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Article

ANALYSING DELAY IMPACT FROM POTENTIAL RISK FACTORS ON PROJECT DELIVERY OF OIL AND GAS PIPELINE: A CASE STUDY IN IRAQ

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Abstarct: The aim of this paper is to present the design and specifications of an integrated Delay Analysis Framework (DAF), which could be used to quantify the delay caused by the Risk Factors (RFs) in Oil and Gas Pipelines (OGPs) projects in a simple and systematic way. The main inputs of the DAF are (i) the potential list of RFs in the projects and their impact levels on the projects and the estimated maximum and minimum duration of each task. Monte Carlo Simulation integrated within @Risk simulator was the key process algorithm that used to quantify the impact of delay caused by the associated RFs. The key output of the DAF is the amount of potential delay caused by RFs in the OGP project. The functionalities of the developed DAF were evaluated using a case study of newly developed OGP project, in the south of Iraq. It is found that the case study project might have delayed by 45 days if neglected the consideration of the RFs associated with the project at the construction stage. The paper concludes that identifying the associated RFs and analysing the potential delay in advance will help in reducing the construction delay and improving the effectiveness of the project delivery by taking suitable risk mitigation measures.

Keywords: Oil and Gas Pipelines; Risk Factors; Risk Analyses; Delay Analysis Framework; @Risk; Monte Carlo Simulation; Construction Delay; Time Impact.

1. Introduction

Delay is one of the most common problems in construction projects in both developed and developing countries in the majority of projects[1]. Construction delay generates long-term severe economic consequences and environmental impacts for nations. One of the main reasons that lead to construction delay is building the new projects without identifying and analysing the Risk Factors (RFs) associated with the projects at the planning stage. Therefore, it is important to understand the RFs and their level of impact on projects, which may help to avoid or minimize the delay at the construction stage[2]. Provide good knowledge about the RFs and using analytical or simulation techniques are the most effective methods of risk assessment[3].

As well as, analysing the impact of the RFs on the projects at the planning and design stage could help the stakeholders to make sound decisions in response to risk management to keep the delay interruption in the projects to minimum, as much as possible. However, there is a lack of studies about risk quantification analysis and its impact on the projects particularly, in developing countries like Iraq[4],[5]. Moreover, developing countries with low levels of security have extra risk situations compared to safe countries due to internal wars and security related RFs that affect the safety of the projects in these countries. Abudu and Williams[6] made recommendations of continually analysing the hazards and risks in the projects that related to socio-political, socio-economic and religious factors because the data about such kinds of risk are often unavailable, unreliable or recommended to be considered in the future work of the past studies. In addition to the RFs that threat the projects, oil and gas projects have a unique characterization compared to the other types of projects; this is because of their massive interface, large investments and complex engineering endeavours[7],[8].

This paper focuses on analysing and quantifying the impact of the associated RFs on the duration of the newly developed Oil and Gas Pipelines (OGP) projects at the planning stage in order to quantify the delay impact caused by these RFs during the construction stage of these projects. The aim of this paper, therefore, is to design an integrated Delay Analysis Framework (DAF) which will be used to analyse and quantify the construction delay in OGP projects that caused by the associated RFs. The DAF will be helpful in identifying and analysing the RFs in the projects using a systematic and integrated way based on the findings of the literature review, an industrial survey, the fuzzy theory and Monte Carlo Simulation (MCS) algorithm. The functionality of the DAF will be tested in a case study project, which is an export oil and gas pipeline that going to be built in the south of Iraq.

The rest of the paper is organized as follows. Section 2 explains the limitations of using the existing DAFs to quantify the impact of the RFs on OGP projects (literature review). Section 3 and 4 illustrate the methodology and the results of this paper, respectively. Finally, section 5 discusses the results of the paper and section 6 presents the conclusions and recommendations.

2. The Literature Review

This paper has reviewed some of the past studies that analysed the RFs that cause construction delay in the projects. Several prior studies engaged with the stakeholders in the projects using questionnaire surveys or interviews to analyses the constriction delay in the projects. For instance, Shah[9] identified the comparative delay factors in construction projects in countries like Australia, Ghana and Malaysia via a questionnaire survey and recommended the potential measures to reduce their impact on the projects. This study has analysed the possible minimum, the mean and the maximum duration of construction projects and the sensitivity of the work activities in these projects in the mentioned countries. Prasad et al.[10] used a questionnaire survey to identify and analyse the delay factors in transportation, power and water projects in India. Another questionnaire survey was carried out by Chiu and Lai[11] to analyse the frequency and the severity levels of the delay factors in the construction of electrical projects in Hong Kong. Mpofu et al[12] analysed the delay factors in construction projects in the United Arab Emirates (UAE) via exploring the perceptions of the clients, the contractors and the consultants about the delay problem in their projects. Kadry et al.[13] analysed the delay factors in construction projects in 16 countries with a high geopolitical risk. The delay factors considered in this study were analysed using qualitative document analysis and quantitative risk analysis via engaging with several experts in these countries. However, the risk assessment methods used in these studies are limited to their regions of study, which means they cannot be effectively applied to analyse the impact of the delay factors in construction projects elsewhere. Fallahnejad[14] used document analysis and a questionnaire survey to identify the main delay factors and analyse their impact on pipeline projects in Iran. Similarly, Sweis et al.[8] used a questionnaire survey to identify the root causes of the delay factors in gas pipeline projects in Iran. Ruqaishi and Bashir[7] investigated the delay factors in the construction of oil and gas projects in Oman as a case study for the countries of GCC (Gulf Cooperation Council): Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE. Rui et al.[15] carried out a comprehensive study to identify the RFs that affect the schedule of oil and gas projects in Nigeria. However, these studies have identified the RFs in the projects, but they did not quantify the potential delay in these projects caused by the RFs.

