DEVELOPMENT OF AN INTEGRATED RISK MANAGEMENT FRAMEWORK FOR OIL AND GAS PIPELINE PROJECTS

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DEDICATION

To the cradle of civilisation, IRAQ

This thesis is dedicated to my father, Ahmed Kraidi, my mother, Shdha Manji, my brothers, Zaid, Maytham and Ali, my niece, Ellen, and my nephew, Ali.

ABSTRACT

Introduction- Oil and Gas Pipelines (OGPs) are a safe and economical mode of transportation of petroleum products around the world. However, they face different types of challenging Risk Factors (RFs) that affect the safety of the OGP projects at planning, construction and operational stages. Moreover, the OGP projects often suffer from the risks associated with Third-Party Disruption (TPD) such as terrorism and sabotage attacks, which make the pipelines vulnerable and add complexity in managing the RFs and safety threats to OGPs in developing countries with low levels of security.

Problem - After an in-depth review of the literature about the existing risk management approaches in OGP projects, it was found that these approaches have the following limitations. (I) Most are designed at the local scale and focus on certain types of RFs, so they are not applicable in OGP projects elsewhere. (II) They are not effective in mitigating the RFs in OGP projects when the data and records about them are scarce particularly in developing countries, where the documentation is poor. (III) Building new pipelines without analysing the potential level of risk in the potential routes at the planning stage could result in vital safety consequences in the future with supply chain disruption and loss of big investment. (IV) There is a lack of awareness about the potential impact on project delivery when developing new OGP projects without a an appropriate analysis of the RFs. The literature review concludes that there is a need for a logical and integrated risk assessment approach for the RFs relevant to OGP projects, specifically, the safety RFs relevant to TPD because they have not been accurately analysed in the past. Moreover, these approaches are mainly focusing on managing the associated RFs at the operational stage of OGP projects. However, managing the RFs during the entire project's life makes risk management more comprehensive and effective. Finally, the literature revealed that there is a lack of effective Risk Mitigation Method (RMM) suggestions to mitigate the RFs in OGP projects because the RMMs have not been analysed with regard to their degree of effectiveness in past projects.

Aim and Objectives- This study aims to design an integrated Risk Management Framework (RMF) for OGP projects. The objectives are (I) identity, analyse and rank the RFs in OGP projects; (II) select safest pipeline routes/alignments for the new projects; (III) identify and recommend the effective RMMs in the projects; and (IV) quantify the impact of the recorded RFs on a project's duration and forecast the probability of the project's delivery on time.

Originality- The novel idea in this research is to develop an RMF which enables users to deal with all the types of RFs in the projects on one platform. The RMF will contribute in providing a wide range of knowledge about the RFs and RMMs in OGP projects. And also, it will enhance the reliability of the results of RFs analysis by analysing them based on the findings of the literature review and the results of an industrial survey, the application of fuzzy theory and Monte Carlo Simulation (MCS).

Method- A mixed approach was used to collect and analyse the research data for the design of an integrated RMF using the following steps (I) A comprehensive literature review, an industrial survey and the fuzzy logic theory integrated within MATLAB software were used to identify and analyse the critical RFs and RMMs in OGP projects. (II) A risk optimisation method was used to select the safest route/alignment for a new project based on risk levels in the potential routes/alignments. (III) The findings from the survey were used to identify and recommend the effective RMMs to mitigate the potential RFs in the projects. (IV) MCS integrated within ASTA and @Risk programs were used to analyse and quantify the delay impact of the RFs in OGP projects.

Results- The study recognised 30 common RFs and 12 RMMs in OGP projects based on the literature review. The survey results revealed that TPD RFs such as terrorism, sabotage and theft are the most critical RFs in OGPs particularly in Iraq, whereas anti-corrosion measures, laying the pipes underground, and advanced monitoring system of the RFs are the most effective RMMs. The developed RMF was used to optimise the risk level in the routes suggested to build a new pipeline project in the south of Iraq. It was found that route number 4 (from Badra field to Basra via, Bazirgan, Gharraf–An Nassiriyah and Zubair) is the safest route for this OGP project. In addition, the average project delay caused by the associated RFs within the project was found to be 15-18 days when using ASTA risk simulator but 45 days when using @Risk Simulator.

Contribution and Value- This study is the first research related to making a comprehensive study for the OGP projects in Iraq to develop an integrated RMF. It was concluded that the developed RMF is a useful risk assessment tool that could be used by the stakeholders and academics for understanding, identifying and ranking the RFs in OGP projects, selecting the safest pipeline routes/alignments for the new projects, and quantifying the delay impact caused by RFs in OGP projects.

Keywords: Oil and Gas Pipelines; Pipeline Failure; Pipeline Safety; Third-Party Disruption; Risk Management Framework; Stakeholders' Judgement; Fuzzy Theory; Fuzzy Inference

System; Pipeline Routes and Alignments; Risk Mitigation Methods; Monte Carlo Simulation; Project Delivery; Delay Impact in Projects; Iraq.

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DECLARATION

This submission is my own work and contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the University or other institute of higher learning, except where due acknowledgement has been made in the text, in the United Kingdom or overseas.

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PUBLICATIONS

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Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2019. Analyzing Stakeholders' Perceptions of the Critical Risk Factors in Oil and Gas Pipeline Projects. *Journal of Periodica Polytechnica Architecture (PPA),*50(2), pp. 155-162. http://dx.doi.org/10.3311/ppar.13744

Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2019. Analyzing the Critical Risk Factors Associated with Oil and Gas Pipeline Projects in Iraq Elsevier. *International journal of critical infrastructure protection – Elsevier*, 24(March 2019), pp. 14-22. https://doi.org/10.1016/j.ijcip.2018.10.010

Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2020. Quantitative Analysis of the Delay Factors in Oil and Gas Pipeline Projects. *International Conference 56th Annual Associated Schools (ASC) of Construction International Conference*. Liverpool, UK, UK: EasyChair, EPiC Series in Built Environment, 356–363. https://doi.org/10.29007/1qfh

Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2019. Application of Fuzzy Logic Theory to Risk Assessment in Oil and Gas Pipeline Projects. *International Conference 55th Annual Associated Schools (ASC) of Construction*. 10-13 April, Denver, USA. pp. 363-370. Available online http://ascpro0.ascweb.org/archives/cd/2019/paper/CPGT261002019.pdf

Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2018. Developing A Risk Management Framework For Oil And Gas Pipelines Projects In The Insecure Countries. *34th ARCOM Annual Conference* – Belfast, UK, pp. 360-369.

http://www.arcom.ac.uk/-docs/archive/2018-Working-Papers.pdf

http://content.buid.ac.ae/bdrc/BDRC2017-Full-Proceedings-Faculty-of-Engineering-and-IT.pdf

Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2019. Development of Risk Optimisation Model for Oil and Gas Pipeline Routes. *International Conference on Civil and Environmental Engineering Technologies (ICCEET 2019)*. Al- Kufa University, Iraq on April 23-24, 2019. (IOP Publishing). Vol. (584), pp. 1-8. https://doi:10.1088/1757-899X/584/1/012025

Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2018. Analyzing the Critical Risk Factors in Oil and Gas Pipelines Projects Regarding the Perceptions of the Stakeholders. *Creative Construction Conference (CCC),* 30 June - 3 July 2018, Ljubljana, Slovenia. ISBN, e-ISBN 978-615-5270-45-1, pp. 304-311. DOI https://doi.org/10.3311/CCC2018-041

Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2018. The Development of a Questionnaire Survey to Investigate the Critical Risk Factors in Oil and Gas Pipelines Projects *Creative Construction Conference (CCC)*, 30 June - 3 July 2018, Ljubljana, Slovenia. ISBN, e-ISBN 978-615-5270-45-1, pp. 63-670. https://doi.org/10.3311/CCC2018-088

Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2017. Analysing the Critical Risk Factors in Oil and Gas Pipeline Projects in Iraq. *The 3rd BUiD Doctoral Research Conference* - 13 May dubai, UAE, pp. 133 – 148.

Kraidi, L., Shah, R., Matipa, W., and Borthwick. F., 2020. Investigation of the Risk Factors Causing Safety and Delay Issues in Oil and Gas Pipeline Construction Projects. *15th Global Congress on Manufacturing and Management (GCMM). Liverpool, UK*. (ACEPTED).

Kraidi, L., Shah, R., Matipa, W., Borthwick, F. (20xx). Analyzing the Delay Impact of the Risk Factors on the Project Delivery of Oil and Gas Pipeline: A Case Study in Iraq. Journal of Construction Economics and management, Taylor & Francis (**Under Review**)

ABBREVIATIONS

Analytic Hierarchy Process	AHP
Artificial Neural Network	ANN
Basra Oil Company	BOC
Basrah Gas Company	BGC
Central Control Room	CCR
Central Processing Facility	CPF
China National Petroleum Corporation	CNPC
Cronbach’s alpha correlation coefficient	α
Energy Information Administration	EIA
Fuzzy Inference System	FIS
Geographic Information System	GIS
Global Positioning System	GPS
Gross Domestic Product	GDP
Gulf Cooperation Council	GCC
Health & Safety and Environment	HSE
High	H
Influencing Risk Factors	IRFs
International Energy Agency	IEA
Kurdistan Regional Government	KRG
Latin Hypercube Simulation	LHS
Liquefied Natural Gas	LNG
Liverpool John Moores University	LJMU
Low	L
Midland Oil Company	MDOC
Million Barrels Per day	MMbbl/day
Million Standard Cubic Feet per day	MMSCF/day
Ministry of Oil	MoO
Moderate	M
Monte Carlo Simulatio	MCS
Oil and Gas Pipelines	OGPs
Oil Pipelines Company	OPC
Operational Risk	OR
Organization of the Petroleum Exporting Countries	OPEC
Pipeline Location	PL
Prototype of Risk Simulation Model	PRSM
Right of Way	ROW
Risk Factors	RFs
Risk Impact Equation	RIE
Risk Importance Impact	RII
Risk Index	RI
Risk Management Framework	RMF
Risk Mitigation Methods	RMMs

Risk Probability	RP
Risk Seventy	RS
Rules and Regulations	R&R
Security and Societal	S&S
Standard Deviation	Std
State Company of Oil Projects	SCOP
Statistical Package for the Social Sciences	SPSS
Third-Party Disruption	TPD
United Nations	UN
University Research Ethics Committee	UREC
United Arab Emirates	UAE
Very High	VH
Very Low	VL

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CHAPTER 1:   INTRODUCTION

1.1 Introduction

This chapter presents the research background; research problem; rationale and hypothesis; research questions; research aim and objectives; adopted research methodology; research scope and limitation; and research contributions followed by the thesis structure for the rest of the chapters. The next section describes the research background of the Oil and Gas Pipeline (OGP) projects and the importance of managing the risks associated with these projects.

1.2 Research Background

Oil and gas production is the cornerstone of the world's economy (Torres et al. 2012) and the lifeblood of the industrial economy as well (Quan, 2015). Since its origins, the petroleum industry has contributed to the world's economic growth and enhanced the standard of living in many countries (Duch-Brown and Costa-Campi, 2015). Oil and gas are vital energy resources, which have a significant influence on the economy of countries that produce or consume them (Dolatabadi et al. 2017). Oil and natural gas are the most used energies in the world, contributing to 57.5% of global primary energy consumption (Chen et al., 2020). Although nuclear and renewable energy are the world's fastest-growing energy sources at a rate of 2.5% each year, it is estimated that petroleum products (oil and gas) will continue to supply about 80% of the world's energy until 2040 (EIA, 2016; Leira et al. 2016), see Figure 1.1. This means that, in the coming years, these products will make a strong contribution to the world's natural energy resources (Almadhlouh, 2019).

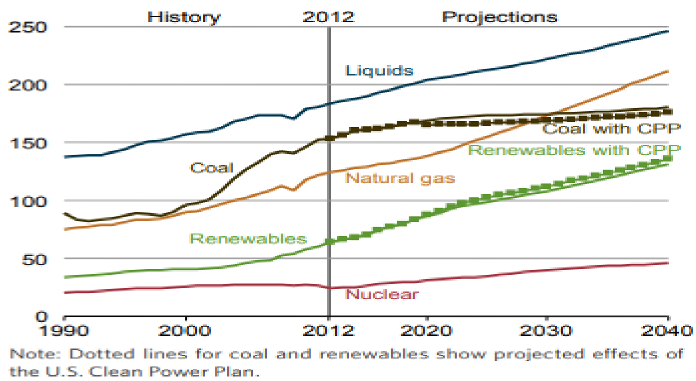

Figure 1.1: Snapshot of energy growth trends across the world until 2040 (EIA, 2016).

Pipelines are the most used mode to transport petroleum products. The next section, therefore, provides an overview of the OGPs industry, pipeline design, construction and operations, and outlines the importance and characteristics of risk management in the field of oil and gas projects.

1.2.1 Overview of the Oil and Gas Pipeline (OGP) Industry

Oil and gas projects are divided into three sectors, which are upstream, midstream, and downstream projects. Upstream projects deal with the exploration and drilling activities and the extraction of crude oil and natural gas from the ground. Midstream projects involve the infrastructure and facilities that transport the extracted products to the refinery or consumption points, such as OGPs. Downstream projects are the projects that provide the products to the final users (Gabrielson, 2015; Almadhlouh, 2019). The figure below shows the three sectors.

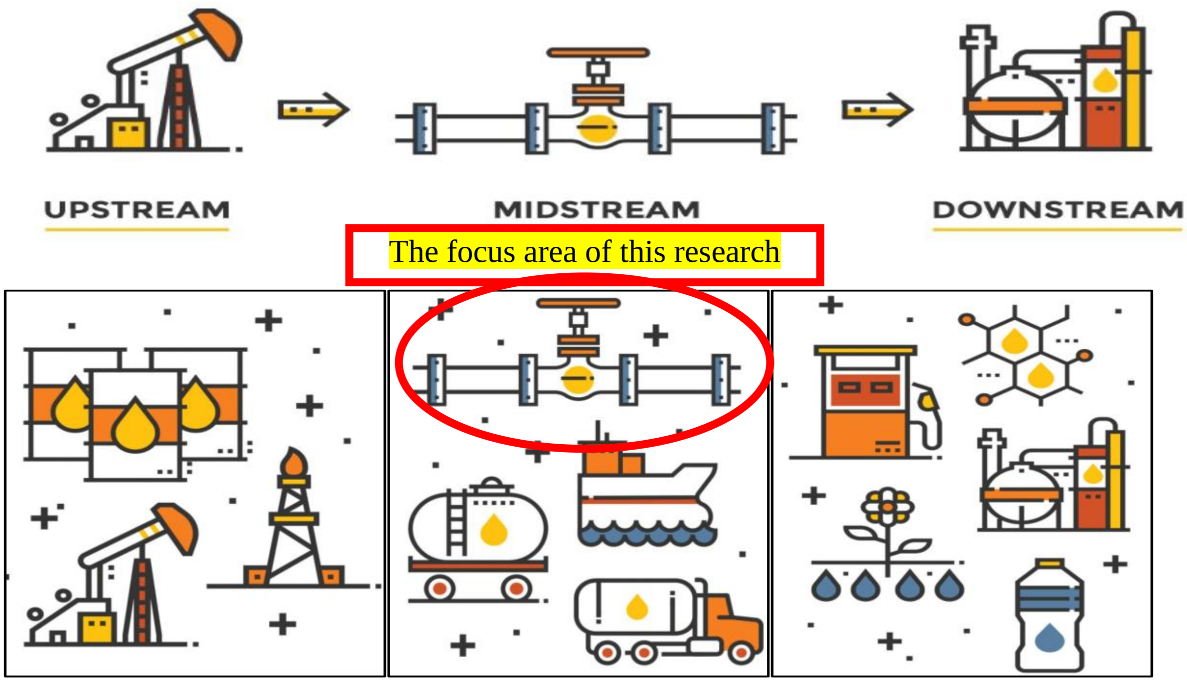

Figure 1.2: A general view of the upstream, midstream and downstream in the oil and gas industry (Energy HQ logo, 2020).

OGP projects are used in the process of gathering and transporting petroleum products (e.g. oil and gas) (Gunes, 2013). These projects include the pipes that transport petroleum products and the components that control the process of transportation, such as the valves, meters, regulators, delivery stations and compressor units, and other components (Liu, 2003;

Devold, 2006). The mission of these pipelines is to transport oil products to the storage facilities and from storage to distribution points across the world.

This research focuses on the pipelines that transport the petroleum products in the midstream sector of the oil and gas industry, as shown in Figure 1.2. In other words, this research does not focus on the transportation of the oil and gas products within the upstream sector of the oil and gas industry. This is because the transportation of the extracted crude petroleum products in this sector (i.e. the upstream sector) is limited between the wells and the storage facilities inside the production area. In contrast, the transportation of petroleum products in the midstream sector is wider and goes further. This is because the pipelines in this sector are transporting the products to the refinery stations, and end users, such as commercial customers and electricity generation stations, export points, storage facilities, etc. This research, therefore, focuses on such pipelines as they have a significant social and economic impact on countries and nations.

The pipelines are safe and economical compared to other modes of petroleum product transportation (Vaezi and Verma, 2018; Xie and Tian, 2018; Zarei et al. 2017). For instance, they are 100 times safer than tank trucks, 40 times safer than railroad tank cars, 1.19 times cheaper than ships, 5.29 times cheaper than rail and trucks, and 40 times cheaper than aeroplanes (Hopkins et al. 1999). Lambert and Stock (1993) made a comparison between air, sea, rail, road and pipeline and concluded that OGP transportation is the cheapest mode of transportation. OGPs are the cheapest and quickest mode that could be used to transport petroleum products (AL-Kadi et al. 2013).

OGPs are resource-saving, energy-efficient, high security, durable and provide a stable supply (Ai et al. 2006). With regard to the efficiency of transporting petroleum products using different modes, Antoniades et al. (2018) found that the efficiency of the oil pipeline network is equivalent to 4,200 rail cars or 15,000 vehicles. Therefore, more than half of the petroleum products in the world are transported by pipelines, which are more efficient, flexible, lower cost and less time consuming compared to tank ships and tank cars (Briggs, 2010).

The increment in using oil and gas products requires a massive number of OGP projects in order to transport these products from the extraction fields to the consumption points. Therefore, OGPs are the artery of the economy in the oil-producing and consuming countries (Johnson, 2017). In other words, OGP projects are considered the most important and essential infrastructure projects for any country, as they are transporting millions of barrels of petroleum products daily. The next section explains the importance of risk management in OGP projects.

1.2.2 Importance of Risk Management in OGPs

Since OGPs are transporting flammable products for thousands of kilometres, they will be subject to an infinite number of risk factors that affect their safety and operational performance during the entire life of these projects. For instance, OGPs are subject to a vast range of hazards and accidents that may damage the pipes, and countries with low levels of security often suffer more than other countries from malicious activity such as terrorism and sabotage attacks. Figure 1.3 shows some of the common and critical safety risks of OGP projects, particularly in a developing and insecure country such as Iraq.

Figure 1.3: Typical images of pipeline incidents (SCOP (State Company for Oil Projects), 2016).

OGPs have potential risks that not only affect the safety of these pipes but also generate long-term severe economic consequences and environmental impacts for nations. Additionally, the hazardous environments make risk management in OGP projects more challenging and complex. Accordingly, OGPs must be planned, designed, installed, operated and maintained with regard to the safety requirements. Subsequently, providing the required level of health and safety conditions for these pipelines will reduce their chances and probability of failure and minimise the consequences that result from accidents and failures in these projects.

Although risks, accidents and failures cannot be completely avoided in any type of project, they can be controlled and mitigated through using effective risk management strategies throughout the lifecycle of a project. Therefore, it is important to understand how to manage the risk of OGP projects to avoid loss of life and wealth. Risk management can be defined as a process of identifying, analysing and responding to risk factors and controlling risk factors throughout the life of a project (Al-Bahar et al. 1990; Chua et al. 2003; Wang and Chou, 2003). Risk management focuses on addressing uncertainties and developing a suitable plan of proactive actions in order to decrease the probability and/or impact of the risk factors that may threaten a project (Al Sabah, 2014).

OGPs have different diameters, transport different petroleum products between different cities in different environments and safety conditions, and are built above or under ground and sometimes underwater. This means that the risk factors that affect the safety of these projects vary between projects. Therefore, these projects require different risk management approaches in various geographical regions. Consequently, adopting and using a practical approach to risk management based on trusted data about the risk factors is essential to provide safe construction and operational conditions for the pipelines. The next section describes the problems and the limitations in the existing risk management methods used in OGP projects.

1.3 Research Problems

As mentioned by El-Abbasy et al. (2016b), most of the risk assessment methods are not comprehensive because they only consider one or two types of Risk Factors (RFs) at a time. In addition, after an in-depth review of the literature, it was found that most of the studies about risk management in OGP projects are mainly at the local scale, and few studies have assessed the RFs in OGP projects in more than one region. For example, it was found that OGP projects in European countries mainly suffer from mechanical failures and corrosion risks. This is because the pipelines in these countries are underground and European countries are relatively safe, which means they are less subject to sabotage RFs (Tchórzewska-Cieślak et al. 2018). The stakeholders in OGP projects in the USA focus more on the terrorism risk, especially after 9/11, in addition to corrosion, because the USA uses underground pipelines (Rowland, 2010). African countries pay more attention to theft risks because of the illegal sale of the stolen products in these countries (Rowland, 2010). On the other side, developing countries with low levels of security such as Iraq have different situations compared to safe countries. This difference is due to internal wars and malicious terrorist attacks on OGPs as well as because the pipeline network is above ground, which makes them more affected by the RFs (see Figure 1.4).

Figure 1.4 Examples of above ground pipelines in Iraq. Photos of Iraq's pipelines (Walt, 2009; Adel, 2013).

With reference to the previous paragraph, the existing risk assessment methods cannot be effectively applied to analyse the impact of the RFs in OGP projects and improve the level of safety of these projects elsewhere. This is because these methods focus on different types of RFs in the OGP projects in different regions and situations. This means that the strategies and the process of the risk management used to manage the RFs in the OGP projects could be effective in some geographical areas but ineffective in other areas. Additionally, it is difficult to compare the rankings of the RFs with other countries that have different types of RFs in their OGP projects.

The traditional risk assessment methods used to rank the RFs are based on the product value of Risk Probability (RP) and Risk Severity (RS) levels of the RFs associated with the projects. The details are explained in item II, section 2.4.4 in Chapter 2: and section 4.4.4 in Chapter 4:. Such a method could cause inaccurate ranking of the RFs. For example, an RF with a high value of RS could still be considered as a critical RF that needs to be dealt with a matter of urgency. However, the same RF could not come at the top of the ranking if it had a low RP. This is similar if the RP of the RF is high and the RS is low, which is one of the limitations of the traditional risk assessment methods.

The probability and severity levels of the RFs are often estimated based on a statistical analysis of the records about the failure causes and accidents in OGP projects (Chen et al. 2019; Khakzad et al. 2013). Although accurate values about the RP and RS of the RFs are required for risk management studies, these values are still imprecise, deficient and vague (Khakzad et al. 2011). As Peng et al. (2016) explained, the RP of the safety-related risk factors cannot be calculated using the available risk assessment methods as the historical records about them are not available. This means that the existing risk assessments methods cannot be used to assess the RFs when the data and records about them are scarce (Yazdani-Chamzini, 2014). Chen et al., (2020) analysed 598 of the past studies between 1970 and 2019 which related to the safety and security of OGP projects. The authors have concluded that future research is needed regarding pipeline security, environmental sustainability and pipeline system resilience in OGP projects.

This is the case in developing countries such as Iraq; because the documentary and recording procedures in these countries are poor (Kraidi et al. 2019a, 2018a). Such data conditions lead to a random, vague, uncertain, inaccurate and low reliability assessment of the RFs in OGP projects (Kabir et al. 2015). Hence, the lack of data obstructs risk management in OGP projects in insecure and developing countries.

In conditions of data scarcity, the RFs will be mainly identified based on the literature review. The impact of the identified RFs will be assessed based on stakeholders' judgements as they have real experience about them in their projects (Lavasani et al. 2011; Sa'idi et al. 2014). However, there is a potential problem associated with assessing the RFs depending on the stakeholders' judgement only, as they may not always yield to a consistent and accurate ranking of the RFs (Tang et al. 2018). This is because the stakeholders have different views of the impact levels of the RFs (Lavasani et al. 2015).

Furthermore, building new OGPs without identifying and analysing the RFs in their routes could cause project delay and have a significant impact on project safety at the construction and operation stages, especially if the chosen routes/alignments have a high level of risk. It is essential to make an accurate check to quantify the impact of the RFs on the duration of new pipeline projects. This is because making the correct reactions and strategies towards the RFs during the planning and construction stages of projects will help in avoiding and/or minimising the construction delay in these projects. Otherwise, these projects will be subject to delay problems, which have a significant impact on a country's economy.

Over and above this, it is vital to assess the effectiveness degree of the Risk Mitigation Methods (RMMs) that could be used to manage the RFs in the OGP projects in order to ensure an adequate response to the RFs if they threaten the pipelines. This will contribute to reducing the impact of the RFs in the projects. Such an assessment of the RMMs will be helpful in making effective suggestions and adequate responses for the RFs, which will keep the hazards at the minimal level as much as possible. However, there is a lack of studies about these critical topics in the OGP projects in Iraq.

Based on the problem statement above, the hypothesis of this research is designed and presented below.

1.4 Research Questions

The main question of the research study is "*Can this research provide a comprehensive and accurate way of assessing and managing the RFs in OGP projects, particularly in insecure and developing countries?*"

Based on the research background discussed above, six sub-questions are designed in order to answer the main research question:

- **Question 1**: What are the limitations of the existing risk assessment and management methods that make them inapplicable in assessing the RFs in OGP projects?
- **Question 2**: What are the RFs and RMMs associated with OGP projects?
- **Question 3**: Can this research help in reducing the uncertainty while assessing the RFs and ranking them when the data about risk factors in OGP projects is insufficient?
- **Question 4**: Can this research help with the optimisation of selecting the safest pipeline route/alignment for new OGP projects?

- **Question 5**: What are the effective RMMs that could be used to manage the RFs in OGP projects?
- **Question 6**: What is the impact of the RFs on the project duration of OGP projects?

The section below outlines the aim and the objectives of the thesis that were developed to answer the research questions.

1.5 Research Aim and Objectives

The aim of this research is to develop an integrated and systematic Risk Management Framework (RMF) to manage the Risk Factors (RFs) in OGP projects, particularly in insecure and developing countries. The RMF will address most of the RFs that affect the OGP projects and work with them on one platform, which will help to overcome the limitations of the existing RMFs that analyse only one or two types of RFs at a time. In addition, the RMF will focus on the unique risks in OGP projects that are caused by acts of terrorism, sabotage and other safety-related RFs, in order to make the findings of this research more relevant to OGP projects in insecure and developing countries.

The following objectives were developed to achieve the aim of this research.

