders (Kraidi et al, 2019). The results of the fuzzy theory used to calculate the RFs' degree of impact on the projects, i.e., the values of Risk Index (RI) of the RFs. Analyzing the risk factors using the fuzzy logic theory has three stages, which are fuzzification, knowledgebase, and defuzzification. Stage 1 Fuzzification provides crisp inputs for the Fussy Inference System (FIS) in MATLAB. The probability and severity levels of the RFs are the two required inputs for the FIS in this paper. Stage 2 Knowledgebase defines the membership functions for the inputs and outputs of the model and the 'If-Then rules' to control the FIS. Stage 3 Defuzzification is about obtaining the final outputs of the model, which is RI in this model. In this stage of the FIS, the value of the RI will be calculated for the risk factors depending on the range of RP and RS of each risk factor and the controlling rules of the model. This step will help in ranking the RFs regarding their degree of impact on the projects.

Step 3: Risk allocation and activities analysis: This step of the model involves using the professional and academic knowledge to allocate the RFs to the activities of the project. The case study project of this paper is a 64 km pipeline that will transport the petroleum products from Badra field to the shipping point on the gulf in Basra. This project has been under planning since May 21, 2019, and the targeted delivery date is January 09, 2023, which means the duration of the project is estimated as 3 years and 238 days (1330 days). Risk allocation and calculating the level of risk in the projects activities was carried out using the following steps. The subjective and objective analysis of technical reports and practical guides such as (FTA, 2019) was used to justify the process of risk allocation because they explained what is required in each activity, the nature of each activity and the potential RFs that could affect that activity based on vast experience and a review of the construction process in OGPPs worldwide. Calculate the algebraic summation to calculate the summation of risk impact and the level of risk in each critical activity of the project, using equation 1 and 2 below.

$$\text{The summation risk of an activity} = \sum \text{RI values of the RFs relevant to that activity} \qquad (1)$$

$$\text{The summation risk of an activity (from 100\%)} = \frac{\text{The summation risk of that activity}}{\sum \text{The summation risk in the project}} \text{X}100\% \qquad (2)$$

The impact levels of the associated RFs on the calculation of the project duration (using ASTA planning software) were set up at five different levels of risk variation as follows. (I) Very High (VH) risk [75% - 125%] varies in a task duration when considering all RFs. Similarly, (II) High (H) risk [80% - 120%], (III) Medium (M) risk [85% -115%], (IV) Low (L) risk [90% - 110%] and (V) Very Low (VL) risk [95% - 105%] variations are considered on each task based on the experts' advice and industry survey findings. The findings of step 3 are the impact level of each project task on task duration, see table 2.

Table 2:
The summation of the risk impact and risk level to the project activities of the case study

Activities	Equation 1	Equation 2	Risk Level
Concept and definitions*	18.11	0.86	VL: 95% - 105%
Life-cycle plan	71.8	3.41	H: 80% - 120%
Choosing the route	76.65	3.64	H: 80% - 120%
Route approval	73.14	3.47	H: 80% - 120%
Design and development	43.44	2.06	M: 85% -115%