Hence, there is a need to develop a research methodology that overcomes the highlighted limitations of the previous studies with regard to analysing and quantifying the impact of the RFs on the duration of OGP projects, which is the main aim of this research study.

3. Framework Design

This section of the paper presents the design and specification of the DAF that will assist to analyse and quantify the delay in OGP projects caused by associated RFs. The developed Delay Analysis Framework (DAF) will be used as a risk simulation tool to quantify the potential delay in the OGP projects at the planning and construction stage. The DAF was designed under three phases (inputs, process and outputs) but specifications are presented under four steps. The phase 1 includes step one and step two whereas phase 2 includes step three and phase 3 includes step four. Detailed specifications are discussed below.

- **Step 1: Identify the potential RFs in OGP projects**

  This step involves investigating the past studies about the RFs that may affect the duration of OGP projects worldwide. The findings of this step are the potential RFs in the projects, which could obstruct the construction and extend the delivery time of their projects. This step will help the stakeholders in looking at the problems in their projects at the starting stage and assist in identifying the causes of the problems they might face. The sources of the RFs listed in this research should not be ignored because they were identified based on international investigations about addressing the problems in OGP projects.

- **Step 2: Risk assessment.**

  The RFs were assessed with regard to their degree of impact on the projects based on the results of (i) industrial survey that tested the probability and severity of the RFs; and (ii) the results of the fuzzy theory used to calculate the RFs' degree of impact on the projects. This step will help in ranking the RFs with regard to their degree of impact on the duration of the projects.

- **Step 3: Risk allocation and activities analysis**

  This step of the DAF involves using the professional and academic knowledge to allocate the RFs to the activities of the project. The subjective and objective analysis of technical reports, practical guides and studies such as E.E.P.A.[16], F.T.A.[17], Folga[18], Nandagopal[19], and Williams Companies[20], 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 OGP projects worldwide. As well as, this step involves using algebraic summation to calculate the summation of risk impact and the level of risk in each activity of the project. The final finding of this step is the level of impact of each activity on the duration of the project.

- **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.

The DAF works under three main components, which are inputs, process and outputs, and each one of these components has several working steps as explained in Fig. 1.

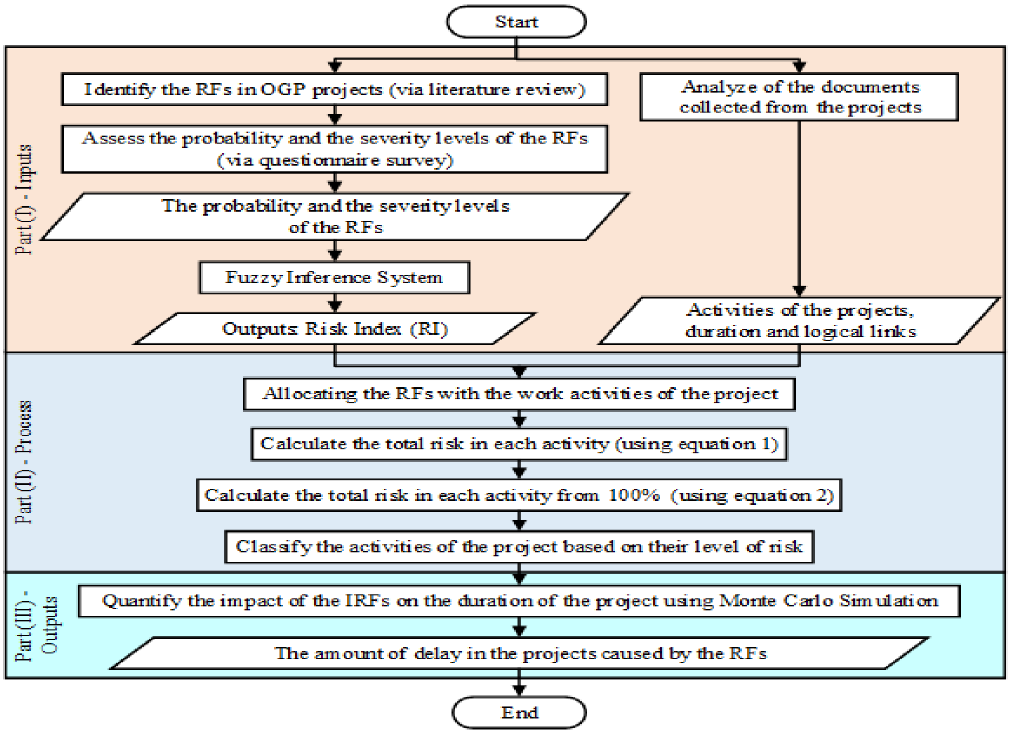

Fig. 1. The information flow chart of the delay analysis framework designed in the paper.