1. To conduct a comprehensive literature review to examine the strengths and the limitations of the existing risk management system, the RFs and the RMMs applicable in OGP projects.
   Objective 1 provides answers for research questions 1 and 2.
2. To explore the perceptions of the stakeholders about the impact of the RFs and RMMs in OGP projects to provide trusted data/inputs for the process of risk assessment in this research.
3. To use fuzzy theory integrated with MATLAB software to assess and rank the RFs in the projects using the findings from items 1 and 2 above.
   Objectives 2 and 3 provide the answers for research question 3.
4. To optimise the pipeline transmission paths/routes/alignments considering the identified influential risk factors in OGP projects.
   Objective 4 provides the answers for research question 4.
5. To provide recommendations for identifying effective risk mitigation methods in OGP projects.
   Objective 5 provides the answers for research question 5.

6. To quantify the delay impact caused by relevant IRFs on the duration of OGP projects using ASTA risk simulator and @Risk simulator.
   This provides the answers for research question 6.

The section below explains the research method that was followed and used to achieve the aim and objectives of this thesis.

1.6 Research Methodology and Approach

This research adopted a systematic research strategy and pragmatic research approach to explain the procedure, the sequence, the steps and the techniques used to accomplish the aim of this research. The systematic research strategy in this study consists of several research methods to provide risk identification, assessment, ranking and management tools. In other words, the systematic research strategy adopted in this study explains how to assess, rank and manage the RFs in OGP projects by using a combination of both qualitative and quantitative research approaches and primary and secondary data to achieve reliable results from risk analysis and robust recommendations for identifying effective RMMs in OGP projects (Matthews and Ross, 2012). A pragmatic research philosophy is defined as a mixed-method approach (e.g. qualitative and quantitative approaches, and inductive and deductive approaches) to applied research questions and find a solutions for the research problem (Giacobbi et al., 2005). In other words, the pragmatic approach provides for the use of both qualitative and quantitative research methodologies to collect information and make inquiry into complex social and natural phenomena. Therefore, the pragmatic research philosophy provides for the adoption of mixed methods as the data collection method, which opens up the opportunity to be objective and subjective in analysing the points of view of the participants (Ihuah and Eaton, 2013).

Pragmatism emphasises the practical problems experienced by people, the research questions posited, and the consequences of inquiry. The "people i.e. the population" of this research are the stakeholders in OGP projects and the problem that this research tries to solve is how to manage the risk in these projects more effectively.

This research, therefore, will start with using a qualitative approach to analyse the prior studies about the risk factors and the risk management in OGP projects in order to design the research questions of this study. At the first stage of this research, the information that will be collected from the prior studies will be about providing answers for the main research questions, which are about (i) what type of risks that affect the safety of the pipelines worldwide (ii) what is the situation of the pipelines lines in the insure areas, (iii) what are the limitations in the existing risk management approached regrades managing the risks in the projects, and (iv) how to develop a risk management framework to be used to manage the risk in OGP projects more effectively.

In other words, the literature review of this research will explore the risk factors in OGP projects and explain the limitations of the existing approaches that used to manage them. The findings of the literature review will be also used to design a questionnaire survey and a computer-based model to make a quantitative analysis and assessment of the risk factors in OGP projects. Afterwards, the findings of the qualitative and quantitive will be used to develop a framework that would be used in managing the risks in the pipeline projects more effectively.

Also, from the philosophical worldview on how research should be done, it is patent to deduce that focusing only on the qualitative analyses or the quantitative analysis of the risk factors in the projects will not lead to developing an effective risk management framework to be used in managing these risk factors. The pragmatic research philosophy uses both qualitative and quantitative methods to resolve a real-life world challenge are commended. Such a research philosophy is particularly relevant where the research questions do not suggest clearly that they are either qualitative or quantitative. This is because the combination of methods and approaches would better address the aims and objectives of the research (Ihuah and Eaton, 2013). Threfore, the pragmatic research philosophy provides for the adoption of mixed methods as the data collection and analysis methods, which opens the opportunity to be objective and subjective in analysing the points of view of this research about the risk factors that may affect the safety of the pipelines, their degree of impact on the project and how to manage them effectively.

The research methodology in this study, therefore, has two parts, which are the theoretical part and the technical part. The theoretical part refers to the literature review, which provides theoretical explanations about the OGP projects and the different types of RFs that affect the safety of these projects. Meanwhile, the technical part uses an industrial survey, computer models and risk simulation to analyse the RFs in OGP projects.

The methods proposed in this research involve qualitative document analysis and quantitative risk analysis using an industrial survey, fuzzy theory and Monte Carlo

Simulation (MCS) to analyse the impact of the RFs on the projects and risk optimisation to select safest routes/alignments for the new projects. Hence, a mix of qualitative and quantitative approach was used in this study to achieve the research aim. The focus of this study is to develop a holistic and integrated RMF for the OGP projects, which will be developed using the following steps:

1- Carry out an extensive literature review in order to understand and analyse the existing RMFs in OGP projects as well as to highlight their strengths and limitations.
2- Identify and list the relevant RFs and RMMs associated with the OGP projects via a literature review.
3- Assess and analyse the impact level of the RFs in the OGP projects based on their probability and severity levels, which will be calculated via an industrial survey.
4- The industrial survey will be also used to evaluate the RMMs with regard to their usability and effectiveness degrees of managing the RFs in OGP projects.
5- Reduce the uncertainty associated with analysing the RFs, which results from the scarcity of available data about the RFs in the projects, and analyse and rank the RFs based on the literature review and the stakeholders' judgements only. This step will be performed using the fuzzy theory provided by MATLAB software.
6- Identify the safest route/alignment to build new OGP projects by optimising the existing risk impact levels in existing routes/alignments. This step will be performed using subjective and objective document analysis to identify and allocate the RFs with the routes/alignments that are suggested to build the new pipelines. Analysing the risk levels in these routes/alignments and suggesting the safest ones will be carried out based on the results of risk optimisation. In other words, in this phase of the project, risk optimisation based on the algebraic summation of the risk levels in the pipeline routes/alignments was used to select the safest ones for the new projects, which are the routes that have the fewest risk levels.
7- Identify the effective RMMs in the OGP projects to mitigate the risk factors found in these projects (which will be identified based on the usability and effectiveness of the selected RMMs).
8- Quantify the delay impact caused by the associated IRFs in the new OGP projects using Monte Carlo Simulation integrated with ASTA risk simulator and @Risk simulator programs.

Chapter 3: explains the research methods of this research in more detail and Chapter 6: explains the details of designing the RMF. The next section describes the contribution and the originality of this research.

1.7 Research Contributions and Originality

The novel idea in this research is to develop an integrated and systematic RMF, which will enable users to deal with all the types of RFs in the projects on one platform. Moreover, the RMF will analyse the safety RFs that affect the safety of pipeline projects in insecure and developing countries. By addressing the RFs in OGP projects more comprehensively and holistically, such an RMF will be applicable and useful to manage the RFs in OGPs in more countries, especially where these projects are suffering from terrorist and sabotage attacks.

Identifying the RFs and RMMs in OGP projects based on an extensive literature review about them in OGP projects worldwide will make the RMF able to overcome the limitations of the existing RMFs, which are caused by the lack of data about the RFs in the projects. In other words, the RMF will be useful in managing the RFs in OGP projects when the risk management in these projects suffers from the problem of data scarcity and the absence of records about the RFs, which is the case in developing countries.

Moreover, as this is the first study in the country, the RMF will actively contribute to managing the RFs in OGP projects in Iraq, particularly the safety-related risk factors. The findings of the RMF could help decision-makers, policy-makers and researchers to understand, identify, analyse, evaluate and control the OGP critical risks in a more comprehensive, holistic and effective way. The following are the main contributions of this study:

1- The first contribution of the study is to help in overcoming the problem of data scarcity about the RFs and RMMs in OGP projects in developing countries such as Iraq. This will also help in providing a wide range of knowledge about risk factors and the methods of managing them.
2- The study will provide a great deal of knowledge about risk factors and the methods of managing them in the field of the oil and gas pipeline industry while developing an integrated RMF. Hence, it will be enhancing the reliability of the results of risk analysis by integrating the risk assessment model with fuzzy theory to reduce the uncertainty caused by the lack of data about the RFs and the biases associated with

stakeholders' judgements about their impact. This is the second and key contribution in this study.

3- The third contribution of this research is that it will help in identifying safest/optimum transportation path/routes/alignments based on existing risk levels for new OGPs considering the existing safety-related RFs.
4- The fourth contribution of the study is the list of recommendations of the effective RMMs to use to design suitable risk management actions and response plans for pipeline projects.
5- The fifth and final contribution of the study is the effective delivery of the OGP projects by quantifying the delay impact caused by relevant RFs during their planning, design and construction stages.
6- One of the key findings of this research is an integrated RMF which will help in overcoming the limitations of the existing risk management approaches in OGP projects. The developed RMF will provide a great deal of knowledge in identifying, analysing and managing the RFs in OGP projects. The RMF will help in enhancing the culture of risk management in OGP project that will improve the safety level in these projects in a developing and insecure country such as Iraq.
7- Ten publications were produced from this research, three journal articles and seven conference papers. These publications have delivered most of the findings of this research, which are the common RFs and RMMs in OGP projects worldwide, the limitations in the existing approaches to risk management in the projects, the ranking of these RFs in OGP projects in Iraq, and the design of an integrated RMF for OGP projects. Additionally, the publications that came out of this research have published the findings of the designed RMF, which were the safest pipeline route, effective RMMs and the delay impact caused by the associated RFs in the case study project, which is a new oil and gas export pipeline in the south of Iraq.

1.8 Research Scope

The objectives of this study are limited to identify, understand, assess and develop an integrated risk management framework for managing the RFs in OGP projects, particularly in developing and insecure countries such as Iraq. This research focuses more on the risk factors caused by sabotage, terrorism and thefts in insecure countries where data bout the risk factors in the projects are limited or unavailable. The lack of sufficient data obstructs and limits the development of more effective risk management practices in OGP projects, particularly in developing countries. This research tries to help in understanding and identifying the RFs that threaten the safety of OGP projects in the countries that have a similar security situation to that in Iraq. 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 are limited to Iraq only. The developed RMF is unable to draw failure scenarios to calculate the consequences of any hazardous event. It is also unable to compare between the RFs in OGP projects in different countries. Since the safety and security risks are dynamic risks and always impacted by the political, social, environmental and economic situations, the analysis and management of such complicated risk factors are beyond the knowledge of this research. The RMF was designed based on an extensive and worldwide literature review about risk management approaches in OGP 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. Therefore, it is recommended to carry on another case study project before using the RMF and applying the findings of this research for assessing and managing the RFs in that country.

As explained in Figure 1.2 and section 1.2.1 the focus of this research is to identify, analyse and manage the RFs in OGPs in the midstream projects. Because the OGPs in Iraq are either above or under the ground, the focus of this research, therefore, is to study the RFs in onshore pipelines projects in the country. In short, onshore OGPs refer to the pipelines that are built under the earth’s surface, which is the type of pipelines that are used to transport the petroleum products in Iraq, and it is the focus of this study. Whereas offshore pipelines are the pipelines that are built underneath the seabed, which is not used in Iraq. The next section details the structure and layout of the chapters of this thesis.

1.9 Thesis Structure

This thesis has 10 chapters, which have been written to achieve the research’s aim. Figure 1.5 shows the structure of the thesis and the layout of the chapters.

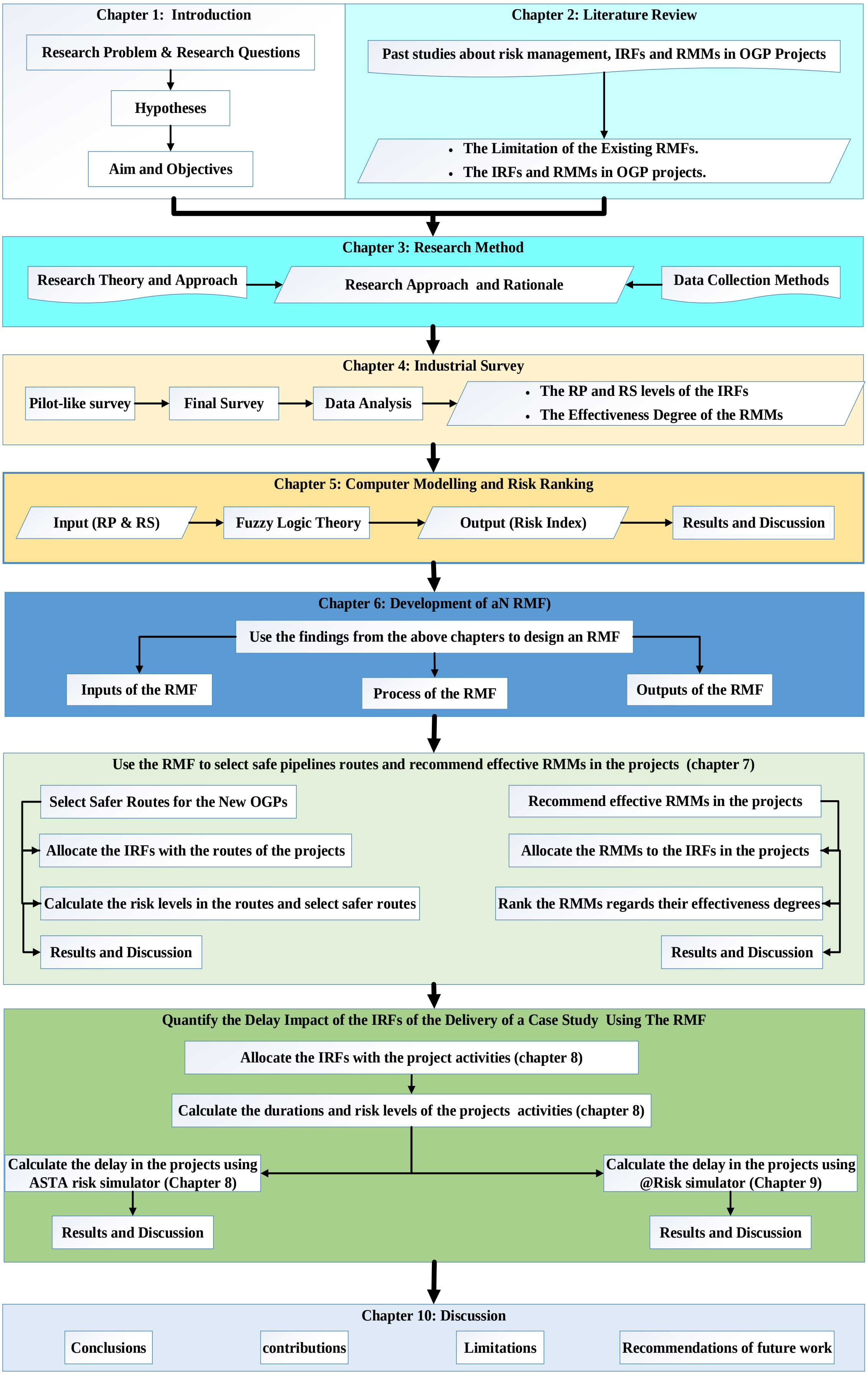

Figure 1.5: Thesis structure and flowchart.

- 0 explains the introduction of the OGP projects, the research problem, research questions, and the scope and the structure of the thesis.
- Chapter 2: provides the background about OGP projects and the RFs and RMMs associated with these projects worldwide. In addition, this chapter reviews the prior studies about risk management in OGP projects in order to understand and highlight the limitations of the existing approaches to risk management in these projects.
- Chapter 3: explains the conceptual theory, and the design and research approach used in this thesis. It also explains the data collection methods, and the rationale of this research.
- Chapter 4: uses the findings of Chapter 2: and Chapter 3: to design an industrial survey in order to understand the stakeholders' perceptions about the RFs and RMMs in their projects.
- Chapter 5: uses the results of Chapter 4: as inputs for a computer-based risk analysis model, which uses fuzzy theory to assess and rank the RFs.
- Chapter 6: is about using the findings of the previous chapters in order to design an integrated RMF to analyse and manage the RFs in OGP projects.
- Chapter 7: describes the case study project of this research. Additionally, it tests the functionality of the RMF with regard to selecting safe routes/alignments for the new pipelines and making useful recommendations for identifying some of the effective RMMs in the projects.
- Chapter 8: tests the functionality of the RMF with regard to quantifying the construction delay caused by the IRFs in the projects using ASTA risk simulator.
- Chapter 9: uses @Risk simulator to quantify the construction delay caused by the IRFs in the projects and to compare the results with the previous chapter to provide trusted outcomes.
- Chapter 10: explains the conclusion of the research. Furthermore, it provides the contribution, the limitations and the future work of the research.

1.10 Summary

This chapter has:

- Provided an introduction to the research study, and an overview about the oil and gas industry, the importance of petroleum products as a source of energy, the importance of OGP projects (section 1.1), and the importance of risk management in OGP projects (see section 1.2).

- Identified the limitations of the existing RMFs in OGP projects, which were used to highlight the research problem of this research (see section 1.3).
- Outlined the research questions (section 1.4), and research aim and objectives (section 1.5).
- Explained the research methods in sections 1.6 and section 1.7, and demonstrated the contribution and the originality of the research.
- Discussed the scope and the limitations and the structure of this research in sections 1.8 and 1.9 respectively.

In this chapter, it was found that it is significant to focus on the security and safety-related risk factors that affect OGP projects. The scope of this research is to use the research findings with regard to the analysis and ranking of the RFs for the following:

1- Calculate the impact of the RFs on OGP projects using a more comprehensive and accurate way, which could reduce the uncertainty and the biases associated with analysing and ranking the RFs in OGP projects based only on the literature review and the stakeholders' judgements.
2- Develop an optimisation alignment model selecting the routes that have less risk impact on OGP projects. Due to the nature of the safety and security risks, which are dynamic risk factors and which are always impacted and changed by the political, social environmental and economic situations, etc., nobody can guarantee that the selected route/alignment is the safest one for the project. However, the research findings will be useful in selecting the optimum (i.e. the least risky) route/alignment to build new pipelines considering the impact of the RFs on the pipeline projects.
3- Make effective suggestions and recommendations about identifying some of the effective RMMs in OGP projects by suggesting some of the effective RMMs to manage the RFs in the projects.
4- Estimate the duration of projects after considering the impact of the related RFs on them. This research, therefore, will quantify the impact of the RFs on the duration of new pipeline projects. In other words, it is essential to estimate if the projects could be delivered on time after calculating the impact of the RFs on their duration.

Iraq is facing many challenges to expand the export rate for oil and gas products; the inadequate risk management in OGP projects is the key challenge that hinders the export activities. So, this research sought to provide a comprehensive survey about the challenges which are facing risk management in OGP projects in Iraq. This research will contribute by identifying and analysing the RFs that may hinder the Iraqi government's planned increase in oil and gas export rates after 2003. Understanding and evaluating the IRFs in OGP projects will help stakeholders, decision-makers, policy-makers and researchers to adopt a sustainable risk management strategy during the different stages of these projects.

The next chapter critiques the past studies, technical reports and databases about risk management in OGP projects in order to understand their limitations and identify the RFs and RMMs in OGP projects.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter provides an overall review of the Oil and Gas Pipeline (OGP) projects and their importance in the world market and global economy, as explained in section 2.2. Section 2.3 provides an overview of the OGP projects in Iraq including the importance of the oil and gas industry to the country and the global market. Section 2.4 reviews the findings of the past investigations about understanding, identifying and classifying the Risk Factors (RFs) associated with the pipelines in different countries and under different geographical locations. In addition, this section describes different types of Risk Mitigation Methods (RMMs) that are adopted to manage the RFs in these projects. Section 2.5 identifies the seminal works OGP projects and it presents the strengths and limitations of the existing Risk Management Frameworks (RMFs) in the OGP projects, and is followed by the summary of the chapter in section 2.6.

The next section provides an overview of the OGP projects.

2.2 The Production and Transmission System in the Oil and Gas Industry

This section explains the production phases of the petroleum products, the main types of pipelines that transport petroleum products and the types of accidents facing these pipelines.

The production process in the oil and gas industry is usually divided into three phases, which are upstream, midstream and downstream. **The upstream phase** includes the exploration, drilling and production activities relating to the crude oil and gas products. **The midstream phase** includes the storage, the transportation and the trading facilities of the extracted oil and gas products. In this phase, the extracted products will be transported either to the refinery plants or to the export points. **The downstream phase** includes distributing the refined oil and gas products for the final consumers in the local market (De Graaff, 2011).

As explained earlier, in 00, the OGP projects are the main mode of petroleum product transportation. Therefore, this research is focusing on analysing the RFs that affect the safety of OGPs in the midstream phase of the oil and gas industry, as justified in section 1.2.1 in 0. Johnson (2017) suggested that OGPs are generally categorised into three main types as follows: (i) flow-lines (gathering pipes), (ii) transmission pipelines and (iii) product (distribution) pipelines. The definitions of these pipelines are explained below:

1- Flow-lines (gathering pipes) collect the crude oil or natural gas from the wells to transport them to the storage tanks or treatment plants inside the production areas.
2- Transmission pipelines transport the crude products to the refineries and other storage facilities outside the production areas. They also transport crude oil or the refined products between cities, states, countries and sometimes continents.
3- Product (distribution) pipelines transport refined products to the storage tanks and final consumers.

Figure 2.1 provides an integrated view of the gathering, transmission and distribution pipelines and other key components in OGPs.

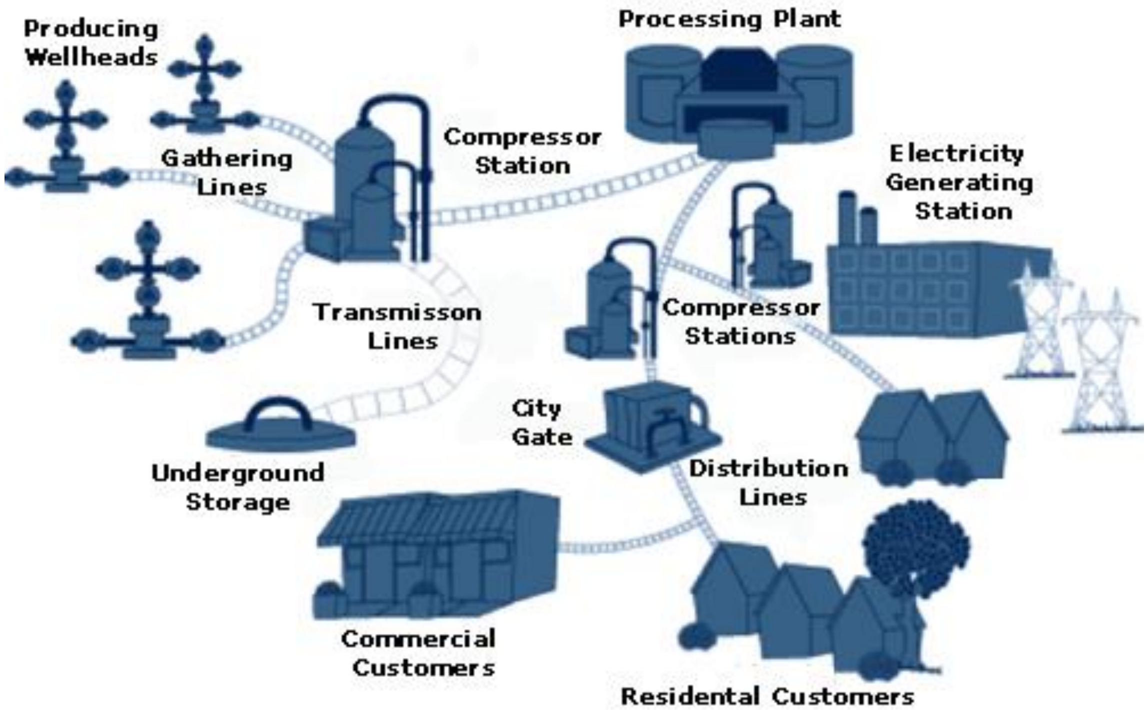

Figure 2.1: Integrated view of gathering, transmission and distribution OGPs (SSVSC, 2020).

The figure above shows the main types of pipelines used to transport petroleum products from the production points to the processing planets (refineries) or to the end users, such as commercial customers, electricity generation stations, export points and storage facilities, etc. This research, therefore, focuses on the RFs that affect the safety of the transmission pipelines as they run for thousands of kilometres outside the production areas, which makes them more subject to the RFs that affect their safety. Additionally, these pipelines have a significant social and economic impact on countries and nations, as any failure in them could obstruct the transmission, export and import activities of the petroleum products. Moreover, any disruption in the pipeline networks that transport the oil and gas products to the electrical power generators or refinery units has a significant impact on the supply chain of the electric power and petroleum products that are required by nations. The next paragraph describes the main types of accidents facing OGPs.

Briggs (2010) says, "*Despite the indisputable successes achieved by the modern technology of pipeline construction and exploitation under different natural conditions, including the extreme ones, pipeline oil transportation does not eliminate the possibility of serious accidents and consequences*", p.95. For example, some of these pipes are beyond their estimated engineering life (Epstein et al. 2002); suffering from human-related RFs; material defects (e.g. pipe corrosion and ground erosion); soil movements (Kraidi et al. 2019a); or, with regard to underwater pipelines, encountering ship anchors and bottom trawls. These RFs could cause accidents and failures in OGPs and damage them, which would obstruct the transportation system of petroleum products. Meanwhile, pipeline failures have a grave economic and environmental impact on countries. For instance, the database of the US Office of Pipeline Safety shows that 316 million gallons of crude oil, gasoline and other petroleum products dripped and poured from damaged pipes during the period between 1980 and 2010 (Briggs, 2010). This obviously caused massive economic losses for the country and had a severe environmental impact on the surrounding areas.

Guo et al. (2018) classified the failure in OGP projects into three types depending on who is damaging the pipelines, as follows.

I. First-party disruption, which is failure in a pipeline caused by the pipeline's company itself;
II. Second-party disruption, which is failure in a pipeline caused by the companies or individuals that work for the pipeline's company; and
III. Third-Party Disruption (TPD), which is failure in a pipeline caused by companies or individuals not related to the pipeline's company such as farming, digging or construction activities of other projects.

Even though countries have different forms of accidents in their projects, the focus nowadays in the oil and gas industry is on TPD (Lambrechts and Blomquist, 2017; Rezazadeh et al.

2018). This is because TPD is one of the major causes of OGP failure in European countries and the USA (Hopkins et al. 1999), in African countries (Rowland, 2010), and globally (Minsner and Leffler, 2006; Wan and Mita, 2010).

Day (1998) and Muhlbauer (2004) define TPD as any individual or group action that obstructs the functionality of the infrastructures' systems in any direct or indirect manner, such as theft, sabotage and terrorist attacks. This research classifies such kinds of risks as "***intentional TPDs***". Intentional TPD refers to the deliberate and illegal intrusion into OGPs without consent or permission from the stakeholders. The activities of intentional TPD include vandalism; smuggling; trespass; conspiracy; pilfering; sabotage and terrorism; guerrilla warfare; mechanical equipment, firearms, explosives; and cyber (internet) attacks on the operating system to cause physical damage (Watts, 2008). Therefore, the main focus in the global oil and gas industry is on the intentional TPD (Parfomak, 2008). Such disruption is strongly affected by the environmental, social and economic conditions of the areas in which the pipelines are situated.