Installation procedure	29.28	1.39	L: 90% - 110%
Risk assessment	49.67	2.36	M: 85% -115%
Time schedule	22.08	1.05	L: 90% - 110%
Cost estimation	22.08	1.05	L: 90% - 110%
Communications	25.43	1.21	L: 90% - 110%
Materials order	18.41	0.87	VL: 95% - 105%
Survey, staking and setting out	75.77	3.60	H: 80% - 120%
Clearing and grading the right-of-way	73.46	3.49	H: 80% - 120%
Topsoil stripping	57.88	2.75	M: 85% -115%
Buildings, roads and river crossings	76.63	3.64	H: 80% - 120%
Pipe transportation to site	59.02	2.80	M: 85% -115%
Temporary fencing and signage	51.09	2.43	M: 85% -115%
Trenching	54.05	2.57	M: 85% -115%
Erosion control & side support	57.48	2.73	M: 85% -115%
Pipe set-up	43.84	2.08	M: 85% -115%
NDT tests	32.77	1.56	L: 90% - 110%
Welding, fabrication and installing	36.28	1.72	L: 90% - 110%
Sandblast	32.82	1.56	L: 90% - 110%
Painting	32.81	1.56	L: 90% - 110%
Coating	54.69	2.60	M: 85% -115%
Lowering pipe and backfilling	46.71	2.22	M: 85% -115%
Cathodic protection of the pipe	68.64	3.26	H: 80% - 120%
Final fitting	32.61	1.55	L: 90% - 110%
As-built survey	32.48	1.54	L: 90% - 110%
Hydro, pressure test	29.1	1.38	L: 90% - 110%
Backfilling	36.16	1.72	L: 90% - 110%
Fencing and signage	61.49	2.92	M: 85% -115%
Final clean-up	40.11	1.90	L: 90% - 110%
Right-of-way reclamation	54.03	2.57	M: 85% -115%
Safety barriers	55.53	2.64	M: 85% -115%
Operation within design limits	97.54	4.63	VH: 75% - 125%
Commissioning operation value	97.54	4.63	VH: 75% - 125%
Performance and efficiency	29.26	1.39	L: 90% - 110%
Enhanced performance and efficiency	97.54	4.63	VH: 75% - 125%
Monitoring and inspection	42.57	2.02	M: 85% -115%
Maintenance	59.54	2.83	H: 80% - 120%
Risk control	36.31	1.72	L: 90% - 110%

- **Step 4: Quantify the potential delay in the project.**

This step is about using the findings of the steps above and run the simulation model to quantify the impact of the RFs on the duration of the project, i.e., the delay, using MCS. The final finding of this step is the amount of the potential delay in the project caused by the associated RFs, see figure 2. As explained above, the duration of the project is estimated as 1330 days. The results of risk simulation show that the minimum and maximum duration of the project are 1329.30 days and 1441.84 days, respectively. The project has a chance 5% of been completed of a duration between 1374.94 days to 1349.1 days or between 1404.5 days to 1441.84 days. The project has a probability of 50% to be finished in the mean duration, which is 1374.94 days. And the project has a probability of 90% to be finished between 1349.0 days to 1404.4 days (see Figure 2).

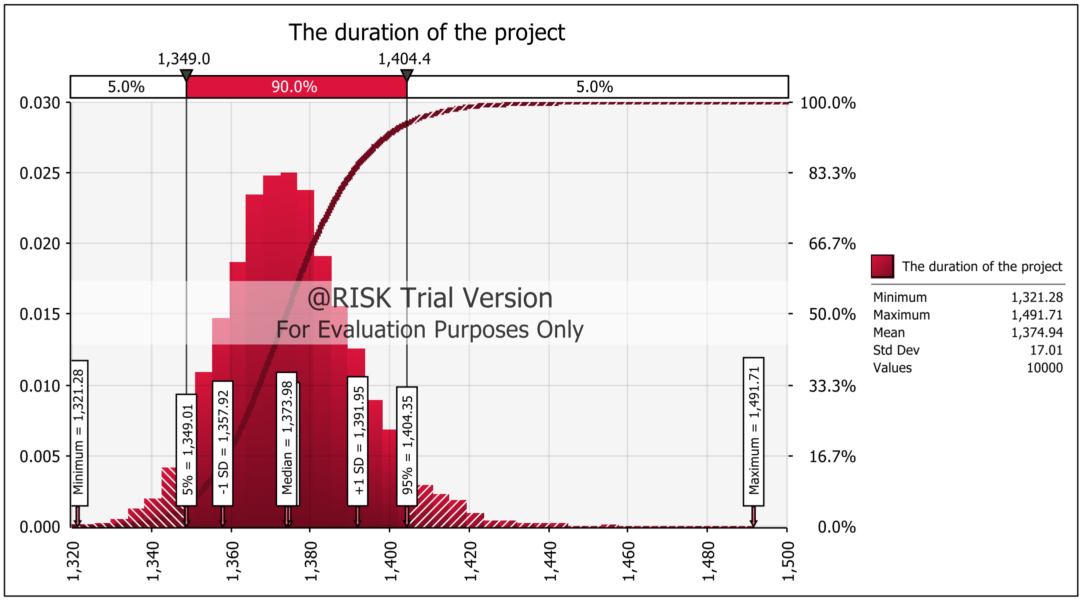

Figure 2. The results of simulating the duration of the project.