The three sections below explain the design and work process of the DAF as follows. Section a explains the inputs of the framework and to find them, section b explains the process part of the framework and illustrators how to ling the RFs to the activities of the projects and calculate the risk level in each activity, and section c explains the outputs of the framework.

a. Part 1 (Inputs): Identify, assess and document the potential RFs in OGP projects.

In order to overcome the problem of data scarcity about the RFs in OGP projects in the developing and insecure countries, the DAF will start with an extensive and worldwide literature review to identify the RFs in the projects. Then the framework will engage with the stakeholders in the projects via a questionnaire survey to assess the RFs regards their degree of impact on the projects. However, the absence of enough information, the inaccurate values about the probability and severity levels of the RFs in the projects, and the uncertainty and basicness of the external judgements about their impact lead to vague, imprecise understanding and low reliability of the results of risk analyses[21]. This is because the stakeholders have different views on the impact levels of the RFs[22], [23]. Therefore, in order to reduce the uncertainty associated with analysing the RFs, the DAF will use the fuzzy theory to calculate the degree of impact of the RFs on the OGP projects. This is because the fuzzy theory uses interpolation between ranges and intervals to assess the probability and severity levels of the RFs like very low, low rather than exact values of these levels. Such a theory of risk assessment could deal with risk analysis and ranking in the situations of vague and uncertain values of risk probability and risk severity of the RFs, which result from the basicness of the external judgements about the impact of the RFs on the projects[24], [25], [26], [27], [28]. In this paper, the process of identifying and assessing the RFs in OGP projects in Iraq was carried out via an extensive literature review[29]. The probability and severity levels of the RFs were assessed via engaging with 198 participants who have real experience about the RFs and their degree of impact on OGP projects in Iraq[4], [5], [30]. The results of the survey were used as inputs for the Fuzzy Inference System (FIS) toolbox in MATLAB, which was used to calculate the index values of the RFs[31], [32], [33]. Additionally, the inputs of the DAF included the activities and the time schedule of the project including the activities' start and finish dates and the logical link between the activities. Section 4.b.i explains how to use the DAF in a real project to find the inputs that required for quantifying the delay in the projects.

b. Part (II- Process): Calculate the risk level in each activity of the project

The DAF has used the following steps in order to analyse the risk level and the impact of the project activities on the duration of the case study project.

i. Allocating the RFs to the work activities of the projects. The RFs were allocated to the work activities of the project depending on the type of RFs and the nature of the activities.

ii. Calculate the summation of risk impact of each project activity using equation (1), which calculates the summation of the RI values of the RFs allocated to these activities.

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

iii. Calculate the summation of risk for the project activities from 100% using equation (2).

$$\textit{The summation risk of an activity (from 100\%)} = \frac{\textit{The summation risk of that activity}}{\sum \textit{The summation risk in the project}} X100\% \quad (2)$$

iv. Classify the project activities based on their level of risk as follows. The activities with [0-1] risk summation were considered as Very Low (VL) risk activities; the activities with [1-2] risk summation have a Low (L) risk; those with [2-3] risk summation have a Moderate (M) risk; those with [3-4] risk summation have a High (H) risk; and those with [4-5] risk summation have a Very High (VH) risk.

v. Based on the level of risk in each activity, the set up the impact level on the duration of the project was as follows. The activities with VL level of risk could make a 95% - 105% of variance on the duration of the projects. The activities with L, M, H and VH level of risk could make a 90% - 110%, 85%-115%, 80%-120% and 75% - 125% of variance on the duration of the projects, respectively.

vi. After allocating the RFs to the project activities, Monte Carlo Simulation (MCS) integrated @Risk simulator program will apply the iterations between the minimum and maximum duration for each activity in order to calculate the duration of the activity[34], [35].

Section 4.b.ii explains how to implement the process part of the DAF in real OGP projects and the findings of this part of the project in a case study project.

c. Part (III-Outputs): Potential delay of a project

The final output of the DAF is the amount of delay in the project caused by the associated RFs. Section 4.b.iii explains the outcomes and the delay in a real project, which was quantified using the DAF that designed in this paper.

4. Case Study Demonstration

In order to demonstrate the effectiveness of the developed the DAF and measure practical benefits, a case study project in Iraq was selected and evaluated. The framework specifications and its functionality to quantify the delay in a case study project that explained below.

a. Background of the Case Study

The oil and gas pipeline is going to be built in the south of Iraq. The length of the pipeline is 164 km. It links Badra oil and gas field with the export point on the Gulf in Basra via Gharraf–An Nassiriyah, see Fig. 2. This project has been under planning since May 21, 2019 and the targeted delivery date is January 9, 2023. This means the overall duration of the project is estimated as 3 years, 7 months and 20 days (1330 days)[36], [37].