Peng et al. (2016) added that TPD results from any action that accidentally damages the OGPs. This includes human errors (e.g. operational errors that result from using the wrong information), natural phenomena (e.g. floods and earthquakes), soil movement (e.g. foundation collapse, landslides and mudslides), and surface loads (e.g. illegal building, blast construction and live ground loads that compress pipelines). This research classifies such kinds of risks as "***unintentional TPDs***". Unintentional TPD refers to any unexpected events and activities that cause accidental damage to OGPs. This includes pipeline failure caused by mechanical failure; operation error; control system failure; human and natural hazards (e.g. road construction, farming and drilling), landslides, erosion and earthquakes (Rowland, 2010).

In this study, TPD refers to all intentional and unintentional individual and group actions that result in expected or unexpected damage to a pipeline at any stage of a pipeline project. As TPD is the main cause of pipeline failure, it is worthwhile and important to understand and analyse the TPD in OGPs to minimise the causes of failure and accident in these projects. As the scope of this research is to analyse the RFs in OGP projects in insecure environments, the case study of this research should be carried out in a country in which the OGPs are subject to the TPD more often. Iraq has been selected as a case study for this research because it is a developing country with security issues that affect the safety of OGP projects. In order to increase the oil and gas export rate, Iraq after 2003 had a strong and rapid development in oil and gas infrastructures with a massive number of pipeline projects under construction, which were obstructed by the risk management in the country. Also, Iraq is one of the most important petroleum countries that has a strong impact on the global economy. The next section provides an overview of the OGP projects in Iraq.

2.3 Overview of Oil and Gas Pipeline Projects in Iraq

In Iraq, oil exploration and production activities were started in 1920 by several international oil companies, and, by 1975, the process of oil production was ultimately under the control of Iraqi oil companies (Crocker, 2004). Iraq was a founding member of the Organisation of Petroleum Exporting Countries (OPEC), which was established at a conference held in Baghdad in 1960 (Danielsen, 2015). Subsequently, Iraq was amongst the first crude oil-producing and exporting countries in OPEC (Mikdashi, 1974; Al-Rashed and León, 2015).

With regard to exporting Iraqi oil to other countries, the first shipment of Iraqi crude oil was exported via Haifa port through the Haifa pipeline, which has been obsolete since 1934. During 1943, Iraqi crude oil was exported via Banias port in Syria, through the Iraqi-Syrian pipeline. The first port in the south of Iraq was Al Faw, which has been used for exporting the Iraqi crude oil through the Persian Gulf since 1951. In the north of Iraq, the Iraqi-Turkish pipeline was used to transport the crude oil extracted from the north of Iraq to the Ceyhan port in Turkey. Another exporting pipeline was constructed in 1985 to export Iraqi crude oil through the Red Sea, which has been out of service since 1990. Table 2.1 shows the main pipelines in Iraq.

Table 2.1: The main OGPs in Iraq (Moosa, 2013; Danielsen, 2015).

Connection		**Owner or operator**	**Length (Miles)**	**Diameter (inches)**
From	**To**			
Kirkuk	Salah el-Dien	Oil Pipeline Company	83	26
Baiju (K2)	Daura	Oil Pipeline Company	213	12/16
East Baghdad/	Daura refinery	Oil Pipeline Company	60	16
Naft Khaneh	Daura	Oil Pipeline Company	130	12
Strategic Pipeline	Nasiriyah refinery	Oil Pipeline Company	32	20
Strategic pipeline	Daura refinery (2)	Oil Pipeline Company	108/110	18/26
Strategic Pipeline	Musaiab PWR st	Oil Pipeline Company	48	16
Strategic Pipeline	Al-Khairat PWR st	Oil Pipeline Company	29.5	14
Al-Ahdeb	Al-Zubaydia PWR st	Oil Pipeline Company	73	10
North Rumaila PS	Basrah port	South Oil Company	115	48
Zubair	Khor Al Amayah port	South Oil Company	114	42
Zubair	Basrah port	South Oil Company	99	42
Tuba	Zubair 1	South Oil Company	9.5	48
Tuba	Zubair 2	South Oil Company	13.3	30/ 32/ 36
Faw	Khor AlAmea (naval) X3	South Oil Company	28.1	42/32/32
Zubair 1	Saudi	South Oil Company	28.1	48
Tuba	Basrah SPM: 2 and 3 (2)	South Oil Company	95/99	2 * 48
Faw	Basrah SPM: 2 and 3 (2)	South Oil Company	95/99	2 * 48

Figure 2.2 shows the main units of oil and gas infrastructures in Iraq on the map.

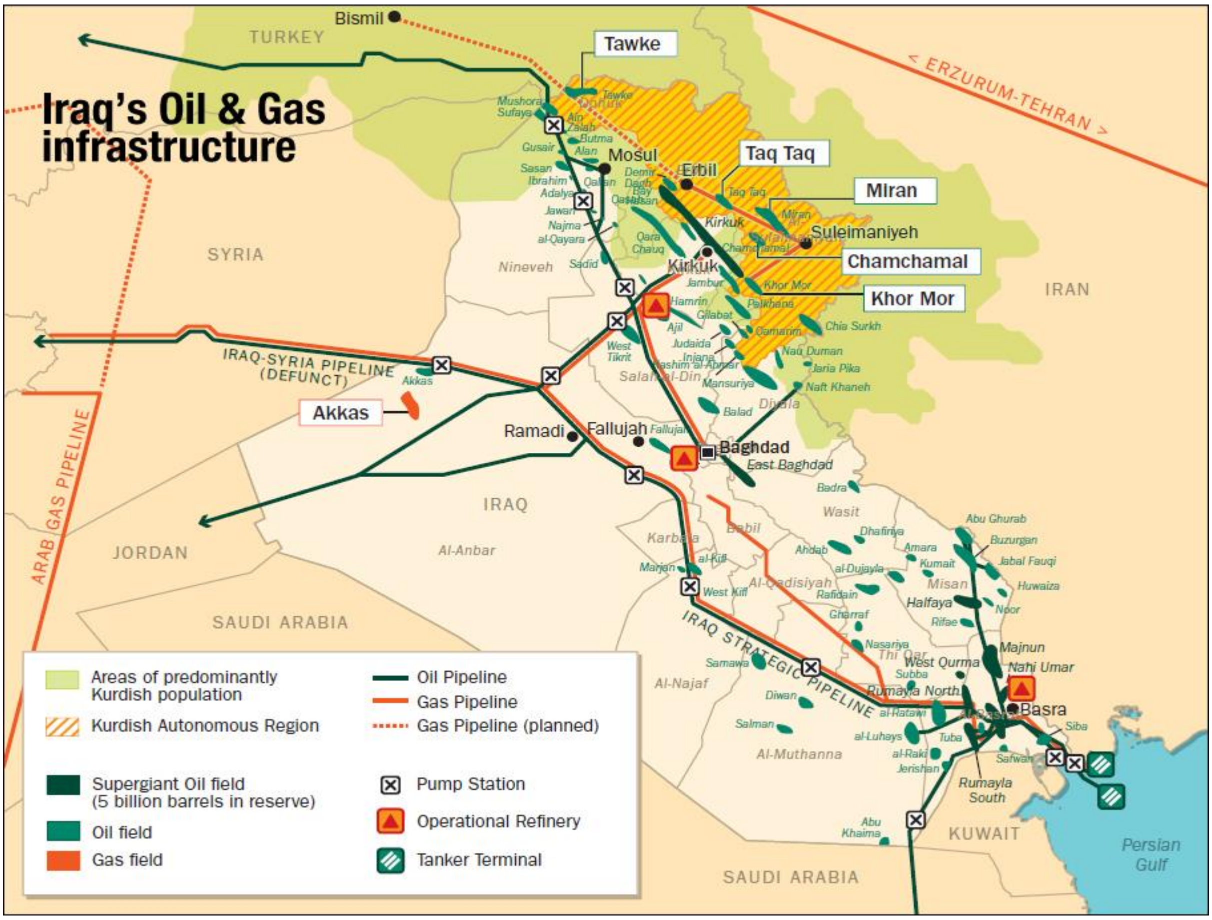

Figure 2.2: A map showing the main infrastructure units of OGP projects in Iraq (Jamie McDuell, 2014).

The next section shows the importance of Iraqi oil and gas products to the global and local markets.

2.3.1 The Importance of Iraq's Oil and Gas Industry in the Global Market

Iraq has been selected as the case study in this research because its oil reserves are about 112 billion barrels (Chalabi, 2000; Kumins, 2003; Luft, 2005), which is the fifth largest in the world (EIA, 2015). Iraqi crude oil reserves represent 10% to 11% of the total global oil reservoir (Muttitt, 2006; OPEC, 2017). Moreover, Iraq has the lowest cost of crude oil production in the world, which can break the price of crude oil in the global market (Gunter, 2013). Furthermore, it is estimated that Iraq's gas reserves are amongst the 10th to 13th largest reserves globally, which represents about 1.7% of the total gas reserves in the world, in addition to the possibility of the country having a vast number of undiscovered reserves (IEA, 2013).

Iraq has a significant impact on the growth of the global oil market (IEA, 2012). This is because the country was providing 18% of the crude oil produced in the Middle East (IEA, 2015). Additionally, Iraq is forecast to be the key supplier to fast-growing Asian markets, mainly China, up to 2030 (OPEC, 2017). Figure 2.3 shows the exported Iraqi oil by destination during 2014.

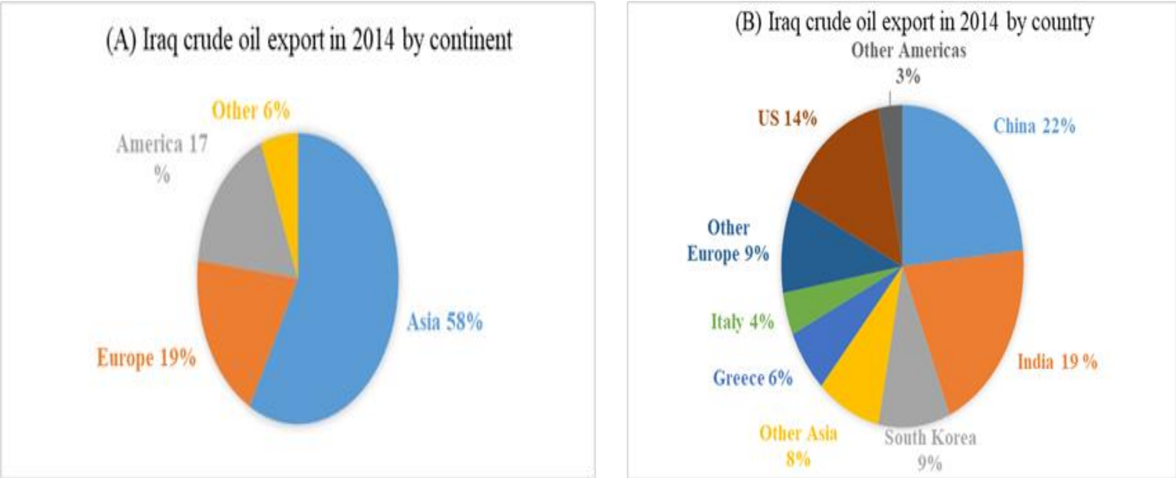

Figure 2.3: The exported Iraqi crude oil by destination in 2014 (A) by continent and (B) by country (EIA, 2015).

The next section outlines the importance of Iraqi oil and gas products for the country's economy.

2.3.2 The Contribution of the Oil and Gas Industry to Iraq's Economy

The population in Iraq increased from approximately 13.7 million in 1980 to approximately 31 million in 2010; the population today is approximately 34 million, and it will have grown to almost 50 million by the end of 2030 (Figure 2.4). It is estimated that the population will keep on increasing to reach 71.3 million in 2050.

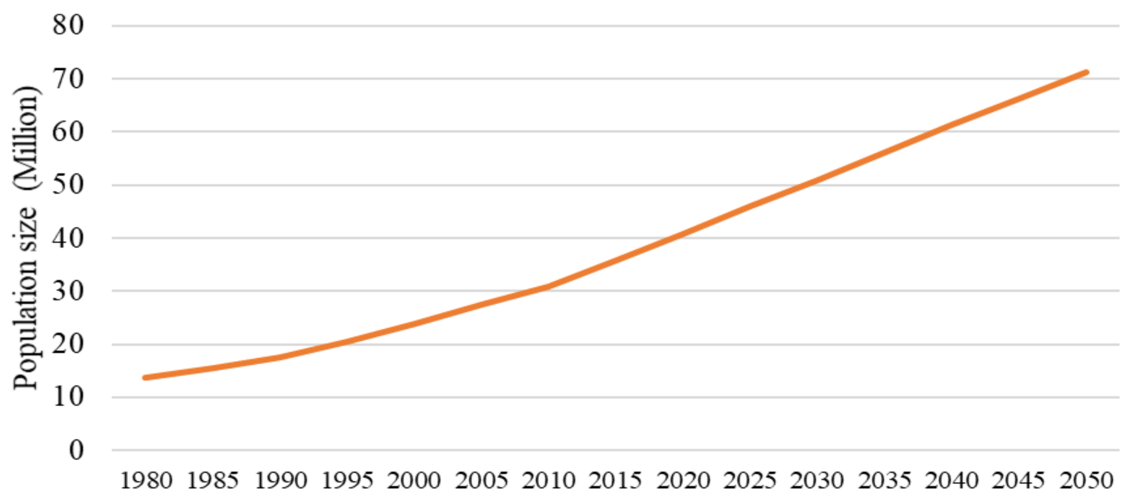

Figure 2.4: Population size in Iraq (1980-2050) (UN, 2019).

The population growth rate in Iraq increased from 2.64 % in 1980-1985 to 3.12% in 1995-2000. Then it decreased to 2.46 % in 2005-2010 and rose again by 2.89% in 2010-2015. It was expected to keep rising by 3.6% between 2015 and 2019 and from then on to start decreasing, to reach 1.45% in 2045-2050 (Figure 2.5).

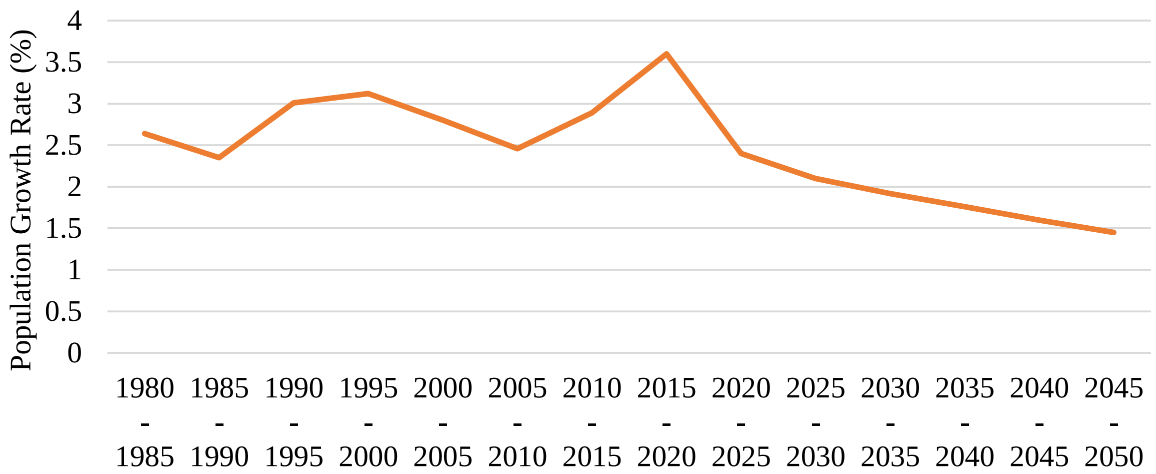

Figure 2.5: Population growth rate in Iraq (1980-2050) (UN, 2019).

The export of crude oil products has had a significant impact on the economic situation in Iraq because it is the cornerstone of the economy and the key source for the future development of the country. The oil export business provides Iraq's main resources of income because it represents 99% of total government revenues, as shown in Figure 2.6. In addition, oil exports make up 95% to 99% of the country's exported goods and provide 80% of foreign exchange currency to the country, as shown in Figure 2.7.

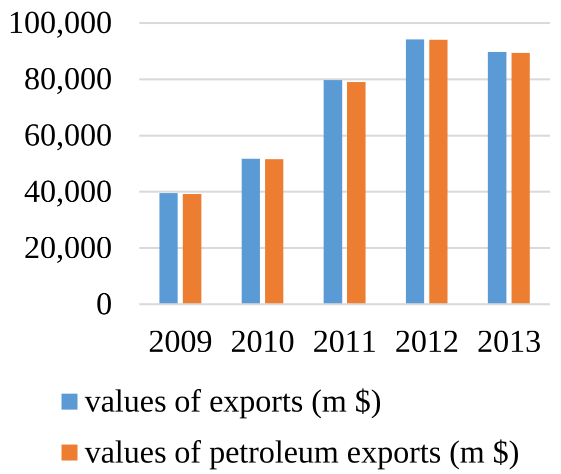

Figure 2.6: Oil export value to total export (2009 to 2013) (Crocker, 2004; Squalli, 2007).

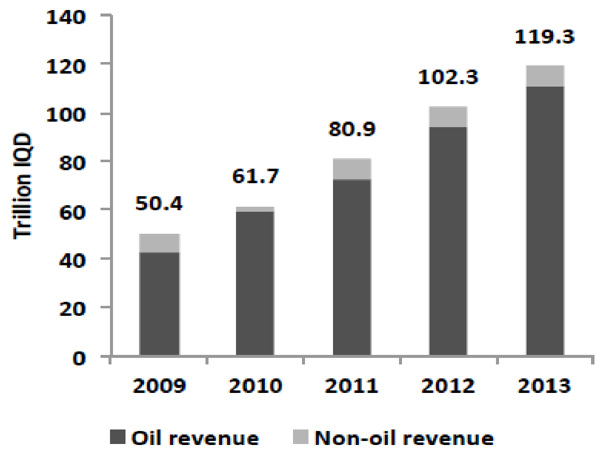

Figure 2.7: Iraqi government total revenues between 2009- 2013 (The Revenue Watch Institute, 2014; Mansour, 2018).

The business of oil exporting in Iraq makes up 70% to 75% of the Gross Domestic Product (GDP) of the country (The Revenue Watch Institute, 2014). During the period between 1980 and 2003, the living standard in Iraq dropped sharply because of the first Gulf War (1980 to 1988) and the second Gulf War in 1990. In that period of time, Iraq's GDP declined by more than 20% in real terms. After 2003, Iraq started to recover from three decades punctuated by wars and conflict and sought to gain a chance to change its future (as shown in Figure 2.8 and Figure 2.9) (Mansour, 2018). Also, the internal conflict was even worse for a number of years after 2003, as explained in section 2.3.3.

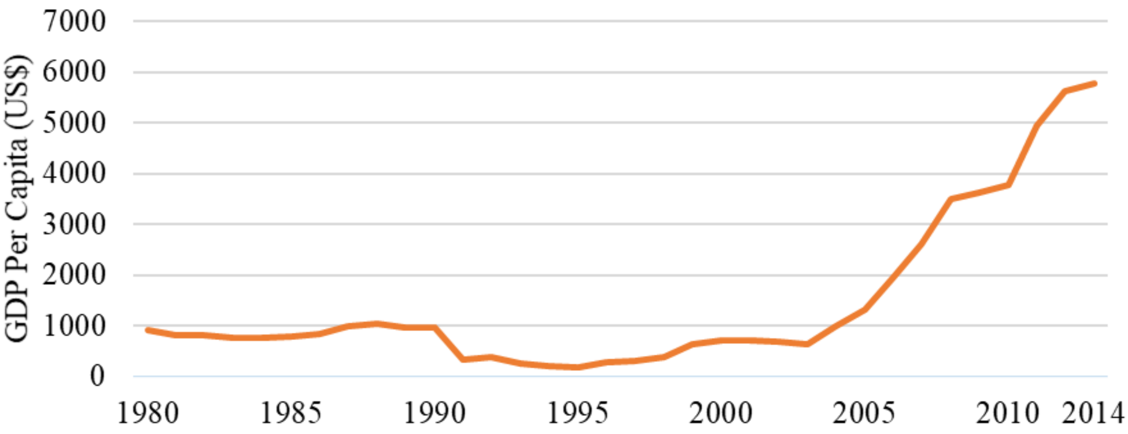

Figure 2.8: Iraq's GDP per capita (1980-2014) (UN, 2019).

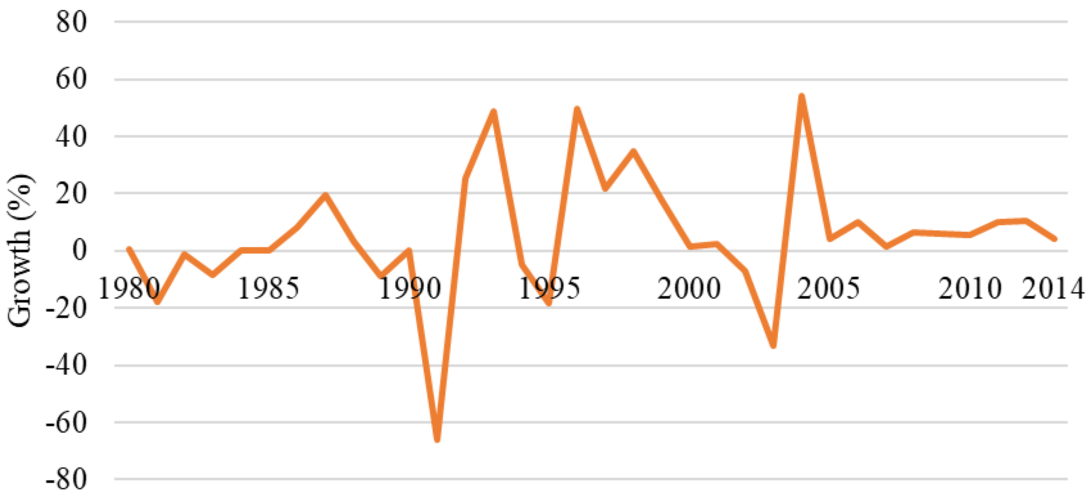

Figure 2.9: Iraq's GDP per capita growth (%) (1980-2014) (UN, 2019).

After 2003, Iraq had three continuous plans with regard to increasing the export rates of oil and gas products. Since then, it has been increasingly accepted that the development of the infrastructures in the oil and gas industry needs to be at the top of the agenda when contemplating the development of the country's infrastructures in the country. Figure 2.10 shows the three scenarios of increasing the oil export rate in Iraq until 2035. Meanwhile, Figure 2.11 shows the effectiveness of each scenario on Iraq's GDP and economy until 2035.

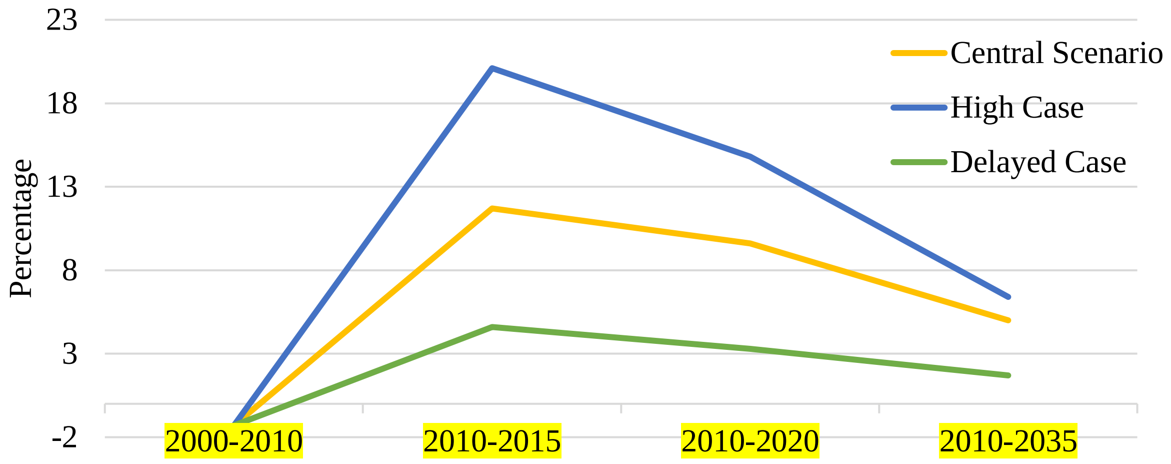

Figure 2.10: Iraqi oil output compounds the average annual growth rates between 2000 and 2035 (IEA, 2012).

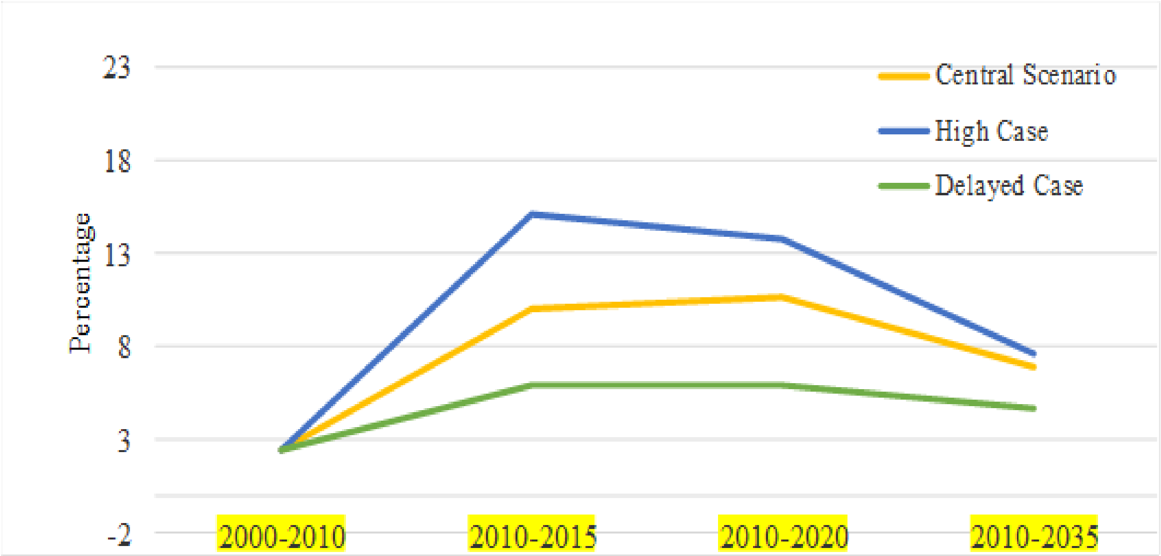

Figure 2.11: Iraqi GDP compounds the average annual growth rates (2000 to 2035) (IEA, 2012).