Results

The paper has analyzed the delay in the overall duration of the project as well as by the project's stages as explained in table 3 below.

Table 3:
The results of @Risk and the delay in the project considering the impact of the RFs.

Project Stages	Planned duration	@Risk results	Delay#	Standard Deviation
The total duration of the project	1330 days	1374.94 days	44.94* days	17.01
The duration of the planning stage	812 days	796.84 days	-15.16 days	9.39
The duration of the pre-construction stage	200 days	242.12 days	42.13 days	7.78
The duration of the construction stage	213 days	224.45 days	11.44 days	10.75
The duration of the post-construction stage	105 days	111.52 days	6.53 days	5.53

= Delay = the duration of @Risk – planned duration
*44.94 = -15.16+42.13+11.44+6.53. #This stage might be finished before the planned date.

As shown in Table 3 above, the highest delay of the project comes from the pre-construction stage with a delay of 42.13 days. Meanwhile, the results of @Risk revealed that the planning and design stage of the project could be finished 15.16 days earlier than expected. Which means the RFs that associated with the case study project have the highest impact of its duration. Fishburn (1984) defined risk as a bad event. The word risk generally means negative results caused by a bad or an unexpected event (Alali, 2010). Risk is an uncertain incident or situation, which has a positive or negative effect on the project's goals if it happens (PMI, 2013, as cited by Almadhlouh, 2019). Ahmed et al. (2007) defined risk as any unexpected or unplanned event that affects a project in either a positive or a negative way. Which may explain the positive impact of the RFs that associate with the project at the planning stage. As well as it was found that the delay in the pre-construction, the construction and the post-construction stages is around 42.13 days, 11.44 days, and 6.53 days, respectively.

Discussion and Conclusions

Having noticed a gap in the delay analysis system of risk factors, this research introduced Fuzzy logic theory to reduce biasness of relative importance index/values of risk probability and consequences on all risk factors affecting in all critical tasks/activities in the critical path identified using ASTA planning tool. It also used @risk simulator integrated with Monte Carlo simulation to identify and quantify the delay impact on the project duration in an oil and gas pipeline construction project, which is key knowledge contribution in this paper. The key output of the DAM is to determine the possible project durations and associated RFs for the successful delivery, and this is considered as a useful tool. The model was evaluated using a case study of an OGPP in Iraq. The results of the case study project suggested a potential delay might occur if considering the associated RFs. The sources of the RFs listed in this research should not be ignored because they were identified based on international investigations and industry experience. Fuzzy logic theory was used to estimate the RI values of the RFs, which reduces the uncertainty associated with the risk analysis and overcomes the data scarcity problem and the prejudices in stakeholders' judgements about their level of impact Kraidi et al. (2019c and 2020b). @Risk Simulator used these risk distribution methods for each RFs of the project rather than one distribution method at a time, with a degree of impact on the duration of the project. For example, RiskTriang (0,0.7,1) distribution was assigned to the stealing the products and the materials RFs, which is different from assigning Uniform, Normal, Triangular or Skewed Triangular with no degree of impact on the duration of the project. RiskTriang is a function within @Risk simulator and generates a triangular distribution of probabilities.

The average delay in the project after considering the RFs within critical work activities was found as 42 days from the planned duration at pre-construction stages when using four risk distribution methods. A single case study was used in this research to evaluate the DAM that developed in this research. While a single case study was used in this research, the results of this research came from a long pipeline project, which extended for 164 km. The pipeline is crossing 3 different cities, which are Al Kut, Maysan, and Basra in Iraq. It crosses different geographical environments and topographies, like rivers, lakes, roads, residential areas, green areas, etc. Therefore, the results of the case study reflect highly reliable and valid findings. The paper concludes that the developed delay risk analysis model is useful to quantify the potential delay at the starting stage and assist in identifying the causes of delay they might face at execution and operation stages.

The future study involves developing a computer-based model that analyses the potential correlations between the RFs and the activities of the projects. Such proposed model will provide a better understating about different project uncertainties in the construction industry. It is recommended that more case studies with different graphical locations in different country of oil and gas line project need to be conducted and calibrated before implementing as a practical and commercial tool in the oil and gas industry.

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