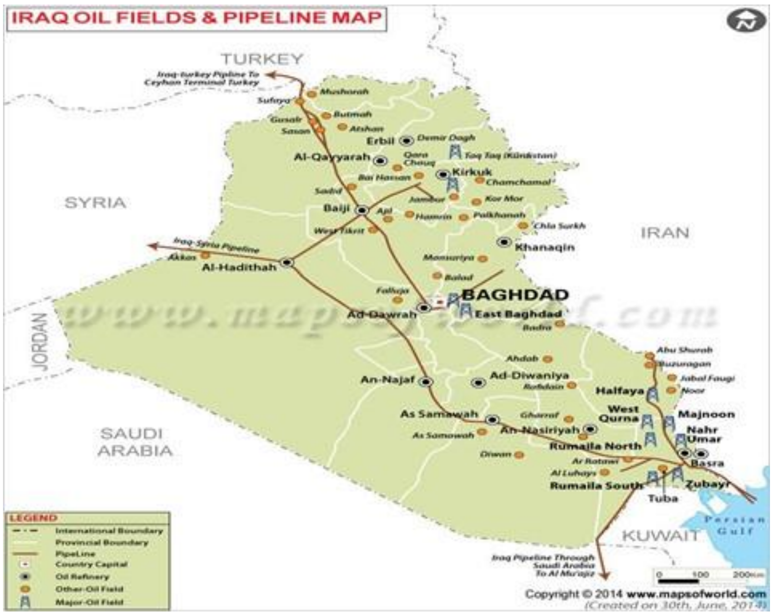

Fig. 2. Iraq oil fields and pipelines[38].

The next sections explain the results of using the DAF to quantify the delay caused by the associated RFs with the case study project.

b. The demonstration of the developed DAF

i. Inputs: Assessment of RFs and their degree of impact on the case study project

The inputs of the DAF are the RFs associated with the OGP project and their degree of impact on the pipeline construction project in Iraq. The calculation process and methods used for the determine Risk Index (RI) of each risk factor are discussed in section 3.a. The results are presented in Table 1 below.

The findings of the literature review	The findings of the survey		The result of the (FIS)
RFs	Probability	Severity	Risk Index (RI)
Terrorism & 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 & modern equipment	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 & monitor the threats	3.631	3.899	3.67
The pipeline is easy to access	3.626	3.646	.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 are not paying proper 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 the operating or control system	1.894	2.970	3.03
Animal accidents	3.995	4.490	1.95

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

ii. Process: The risk level in each activity of the case study project

The process of the DAF includes calculating the summation of risk impact and risk level of each project activity using equation (1) and equation (2), which is presented in section 3.b above. The assigned the variance of impact of each activity on the duration of the project. Table 2 explains the summation of risk impact, the risk level and variance of impact of each activity of the case study project.

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

Activities	Equation 1	Equation 2	Risk Level	The impact level on the duration of the project
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%

*For example, the RFs like terrorism; sabotage; threats to staff; leakage of sensitive information; lack of proper training; lack of records about the RFs; little research about the RFs; insecure areas; conflict over land ownership; improper safety regulations; natural disasters; weather conditions; weak ability to identify and monitor the threats; shortage of IT service; and construction defects were allocated to the trenching work activities (e.g. digging the trench, laying the pipelines, backfill, etc.).

iii. *Outpost: Delay in the case study project*

@Risk simulator used to analyse and quantify the delay impact of the RFs on (i) the overall duration of the project, (ii) the four stages (planning, pre-construction, construction and post-construction stages) of the project and (iii) each activity of the project, as explained in Table 3.

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	44.944* days	17.01
The duration of the planning stage	812 days	796.84 days	-15.156 days	9.389
The duration of the pre-construction stage	200 days	242.12 days	42.130 days	7.776
The duration of the construction stage	213 days	224.45 days	11.444 days	10.75
The duration of the post construction stage	105 days	111.52 days	6.526 days	5.531

^ = Delay = the duration of @Risk – planned duration

*44.944 = -15.156+42.130+11.444+6.526. ^This stage might be finished before the planned date.

As explained in Table 3 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 1349.1 days to 1404.5 days. The results are explained in Fig. 3.