As explained in the figures above, the oil and gas industry is the most important and critical source of revenue in Iraq, which means that the development of the oil and gas resources in Iraq underpins the reconstruction and the social and economic development of the country. So, it is vital to support a quick and acceptable development rate for OGP projects to match the requirements of increasing the exports rates of Iraqi oil and gas products rapidly. This is because the business from these export activities is required to rebuild the country and provide the required economic resources for the nation. One of the requirements for supporting the developments in OGP projects is enhancing the safety levels of these projects.

This is because enhancing the safety levels of the projects helps in reducing their failure rate, which helps to: (i) enhance the safety level of the transportation system for the petroleum products; (ii) reduce the economic losses that result from repairing the damaged pipes and losing the leaked products; and (iii) reduce the environmental impact caused by the spilt products.

The aim of this research, therefore, is to develop an integrated RMF, which could be used to understand, identify, analyse and manage the RFs in OGP projects in Iraq in a comprehensive way. Such an RMF will be useful to stakeholders in OGP projects to improve the safety level of OGPs in Iraq during the planning, design, construction and operational stages of these projects. In other words, the RMF will contribute to enhancing the development of OGPs in Iraq, which will help in improving the oil and gas export activities that represent an important source of revenue to the country.

The next section details the situation regarding OGP projects in Iraq.

2.3.3 The Current Situation of the OGP Projects in Iraq

The wars in 1980-1989, 1991 and 2003 had a harmful impact on Iraq's oil and gas industry because most of the oil and gas infrastructures suffered from direct and indirect attacks that damaged the pipelines. Oil production, therefore, explicitly declined specifically after 2003, due to the damage that occurred in many depots and pipelines, which reduced the capacity of the storage and transportation facilities and obstructed the oil-exporting activities. After 2003, Iraq started to re-develop its oil and gas infrastructures to increase the production and export of the crude oil. Thus, the production of crude oil in Iraq rose from 0.95 Million Barrels Per day (MMbbl/day) in 2003 to 2.4 MMbbl/day in 2010 and to 3.4 MMbbl/day in 2014 (EIA, 2015). The crude oil production in 2015 was 3.6 MMbbl/day, and the Iraqi government aimed to reach up to 8.3 MMbbl/day of crude oil in 2035 (De Graaff, 2011; EIA, 2015), (see Figure 2.10 and section 2.3.2). However, this plan has been renegotiated to lower levels because the capacity of the transportation system is low (Ali, 2015; EIA, 2015). Meanwhile, the revised targets are still overly optimistic because of the ongoing delays in the development of the oil and gas infrastructures in the country. Furthermore, the militant activity and the poor security situation during the recent years with regard to ISIS have impeded these projects (IEA, 2012; Moosa, 2013; EIA, 2015). Table 2.2 shows the status of the main pipelines used to export crude oil produced in Iraq.

Table 2.2: The status of the main pipelines used to export crude oil produced in Iraq.

Name	Pipeline direction	Location	Nameplate capacity (1000 MMbbl/day)	Status	Notes
Turkey (Ceyhan) pipeline	Fishkhabur (Iraqi-Turkey border) to Ceyhan port (Turkey)	southern Turkey	1,500	The 40-inch line is not operating	Two parallel pipelines (a 40-inch and 46-inch) transport the oil produced in northern fields in Iraq to Ceyhan port in Turkey. The 46-inch line has been out of service since late 2014 due to the unsafe security situation in the area. The 40-inch line has a usable capacity of 500,000 MMbbl/day and it is connected to the two main pipelines in Kurdistan Regional Government (KRG).
KRG's main pipeline that connects to Turkey pipeline	Khurmala Dome to Fishkhabur	northern Iraq	300	operating	It carries the crude oil produced at the Khurmala Dome, Taq Taq and the nearby fields to the export points. The local government in the KRG region is working to increase the capacity of this pipeline.
DNO-KRG connection to Turkey pipeline	Tawke field to Fishkhabur	northern Iraq	100	operating	This pipeline transports the oil produced at Tawke field to Fishkhabur, then to the export point: Ceyhan port in Turkey.
Iraq (Baghdad) section of Iraq to Turkey pipeline	Kirkuk to Fishkhabur	northern Iraq	600	not operating	This pipeline was a target for sabotage by ISIS. It has been out of service since March 2014.
Kirkuk-Banias/Tripoli Pipeline	Kirkuk to Banias (Syria) and to Tripoli (Lebanon)	northern Iraq	700	not operating	This pipeline has two branches; one goes to Syria, and the other one goes to Lebanon. The pipeline was out of service between 1980 and 2000. And it was damaged during the war in 2003.
Strategic Pipeline	Kirkuk to the Persian Gulf	north to south (Iraq)	800	not operating	This is a reversible pipeline, which transports crude oil between Kirkuk in the top north of Iraq to Basra in the bottom south of the country, and vice versa. The pipeline section from Basra to Karbala transports the crude oil from Basra to the refineries in Baghdad. The other section (from Baghdad to Kirkuk) is out of service.
Iraq Pipeline to Saudi Arabia	southern Iraq to the port of Mu'ajjiz in Saudi Arabia	southern Iraq and Saudi Arabia	1,650	Iraq portion is not operating	The section that is supposed to transport crude oil to the Red Sea through Saudi Arabia is out of service.

The table above shows the majority of the main export pipelines in Iraq (five out of seven) are not in operation, particularly the pipelines in the north of the country. This is because of the security situation in the north after ISIS occupied Mosul city in 2014. This means that there is a vital need to have a practical and effective risk management system in these projects, which is the main aim of this research.

The next section details the impact on the scenarios of oil export until 2035 in Iraq and the challenges that obstruct the pipeline projects in the country.

2.3.4 The Impact of OGP Projects in Oil Export until 2035 in Iraq

Iraq has the resources and plans to increase the oil and gas production and export rate rapidly. However, the scenario of increasing oil export rates by 2035 (explained in Figure 2.10) is going slow because of many challenges. In 2008, after the first and second oil licensing rounds in Iraq, the Iraqi Ministry of Oil (MoO) and the international oil companies actively recovered and developed the upstream phase of oil production, i.e. the active producing wells, see

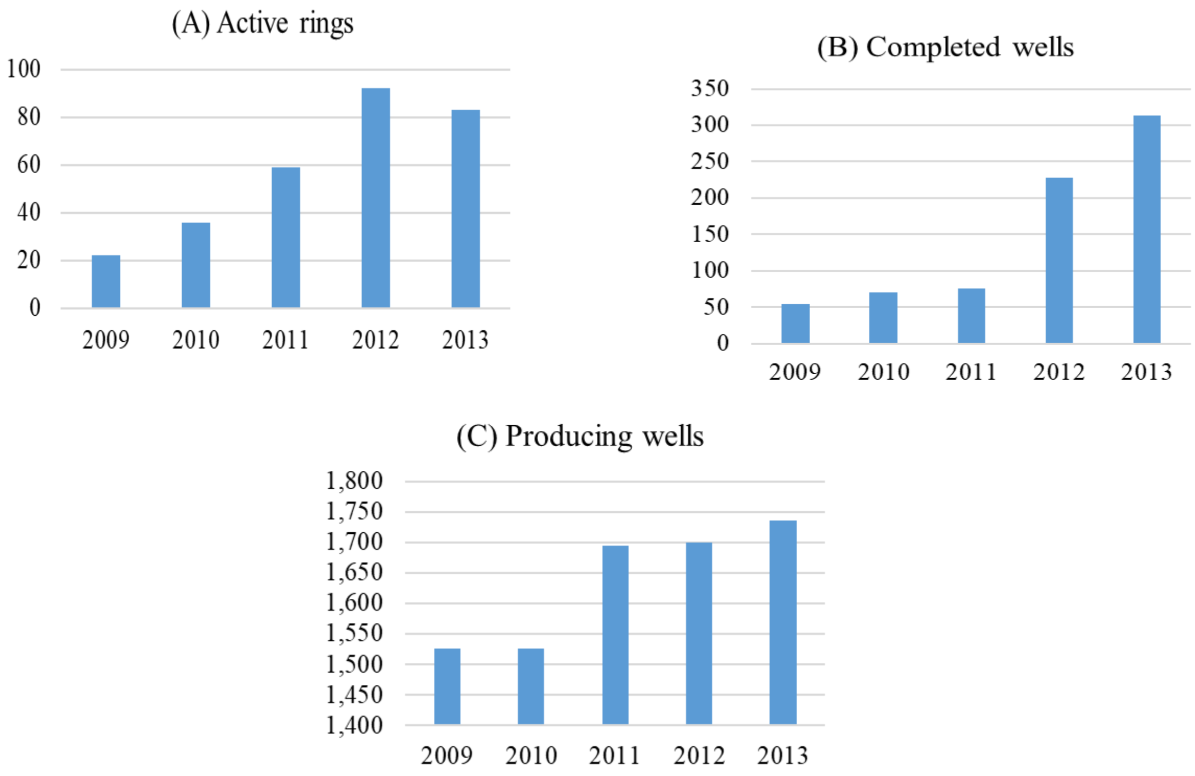

Figure 2.12 The active rigs, completed wells and oil-producing wells in Iraq (OPEC, 2017).

Additionally, the capacity of the downstream projects was increased by adding new export points to Al-Basra and Khor al-Amaya ports in the south of Iraq. However, the capacity of the production and export projects was increased at a faster rate than the increment rate of the capacity of the midstream projects, which is the main reason obstructing the oil export activities in the country (Jaffe, 2007; Jaffe and Soligo, 2007; Moosa, 2013; Ismael, 2018).

Iraq has an extensive pipeline network to transport oil and gas products for local consumption, and exports through ports and neighbouring countries. However, a substantial number of new pipelines have to be built, both inside and outside of Iraq, to increase oil and gas production and exports rates in the country. The scenarios of oil exports rate by 2035 (see Figure 2.10) were changed for a lower export rate because of the low capacity of the transportation system and the slow development in that system (i.e. OGP projects). In other words, the successful development of OGP projects in Iraq and an effective management system in these projects will have a strong impact on the social and economic development in the country. On the other hand, the slow development and ineffective risk management system in these projects are hindering Iraq's reconstruction, development and economic growth. At the same time, there is an urgent need for the country to overcome the many formidable challenges and RFs that work to obstruct the performance of the current pipelines and the development of new projects.

At the present time, a vast range of RFs is threatening the OGP projects in Iraq, and the inadequacy of mitigating these factors is hindering the oil export business, which has been in high demand since 2003. Although risks, accidents and failures cannot be completely avoided in any projects, they can be controlled and mitigated through using effective risk management strategies throughout the lifecycle of a project. Reliable risk assessment and an effective risk protection system are providing proactive actions minimising the impact of the RFs in the projects continuously (Torabi et al. 2016; Zafra-Cabeza et al. 2007). Therefore, there are enormous valid reasons for conducting this research in order to contribute to improving the safety level of OGP projects in Iraq by proposing a very robust framework of risk management, which could be used to analyse and manage the RFs in these projects. In other words, this research will contribute to enhancing the development of OGPs in Iraq, which will help in improving the oil and gas export activities that represent an important source of revenue to the country.

The next section explains the definition of "*risk management*", which is the process of managing the RFs in the projects. In other words, the next section discusses the application and the importance of risk management in OGP projects.

2.4 The Risk Management Process in the OGP Projects

This section explains the definition of RFs in the projects (see section 2.4.1) and how to manage them (see section 2.4.2). In addition, this section will identify and classify the RFs associated with OGP projects based on an extensive literature review about them, as described in section 2.4.4 and 2.4.5, respectively. Similarly, section 2.4.6 provides an identification and classification of the RMMs used to manage the RFs in OGP projects.

2.4.1 What is Risk?

Fishburn (1984) defined risk as a bad event. The word risk generally means negative results caused by a bad or an unexpected event (Perminova et al. 2008, as cited by Alali, 2010). Williams et al. (1997) defined risk as the possibility of suffering harm, loss or danger. Risk has also been considered as a future problem affecting the management and/or the control systems in projects (Cervone, 2006). 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 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. Raz et al. (2002) defined risk as any unplanned event that affects the success of a project as it may cause time and/or cost overrun, safety accidents, environmental hazards, property failure, etc. In this study, the authors concluded, "there is no risk free project", p. 101. In other words, any uncertain event that leads to not achieving any of the project goals is defined as a project risk (Nieto-Morote and Ruz-Vila, 2011). Kaplan (1997) gave a more comprehensive definition of risk. He stated that, when talking about risk, we are asking three questions: What can go wrong? How likely is that? What are the consequences?

The next section provides the definitions of risk management in projects and the answers to these three questions.

2.4.2 What is Risk Management?

The process of managing and dealing with the risk in projects is called "*Risk Management*" (Al-Bahar et al. 1990). NASA defined project risk management as follows: "*Project risk management seeks to anticipate and address uncertainties that threaten the goals and timetables of a project*" (Wu et al. 2006, p. 708 as cited by (Alali, 2010, p. 14). Risk management is about providing the policies, strategies and actions required in managing and coping with the RFs in projects in order to control and minimise their impact (Hillson, 2002; Carbone and Tippett, 2004). The goal of corporate risk management is to create a reference framework that will allow companies to handle risk and uncertainty (Dionne, 2013). The premise of risk management is that risk to a system, as well as its vulnerability and resilience, can be understood, defined, and possibly quantified most effectively through a systems-based philosophical and methodological approach, and by recognising the roles and actions required in this process (Haimes, 2009). The objective of risk management is to maximise the chance of a project's success via the reduction of the impact of different risks associated with that project. Risk management is considered as one of the main processes in project management (PMI, 2000). This is because reasonable and accurate risk evaluation measures and an effective risk management system can contribute to the reduction of the overall risks in projects (Guo et al. 2016).

Risk management addresses each risk factor and its consequences and the different mitigation policy options that may be addressed to reduce these consequences more effectively. Haimes (2009) explained in his/her study that each risk has a scenario that must be addressed and analysed using the following as risk assessment questions: What can go wrong? What is the likelihood? What are the consequences? and What is the time frame? Then the risk management process asks: What can be done and what options are available? What are the trade offs in terms of all relevant costs, benefits, and risks? and What are the impacts of current decisions on future options?

The next section explains some of the approaches of risk management used in the projects.

2.4.3 Risk Management Approaches

Risk management strategies include risk avoidance; loss reduction and risk prevention; risk retention and assumption; risk transfer (non-insurance or contractual); and insurance (Al-Bahar et al., 1990). The definitions of these risk management strategies are as follows.

- **Risk avoidance** means avoiding risk exposure to the projects, which is a useful, fairly common risk management strategy. Using risk avoidance risk management strategy will make the projects not experience the potential losses that the risks exposure may generate. However, the stakeholders of the projects (e.g. the contractor) loses the potential gains (opportunity) that may have been derived from assuming that risk exposure. To illustrate, if a contractor is concerned about potential liability losses associated with an asbestos material or hazardous waste, he/she could avoid the risk by never acquiring any project that involves operations with such materials. Similarly, a contractor may avoid the political and financial risks associated with a project in a particular unstable country by not bidding on projects in this country.

- **Loss reduction and risk prevention** mean working on reducing the potential risk exposure to projects in two ways, which are reducing the probability of a risk; and reducing the consequences of risk if it does occur. For example, the installation of the anti-theft devices on construction equipment may reduce the chances of theft. A building sprinkler system, on the other hand, may reduce the financial severity caused by fire. The success of risk reduction and prevention strategy leads to a direct action of preventing the potential risks in the projects and reducing their consequences. Also, it is found that by adopting a loss-prevention program, the insurance premiums are reduced significantly.

- **Risk retention and assumption** mean making internal assumptions, partially or completely, of the impact of the risks on the projects by using one of the two different types of retention, which are planned or unplanned risk retention. The planned risk retention is a conscious and deliberate assumption of recognised or identified risks by the stakeholders. Under such a plan, risks can be retained in any number of ways, depending upon the philosophy, the particular needs, and the financial and risk management capabilities of the stakeholders. For some projects, the task of risk identification has been so poorly performed that far too much risk is being passively retained. On the other hand, unplanned risk retention exists when the stakeholders do not recognise or identify the existence of a risk and unwittingly or unconsciously assume the consequences of a risk that could occur. A related form of unplanned retention occurs when the stakeholders have properly recognised the risk exposure but have underestimated the magnitude of the potential consequences of the risk factors.

- **Risk transfer** means risk transfers are possible, through negotiations, whenever the stakeholders enter into a contractual arrangement with various parties such as owners, contractors, subcontractors, or material and equipment suppliers. There are two ways of risk transfer, which are insured and non-insured transfer. These non-insurance transfers differ from insurance in that the transferees (i) are not insurers, and (2) due to inadequate historical data or their inability to adequately evaluate risk exposure, transferees usually do not accept enough exposure units for their losses. Most non-insurance risk transfers are accomplished through provisions in contracts such as hold-harmless agreements and indemnity clauses or contractual adjustments. For example, an adjustment in price where an extra compensation will be granted to the contractor if different subsurface conditions are encountered. The essential characteristic of the contractual transfer is that the potential consequences of the risk, if the risk does occur, are shared with or totally carried by a party other than the contractor.

- **Insurance**. The difference between the response option of insurance and transfer is that insurance only shifts the financial potential consequences of the risk, whereas risk transfer, also involves shifting responsibility for the risk. For that reason (the coverage of the financial consequences of the risk), commercial insurance is probably the most important and frequently used method of handling risk that is employed by the stakeholders (e.g. the contractors). In fact, many contractors think of risk management as insurance management. Therefore, the majority of contractors rely upon insurance for the more serious loss exposures through the purchase of an insurance policy with certain deductibles. Regardless of the form of deductibles, the obvious effect is a reduction in the premiums for a given amount of insurance protection. Loss-adjustment expenses are also reduced for the insurer. These two reasons explain why deductibles are usually used, especially when the frequency of small losses is fairly high. However, the insurance policies and companies are not active in developing and insecure countries such as Iraq due to the security situation and problems. Also, the aim of this study is to contribute in managing the risk factors in OGP projects in Iraq in a way that enhances the performance of the pipeline projects and reduces the time loss and delay in the projects caused by the risk factors.

Also, developing countries suffer from fundamental weaknesses in their financial structures, namely, the absence of prudent supervision, rudimentary regulatory structures of financial intermediaries, corrupt lending practices, insufficient bank capital, poor regulatory experience, and the absence of sound deposit insurance schemes, and these and other factors contribute to the result with a rapid accumulation of useless loans resulting in banking crises in these countries (Salman and Mohammed, 2020). These limitations in the insurance policies and companies in Iraq make "Insurance" not an effective risk management strategy in the country.

The oil and gas industry is complex by nature (Lameda and Van den Berg, 2009). Oil and gas projects are recognised as highly technical projects by nature which are complex, have a high level of uncertainty, demand careful risk assessment and require appropriate risk management strategies (Almadhlouh, 2019; Aseeri et al. 2004; Bowers and Khorakian, 2014; Durney and Donnelly, 2015; Rolstadås and Schiefloe, 2017). Oil and gas projects are usually costly, and the associated RFs in these projects are enormous (Marshall, 2016). Managing the RFs in such complex projects is difficult (Laufer et al. 2008) and requires a high level of experience in risk management (Aarseth et al. 2013).

The current trend in risk management is to take a holistic and comprehensive view of the RFs in the projects (Zhao and Singhaputtangkul, 2016). The process of risk management includes the following main steps, which are: (I) risk identification and registration; (II) risk assessment and ranking; (III) risk response and mitigation; and (IV) risk monitoring and control (Fang and Marle, 2012; X. yu Peng et al. 2016; Rezakhani, 2012; Sohrabinejad and Rahimi, 2015). The purpose of these steps is explained as follows.

I. **Risk identification and registration** are about identifying the RFs that affect the success of a project. Risk management is based on the premise that the RFs are identifiable, as defending a system from an unknown risk is impossible (Labaka et al. 2016). Therefore, risk identification and registration is the first step of the process in risk management. Risk identification and registration, therefore, should contain all the RFs that may affect the success of a project in order to prioritise the areas that require managerial attention (Filippina and Dreherb, 2004; Whipple and Pitblado, 2009).

   Accordingly, risk identification and registration must be based on appropriate knowledge, a trusted database and accurate historical records about the accident and failure causes in OGP projects (Anifowose et al. 2012; Balfe et al. 2014). These historical records are a valuable source of information that could be used to ensure adequate 'risk registration' and 'risk assessment' facilities, which are essentially required for risk management studies (Whipple and Pitblado, 2009; Ruijsscher, 2016). In other words, ideally, real and trusted historical data about the causes of failures and accidents in OGP projects provides reliable results of risk assessment (Okaro, 2017b).

Hopkins et al. (1999) defined a database as one that contains the pipeline records, such as the pipeline's designs sheets; maps; failure causes; operational pressure; inspections, tests and maintenance records; surveillance and modifications, etc. This means that the lack of such data is hindering the process of identifying the potential RFs that might affect the safety of the projects at any stage. However, the absence of data and historical reports makes providing observations about the RFs a challenging task, which harms the risk management system in the projects.

II. **Risk assessment and ranking** are about evaluating the degree of influence of the RFs on a project concerning their chances of happening (i.e. their probability, frequency or likelihood levels) and their degree of impact on the project (i.e. their severity levels) (Fang and Marle, 2012; Hopkins et al. 1999; Jamshidi et al. 2013; Miri Lavasani et al. 2011). Assessing and ranking the RFs regarding their degree of influence on a project is significant because dealing with each RF as if it is the most critical one results in substantial losses in terms of resources (Srivastava and Gupta, 2010). Therefore, it is vital to analyse the RFs in a project in an accurate way, as providing accurate results about the degree of impact of the RFs enhances the outcomes of the project's risk management system.

III. **Risk response and mitigation** are about making responses to the risk events and choosing actions that could reduce the hazards and minimise the consequences of that risk. Therefore, the project stakeholders must follow an effective risk management system in their project. In other words, this step focuses on applying suitable policies, strategies and actions of risk management to mitigate the RFs in a project using effective RMMs.

IV. **Risk monitoring and control** are continuous processes of identifying and analysing the newly arising RFs in a project, and re-evaluating the current RFs and improving the existing responses to the RFs to ensure adequate risk management during the project's stages, and to improve the project's safety levels continuously. In summary, the questions in the risk management process address the policy options, their trade-offs, the future dynamics of the system and its environment, and the emergent forced changes. These cannot be addressed correctly and effectively without adhering to and tracking the evolution of the states of the system as functions of the risk management decisions and time (Haimes, 2009).

The next section explains the identification of RFs in OGP projects based on an extensive literature review about them.

2.4.4 The Risk Factors (RFs) in OGP Projects

Extensive investigations were carried out to identify the RFs in OGP projects in different circumstances, countries and geographical regions worldwide. More attention was paid to understand and identify the RFs in OGP projects in developing and insecure countries where these projects are suffering security problems similar to those in Iraq. The scope of this study is about analysing the RFs that affect the safety of OGP projects during the construction and operation stages. In order to meet with the scope of this research, therefore, this research has identified RFs associated with OGPs at construction and operation stages of these projects based on a worldwide literature review. The investigations of the literature review were extended to identify the RFs that are associated with OGP projects at the planning and design stage in order to provide a good estimation about their impact on the construction duration of the projects. In summary, the investigations of the literature review were about identifying the RFs associated with OGP projects at the planning, design, construction and maintenance stages of the projects, which might affect the construction duration and the safety of OGP projects. The decommissioning issues were not considered in this study because they are beyond the scope of this research.

This section provides some examples of the RFs that affected the safety of OGP projects in different countries, such as Nigeria, India, China and Pakistan. Nnadi et al. (2014) found that many RFs affected the safety of OGPs in Nigeria: terrorism & sabotage attacks; official corruption; theft; corrosion and lack of protection against it; improper inspection and maintenance; weak ability to identify and monitor the risks; stakeholders not paying appropriate attention; lack of appropriate training, shortage of modern IT services; limited warning signs; lack of risk registration; little research on this topic; public poverty and education level; operational errors; inadequate risk management; natural disasters and weather conditions. Moreover, Rowland (2010) stated that the exposed pipelines and threats to staff were affecting the safety of OGPs in Nigeria.

Srivastava and Gupta (2010) draw a scenario about a terrorist attack that might happen in India and they expect RFs such as insecure areas, easy access to pipeline, and hacker attacks on the operating or control systems might affect the safety of OGPs in their country.

Studies from China identified more RFs in the projects such as lawlessness, low public legal and moral awareness, vehicular accident (X. Peng et al. 2016), improper safety regulations, design, construction and material defects, geological risks (Guo et al. 2016), conflicts over land ownership (Macdonald and Cosham, 2005), and leakage of sensitive information (Wu et al. 2015).

Over and above, in addition to the mentioned RFs, animal accidents were added as a kind of RF affecting pipeline projects in Pakistan (Mubin and Mubin, 2008).

Table 2.3 shows the list of the potential and influential RFs in OGP projects based on an extensive literate review about them in different countries across the world.

Table 2.3: The identified risk factors in the OGP projects based on the literature review.