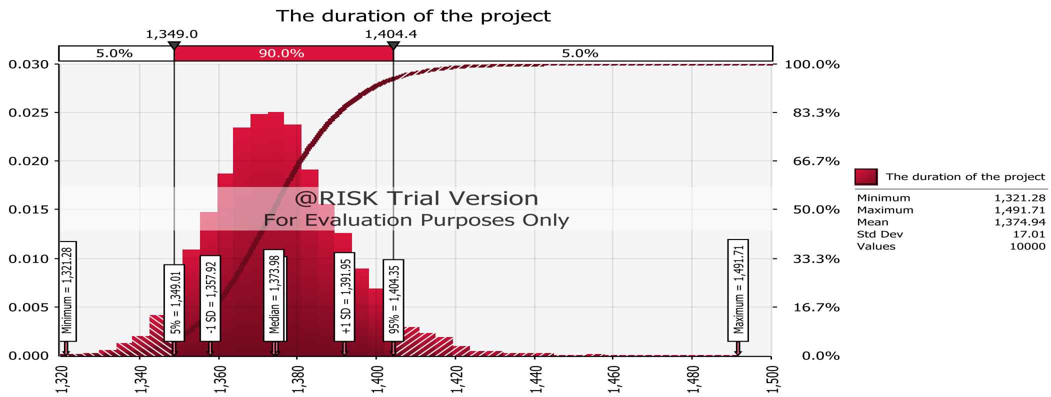

Fig. 3. The results of simulating the duration of the project.

The figures below summarize the results of minimum, maximum and mean duration of the planning, pre-construction, construction and post-construction stages of the project. And this table shows the 5% and 90% probability of the duration of the project.

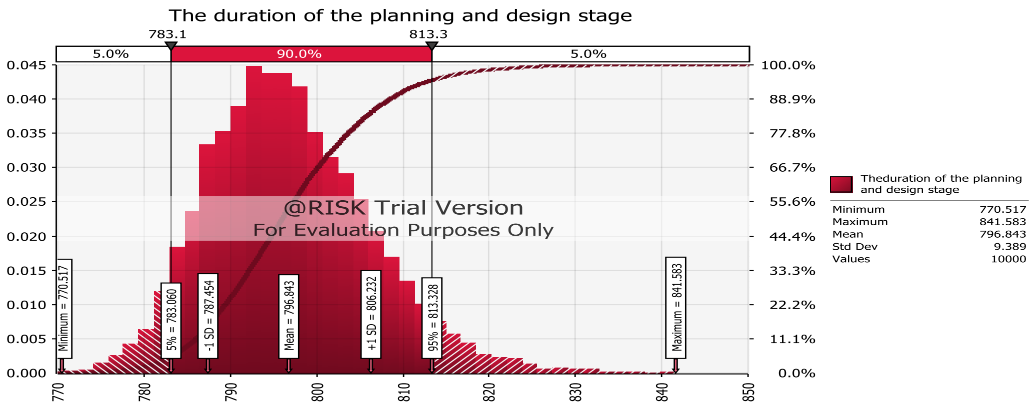

Fig. 4. The results of simulating the duration of the planning stage of the project.

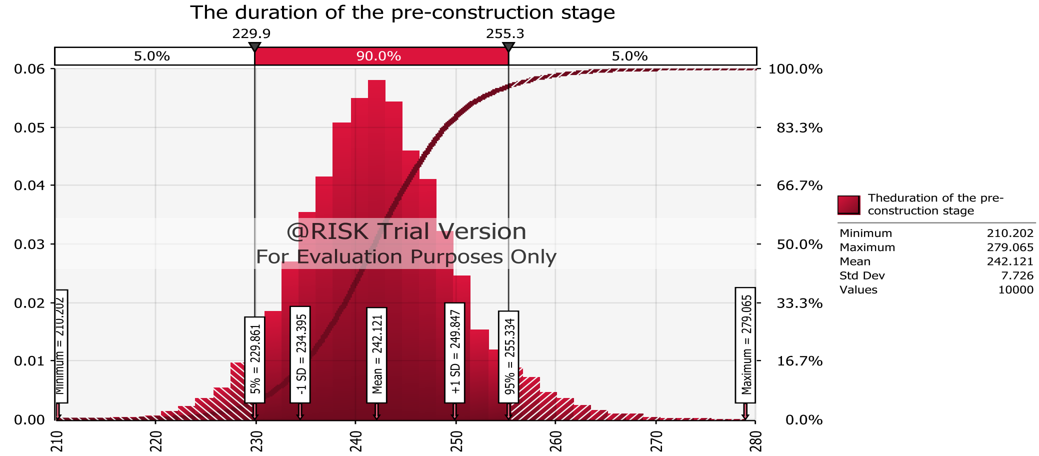

Fig. 5. The results of simulating the duration of the pre-constriction stage of the project.