Potential Risk Factors (RFs)	Authors
Low levels of the general public's legal and moral awareness about OGPs	Li et al. (2016), X. yu Peng et al. (2016) and Olujobi, (2017)
Socio-political factors such as poverty and education level in the project areas	Anifowose et al. (2012), Guo et al. (2016), Nnadi et al. (2014), X. yu Peng et al. (2016) and Chinonyerem, (2017)
Theft	Li et al. (2016), Lu et al. (2015), Nnadi et al. (2014), Onuoha, (2008) and Adishi and Hunga, (2017)
Terrorism & sabotage	Dawotola et al. (2010), Anifowose et al. (2012), Lu et al. (2015), Nnadi et al. (2014), Onuoha, (2008), Komarov et al. (2018) and Onyi-Ogelle, (2020)
Threats to staff (kidnap and/or murder)	Rowland, (2010), Adebayo and Adeniyi, (2019) and Mai-Bornu, (2017)
Leakage of sensitive information (e.g. the location of the valves, the location of the hidden units, etc.)	Wu et al. (2015), Urquhart and McAuley, (2018) and Ballentine et al. (2019)
Geographical location such as 'Insecure Zones'	Srivastava and Gupta (2010) and Lommer, (2018)
Conflicts over land ownership	Macdonald and Cosham (2005), Mather et al. (2001), Spice, (2018), EZE, (2019) and Adunbi, (2017)
Accessibility of pipelines	Srivastava and Gupta (2010), Sun et al. (2017) and Wang et al. (2019)
Geological risks such as erosion, soil movement and landslides	Guo et al. (2016), Riegert (2011), Zhirov et al. (2017) and Monaldi, (2017)
Vehicle accidents	X. Peng et al. (2016) and Galli and Khizar, (2019)
Animal accidents	Rowland (2010) and Kraidi et al. (2019b)
Lack of compliance with the safety regulations	Guo et al. (2016), Carroll and Hayes, (2018) and Manouchehri, (2017)
Non-availability of warning signs	Guo et al. (2016), Kabir et al. (2015), Li et al. 2020) and Guo et al. (2018)
Sabotage opportunities arising due to the exposed pipeline, e.g. above ground pipeline and not enough safety barriers	Rowland (2010) and Kraidi et al. (2019b)
Lack of regular inspection and appropriate maintenance	Guo et al. (2016), Lu et al. (2015), Nnadi et al. (2014),Wu et al. (2015) and Yang et al. (2017)
Inadequate risk management methods	Balfe et al. (2014) and Ogulu et al. (2019)
Natural disasters and weather conditions	Nnadi et al. (2014) and Badida et al. (2019)
Shortage of high-quality IT services and modern equipment	Nnadi et al. (2014) and Grüger and Schneider, (2019)
Weak ability to identify and monitor the threats	Nnadi et al. (2014) and Holdsworth et al. (2021)
Corrosion: lack of cathodic protection and anticorrosive coating	Guo et al. (2016) Lu et al. (2015), Nnadi et al. (2014), Riegert (2011), Sulaiman and Tan (2014), Wu et al. (2015) and Danylov et al. (2017)
Design, construction, material and manufacturing defects	Guo et al. (2016), Lu et al. (2015), Riegert (2011), Sulaiman and Tan (2014), Wu et al. (2015), Bai and Bai, (2017) and Koduru and Nessim, (2017)
Operational errors such as human errors and equipment failure	Balfe et al. (2014), Guo et al. (2015), Lu et al. (2015), Wu et al. (2015) and Hou et al. (2017)
Hacker attacks on the operating or control system	Srivastava and Gupta (2010), Veilleux and Dinar, (2019) and Style and Maglaras, (2020)
The law not applying to saboteurs (lawlessness)	X. Peng et al. (2016) and Kraidi et al. (2019b)
Stakeholders are not paying appropriate attention	Nnadi et al. (2014) and Kraidi et al. (2019b)
Few researchers are dealing with this problem	Nnadi et al. (2014) and Kraidi et al. (2019b)
Lack of historical records about accidents and lack of risk registration	Balfe et al. (2014) and Kraidi et al. (2019b)
Lack of appropriate training schemes	Balfe et al. (2014) and Galli and Khizar, (2019)
Corruption	Nnadi et al. (2014) and Johnson, (2017)

From the table above, it can be seen that different types of risks affect the safety of OGPs in different countries across the world. For example, OGPs in European countries mainly suffer from mechanical failures and corrosion RFs (Tchórzewska-Cieślak et al. 2018) because their pipelines are underground and they are less subject to sabotage RFs. The USA focuses more on the terrorism risk, especially after 9/11, in addition to corrosion, because the USA uses underground pipelines (Rowland, 2010). African countries pay more attention to theft risks because there is a strong illegal market for selling the stolen products in these countries (Rowland, 2010). Therefore, it is difficult to compare the ranking of the RFs with other countries that have different types of RFs in their projects. Moreover, there is no available study analysing the RFs in OGP projects in developing and insecure countries such as Iraq (Kraidi et al. 2019b, 2019a, 2019c, 2018b).

The finding of the above investigations will help in overcoming the problem of the shortage of data about the potential RFs that might affect the safety of OGP projects in Iraq. This is because the investigations of this research have identified the RFs associated with OGP projects worldwide. Therefore, the findings of this research will be suitable for and applicable to manage the RFs in OGP projects in many countries as the RFs were identified from OGP projects in different countries and environments.

As the identified RFs in the table above are influencing the safety of OGP projects, the RFs in this research are named Influencing Risk Factors (IRFs). The identified IRFs in the OGP projects will be used to design a questionnaire survey, which is discussed in Chapter 4:, in order to analyse their degree of probability and consequences in the OGP projects. The next section describes how the RFs are classified based on their types and characters.

2.4.5 The Classification of Influencing Risk Factors (IRFs)

Several studies were found to be useful for classifying the IRFs in the oil and gas industry. For example, Mubin and Manna (2013) classified the IRFs that affected pipeline projects in Pakistan during the construction and operation stages into eight types, which are socio-economic, technical, natural catastrophic, organisational, financial, environmental, safety and security IRFs. El-Abbasy et al. (2014, 2016a and 2016) classified the IRFs that affect pipeline conditions in Qatar and Canada into three main groups, namely physical factors (e.g. pipes, age, diameter, metal loss, and coating conditions); operational factors (e.g. corrosion, operating pressure, and flow rate); and external IRFs resulting from the environment surrounding the OGP projects (e.g. traffic, weather conditions, TPD, and soil properties). Li et al. (2016) classified IRFs that influence global investment in shale gas into five types: economic, political, geological, technological, and internal RFs.

However, these IRF classifications were broad and needed to be more specific. Moreover, they also missed out certain IRFs that may affect the safety of OGP projects, which will be covered in this study. In this study, the IRFs that affect the general safety of the OGPs in addition to the economic challenges are classified into five types depending on their characteristics: (1) Security and Societal (S&S); (2) Pipeline Location (PL); (3) Health, Safety and Environment (HSE); (4) Operational Risk (OR); and (5) Rules and Regulations (R&R). Table 2.4 shows the five classifications of the IRFs associated with the OGP projects.

Table 2.4: The list of IRFs found in the OGP projects with relevant classification.

IRFs	**Type**
Terrorism, sabotage and security risk	Security and Safety (S&S)
Theft of the products.	
Public awareness	
Threats to staff	
Socio-political effects	
Leakage of sensitive information	
Corruption	Rules and Regulations (R&R)
The absence of the law on TPD	
Lack of risk management practice	
Lack of appropriatetraining	
Lack of risk registration	
Little research on this topic	
The geographical location	Pipeline Location (PL)
The pipeline is easy to access	
Land ownership conflicts	
Geological risks	
Vehicle accidents	
Animal accidents	
Improper safety regulations	Health, Safety and Environment (HSE)
Improper inspection and maintenance	
The risk related to the above ground pipeline	
Limited warning signs	
Inadequate risk management	
Natural disasters	
Corrosion	Operations Risks (OR)
The weak ability to manage the risk	
Shortage of modern equipment	
Design, construction and material defects	
Operational errors	
Hacker attacks on the system	

The next section provides the findings of the investigations about identifying and classifying the RMMs which could be used to manage the IRFs in OGP projects.

2.4.6 Identification and Classification of RMMs in OGP Projects

In order to make some suggestions about managing the IRFs in OGP projects in Iraq, the investigations of the literature review were extended to identify some of the RMMs which are used to manage the IRFs in OGP projects in different countries and geographical regions. The RMMs were classified according to project stages, depending on an estimate of when these RMMs could be applied during the project stages as follows: planning and design; construction; and operation and maintenance stages (see Table 2.5).

Table 2.5: The identified RMMs in the OGP projects based on the literature review.

RMMs (Hopkins et al. 1999; Rowland, 2010)	Planning & design stage	Construction stage	Operation & maintenance stage
Anti-corrosion such as isolation & cathodic protection		√	√
Move to an underground pipeline	√		
Advanced technological & professional remote monitoring	√	√	√
Proper inspection, tests & maintenance			√
Proper training	√	√	√
Avoid insecure areas	√		
Anti-terrorism design	√		
Avoid registered risks & threats	√	√	√
Protective barriers & perimeter fencing	√	√	√
Government/public cooperation	√	√	√
Warning signs & marker tape above the pipeline		√	√

The RMMs mentioned in the above table are some of the methods used to manage the IRFs in OGP projects. These methods were identified based on the literature review about them worldwide. The findings of the investigations about the RMMs in OGP projects will make the findings of this research suitable for and applicable to many countries as the RMMS were identified from OGP projects in different countries and environments. The identified RMMs in OGP projects will be used to design an industrial survey Chapter 4:) in order to test their degree of effectiveness in managing the IRFs in OGP projects in Iraq. In addition, these methods will be discussed and used to make effective suggestions about risk management in OGP projects in Iraq, as discussed in Chapter 6: and Chapter 7:.

The next section reviews the existing RMFs in OGP projects in order to understand them and highlight their strengths and limitations.

2.5 The Seminal Works in OGP Projects

Section 2.4 explained the process of risk management in the projects in general and identified the term “Risk” in section 2.4.1 and “Risk Management” in section 2.4.2. It also explained the process of risk management in the projects, which includes the main four steps of (i) risk identification and registration, (ii) risk assessment and ranking, (iii) risk response and mitigation, and (iv) risk monitoring and control. With regards to the seminal work on risk management in OGP projects, section 2.4.4 identified the IRFs in OGP projects based on the literature review and section 2.4.5 classified them by their types. Then, section 2.4.6 has identified some of the applied RMMs in OGP projects based on the investigations of the literature review. In addition to the past studies is also about identifying and classifying the RFS and RMMs in OGP projects mentioned in section 2.4.4, 2.4.5 and 2.4.6 .This section is about analysing and criticising the past studies and the seminal works about risk management in OGP projects. It analyses the existing RMFs in the projects mentioned in the past studies as follows. Section 2.5.1 makes a review of the existing RMFs or systems in OGP projects in order to understand their theories and highlight their limitations and strengthens. Carrying on with the criticism of the existing RMFs, section 2.5.2 reviews some of the past studies about selecting safe pipeline routes of the new projects. Section 2.5.3 reviews some of the past studies about analysing the impact of the IRFs on the construction duration of the new pipeline projects.

2.5.1 Review of Existing Risk Management Frameworks (RMFs) or Systems in OGP Projects

There have been many studies conducted in the past about developing a risk management system with the aim of managing the IRFs in OGP projects in a specific country or geographical region. For instance, Mubin and Mubin (2008) developed a risk management system that identified and classified the IRFs in gas pipeline projects in Pakistan. This system identified the IRFs based on analysing a number of local projects and reviews from local clients and contractors. The authors used the Monte Carlo Simulation (MCS) method to simulate the IRFs and provide recommendations for risk management in these projects. Schwarz et al. (2015) proposed a risk management procedure to support decision-making processes in construction projects. The authors started with defining the scope of the projects and the criteria of risk management, and they identified the IRFs in the projects using checklists. They used experts' judgements and the Artificial Neural Network (ANN) technique to analyse the IRFs and provide some recommendations to support the stakeholders regarding risk management. In these two studies, the IRFs were identified only from local review and during the construction stage of these projects. El-Abbasy et al. (2016a) assessed the performance of water distribution networks in Qatar and Canada using a fuzzy analytical network. El-Abbasy et al. (2015, 2016b) carried out similar work in order to assess the conditions of the OGP network in Canada and Qatar. These four studies used available databases to identify the IRFs in the projects.

El-Abbasy et al. (2014) used a historical database and ANN to predict the conditions of offshore OGPs in Qatar and to prioritise the maintenance work in these projects. Li et al., (2019) analysed the IRFs in the subsea OGPs via analysing the precursor data and the fuzzy theory in order to reduce the uncertainty associated with assessing the IFRs and their consequences in the projects. The authors have reduced the uncertainty of analysing the impact of the IRFs on the projects and their scenarios and consequences in the project using the Bayesian analysis. Cheliyan and Bhattacharyya, (2018) and Arzaghi et al., (2018) used the fuzzy fault tree analysis of oil and gas leakage in subsea production systems. However, the authors of the last three mentioned studies did not make suggestions for risk management in the projects. Jiang and Dong, (2020) used the finite elements and machine learning scheme to analyse the impact of the falling objects on the offshore pipelines. In this study, the authors have analysed the correlation between some of the design variables and the safety of the offshore pipelines and they concluded increasing the depth of the pipelines will enhance the safety levels of the pipelines. This study has tried to find the design variables that provide the best performance of the pipelines. However, it did not make suggestions of risk management in term of the actions and recondensations that are required to manage the RFs in the projects. Hameed et al., (2020) and Schjølberg et al., (2016) made a risk-based inspection plan to prioritise the maintenance activities in a way that reduces the time and cost of pipelines repairs. These studies focused on stress-strain risk factors such as corrosion but it did not consider TPD IRFs such as security-related risks. Fuad et al., (2020) developed a risk matrix in order to assess the impact of the fishing trawl activities on the subsea oil and gas pipelines at Sabah and Labuan offshore. The recommendations of this study are applicable to reduce the risk in the offshore OGP projects which results from fishing activities. A study was done by Marcjan et al., (2017) in order to analyse the criteria of accidental damage by shipping anchors of subsea gas pipelines in the Gdańsk bay area. Kawsar et al., (2015) made an assessment of dropped object risk on the corroded subsea pipeline. The measures and recommendations of these two studies were applicable to reduce the damage in the offshore pipelines, which results from dropped objects and ships' anchors.

The studies that are mentioned in the above paragraphs would not be effective to manage the IRFs in OGP projects elsewhere because of the following gaps in knowledge.

1- These studies are based on only a local review of identifying the IRFs in the projects, while the types and characters of the IRFs that affect the safety of the projects in other countries or geographical regions are different.
2- These RMFs are limited to analysing the IRFs during the operation stage of OGP projects. Meanwhile, there is an enormous number of IRFs that affect the safety of the projects during the planning, design and construction stages too.
3- The lack of data about the IRFs in the projects is making the existing RMFs not effectively applicable elsewhere, particularly in the developing countries. This is because unfortunately, there is no good database about the IRFs that affect the safety of OGP projects in the developing countries, where the documentation is not in the best conditions, and there are no appropriate records about the accidents in the projects.
4- These frameworks have not tried to overcome the uncertainty that results from analysing the IRFs based only on the experts’ judgements. This means that the results of risk analysis of these frameworks have a low reliability level.
5- As explained in Chapter 1: the focus of this research is to identify, analyse and manage the RFs in onshore OGPs projects because the OGPs in Iraq are either above or under the ground. In short, onshore OGPs refer to the pipelines that are built under the earth’s surface, which is the type of pipelines that are used to transport the petroleum products in Iraq, and it is the focus of this study. Whereas offshore pipelines are the pipelines that are built underneath the seabed, which are not used in Iraq.

Therefore, it means that the existing RMFs do not have a holistic and comprehensive view about the IRFs in OGP projects. Hence, in order to develop a more integrated RMF, the developed framework must identify the IRFs in the projects based on a comprehensive and worldwide view about them. Additionally, the framework has to address the IRFs that affect the safety of OGP projects during the entire life of the pipeline projects (e.g. during the planning, design, construction and operation stages of the projects). In doing so, the developed RMF will be more applicable and suitable for managing the IRFs in OGP projects in different countries and circumstances across the world.

2.5.2 The Limitations of Using the Existing RMFs for Optimising Safest Pipeline Routes Based on the Impact of the Associated IRFs

Selecting appropriate routes for the new OGP projects during the planning and design stage is essential for obtaining efficient, cost-effective and successful projects (Balogun et al. 2012; Hutson, 2006; Saaty and Özdemir, 2014). The process of analysing the routes of OGPs to select the best ones for the new projects includes analysing many parameters such as the size and the material of the pipes, coating, wall thickness, topography and cathodic protection, and other similar factors Chakrabarti, (2005). In other studies such as Feldman et al. (1995), Montemurro et al. (1998) and Matori and Lee (2009), the authors have considered more parameters to select the best route for the new OGP project, such as environmental, physical, societal, political, regulatory, technical and economic issues.

With regard to selecting optimal locations for oil and gas projects, Çetin Demirel et al. (2017) have used the fuzzy theory in order to choose a good location for a gas depository in Turkey. The criteria that were suggested to compare between the locations to build the gas depository were (i) cost (e.g. step up, manufacturing and operation costs); (ii) time (e.g. materials delivery time, and facilities lifetime); (iii) risks (e.g. earthquake, ecological effects, and security); (iv) social factors (e.g. local policy, political situations, and other social factors); and (v) environmental factors (e.g. nature areas, roads, water resources, etc...). The mentioned criteria were suggested based on communications between the authors and one of the staff members in the project, which is one of the limitations of this study. This is because even such communications could provide data for the study; this data will be limited to the personal thinking of both the staff member and the authors. In such a case, the data will not provide extensive knowledge about the IRFs that might affect the safety of the gas depository. Moreover, the criteria of the study were evaluated based on the review of five decision-makers, which is not enhancing the reliability level of the findings of that study, as the size of the participants' sample of the study is small. Additionally, selecting a good location for a gas depository is easier than selecting the safest pipeline route from the safety aspect in OGPs, as these pipelines are stretching over thousands of kilometres, which makes them more vulnerable to safety hazards and supply reliability.

With regard to selecting optimal routes of pipeline in the OGP projects, Kang and Lee, (2017) have designed an automated obstacles avoidance method to select a route with lower cost for subsea offshore pipelines. Balogun et al. (2017) have used the fuzzy theory and the Geographical Information System (GIS) to choose optimum routes of subsea oil pipelines. They have assessed the pipeline routes based on the environmental impact, cost-effectiveness, and engineering constructability. The subsea oil pipelines are underwater, which means they are subject to different types of IRFs compared to the above ground pipelines.

Mundia and Macharia (2018) developed a GIS model in order to select optimal routes for the oil pipeline projects in Isiolo Nakuru. This study has considered several criteria such as the length of the pipeline; the topography, geology and soil types and pollution in the routes; the environmental impact of the pipelines (e.g. crossing forests, rivers, wetlands, and groundwater); and the clash with other projects (e.g. parks, rail-line and roads) to identify optimal routes for these projects. The criteria were weighted via engaging with a number of experts in the field using the Analytic Hierarchy Process (AHP) technique. The fuzzy theory was used to reduce the uncertainty associated with using the experts' judgements to weight the criteria of the study. Abudu and Williams (2015) used a GIS-based methodology to select optimal routes for OGP projects in Uganda. The routes were evaluated after considering the environmental, economic and security concerns associated with the projects. One of the recommendations of this study is to make further studies about the socio-political, socio-economic and religious related IRFs 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.

Risk avoidance is one of the vital things that have to be considered during the process of route selection of OGPs. In troubled regions, OGPs are frequently suffering from a massive number of sabotage and terrorist attacks. Therefore, selecting the safest routes for the new pipelines in these regions is vital. However, the past studies (as explained in the paragraphs above) have mainly focused on considering the technical factors (e.g. cost and environmental aspects) while selecting the routes for the new OGP projects. Which means in most cases, the past studies were selecting the pipeline routes that have less cost and environmental impact for the new pipeline projects. In other words, the majority of the past studies have not analysed or considered the impact of the external IRFs such as TPD on the routes of the pipelines projects. Also, due to the limitations of these studied that result from being based on local reviews and using local scales about assessing the IRFS in the pipelines routes, the existing models about analysing the routes of OGPs will not be effectively applicable elsewhere. The selection of the pipes' routes, therefore, requires more human investigations by skilled engineers with good experience in this field, which is time-consuming (Kang and Lee, 2017). Due to the mentioned limitations of the existing RMFs in OGP projects and the lack of data about the IRFs in OGP projects in the developing and insecure countries, a questionnaire survey with a good number of responses and appropriate data sampling is required to provide trusted data for analysing the pipeline routes see Chapter 4:, Chapter 6: and Chapter 7:.

The next section shows the limitations of using the existing RMFs to analyse the impact of the IRFs on the duration of OGP projects.

2.5.3 The Limitations of Using the Existing RMFs to Quantify the Impact of the IRFs on OGP Projects

Project management involves making schedules for the project activities in order to monitor the project's time progress (Shah and Dawood, 2007). Delay is one of the most common problems in the majority of construction projects in both developed and developing countries (Ahmed et al. 2003; Shebob et al. 2012; Enshassi et al. 2009). Delay may happen in every project during the construction stage, but it varies between the different projects and the different countries (Alaghbari et al. 2007; A. Shebob et al. 2012). Understanding the delay factors and their level of impact on a project may help to avoid or minimise the project delay (A. Shebob et al. 2012; Abdulhamid Shebob et al. 2012). Providing good knowledge about the IRFs and using analytical or simulation techniques are the most effective methods of risk assessment (Ruwanpura et al. 2004). Morano et al. (2006) explained that several techniques could be used to analyse the risks in construction projects. For instance, checklists, interviews with the stakeholders, brainstorming, surveys and the Delphi technique, as discussed below.

Morano et al. (2006) identified the main delay factors in construction projects in Jordan via examining the records of 130 public projects in the country. Choong Kog (2018) identified and ranked the delay factors in construction projects in Portugal, the UK, and the US via examining 13 studies about the problem of construction delay in these countries. These two studies were limited to analysing the delay factors in construction projects in the mentioned countries only. Kim et al. (2005) analysed the delay in construction projects via dividing the projects into sections and calculating the delay in each section. Eizakshiri et al. (2015) analysed the delay factors in construction projects internationally. These studies did not make any assessment about the delay factors or quantify their impact on the projects. For example, they did not use any kind of survey, computer modelling or simulation methods to analyse the delay factors and quantify their impact on project duration.

Shah (2016) identified the comparative delay factors in construction projects in countries such as 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. (2019) 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 (2017) to analyse the frequency and the severity levels of the delay factors in the construction of electrical projects in Hong Kong. Mpofu et al. (2017) 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. Alaghbari et al. (2007) distributed a questionnaire survey to analyse the delay factors in construction projects in Malaysia. Kadry et al. (2017) 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 a number of experts in these countries. (A. Shebob et al. 2012) analysed 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 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 oil and gas projects and improve the level of safety of these projects elsewhere.

Fallahnejad (2013) 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. (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 for the countries of GCC (Gulf Cooperation Council): Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE. Rui et al. (2018) carried out a comprehensive study to identify the IRFs that affect the schedule of oil and gas projects in Nigeria. 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 oil and gas projects and improve the level of safety of these projects elsewhere.

Analysing the impact of the IRFs on the duration of 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 a minimum, as much as possible. However, there is a lack of studies analysing and quantifying the impact of the IRFs on the duration of OGP projects in developing countries such as Iraq. In addition, oil and gas projects have a unique characterisation compared to the other types of projects; this is because of their massive interface, large investments and complex engineering endeavours (Ruqaishi and Bashir, 2015; Sweis et al. 2019). 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 IRFs on the duration of OGP projects, which is the main aim of this research study.

In summary, the methods of delay assessment methods as discussed above (e.g. using the records, checklists, interviews, and surveys) are inadequate to make an accurate estimation of the delay impact caused by the IRFs in OGP project elsewhere. In other words, these methods can not be used to analyse the delay in a developing and insecure country similar to Iraq because of a number of the following gaps in knowledge. For example, the records about delay and risk factors are either not available or not accessible in OGP projects in Iraq and the security level in iraq is low, which makes the projects subject to different types of RFs particularly, the risks related to third-party disruption.

2.6 Summary and Research Gap

This chapter presented an overview explanation of the OGP projects. It also described the importance of the oil and gas industry and the importance of the OGP projects to the global market and local economy in Iraq.

After an in-depth review of the literature about the risk management processes and systems in OGP projects, this research explains the research gap by summarising the limitations of the prior studies regards identifying, analysing, assessing and ranking the IRFs in the projects, as follows.

- Most of the studies about risk management in OGP projects are mainly at the local scale, and only a few studies have analysed the pipeline projects in more than one region. In other words, the risk management methods in these projects are focusing on different types of IRFs in different regions and situations. This means that the existing risk management methods are not effectively applicable in OGP projects elsewhere.
- The existing risk management methods are not active in managing the IRFs in OGP projects when the data and records about them are scarce, which is the case in developing countries such as Iraq. This is because the documentary and recording procedures in these countries are poor. Such data conditions lead to random, vague, uncertain, inaccurate and low reliability assessment results of the IRFs in OGP projects.
- There is a lack of studies about evaluating the risk mitigation methods which could be used to manage the IRFs in OGP projects with regard to their degree of effectiveness in managing the IRFs in these projects, which leads to inadequate responses for these risk factors.

A risk table that identifies the IRFs and RMMs in a project is the first and most fundamental step for any risk evaluation and assessment procedure. This chapter, therefore, provides a comprehensive view about identifying the IRFs and RMMs in OGP projects worldwide. The findings of this chapter provide a list of the potential IRFs and RMMs associated with OGP projects worldwide, in addition to the pros and cons of the existing methodologies of risk management systems used in these projects. These findings will be used to design an integrated RMF, which is the main aim of this research. Moving forward with the study, the findings of this chapter will be used in the next chapter of this research as follows.

- The identified IRFs (Table 2.3 and Table 2.4) and RMMs (Table 2.5) in the OGP projects will be used to design an industrial questionnaire survey in Chapter 4: in order to analyse their effect on OGP projects in Iraq.
- This chapter has highlighted the limitations of using the existing RMFs to manage the IRFs, select safe routes/alignments and analyse the impact of the IRFs on the construction duration in OGP projects in Iraq, see section 2.5. The findings of this

section, along with the findings of the questionnaire survey in Chapter 4: and the findings of the computer model in Chapter 5:, will be used later on in this study to develop the RMF as shown in Chapter 6:.

The RMF will be used in this research to analyse the time impact of the IRFs on the duration and the routes/alignments of the new OGP projects in Iraq. Additionally, the RMF will be used to provide useful recommendations about risk management for OGP projects in the country.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the research philosophy, research approach/theory and research design followed by this study. This research aims to develop an effective Risk Management Framework (RMF), which will be designed based on the results of investigating the impact of the Influencing Risk Factors (IRFs) associated with Oil and Gas Pipeline (OGP) projects in order to ensure safer design and construction for these projects.

This chapter is organised under different sections as follows. Section 3.2 explains a general view of the research philosophy, approaches, theories and design which are normally used in research studies in the construction industry. Section 3.3 explains the data sampling methods used to collect research data in research studies and section 3.4 explains the design of the questionnaire survey used to collect the research data of this study. Section 3.5 explains the sources and the types of the collected research data in this study. Section 3.6 explains the data analysis methods used to analyse the data collected from the survey and the process of evaluating the results of the survey. The research strategy explains the procedure, the sequence, the steps and the techniques used to accomplish the aim of a piece of research (Babbie, 2016). In order to achieve the aim of this research, section 3.7, therefore, will use the findings of the previous section in order to explain how the survey data were used for designing the structure of this research study and it explains the contents of the following chapters as well. Section 3.8 presents the chapter summary and the link between the study chapters.

3.2 Research Method and Methodology

3.2.1 Research Philosophies

P*aradigms are constituted by sets of interconnected philosophical assumptions regarding the reality, knowledge, methodology, and values. The assumptive sets of different paradigms are different in important ways, but paradigms themselves are historical and social constructions and so are not inviolate or sacrosanct. Paradigmatic assumptions importantly guide and direct practical inquiry decisions, along with context and theory. Important paradigm differences should be respectfully and intentionally used together to engage* *meaningfully with a difference and, through the tensions created by juxtaposing different paradigms, to achieve the dialectical discovery of enhanced, reframed, or new understandings*" (Greene, 2007, p. 69 cited in Schoonenboom, 2019, p. 285). In addition to the exploitation in section 1.6, the pragmatic research philosophy was used to make research assumptions of this study; for example, (I) Third-Party Disruption (TPD) is the most influencing risk on the pipeline projects in Iraq. (II) It is more challenging to manage the risks in the projects in the situation of a low level of security and poor documentation about the risks. (III) The existing RMFs would not be effective in managing the risks in the pipeline projects in a country such as Iraq, in which the pipelines are suffering from the frequent attacks of sabotage. (IV) Developing an integrated and holistic RMF could be used to enhance the culture of risk management in the projects. For the purpose of risk identification, risk assessment and the design of the RMF, its research, therefore, tried different research philosophies such as the pragmatism research philosophy as discussed below.

The pragmatist paradigm is adopted when mixed methods and approaches are required to design research studies (Brierley, 2017). The pragmatism philosophy can provide support for mixed methods approaches to design the methodology of a research study (Tashakkori and Teddlie, 2010). In other words, when mixed methods of data collection and analysis are required to design research studies, then a pragmatist paradigm philosophy will be used to achieve their aims. Different methods were needed in this research to identify and assess the risk factors and risk mitigation methods in oil and gas pipeline projects as follows. The literature review was used to identify and classify the risk factors and risk mitigation methods in the projects, and inductive and deductive research approaches and qualitative and quantitative research methods were used to assess the risk factors and design the RMF. In summary, according to the justification presented above, the pragmatist paradigm philosophy is adopted in this study to design the RMF in this research. The strategy of the literature review use in this research is explained in section 3.2.2. The applications and findings of the inductive and deductive research approaches were explained in section 3.2.3. The applications and findings of the qualitative and quantitative research methods were explained in section 3.2.4. Section 3.2.5 explains different mehods used in research studies. The findings of this section will be used to design the methodology of this research, see section 3.7.

3.2.2 Literature Review Strategy

The literature review was conducted according to the standard stages of review, as follows: (i) setting the review question; (ii) making exhaustive searches for studies from different environments and geographical regions; (iii) applying inclusion and exclusion criteria (the RFs that threaten the safety of the pipelines); extracting data; and (iv) synthesizing findings, as explained in the following sentences. This study tries to analyse and evaluate the existing approaches of risk management in OGP projects based on pieces of evidence extracted from peer-reviewed published papers about the risk management of these projects. The review questions were (i) what are the RFs that threaten the safety of OGPs in different environments and geographical regions? (ii) what are the limitations of the existing RMFs regards identifying, assessing, ranking and managing the RFS in OGP projects. The way forward is the development of a systematic literature review started by analysing the secondary data about identifying the RFs based on the analyses of the 22 publications mentioned in Table 2.3. In the second stage of the systematic literature review, this study has analysed the publications about RMFs in OGP projects to understand the theories and highlight the limitations and strengths of the existing RMFs in OGP projects. Similarly, the third, fourth and fifth stages of the literature review were about analysing the theories and highlighting the limitations and strengths of the past publications with regards to identifying safe routes for the new OGP projects, making suggestions of RMMs and analysing the delay in the projects caused by the associated RFs, respectively. In summary, the literature review has addressed the questions beyond the impact of the RFs and the effectiveness of the RMFs in OGP projects. Also, it has highlighted the theories, the limitations and the strengths of the existing RMFs, which were used to develop an integrated RMF that was used in this study to understand, identify, assess, rank and manage the RFs in OGP projects.

The next section explains the different approaches to data collection that are mainly used by research studies.

3.2.3 Research Approaches (Inductive and Deductive Approaches)

The section provides a definition of the inductive and deductive research approaches.

1- **The inductive approach** is defined as "*a study in which the research theory is developed from the observation of empirical reality*" (Alali, 2010) p. 169. The inductive research approach is used to compare data and create themes for a research study (Almadhlouh, 2019). Feibleman (1954) first stated that an inductive research study serves three main objectives, which are discovering the research hypotheses, finding supportive evidence and predicting the future. He also explained other features of inductive study, such as it starts with subjective data analysis, it requires less data compared to the deductive approach, it is not self-corrective, it seeks timeless generality and it discovers new ideas as a hypothesis (Feibleman, 1954; Alali, 2010).

A qualitative research approach is an inductive approach to data analysis (Creswell, 2009). Qualitative research uses inductive data analysis, whereby researchers build from the bottom up (Creswell and Creswell, 2017). In other words, an inductive research study builds the hypothesis, then deduces the approach used to test the answers to the research questions and deduces the results from data analysis (Alali, 2010).

2- **The deductive approach** is used to move the research from the general concept to the practical test of the problem (Collis and Hussey, 2013). This means that the research is moving to test a specific problem, which was identified based on general observations made on the reach topic based on the literature review (Alali, 2010). The deductive research approach discovers pieces of evidence that support each theme and determines whether or not they require more information (Taylor et al. 2015). The deductive research study, therefore, uses empirical observation to test the conceptual and theoretical research structure developed in research studies (Collis and Hussey, 2013). Figure 3.1 shows the inductive and deductive parts of the research.

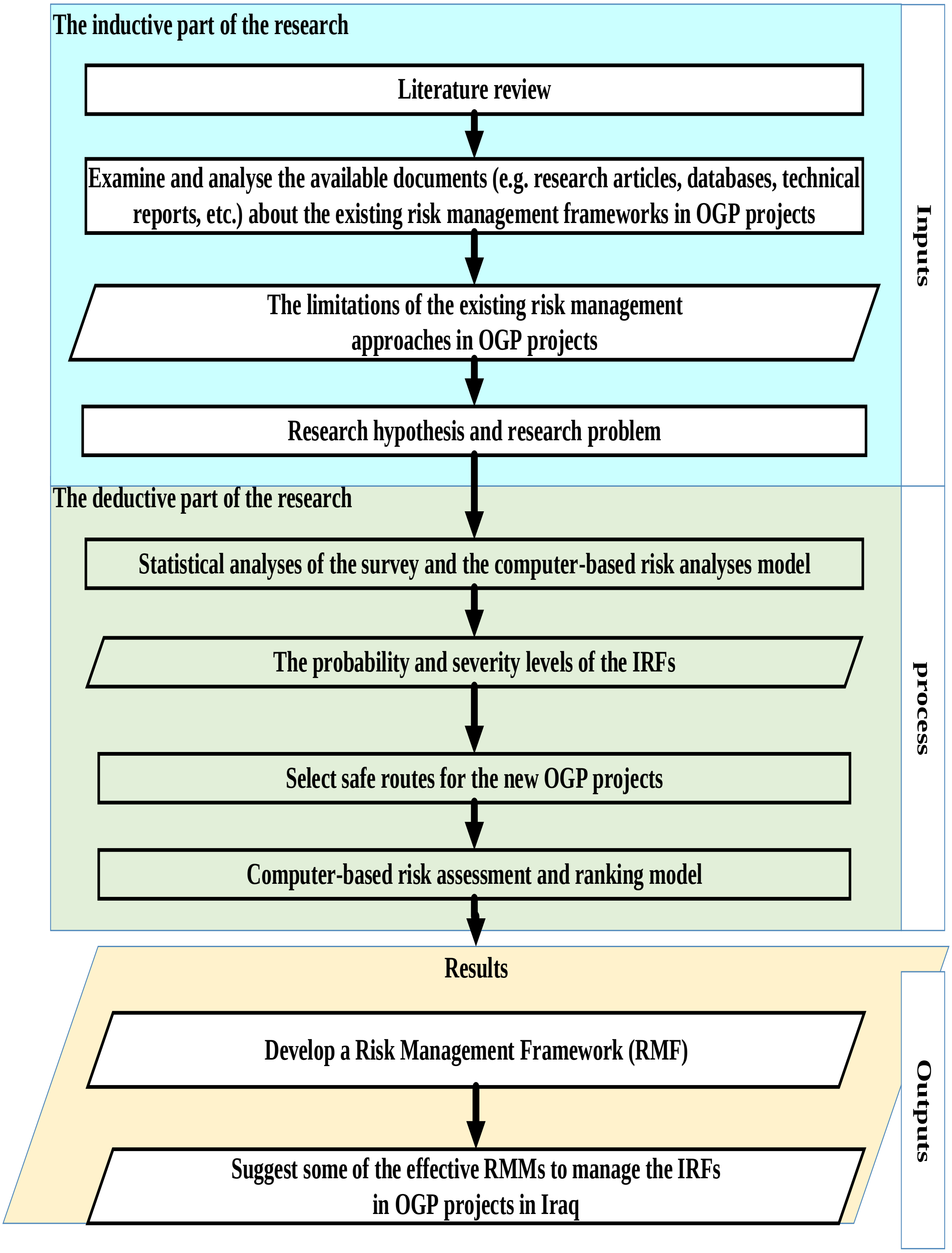

Figure 3.1: The inductive and deductive parts of this research.

As shown in the figure above, the inductive part of this research was the investigation of the literature review about IRFs and risk management in OGP projects, where the research problem has been highlighted. Additionally, this research started with an inductive approach to data analysis of the literature in order to understand the limitations in the existing Risk Management Frameworks (RMFs) in OGP projects, which is where the hypothesis of this research has emerged from. The hypothesis of this research was based on "*overcoming the limitations in the existing RMFs and providing a good culture about risk management will help in improving the level of safety in OGP projects*". Meanwhile, the deductive part is to analyse the impact of the IRFs on OGP projects using an industrial survey, statistical analysis, fuzzy theory and Monte Carlo Simulation (MCS). For that, a mix between inductive and deductive research approaches was used.

The findings of this section will be used to design the research methodology, see section 3.7.

Both qualitative and quantitative methods are used for research data collection and analysis in this research study. The definition and difference between the qualitative and quantitative methods are explained in the next section.

3.2.4 Qualitative and Quantitative Methods

This section provides a definition of the qualitative and quantitative methods used in research studies as explained below.

1- **The qualitative method**: the descriptive qualitative method examines the available documents and studies to understand the situation and define the problem of a particular phenomenon (Davey, 1991; Leedy and Ormrod, 2005; Burns and Grove, 2010). Additionally, this approach uses observations to analyse and collect information from expert individuals (Amaratunga et al. 2002; Dzudie, 2013; Fischer, 2005). A qualitative method approach uses subjective judgement, attitudes, opinions and behaviour analysis to understand and analyse research data (Shah, 2011). This approach uses an exploratory and descriptive rather than a quantitative, interpretive approach to understand an issue without judgement (Dowling, 2007). This approach is an appropriate approach for understanding the features of an observed phenomenon (Dzudie, 2013). A qualitative research method, therefore, is preferred when the available literature regarding the topic of research is limited (Creswell and Poth, 2016). The qualitative research approach involves using several techniques, for example, phenomenological, grounded theory ethnography, narrative, and case study are the main techniques used in the qualitative research approach (McCaslin and Scott, 2003). The definition of each technique is explained below.

   - **Phenomenological** technique. Phenomenology is described as the study of the shared meaning of experience of a phenomenon for several individuals.

"The understanding of meaningful concrete relations implicit in the original description of experience in the context of a particular situation is the primary target of phenomenological knowledge".

- **Grounded theory**. In grounded theory, the researcher generates an abstract analytical schema of a phenomenon, a theory that explains some action, interaction, or process. This analysis occurs primarily through collecting interview data, making multiple visits to the field (theoretical sampling), attempting to develop and interrelate categories of information via constant comparison, and writing a substantive or context-specific theory.
- **Ethnography**. Ethnography is described as a study of an intact culture or social group (or an individual or individuals within a group) based primarily on observations and a prolonged period of time spent by the researcher in the field. The ethnographer listens and records the voices of the informants with the intent of generating a cultural portrait.
- **Narrative Approach**. Narrative research or inquiry is rooted in several social and humanities disciplines such as anthropology, and sociology. Narrative researchers are seeking "experiences as expressed in lived and told stories of individuals.
- **Case studies**. Case studies in qualitative research are investigations of "bounded systems" with the focus being either the case or an issue illustrated by the case(s). A qualitative case study provides an in-depth study of this "system," based on a diverse array of data collection materials. The researcher situates this system within its larger "context" or setting.

In this research, the IRFs and RMMs in OGP projects were identified based on analysing researches, studies, reports and databases about risk management in OGP projects. Therefore, the phenomenological, grounded theory, ethnography and narrative techniques of qualitative research have not been used in this research. In other words, due to the limitations of data about the IRFs and RMMs in OGP projects in the developing countries, the IRFs and RMMs were identified via analysing prior studies and reports about assessing and managing the IRFs in OGP projects in different parts of th worlds rather than making interviews, which also enhances the outcomes of this research by making them applicable in more counties. Which means this research has used a case studies technique of qualitative research because the outcomes of the literature review (i.e. the IRFs, the RMMs and the limitations of the existing RMFs) have been identified after reviewing and analysing the prior studies of risk management in OGP projects.

2- **The quantitative method**: the quantitative approach uses statistical analysis of the collected data (e.g. questionnaires) to understand and measure the studied phenomenon (Blaikie and Priest, 2019). The quantitative approach involves using a questionnaire survey and simulation (Shah, 2011) to assess and rank the risk factors in the projects.

However, in many studies, the qualitative and quantitative methods could be combined to provide the required data for the researches (Miller and Brewer, 2003). After defining the qualitative, quantitative and mixed research methods, this research has used a mixed research approach to achieve the aim of the study, as shown in Figure 3.2.

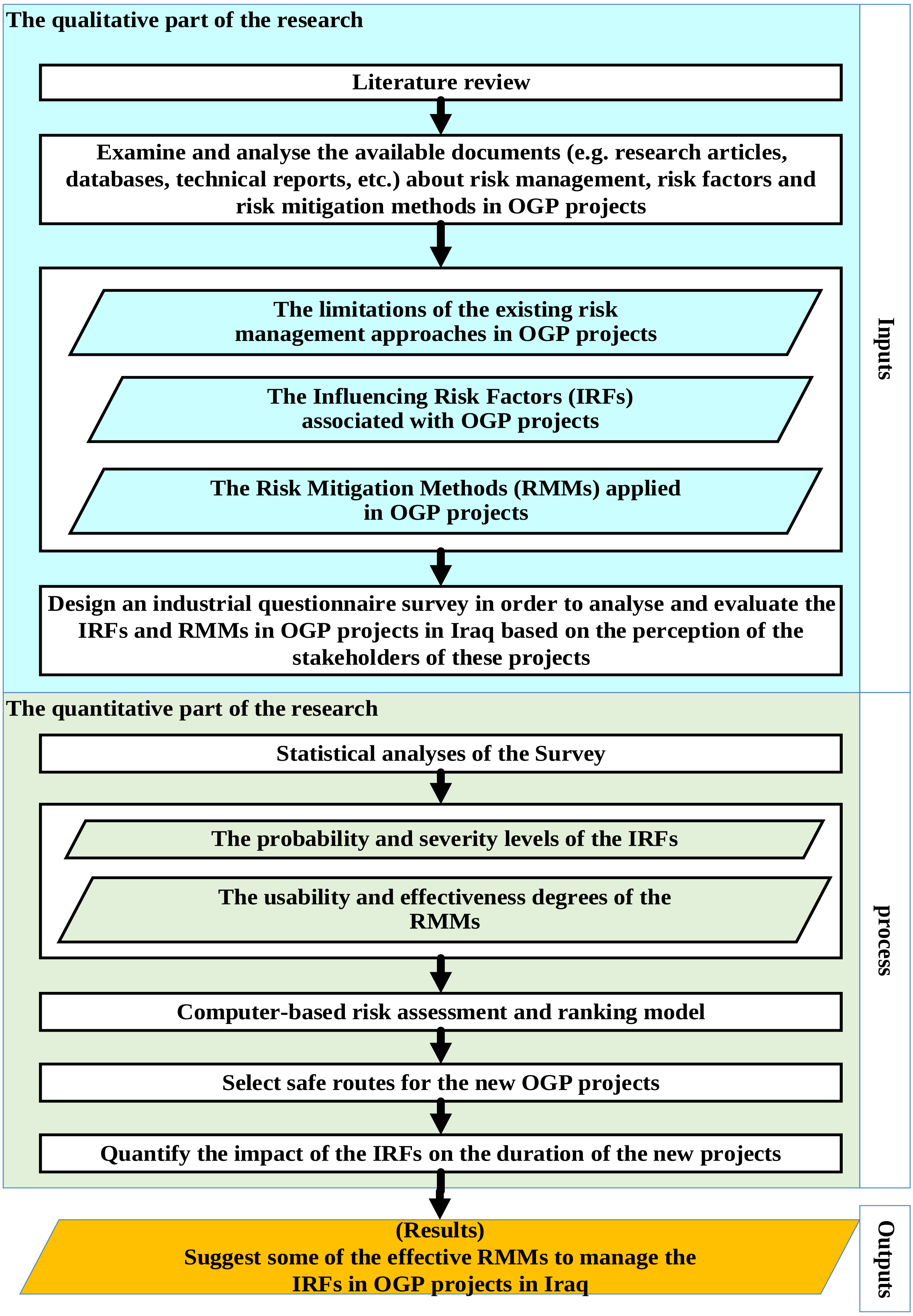

Figure 3.2: The qualitative and quantitative methods of this research.

The qualitative and quantitative methods of this research, as presented in Figure 3.2 above, are detailed below.

1- The purpose of the qualitative part of this research is to identify the IRFs, the Risk Mitigation Methods (RMMs) and the limitations in the existing systems of risk management in OGP projects based on qualitative document analyses of the literature review. This means that no measurements have been made in this part of the study related to assessing, ranking and quantifying the impact of the IRFs in the projects. The advantages of using a qualitative method in this research are: (i) overcoming the problem of data scarcity about risk management, and (ii) identifying the IRFs and RMMs in OGP projects in Iraq. In other words, the findings of the qualitative approach of this research have helped in providing the essential data for this research, which were used to design a questionnaire survey, as explained in Chapter 4:. However, these data could not be used to analyse the impact of the IRFs and the effectiveness of the RMMs in OGP projects.

2- The purpose of the quantitative part of this research is to analyse the impact of the IRFs and RMMs in OGP projects in Iraq. Furthermore, subjective and objective document analysis and fuzzy theory (in Chapter 5:), MCS, LHS (in Chapter 8: and Chapter 9:) were used in this research to analyse and rank the IRFs in the OGP projects and optimise the IRFs in OGP projects using a real case study project.

In summary, the findings of the qualitative approach of this research are the IRFs and the RMMs in OGP projects and the theory, the limitations and the strengths of the existing RMFs, which were identified based on the investigations of the literature review. These findings were used to design a questionnaire survey to analyse the IRFs and RMMs in OGP projects in Iraq and design an RMF, which are some of the outcomes of this research. On the other side, the findings of the quantitative approach of this research are the probability, severity and impact levels of the IRFs, and the effectiveness and usability degrees of the RMMs in the projects; the safest pipeline routes for the new projects (based on the results of risk optimisation); the effective RMMs in the projects; and the delay impact in the projects caused by the associated IRFs (based on the results of MCS and LHS). All of the qualitative, quantitative and mixed methods were meant to continuously improve the safety level of OGPs during the lifecycle of these projects. The next section provides an overview of the research methods mainly used in research studies.

3.2.5 Research Methods

Chu (2015) qualitatively analysed 1,162 research articles, published from 2001 to 2010 in three major journals of library and information, to address some recurring themes about research methods selected and applied in studies in the scholarly domain. In this study, the author identified the main research methods used in these studies, which are questionnaire survey, analysing the historical method previously held, content analysis, experiment, and theoretical approaches. The definitions of these research methods are as follows.

1- A survey can be defined as a method of collecting data or information through collecting the perception of the targeted population about a certain phenomenon (Content Creation Agency, 2016). Questionnaire surveys offer a systematic way of collecting information from individuals and groups via answering a set of questions prepared by the author(s) to collect the research data. These questions might be multi-choice questions, open-ended questions or a mixture of these two types (NFER, 2020).

   The questionnaire is commonly used to ask participants questions prepared by the researcher(s) (i.e. the surveyor(s)) to collect baseline data to be used for analysing a certain phenomenon later on (Gosling and Edwards, 1995, cited in P.E.T.C.P. 2020).
2- Historical data include statistically analysing the available historical data about a certain phenomenon, which is commonly used in economics studies (McDonald, 2006).
3- Content analysis has been conducted by researchers in past research studies to analyse the available documents (e.g. annual reports and historical data) to collect the research data. Content analysis is a highly flexible research method that has been widely used in science research studies, which have varying research goals and objectives. This method uses qualitative, quantitative and sometimes mixed modes of research approaches to analyse the research data to obtain the findings from the research findings (White and Marsh, 2006). Content analysis is a research method for analysing the written verbal or visual data using a relevant strategy for conducting the research data (Cole, 1988).
4- Experiment research is defined as a research method for testing different assumptions (hypotheses) by trial and error under conditions constructed and controlled by the researcher(s). During the experiment, one or more conditions (called independent

variables) are allowed to change in an organised manner and the effects of these changes on associated conditions (called dependent variables) are measured, recorded validated, and analysed for arriving at a conclusion (Winston, 2018).

5- Chu (2015) has also added two recurring themes regarding research methods, which have also been used in past research studies, which are: (i) the use of multiple methods in one study, and (ii) education, training and advocacy, which are used by researchers in research studies to gain a better understanding of research methods and make more informed decisions on research method selection and implementation in their scholarly endeavours.

Based on the explanation above, a questionnaire survey was used as the research method to analyse the IRFs and RMMs in Iraq. This is because the available data about them in OGP projects in Iraq is limited (Kraidi et al. 2020). Moreover, more methods such as statistical analysis of the data collected from the survey and computer modelling (e.g. fuzzy theory and MCS) were used to calculate the degree of impact of the IRFs on the projects.

The next section explains the different methods of sampling the research data.

3.3 Data Sampling

A sampling method is a procedure that is followed for selecting participants from the targeted populations to represent them in a research study (Almadhlouh, 2019). In other words, since it is impossible to study entire populations, research studies need to take samples of these populations, which will work as subsets of the targeted larger populations to represent them in the study (Acharya et al. 2013). In doing so, the research studies can provide and/or use a representative sample to study and analyse a certain phenomenon in a large population with less manpower, less time and less cost.

There is a need in any survey to select the right sample from the targeted population. This is because, in general, questionnaire surveys create many non-respondents. Therefore, getting the right people to participate in the survey is extremely important. Dzudie (2013) explains the main sampling methods in research studies include convenience, purposive, cluster, volunteers, random, surveys (e.g. questionnaire, Delphi, focus group and interviews), and snowball. Bloomberg and Volpe (2008) clarified that sampling methods are either "purposeful" or "random" methods. According to Bloomberg and Volpe (2018) "*The logic of purposeful sampling lies in selecting information-rich cases with the objective of* *understanding the studied phenomenon*". Cited by (Dzudie 2013, p. 75). The purposeful sampling method is useful when the size of the sample is small, such as 20 persons, as done in Dzudie (2013). Meanwhile, a random sample is typically used to enable data gathering from a big group of responses.

Acharya et al. (2013) used a more general way to classify the data sampling methods in research studies. The authors explained that the data sampling methods are either probability or non-probability sampling methods, which are defined as follows.

1. **Probability sampling methods**, which allow the researcher to generalise the findings of the samples to the targeted populations, such as simple random, systematic random, stratified random, cluster, multiphase and multistage sampling methods. The definitions of these sampling methods are provided below.
    1.1. **Simple random sampling**, which uses tables, lottery, currency notes, or computer programs, etc., to select a random number of elements/individuals to represent the targeted population. In this sampling method, all of the elements/individuals have the same chance of being selected. This method ensures the minimum number of the sample that represents the population. However, it requires a framework and it might tend to have a large sampling error, which are some of the limitations of this method (Daniel, 2012).
    1.2. **Systematic random sampling**, which is similar to the simple random sampling. However, the size of the sample (the number of the selected elements/individuals) will be decided from the beginning. This sampling method has a moderate usage, moderate cost, high internal and external validity, and it is easy to verify. However, in this sampling method, the first element/individual is always selected, which means that the elements/individuals do not have the same chance of being selected (Acharya et al. 2013).
    1.3. **Stratified random sampling** is a stereological data sampling method that provides a framework to quickly build an accurate estimation of the distribution of the elements/individuals within the targeted population with a minimum number of observations required. This method allows accurate, unbiased and appropriate sizes of samples within the population. However, it is used mainly in laboratory-based research studies. Additionally, it is laborious, which means it requires the user to make hundreds of samples to get the appropriate sample to use in the research. And it has a high chance of errors being easily made during the sampling work, and it is

difficult to pause and recommence work (Gundersen et al. 1988; Wright et al. 2015). This method is widely used in scientific research studies such as examining the effect of a nuclear station on the surrounding area, DNA analysis, web-based design and virtual analysis tools.

1.4. **Cluster sampling**: this method can be used to conduct rapid assessment and sampling from the targeted populations that are wanted/needed to be studied. This method is useful when rapid assessment/sampling is needed to only estimate the proportion of the population with specific needs (Malilay et al. 1996).

1.5. **Multiphase sampling**: in this sampling method the population is divided into groups. The groups are randomly selected and then the members are randomly selected within these groups (an equal number is selected from each group). This sampling method is mostly carried out to increase precision, reduce costs and reduce non-response. However, it is a complex sampling method and needs different stages to select the samples that represent the targeted population (Acharya et al. 2013).

1.6. **Multistage sampling**: this method involves three main stages, as follows. The first stage of sampling is called ‘primary sampling data”, the second stage is called “secondary sampling data”, and the third stage is known as “tertiary sampling data”. These stages will be followed by the “final” or “ultimate” sampling stages until one sample that represents the targeted population is reached (Acharya et al. 2013). However, it is time consuming and needs different stages to select the sample that represents the targeted population.

2. **Non-probability sampling methods**, such as convenience/purposive, quota, and snowball sampling. These sampling methods are defined below.

2.1. **Convenience/purposive sampling**: this sampling method depends on selecting the elements/individuals when they are in the right place at the right time, such as patients coming out of hospital and meeting the surveyors. This is a widely used method in research studies. However, the variability and the bias of this sampling method cannot be measured or controlled. And, the results from the collected data cannot be generalised to represent the targeted population.

2.2. **Quota sampling**: the sampling procedure ensures that a certain characteristic of a population sample will be represented to the exact extent that the investigator desires.

2.3. **Snowball sampling:** the survey is initially distributed to a number of previously identified participants who are also asked to forward it to others until the required number of responses is reached (Dragan and Isaic-Maniu, 2013).

In this research, the sampling method that will be used should recruit as many participants from the planners, designers, members of construction teams, operators and clients working on the projects as possible. This is because the analysis and evaluation of the IRFs and RMMs must be based on a wide range of experience and number of perceptions of the stakeholders in these projects. Ensuring a wide range of experience and participation from the stakeholders in the survey enhances the results of the survey and provides trusted and valid information about the IRFs and RMMs, which enhances the findings of the RMFs and the findings of this research. Therefore, in order to enhance the research outcomes and recruit a large number of participants in this research, the data were collected using an industrial survey and snowball sampling method, see Chapter 4:. The survey, therefore, was distributed using an online webpage in order to collect the perceptions of the OGPs' stakeholders with regard to the issues in their projects, as explained below.