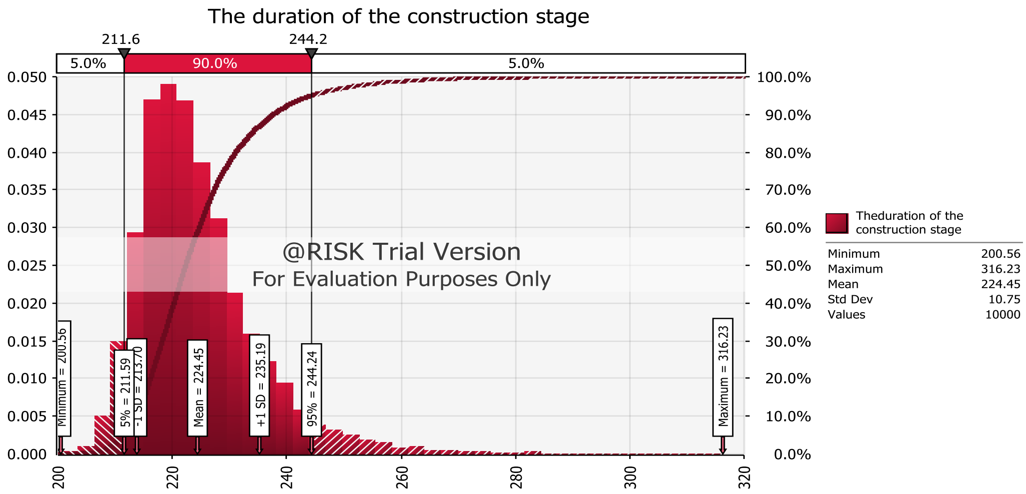

Fig. 6. The results of simulating the duration of the construction stage of the project.

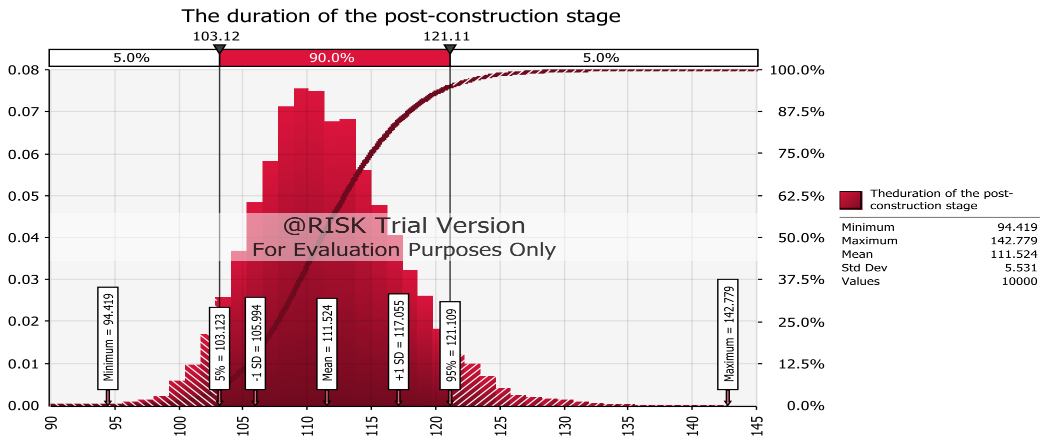

Fig. 7. The results of simulating the duration of the post-construction stage of the project.

As shown in Table 3 and Fig. 4 to Fig. 7, the highest delay of the project comes from the construction stage with a delay of 42.130 days. Meanwhile, the results of @Risk reviled that the planning and design stage of the project could be finished before the planned duration with a delay of -15.156 days. Which means the RFs that associated with the case study project have the highest impact of its duration. Fishburn (1984)[39] defined risk as a bad event. The word risk generally means negative results caused by a bad or an unexpected event[40]. Risk is an uncertain incident or situation, which has a positive or negative effect on the project's goals if it happens (Project Management Institute, 2013, as cited by[41]. Ahmed et al.[42] 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.

Moreover, @Risk could be used to analyse the delay in the duration of the individual activities of the project after considering the impact of the associated RFs. The results revealed that NDT tests, coating, sandblast and welding, fabrication and installing pipe are the activities with the highest delay in the project with a potential delay of 2.883 days, 2.736 days, 2.713 days and 2.667, respectively. Table 4 in Appendix A: The Results Of Risk Simulation Using @Risk explains the level of risk and delay in each activity of the case study project.

5. Discussion and Limitations

Risk analyses and assessment is the foundation and first step for any efforts of risk management. Having good risk assessment results at the planning stage is an essential step in risk management. This is because identifying and analysing the RFs before the projects start helps in avoiding and/or minimizing the delay in the projects during the construction stage. As well as, it will help the stakeholders, the decision-makers and the policymakers of the projects to make suitable policies and take the correct actions related to risk management.

List of thirty risk factors in OGP projects have been identified based on a comprehensive review of the pipeline failure causes and risk management in OGP projects worldwide. These findings help in overcoming the problem of the shortage of data required for risk management in OGP projects. Moreover, this research has engaged with the stakeholders in OGP projects in order to collect real perspectives about the RFs in the projects. The survey helped to assess the probability and severity levels of the RFs. Analysing the RFs regards their impact in the projects using a questionnaire survey as done in this paper will help to provide trusted data and a proper understanding of the RFs. The values of the probability and severity levels the RFs were used as inputs for a computer model that uses fuzzy theory to assess the risk index of the risk factors. The fuzzy theory has helped in reducing the uncertainty and biases associated with analysing the RFs in the project.

Based on the results of the survey and the application of the fuzzy theory, it was found that the RFs related to terrorism and sabotage, corruption, insecure areas, low public legal and moral awareness, thieves and corrosion and lack of protection against it are the most critical RFs in OGP projects in Iraq. On the other side, the RFs related to geological risks, natural disasters and weather conditions, vehicle accidents, hacker attacks on the operating or control system and animal accidents are the RFs that have the less impact on these projects, see Table 1.