3.4 Questionnaire Survey

The literature shows different types of surveys with regard to the distribution methods. For example, face-to-face survey (by giving the participants the paper forms of the survey in person), phone survey (by asking the participants about the survey questions via phone calls), postal survey (by sending the survey forms to the participants via the post), email survey (by sending the survey forms to the participants via email) and online surveys (by distributing the survey forms using online link/webpage). The differences between using these methods to distribute and collect the research are as follows.

- **In the face-to-face survey**, the researchers are going physically (in person) to distribute the survey and collect data from the participants. Such a survey is costly, time-consuming, and it might be applicable if the size of the targeted population is small and they are limited to one or two geographical locations, which are nearby and accessible/reachable by the surveyors.
- Asking the participants **via phone** calls is difficult for both sides, the researchers and the participants. This is because it is difficult to set up appointments with so many

participants depending on their availability, and it is even more complicated if the participants are located in different time zones.

- **The postal survey** requires the sending of too much postal mail (probably thousands) to the participants, which is costly and time-consuming.

  Moreover, none of these survey types are environmentally friendly as paper, ink and electricity are consumed in printing the forms and distributing them.

- **Email survey** is similar to the mail survey, but it does not consume paper, which is one of its advantages.

  Additionally, collecting the participants' answers on individual forms (e.g. post, emails) makes data entry and analysis difficult for the researchers, and it increases the chances of errors and mistakes during transferring the answers to the digital-based platforms (such as SPSS or Excel) to analyse them.

  Furthermore, one of the disadvantages of these methods of survey distribution is that they require collecting identical and personal information about the participants. For instance, their names, organisations, addresses, phone numbers emails, etc. The answers of the participants, therefore, would not be anonymised. Such information reduces the confidentiality of the survey and reduces its response rates. Moreover, the direct contact between the researchers (i.e. the surveyors) and the participants might influence the perceptions of the participants and make biased answers. Further and above, storing the collected data from the above-mentioned surveys safely is difficult, as there will be too many papers that need a secure place, which will cause difficulty to the researcher to work on the collected data elsewhere. Additionally, it is difficult to destroy the physical copies of the collected data after finishing the research studies.

- **An online questionnaire survey** was used in this research as it easy to manage, less costly, quick and environmentally friendly (Kumar, 2019; Dolnicar et al. 2009). There are, however, some disadvantages/limitations associated with online services that could result in a low response rate such as a lack of accessibility to the internet, issues regarding computer literacy, web security and anonymity and knowledge about the website. That said, authors such as Bertot (2009) and Czaja and Blair (2005) have concluded that online surveys are the easiest form of data collection as the open-ended questions provide a chance to the participants to cooperate and write their ideas about the topic of the survey. Additionally, the participants in the online surveys would not need to provide their personal information (if they have not been asked for it), which makes the data of the survey anonymised and confidential; and there will be no direct contact between the researchers (i.e. the surveyors) and the participants, which reduces the chances of collecting biased answers. Moreover, using a secured digital platform for storing the collected data helps in ensuring the confidentiality of the collected data and allows the researchers flexibility to access the data from different locations. Furthermore, destroying the digital forms of data after finishing the research studies is easier than destroying the physical copies of the collected data.

The next section explains the different sources and types of research data used in this research.

3.5 Types of Research Data

The data in research studies are mainly defined as secondary and primary and research data. The types of data that were collected in this research are as follows.

1- **The secondary data:** Hair (2007) defined secondary data as the data used to complete the missing essential data and information required by research studies. After extensive investigations about the IRFs and RMMs in OGP projects, it was found that there is not enough available data about them, which means there were no available data about the IRFs and RMMs in OGP projects in Iraq. Moreover, the past studies about risk management in OGP projects in insecure and developing countries such as Iraq contained very little information with regard to the IRFs and RMMs in these projects. This research, therefore, collected the secondary data from a review of research articles, journal papers, surveys, books, and internet sources and databases (e.g. pipeline accidents, pipeline failure causes and the IRFs in the projects worldwide).

2- **The primary data:** the aim of primary data in research studies is to enhance the studies' originality (Okaro, 2017a). The primary data in this research, therefore, were obtained from an industrial survey about the IRFs and RMMs in OGP projects in Iraq. The industrial survey was designed based on the findings of the literature review (i.e. the findings of the inductive approach of this research). In this research, the industrial survey was designed and distributed in order to understand the stakeholders' perceptions about the impact of the IRFs and the effectiveness of the RMMs in OGP projects in Iraq. In addition, the industrial survey was used to add IRFs and RMMs to the worklist which had not been mentioned in the survey.

Figure 3.3 shows the primary and secondary research data and their applications in the research.

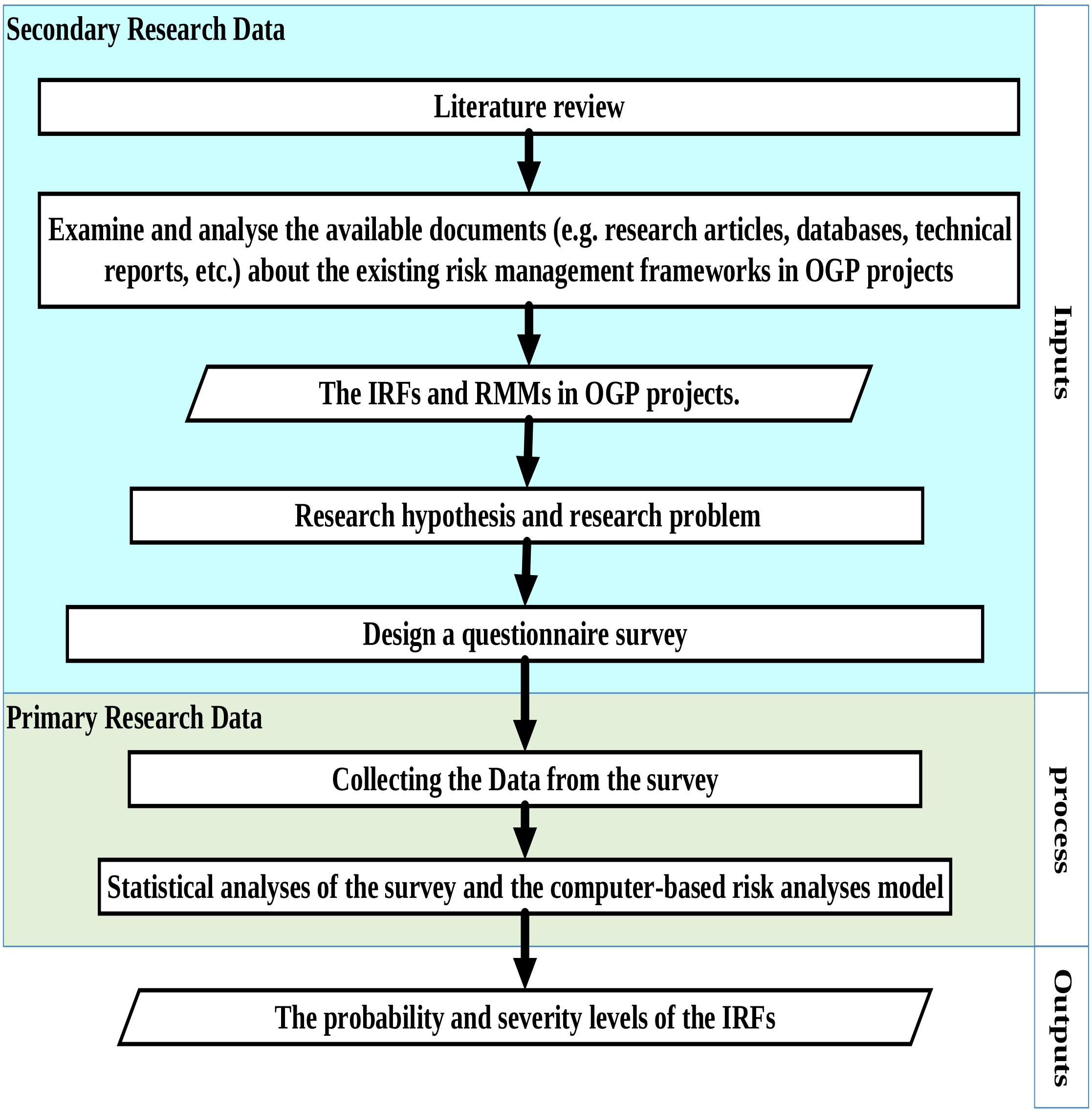

Figure 3.3: The primary and secondary research data of this research.

As shown in the figure above, the findings of the literature review were considered as the secondary source of data because they helped in overcoming the problem of data scarcity in OGP projects in Iraq. Moreover, the findings of the literature review (the secondary data) helped in designing an industrial survey about the issues in OGP projects in Iraq, as will be explained in Chapter 4:. Therefore, the findings of the literature review represented the first contribution of this research because they provide the starting point of this research.

However, the secondary data of this research were not used to analyse the impact of the IRFs and the effectiveness of the RMMs in OGP projects in Iraq.

The main contributions of the primary data in this research (i.e. the results of the industrial survey) were the numerical values of the probability and severity levels of the IRFs and the usability and the effectiveness degree of the RMMs. These values were used as inputs for the models and tools that were developed to assess and rank the IRFs in OGP projects in Iraq (see Chapter 5:), select safe pipeline routes/alignments (Chapter 6:) and quantify the impact of the IRFs on the duration of new pipeline projects (Chapter 8: and Chapter 9:). This represents the main objectives of this research. The survey data, therefore, were representing the primary research data in this study as they helped in achieving the study's objectives, which are about analysing and ranking the IRFs in OGP projects in Iraq. In other words, the survey results have contributed to the originality of the finds of this research.

The next section explains the different methods used to evaluate and validate the research findings and the method used to evaluate and validate the findings.

3.6 Types of Validity Methods for Research Data and Results

Using certain processes to check the accuracy of the research findings is called "Validity" (Creswell and Creswell, 2017). Validity is extended to test the procedures that were followed for data collection and analysis used in research studies (Almadhlouh, 2019), which is necessary for qualitative studies (Wisdom et al. 2012). Creswell (2009) supposed that qualitative research studies are reliable if the researcher's approach was consistent compared with different researchers and projects. Alali (2010) listed the methods of testing the validity in research studies, which are:

1- **Internal validity,** which tests the logical relations between the dependent and independent variables, which is recommended for experiment-based studies (Crowther and Lancaster, 2012).
2- **Statistical validity**, which is similar to **internal validity**, and tests the cause-effect relationships between dependant and independent variables. **Statistical validity** tests if the outcomes of the research confirm the cause-effect relationships between the variables (Crowther and Lancaster, 2012).
3- **Criterion validity**, which tests the internal reliability and the functionality of the scales used in a questionnaire survey (Jenkinson et al. 1994; Taylor et al. 1988).

4- **Pilot validation**, which tests the feasibility and the reliability of a survey's questions; additionally, it examines the assumptions and the design of the survey (Brooks et al. 2016).

5- **Construct validity**, which tests if the research questions were answered and the research problem was solved (Dzudie, 2013). It tests the behaviour and the theoretical ideas that were used in the research (Crowther and Lancaster, 2012). Moreover, Whitely (1983) added that construct validity is concerned with identifying the theoretical mechanisms that underlie responses, such as information processes, strategies and knowledge stores. This approach of data validity is used to test the validity of the methodical and psychometric models of the research.

6- **External validity**, which tests the findings of research studies by applying their results to other situations with different dimensions such as time, location, setting and subject. Additionally, external judgements could be obtained by interviewing experts in the field to validate the results and findings of a research study (Dzudie, 2013).

7- **Face validity**, which uses characteristics, psychological, sensibility or relevant tests to test the participants' answers and the views while answering the survey questions (Holden, 2010). This is not relevant to the scope and the nature of this study.

8- **Case study**, as cited by Allen (2018), Yin (2003) proposed five types of case study, although they are not mutually exclusive but could be used in research. The first is identified as a critical case. This is when the research seeks to gain a better understanding of an existing theory, which means that the findings of the case would be critical to the theory that is tested. This is also known as testing existing theory. A single case study is a valid research approach, when the case study provides a wide demographic background and information for the research. Which what could the case study project provides for this study (Puomisto, 2020). The second is a unique case. This is when the research seeks to investigate a case that has not previously been researched and used in clinical studies. The third type of case is a revelatory case, which means new findings are sought. The fourth type of case study is a typical/representative case that investigates a common everyday situation or form of organisation. The fifth type is a longitudinal case, which means the researcher investigates a case over time. These categories of case study types have been challenged as narrow with a positivist perspective (Lee et al., 2007). However, the categories are useful for identifying the types of case study used in this research. A single case study is used in this research to evaluate the RMF that developed in this research.

During the process of designing the industrial survey, a pilot-like test was carried out in order to test the overall design of the survey, the contingency and the clarity of the questions, and the reliability and the functionality of the used scales, see section 4.2.1. Cronbach's alpha correlation coefficient (α) has been calculated to assess the reliability level of the industrial survey, see section 4.2.2. It measures the average correlation and the internal consistency of the survey items and between the respondents' answers (Cronbach, 1951; Webb et al. 2006). This test covers the statistical and internal validity of the results.

Moreover, a real case study project was used to test the RMF developed in this research. A comparison between two risk simulation algorithms and two risk analysis and modelling software packages was used to test the final findings of the RMF, which are about the time impact of the IRFs on the duration of the new pipeline projects, see Chapter 8: and Chapter 9:. Moreover, the researcher has used peer-reviewed journals and conference publications to obtain feedback from expert reviewers in the field, which validated the findings of this research.

3.7 The Proposed Research Strategy for This Study

This section has used the definitions, explanations and justifications of the above sections related to research methodology, philosophy, approach, methods, sampling methods, questionnaire survey, data types and validation methods to design this study. Research strategy explains the procedure, the sequence, the steps and techniques used to accomplish the aim of a piece of research (Babbie, 2016). A research design is the structure of the research that developed the methodology used to answer the research questions (Okaro, 2017a; Almadhlouh, 2019). In other words, the logical structure developed in research studies in order to reach valid conclusions is called the research design (Okaro, 2017a).

The relevant studies with regard to analysing the IRFs in OGP projects show that the deterministic approach and the simulation approach are the two main approaches used to calculate the pipelines' probability of failure (El-Abbasy et al. 2016b). The difference between these two approaches is as follows.

1. The deterministic approach utilises analysing the related data (e.g. the pipelines' failure causes and the maintenance records) to assess the IRFs and calculate their

degree of influence on the pipelines. As such data are not available to assess the IRFs in OGP projects in Iraq (see section 1.3 in 0), the document analysis of the literature review, therefore, was used to identify the IRFs and RMMs associated with OGP projects (see sections 2.4.4, 2.4.5 and 2.4.6 in Chapter 2:). Such an approach mainly uses qualitative and deductive research methods to analyse the collected documents and collect the research data.

2. The simulation approach utilises correlation analysis with the age and the other conditions of the pipes to assess the likelihood of pipe failure based on the pipes' historical records (Elsawah et al. 2016). However, in a situation of lack of data about the pipeline conditions and in a hazardous environment similar to that in Iraq, risk management requires further investigations to understand the IRFs in OGP projects. Such investigations are required to provide numerical data about the IRFs and RMMs in the projects based on the perceptions of the stakeholders who are in touch with the problems in these projects. Such an approach mainly uses quantitative and deductive analysis such as statistical analyses, computer modelling and programming and simulation software, etc.

Figure 3.4 shows the research design flow diagram.

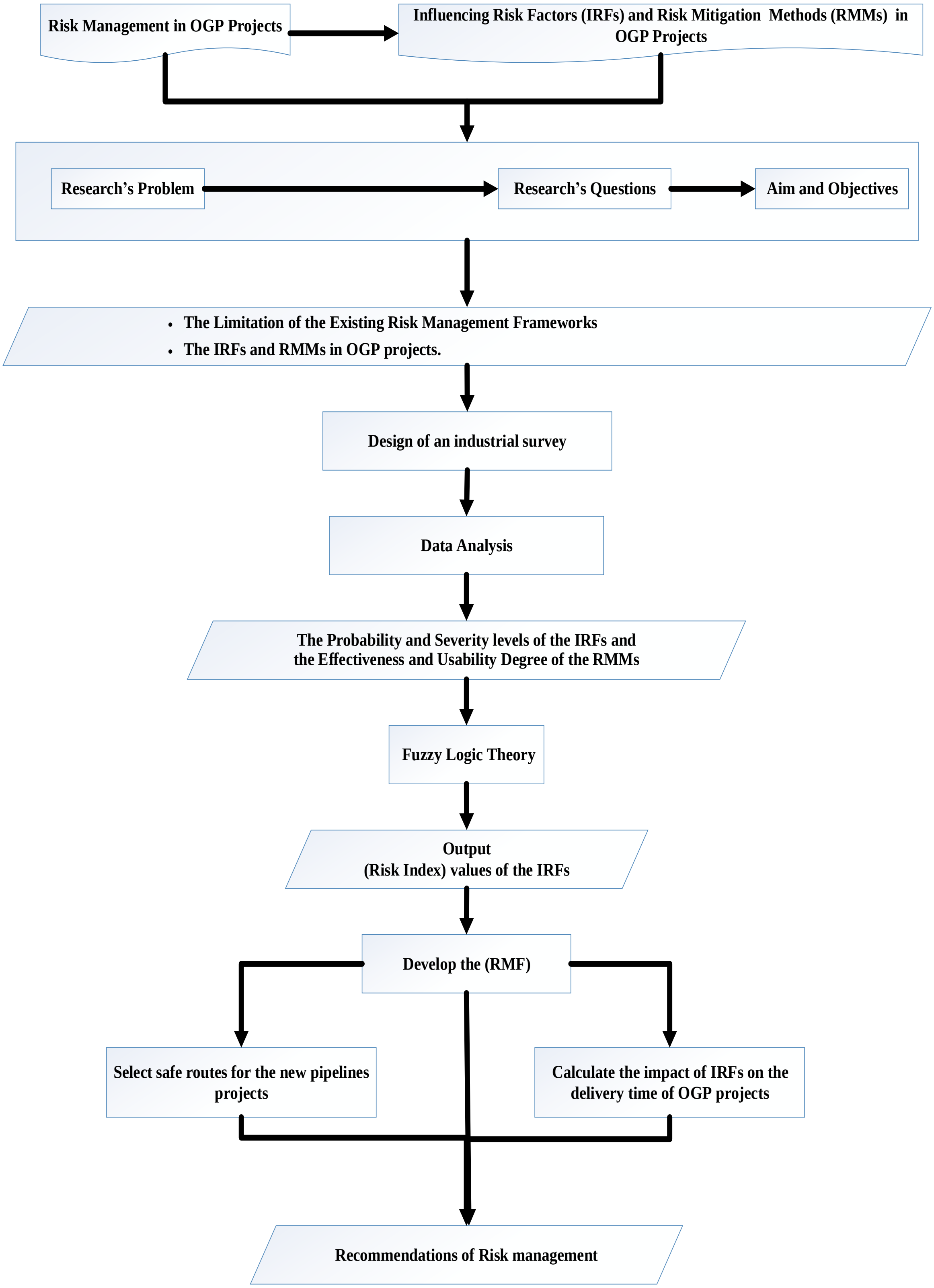

Figure 3.4: Research design flow diagram.

As explained in

Figure 3.4 above, the design of this research includes analysing the literature review in order to understand the existing risk management approaches in OGP projects. The findings of the literature review were the limitations of the existing RMFs and the IRFs and RMMs associated with these projects, see Chapter 2:. Chapter 4: uses the findings of the literature review to design an industry-wide questionnaire survey to analyse and evaluate the identified IRFs and RMMs based on the perceptions of the stakeholders in these projects.

The numerical results of the survey are used in Chapter 4: as input for a computer-based risk analysis model, which uses fuzzy theory to assess and rank the IRFs based on their degree of impact on the projects. To this end, Chapter 5: uses the findings of this research (e.g. the list of the identified IRFs and their degree of impact on the projects, the strengths and limitations of the existing RMFs and the RMMs used in the projects) to design an integrated RMF for OGP projects. The RMF will be used to select safe routes/alignments for the new pipeline projects (as done in Chapter 5:) and quantify the time impact of the IRFs on the duration of these projects (as done in Chapter 8: and Chapter 9:). Chapter 8: and Chapter 9: use MCS to analyse the potential delay caused by the IRFs in a real case study project from Iraq. The real case study project helped to evaluate/validate the functionality of the developed RMF. In addition, the findings of the RMF will be evaluated/validated by comparing the results of two different risk simulation software packages (which are ASTA risk simulator and @Risk simulator) as done in Chapter 8: and Chapter 9:, respectively. Chapter 10: discusses the research findings, the limitations and the future work of this research.

3.8 Summary

This chapter has explained the philosophies, research approaches, research method, data sampling and collection methods used in this research as follows.

- Section 3.1 has explained the philosophies used by past research studies, and the justification of why a pragmatist paradigm philosophy is adopted in this study to design the RMF in this research (section 3.2.1). Section 3.1 has also explained the following
    - The strategy of the literature review of this research, section 3.2.2.
    - The inductive and deductive approaches and the qualitative and quantitative methods used in this research, as per section 3.2.3 and 3.2.4, respectively.
    - The research methods used in past research studies and why a questionnaire survey was the chosen data collection method in this study, section 3.2.5.

- Section 3.3 Explained the data sampling methods used in this research.
- Section 3.4 explained the data distribution and collection methods used in this research (i.e. the questionnaire survey).
- Eection 3.5 explained the secondary and primary research data used in this research,.
- Section 3.6 explained the methods of validating the research findings.
- Section 3.7 explained the research design and structure.

A pragmatist paradigm is adopted to obtain meaningful results from both the qualitative and quantitative methods that were used in this research in order to:

1- Identify the IRFs and RMMs that affect the safety of OGP projects worldwide. Additionally, to understand the limitations of the existing RMFs used in these projects.
2- Rank the IRFs in OGP projects with regard to their degree of influence on the projects.
3- Select the optimum safe pipeline routes/alignments for the new OGPs projects.
4- Quantify the impact of the IRFs on the duration of the new pipeline projects, and estimate whether or not the projects could be delivered on time; and suggest some of the effective RMMs which could be used to manage the IRFs in OGP projects.

CHAPTER 4: INDUSTRY SURVEY

4.1 Introduction

This chapter presents the overview and the process of conducting an industry survey to analyse the Influencing Risk Factors (IRFs) associated with Oil and Gas Pipeline (OGP) projects and examines the potential Risk Mitigation Methods (RMMs) which could be suitable and valuable for these projects.

The chapter explains the designing of a questionnaire survey, which was used to analyse and rank the critical IRFs associated with OGP projects. The recognised lists of IRFs and RMMs were identified through a comprehensive review of the existing literature. This research has used this information (i.e. the IRFs and RMMs) to design a questionnaire survey. The questionnaire was used to collect the perceptions of the stakeholders about the IRFs and RMMs in OGP projects in Iraq

The chapter is structured under five sections. The design of the questionnaire survey is discussed in detail in section 4.2. Section 4.3 explains the method of distributing the questionnaire amongst the targeted stakeholders, and section 4.4 presents the analyses of survey data and discusses the results of the industrial survey. Section 4.5 presents the chapter summary.

4.2 Questionnaire Design

Predicting and recognising the IRFs in a project depends on the personal style of thinking and the cognition and processing capability of the stakeholders because these risk factors are characteristically uncertain, vague and random (Guo et al. 2016). This research, therefore, seeks to engage with stakeholders who have a better understanding of the oil and gas industry and have a piece of real knowledge about the problems, risks and challenges associated with OGPs. Most importantly, the survey aims to obtain consensus views and perceptions from the relevant stakeholders in a way that reflects the reality of the IRFs in OGP projects.

Questionnaire survey is one of the most widely used research methods for data collection, which helps in engaging with respondents or participants in the survey who are eager to engage and understand an attitude or a behaviour of a certain phenomenon (Blaxter, 2010; Creswell and Creswell, 2017). A previous study by Alali (2010) found that around 61% of the research studies in the field of project management normally used surveys and questionnaires to collect research data for their studies. They are also used to collect desirable research data from the participants/stakeholders which might be unavailable elsewhere (Fowler and Cosenza, 2009). Thus, the questionnaire survey is utilised in this research to collect the primary research data about the probability and severity impact of the IRFs and the potentially effective RMMs in the OGP projects based on the perceptions of the relevant stakeholders.

Three types of questionnaires are widely used in the literature, which are structured, open-ended, and semi-structured questionnaire. Polit and Beck (2008) explained the difference between these three types of questionnaires as follows.

- In the structured questionnaire survey (i.e. one with pre-defined and designed questions), the participants have to answer a set of fixed questions only, with no opportunity to comment on the questions. Such a questionnaire does not give the respondents the opportunity to respond to the questions in detail and add comments when some clarification is needed.
- In the survey with only open-ended questions, the respondents have an open space to write their answers to the survey questions. This kind of survey provides the respondents with the opportunity to ask questions and write comments in the survey, which enhances the surveyors' knowledge. However, a survey with only open-ended questions will enable the participants to give a very wide range of answers, and they will use different scales and terminologies to answer the questions based on their personal perspectives, which will make the survey difficult to analyse and will lead to uncertain results.
- The semi-structured questionnaire survey includes both types of questions, fixed and open-ended questions. This survey format uses scales defined by the surveyors to answer the survey questions, and it allows flexibility in data collection by collecting comments from the survey participants.

Considering the above statements and justifications, a semi-structured questionnaire survey is adopted in this study. In this context, the qualitative document analyses of this research (e.g.Table 2.1, Table 2.2 and Table 2.3 in Chapter 2:) were conducted in order to design a semi-structured questionnaire survey. The survey helps to analyse the impact of the IRFs and to discover the effective RMMs in the OGP projects, particularly in developing countries such as Iraq. The University Research Ethics Committee (UREC) at Liverpool John Moores

University (LJMU) reviewed and approved the designed questionnaire before the industrial survey was conducted. The ethical approval is shown in Figure A.1 in APPENDIX A:.

I. The survey was written in English and Arabic languages, and it was up to the respondents to choose the language they wished to use. This survey used the Likert rating scale to assess the IRFs and evaluate the RMMs in OGP projects because it is one of the most widely used scales in the literature (Matell and Jacoby, 1972; Mearns and Yule, 2009). A Likert scale was used despite some negative opinions about the scale which state that respondents can provide biased views based more on their personal perspective to answer the questions. This scale is sensitive and has small standard deviations, which make the results of the survey profoundly meaningful (Cummins and Gullone, 2000). Figure 4.1 presents the process of designing the semi-structured questionnaire survey. This process was conducted in two stages. First, a pilot-like survey was conducted to improve the quality and reliability of the questionnaire, see section 4.2.1, and then the final stage of the questionnaire survey was developed, see section 4.2.1.