After considering the impact of the associated RFs, the activities of the case study project were classified regards their impact level of affecting the duration of the project. The results indicated that operation within design limits, communications and enhanced performance and efficiency are the activities with a very high impact on the duration of the project. However, the activities of concept and definitions and survey, staking and setting out are the activities of a very low level of affecting the duration of the project, see Table 2. The total delay in the project was found 45 days, considering the impact of the associated RFs. The pre-construction stage is the stage of the project that has the highest potential delay impact, with a potential delay of 42 days. On the other side, the results of MCS indicated that the planning duration of the project could be finished 15 days earlier than the expected, i.e. before the planned duration, see Table 3.

The Std measures the dispersion of the data from the mean, which shows the variability within the sample. In other words, the Std characterizes the average distance of the data from the mean of the distribution value of the sample. The values of Std of calculating the (1) duration of the project overall was 17.01 days, (2) planning stage was 9.389 days, (3) pre-construction stage was 7.776 days, (4) construction stage was 10.75 days and (5) post-construction stage was 5.531 days, see Table 3. The values of Std were calculated out of 10000, which is the iteration number. The values of Std for @were low, which also enhances the results of the @Risk simulator and the research. This is because the sample with a low Std is the more significant sample. The stakeholders could use these dates to estimate and/or reanimate the schedule of the project. These dates might help the programmers of the project. For example, if they found that is it definite that the project will be running late then they could either change the time schedule of the project; taking the RFs in consideration and make suitable risk management strategies; or even accepting that the project is going to be delivered late then they can deal with the consequences.

The results of assessing and ranking the RFs in the projects were analysed based on an industrial survey carried out in Iraq. This means the results of the survey regards ranking the RF in OGP projects is limited to Iraq only. The DAF was designed based on an extensive and worldwide literature review about quantifying delay in construction industry projects, nevertheless, the framework was tested and evaluated using a case study project from Iraq, which means the findings and recommendations of this research will be suitable for Iraq and other countries with similar security problems. In other words, the findings and recommendations of this research are more applicable to manage the RFs in OGP projects in Iraq and other countries that have similar circumstances.
With regards to the limitations and the future work of this paper, this paper has evaluated a pipeline project in Iraq that covers 164 km, which is a long pipeline that crosses different regions with different topographies and safety environments. This has helped to quantify the impact on project delay in OGP projects in the south of Iraq. However, the RFs might have a slightly different impact on the OGPs in different regions in the country.

6. Conclusion and Future Work

This research has developed a systematic and integrated DAF, which was useful to quantify the delay impact in the OGP projects. The DAF designed in this study was used to provide a wide range of knowledge about identifying the RFs and analysing their impact on OGP projects is a systematic and accurate way. The DAF that designed in this paper is a useful tool that could be used to analyse the construction delay in OGP during the planning and design stage of these projects.

The DAF was used to analyse the construction delay in a pipeline project in the south of Iraq that caused by the associated RFs. The estimated duration of the case project is 3 years and 235 days (1330 days). After analysing the impact of the RFs on the duration of the project using MCS integrated with @Risk simulator software, it was found that the average delay in the project is 45 days. Moreover, it was found that the average delay in the planning, pre-construction, construction and post-construction stages of the project is -15.156 days, 42.130 days, 11.444 days and 6.526, respectively.
As this paper has analysed the delay in an ongoing project, the future work, therefore, will analyse the real-life delay and the causes behind this delay when the project finishes. As well as, the future work of this paper involves using the DAF to analyse the RFs in other OGP projects in different geographical areas in order to enhance the results of using the DAF to analyse the construction delay in other projects. Moreover, future work will focus on the cost impact of the RFs in these projects.

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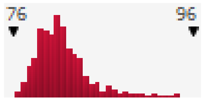
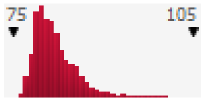
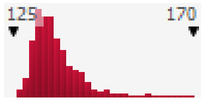
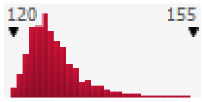
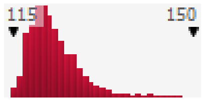
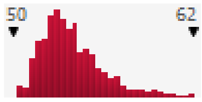
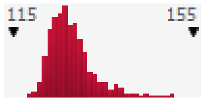
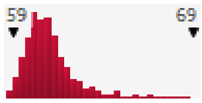
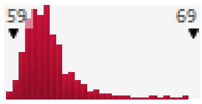
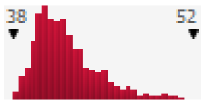
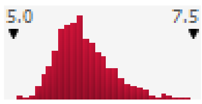
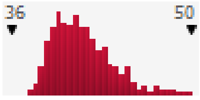
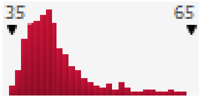
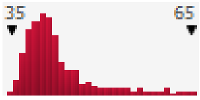
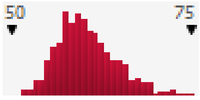
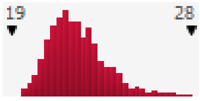
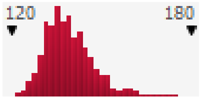
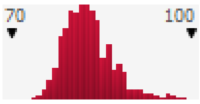
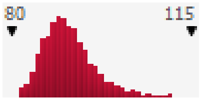
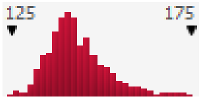
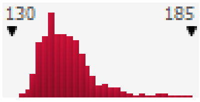
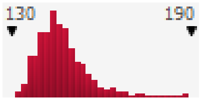
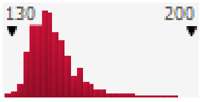
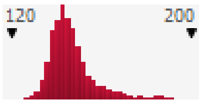
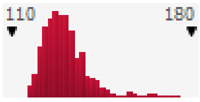
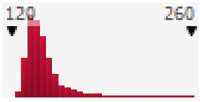
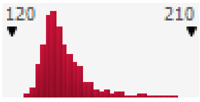
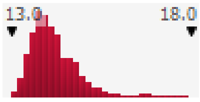
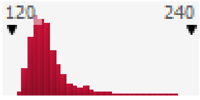
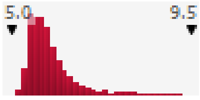
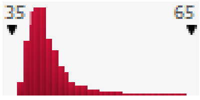
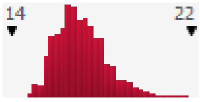
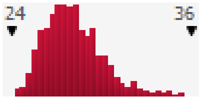
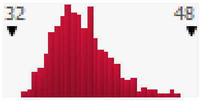
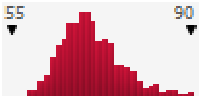
Appendix A: The Results Of Risk Simulation Using @Risk

After considering the impact of the RFs associated with activities of the projects, the table below presents the results of calculating the delay in each activity of the case study project.

Table 4: The level of risk and delay in each activity of the case study project.

Activity	Graph	Planned duration (day)	@Risk Results		
			level of risk	Mean (day)	Delay (days) = mean – planned duration
The duration of the project activities of the planning and design stage					
The concept and definitions activity		84	low 90% - 110%	81.82	-2.184
The of life-cycle plan activity		84	low 90% - 110%	82.55	-1.445
Choosing the route(s) activity		139	low 90% - 110%	136.39	-2.609
Route(s) approval activity		131	low 90% - 110%	128.54	-2.459
Design and development activity		126	low 90% - 110%	123.63	-2.365
Manufacturing and installation (procedure/plan)		55	low 90% - 110%	54.10	-0.899
Risk assessment and management plans activity		131	low 90% - 110%	128.56	-2.441
Time schedule activity		62	very low 95% - 105%	61.25	-0.754
The duration of the project activities of the pre-construction stage					
Staking for construction and communications activity		42	low 90% - 110%	42.35	0.349
Survey, staking and setting out		6	very high 75% -125%	6.016	0.015
Materials order activity		41	low 90% - 110%	41.72	0.715

Clearing and grading the Right-Of-Way (ROW) activity		41	very high 75% - 125%	43.12	2.115
Topsoil stripping and front-end grading activity		41	very high 75% -125%	42.95	1.951
Buildings, roads and rivers crossings		60	very high 75% -125%	60.72	0.717
Temporary fencing and signage activity		22	high 80% - 120%	22.43	0.427
Pipe transporting to sit activity		139	high 80% - 120%	140.18	1.174
The duration of the project activities in the construction stage					
Trenching activity		83	very high 75% -125%	83.074	0.074
Temporary erosion control and side support		90	very high 75% -125%	91.74	1.739
Pipe set-up activity		142	very high 75% -125%	143.91	1.913
Welding, fabrication and installing pipe activity		145	high 80% - 120%	147.67	2.667
NDT tests activity		145	high 80% - 120%	147.88	2.883
Sand blast activity		145	high 80% - 120%	147.71	2.713
Painting activity		145	very high 75% -125%	147.63	2.635
Cathodic protecting the pipe activity		131	very high 75% -125%	131.83	0.834
Coating activity		145	very high 75% -125%	147.74	2.736
Lowering pipe in and backfilling activity		146	very high 75% -125%	147.04	1.036
As-built survey activity		14	low 90% - 110%	14.28	0.276
Final fitting activity		146	very high 75% - 125%	147.07	1.070

Hydro, pressure test activity		6	very high 75% -125%	6.04	0.038
The backfilling activity		41	very high 75% -125%	83.07	0.074
The duration of the project activities of the pre-construction stage					
Fencing and signage activity		17	high 80% - 120%	17.19	0.190
The duration of the final clean-up activity		28	high 80% - 120%	28.31	0.312
Right-of-way reclamation activity		38	high 80% - 120%	38.42	0.424
Safety barriers activity		70	very high 75% -125%	70.78	0.778
Fencing and signage activity		17	high 80% - 120%	17.19	0.190