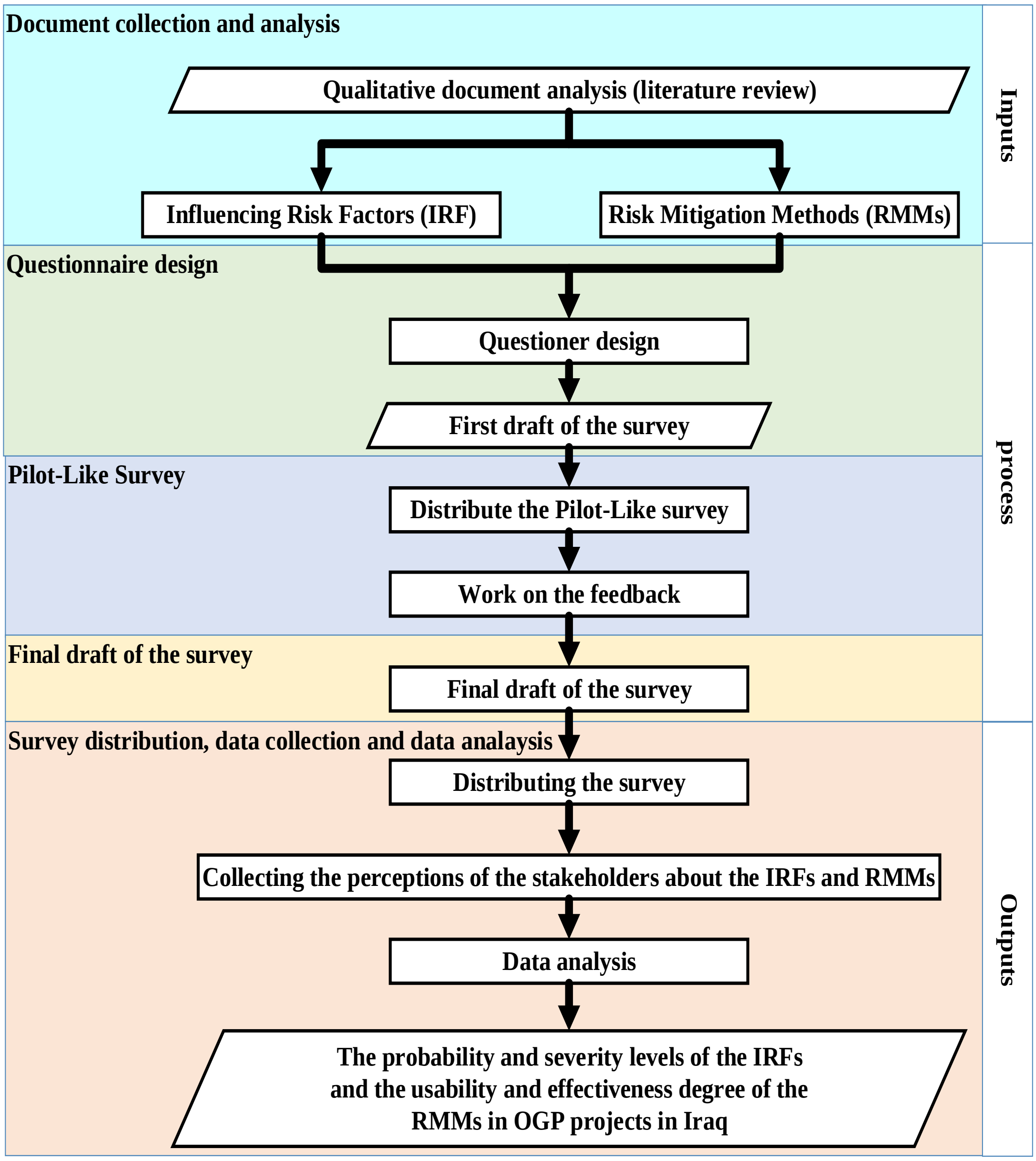

Figure 4.1: Flowchart showing the design process of the questionnaire survey.

4.2.1 Pilot-Like Survey

Testing the survey before distributing it is recommended in the literature (Blaxter, 2010). Pilot-like surveys are used in the literature in order to pre-test surveys and predict the factors that might affect their validity in order to avoid them in the final surveys (Bernard and Bernard, 2013). Bhate (2014) has recommended making a pilot-like survey with a small sample of participants to test and confirm the suitability of the questions and the data collected from the survey. Creswell and Poth (2016) assumed that using external members to check the survey ensures valid responses, which enhances the credibility, accuracy and transferability of the study. Also, the pilot-like survey is used in the literature to estimate the length of the survey and determine the best environment for the participants (Brooks et al. 2016). Additionally, pilot-like surveys were used in research studies to estimate the response rate of the targeted population in participating in the survey.

The survey was designed under three sections as follows.

- Section I introduced the research topic and the aim of the survey to the participants. Additionally, in this section, the participants were asked about their degree of education, their occupations, roles and experience in OGP projects.
- In section II, the participants were asked to
  - Assess the probability of the IRFs on a scale (Certainly, Very often, Often, Sometimes, Seldom, Do not happen at all, Undecided), which means a seven-point Likert scale was used in this question.
  - Rank the five groups of the IRFs with regard to their degree of impact on the projects.
  - Add more IRFs to the worklist which have not been mentioned in the survey.
- In section III, the participants were asked to
  - Evaluate the RMMs with regard to their frequency of application in the projects' "usability" on a scale (Certainly, Very often, Often, Sometimes, Seldom, Did not use at all, Undecided), (i.e. seven-point Likert scale).
  - Compare between the underground and above ground pipelines subject to the IRFs that affect the safety of these pipelines.
  - Rank the stages of the projects with regard to the priority of applying the RMMs in the projects.
  - Add more RMMs to the worklist which have not been mentioned in the survey.

An online tool survey, "Google Forms", was used to distribute the pilot-like survey. The pilot-like survey was sent to 10 experts in OGP projects in Iraq to answer the survey questions and provide comments on the survey. The respondents were notified that their answers would be treated anonymously. After one week, six of these experts had completed their forms and sent their feedback and comments to the surveyors. The general information about these experts is shown in Table 4.1.

Table 4.1: Experts' general information.

Education		Occupation		Experience (years)	
Provisional degree (diploma)	2	A member of a construction team	5	6 to 10	1
Bachelor's degree or Higher diploma	2	A researcher or student	1	11 to 15	3
Master's or PhD	2			> 15	2
Total	6	Total	6	Total	6

The pilot-like survey was used to assess:

1- The clarity of the questions, and the overall language, consistency and design of the questionnaire.

2- The functionality of the used rating scales.

3- The functionality of the online tool survey used to collect the data from the participants.

The experts made the following comments about the pilot-like survey.

- They felt that the survey was long. Therefore, the whole survey was revised to be shorter.
- The survey has missed assessing the severity levels of the IRFs. Therefore, a question was added to the final survey to assess the severity of the IRFs in OGP projects in Iraq.
- The survey has missed evaluating the effectiveness degrees of the RMMs. Therefore, a question was added to the final survey to evaluate the effectiveness of the RMMs in OGP projects in Iraq.
- The participants complained that the seven-point Likert scale was confusing to them and made the questions difficult to answer. Thus, a five-point Likert scale was used in the final survey, which is easier to follow, as they suggested. Moreover, the five-point scale is widely used in the literature to assess the IRFs (Elsawah et al. 2016).
- After making phone calls to the participants, the overall clarity of the survey was improved; questions that were found to be vague were revised or discarded; and the lists of IRFs and RMM methods were revised for better clarity.
- Some of the IRFs and RMMs have been paraphrased to make sure that they fit with the aim of this research and the situation of OGP projects in Iraq.
- Some typos, spelling and grammar mistakes were spotted in the pilot survey and changed in the final draft.

- The functionality of the Google Forms online survey tool was found to be limited. Therefore, there was a need to use another online survey tool to distribute the final survey.
- The statistical analysis of the pilot-like survey was used to test the functionality of the survey for the research.

A draft of the pilot-like survey is shown in Table A.1 in 00 . The next section uses the feedback from the pilot-like survey in order to design the final draft of the survey.

4.2.2 Final Design of the Questionnaire Survey

The final draft of the survey had 13 questions divided into three sections, as follows.

I. Section I was similar to section I in the pilot-like survey, but the introduction was revised to be shorter.

II. Section II comprised four questions to analyse the IRFs as follows.

   - Question 4 asked the respondents to assess the probability levels of the IRFs on a scale [almost certain, likely, possible, unlikely, and rare] (Stephan and Badr, 2007; Alali, 2010). In other words, a five-point Likert scale was used in this question.
   - Question 5 asked the respondents to assess the severity levels of the IRFs on a scale [catastrophic, major, moderate, minor, and negligible] (Stephan and Badr, 2007; Alali, 2010). That is, a five-point Likert scale was used in this question.
   - Question 6 asked the respondents to rank the five types of IRFs (S&S, PL, HSE, OR, and R&R) regarding their degree of impact on OGPs, where rank (1) means the IRF has the highest impact and (5) means the lowest.
   - Question 7 was an open-ended question that asked the participants if they could add more IRFs to the survey which have not been mentioned by the surveyors.

III. Section III had five questions to evaluate the RMMs.

   - Question 8 asked the participants to evaluate the usability degree of the RMMs on a scale [almost certainly used, likely used, possibly used, unlikely used, and rarely used]. That is, a five-point Likert scale was used in this question.
   - Question 9 asked them to evaluate the effectiveness degree of the RMMs on a scale [extremely effective, very effective, moderately effective, slightly effective, and insignificant]. I.e. five-point Likert scale was used in this question.

- Question 10 was an open-ended question asking the participants if they could add more RMMs to the survey which have not been mentioned by the surveyors.
- Question 11 asked them to rank the stages of pipeline projects regarding the priority of managing the IRFs and applying the RMMs in the projects.
- Question 12 was about an overall comparison between above ground and underground pipelines with regard to the IRFs in each one of these pipelines.
- The final question was to collect the participants' contact details if they were willing to share them with the authors.

A draft of the final survey is shown in Table A.2 in APPENDIX A:. The next section shows the method used to distribute the survey between the stakeholders in the OGP project in Iraq.

4.3 Questionnaire Distribution and Data Sampling Methods

The survey was conducted using an online survey tool called "SoGoSurvey" to recruit respondents from government organisations, international companies and private agencies who have relevant experience with OGP projects, for example, consultants, planners, designers, construction workers, operators, maintenance workers, owners, clients and researchers. The justification for using an online survey tool compared to existing tools of distribution methods is discussed in detail in section 3.4 in Chapter 3:.

Section 3.3 in Chapter 3: explained the different methods of data sampling which are normally used to select participants in a survey and the justification for using the snowball-sampling method in this study. Snowball sampling is utilised in this survey to ensure widespread distribution of the questionnaires amongst the OGP stakeholders. The industry survey was distributed via an online survey tool to potential participants via social networks and emails. The survey lasted for four months to collect sufficient responses from the targeted population. The next section presents the types of research data that were collected via the industry survey in Iraq and the details of the data analysis. The justification for using OGP projects in Iraq as the area of research in this study is explained in sections 1.2 and 1.3 of 0Chapter 1: and section 2.3 of Chapter 2:.

4.4 Collection and Analysis of the Survey Data

The data collected from the survey in this research were divided into three types as follows.

1. The demographic information of the participants (e.g. their occupations and experience level in the projects and educational degree) from the first three questions.
2. The perceptions of the participants regarding the impact of IRFs in OGP projects in Iraq as follows.
   2.1. The probability of the identified risk factors affecting the projects, from question 4.
   2.2. The severity levels of the IRFs on the projects, from question 5.
   2.3. The ranking of the five groups of the IRFs with regard to their degree of influence on the projects, from question 6.
   2.4. The comments of the participants with regard to adding more IRFs to the work list which have not been mentioned in the survey, from question 7.
3. The perceptions of the participants regarding the applications of the RMMs in OGP projects in Iraq as follows.
   3.1. The usability degree of the RMMs in the projects, i.e. the chance of these RMMs being used to manage the IRFs in the projects, from question 8.
   3.2. The effectiveness degree of the RMMs with regard to managing the IRFs in the projects, from question 9.
   3.3. The comments of the participants with regard to adding more RMMs to the work list which have not been mentioned in the survey, question 10.
   3.4. The priority of applying the RMMs to manage the IRFs in OGPs during the different stages of the projects, from question 11.
   3.5. A comparison between the above ground and underground pipelines based on the subjected risk factors in each type of these pipelines, from question 12.

The Statistical Package for the Social Sciences 23 (SPSS 23) was used to statistically analyse the survey data collected through the questionnaire. The next sections provide the results of the survey.

4.4.1 Response Rate of the Survey

The questionnaire survey was sent to 400 potential participants. The response rate was 49.5% since 198 participants responded. The response rate in this research was high compared to past studies. For example, Bennett and Nair (2010) and Nair, (2013) put the average response rate for online surveys at about 30% to 36%, which means the response rate in this research is more than the expected rate. This rate is good compared to Okaro (2017) with a response rate of 33% and 82 participants, and Rowland (2010) with a response rate of 23% and 151 participants. One of the reasons for achieving a high response rate to the survey is that the researcher had been working in different OGP projects in Iraq for approximately three years, and used networking to recruit participants to the survey. Additionally, the appropriate design of the survey, the clear questions and addressing the feedback of the pilot-like survey have helped in obtaining a high response rate to this survey. Additionally, the confidentiality of data has helped in reaching such a response rate to this survey. The next section presents the survey results about the demographic information of the participants in the survey, which are some of the stakeholders in OGP projects in Iraq.

4.4.2 Participants' Demographic Information

The participants were working either for (I) governmental companies, which belong to the Ministry of Oil (MoO), such as the State Company of Oil Projects (SCOP), Oil Pipelines Company (OPC), Basra Oil Company (BOC), Midland Oil Company (MDOC), Basrah Gas Company (BGC) and other governmental companies. (II) International companies (e.g. British Petroleum, Gazprom, Shell, Samsung, and Petrofac). Or (III) Private companies (e.g. MSK Iraq for oil and gas services). However, due to data confidentiality, participants were not asked to provide the names of their organisations. Figure 4.2 shows the demographic information of the participants.

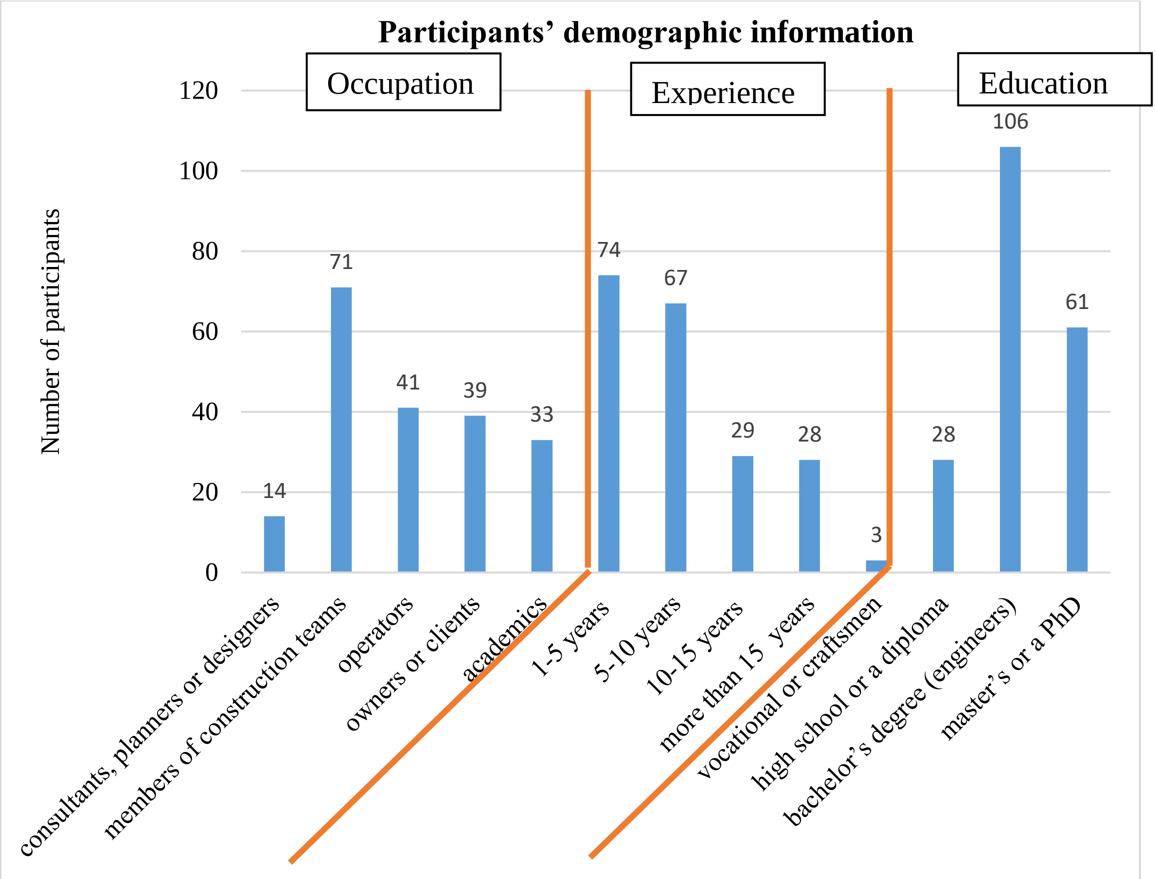

Figure 4.2 Participants' demographic information.

According to the participants' occupations, as recorded in the survey, 14 participants were consultants, planners or designers, 71 were members of construction teams, which means executive engineers, 41 were operators, 39 were owners or clients, and 33 were either researchers or postgraduate students associated with the OGP projects. The students are employed in the OGP projects and at the same time studying for their master's or PhD, which means they have experience of working on these projects.

In terms of participants' experience, 74 have between one and five years of experience in OGP projects, 67 have five to 10 years, 29 participants have 10 to 15 years, and 28 of them have more than 15 years of experience.

In respect of the participants' education, three of them were vocational or crafts-based, 28 have a high school or a diploma degree, 106 have a bachelor's degree (engineers), and 61 have a master's or a PhD degree.

The appropriate sampling of the targeted population, as shown above, enhances the results of this research because all the stakeholder categories during all stages of a project were represented in the survey. The participants were asked asbout their roles in the projects in order to understand the analysis of the IRFs and RMMs from different perspectives. Understanding the experience levels of the participants helps to estimate the reliability of the survey. As shown in Figure 4.2, the percentage of participants who have more than five years of experience in the projects is more than 62.6%. The case is similar when asking the participants about their degree of education, which helps in estimating how many engineers participated in the survey. In this survey, 106 out of 198 participants were engineers with a B.Sc. degree, and 61 participants were engineers with a master’s or PhD degree. These numbers enhance the results of the survey.

The next section presents the reliability and validity test of the survey data.

4.4.3 Reliability and Validity of the Survey Data

Due to the nature of human observations and responses, surveys may come with a range of errors. Therefore, testing the reliability levels of the data collected from research surveys is important. Keeping the data of the survey confidential reduces personal biases during data collection, which helps in avoiding any threats to the reliability and validation levels of the survey (Dzudie, 2013). Cronbach's alpha correlation coefficient (α) has been calculated to assess the reliability level of the questionnaire survey. It measures the average correlation and the internal consistency of the survey items and between the respondents’ answers (Cronbach, 1951; Webb et al. 2006). Different levels of reliability are required depending on the purpose and the nature of the study. Meanwhile, if the value of the α was equal to 0.7, it means the results of the survey are above the minimum level of reliability (Pallant, 2001; Kline, 1999; Mpofu et al. 2017; Nunnally, 1994; Prasad et al. 2019; Ruqaishi and Bashir, 2015 and Santos, 1999). In this research, reliability testing was carried out for questions 4, 5, 8 and 9 of the survey as these were rated on a Likert rating scale. Table 4.2 shows the values of α, which are above the acceptable value of 0.7.

Table 4.2: Cronbach’s alpha coefficient factor (α) case processing summary of the survey.

The reliability levels of:	**Valid %**	**Items**	**α**
the questionnaire overall	100	95	0.910
question 4, which is about risk probability	100	30	0.919
question 5, which is about risk severity	100	30	0.863
question 8, which is about the usability of RMMs	100	12	0.867
question 9, which is about the effectiveness of RMMs	100	12	0.867
answers of the participants who are consultants, planners or designers	100	95	0.863
answers of the participants who are members of construction teams	100	95	0.892
answers of the participants who are operators	100	95	0.927
answers of the participants who are owners or clients	100	95	0.917
answers of the participants who are researchers or students	100	95	0.899

The reliability testing is not applicable for the rest of the questions for the following reasons. Questions 1, 2 and 3 asked about the participants' demographic information. Question 6 asked the participants about their opinions in ranking the five groups of IRFs based on their degree of impact on the projects. Questions 10 and 11 asked about ranking the priority of the project stages with regard to applying the RMMs in the projects and comparing between the above and underground pipelines, respectively. There was no scale used in these questions. Therefore, reliability testing does not apply to them.

The next section explains the analysis of the probability and severity levels of the IRFs in the OGP projects based on the survey conducted in Iraq.

4.4.4 Risk Probability (RP) and Risk Severity (RS) of the IRFs

A descriptive statistical analysis method is used to analyse the IRFs in the survey. The mean of the five-point Likert scale was calculated to determine the numerical values of probability and the severity levels of the IRFs in OGP projects in Iraq. This research has analysed the IRFs based on the overall results of the survey as well as based on the occupations of the stakeholders in the projects. Table 4.3 and Table 4.4 show the probability and severity levels of the IRFs in OGP projects in Iraq, respectively.

Table 4.3: The probability levels of the IRFs in OGP projects in Iraq based on the results of the survey.

IRFs	Risk Probability (RP)					
	Total	**I**	**II**	**III**	**IV**	**V**
Terrorism & sabotage	3.995	3.357	3.958	4.195	4.000	4.091
Corruption	3.980	4.000	3.986	3.878	3.846	4.242
Insecure areas	3.717	3.286	3.634	3.805	3.769	3.909
Low public legal & moral awareness	3.712	4.000	3.761	3.561	3.513	3.909
Theft	3.692	3.214	3.845	3.659	3.564	3.758
Corrosion & lack of protection against it	3.687	3.429	3.648	3.390	3.795	4.121
Improper safety regulations	3.687	3.643	3.662	3.561	3.872	3.697
Exposed pipelines	3.667	3.429	3.437	3.854	3.897	3.758
Shortage of IT services & modern equipment	3.667	3.643	3.592	3.585	3.615	4.000
Improper inspection & maintenance	3.657	3.571	3.606	3.537	3.769	3.818
Lack of appropriate training	3.646	3.571	3.761	3.439	3.462	3.909
Weak ability to identify & monitor the threats	3.631	3.571	3.577	3.561	3.692	3.788
The pipeline is easy to access	3.631	3.571	3.563	3.732	3.538	3.788
Limited warning signs	3.626	3.429	3.648	3.341	3.974	3.606
Little research on this topic	3.621	3.429	3.789	3.366	3.359	3.970
Lawlessness	3.606	3.786	3.676	3.268	3.795	3.576
Lack of risk registration	3.566	3.214	3.606	3.390	3.615	3.788
Stakeholders are not paying appropriate attention	3.530	3.286	3.676	3.439	3.462	3.960
Conflicts over land ownership	3.495	3.571	3.451	3.659	3.667	3.152
Public's poverty & education level	3.449	3.357	3.521	3.439	3.256	3.576
Design, construction & material defects	3.333	2.429	3.254	3.293	3.385	3.879
Threats to staff	3.323	2.714	3.394	3.268	3.410	3.394
Inadequate risk management	3.227	2.929	3.183	2.976	3.436	3.515
Operational errors	3.101	2.857	3.042	2.878	3.205	3.485
Leakage of sensitive information	2.980	2.643	3.070	2.707	2.949	3.303
Geological risks	2.747	2.714	2.662	2.537	2.795	3.152
Natural disasters & weather conditions	2.652	2.429	2.606	2.537	2.692	2.939
Vehicle accidents	2.465	2.357	2.380	2.293	2.333	3.061
Hacker attacks on the operating or control system	2.237	1.929	2.268	2.024	2.179	2.636
Animal accidents	1.894	1.929	1.986	1.561	1.821	2.182
Note: Total means the overall results of the survey, (I) means the consultants, planners and designers; (II) means the construction workers; (III) means the operators; (IV) means the owners and clients; and (V) means the researchers.						

Table 4.4: The severity levels of the IRFs in OGP projects in Iraq based on the results of the survey.

IRFs	Risk Severity (RS)					
	Total	**I**	**II**	**III**	**IV**	**V**
Terrorism & sabotage	4.490	3.571	3.732	3.829	3.718	3.939
Corruption	4.192	3.286	3.732	3.512	3.769	3.939
Insecure areas	4.106	3.286	3.634	3.659	4.000	3.606
Low public legal & moral awareness	3.859	3.357	3.535	3.244	3.590	3.727
Theft	4.081	3.000	3.662	3.585	3.846	3.818
Corrosion & lack of protection against it	3.990	3.357	3.676	3.683	3.641	3.697
Improper safety regulations	3.949	3.214	3.592	3.488	3.872	3.667
Exposed pipelines	3.682	2.500	3.042	2.951	3.000	3.000
Shortage of IT services & modern equipment	3.652	1.714	2.155	1.951	2.000	1.970
Improper inspection & maintenance	3.924	3.357	3.746	3.610	3.641	3.394
Lack of appropriate training	3.773	3.500	3.408	3.098	3.410	3.697
Weak ability to identify & monitor the threats	3.899	3.000	3.690	3.488	3.487	3.758
The pipeline is easy to access	3.646	3.571	3.732	3.829	3.718	3.939
Limited warning signs	3.571	3.286	3.634	3.659	4.000	3.606
Little research on this topic	3.697	2.857	3.042	2.854	3.077	3.455
Lawlessness	3.682	2.500	3.042	2.951	3.000	3.000
Lack of risk registration	3.697	2.857	3.042	2.854	3.077	3.455
Stakeholders are not paying appropriate attention	3.143	3.577	3.829	3.692	3.727	3.960
Conflicts over land ownership	3.611	3.286	3.732	3.512	3.769	3.939
Public's poverty & education level	3.409	3.357	3.676	3.683	3.641	3.697
Design, construction & material defects	3.848	3.571	3.549	3.390	3.179	3.333
Threats to staff	3.399	3.143	3.577	3.829	3.692	3.727
Inadequate risk management	3.505	3.000	3.662	3.585	3.846	3.818
Operational errors	3.611	3.500	3.958	3.537	3.692	3.636
Leakage of sensitive information	3.505	3.000	3.662	3.585	3.846	3.818
Geological risks	3.182	3.214	3.592	3.488	3.872	3.667
Natural disasters & weather conditions	3.066	3.357	3.746	3.610	3.641	3.394
Vehicle accidents	2.712	3.357	3.535	3.244	3.590	3.727
Hacker attacks on the operating or control system	2.970	3.000	3.690	3.488	3.487	3.758
Animal accidents	2.020	3.571	3.549	3.390	3.179	3.333

Note: Total means the overall results of the survey, (I) means the consultants, planners and designers; (II) means the construction workers; (III) means the operators; (IV) means the owners and clients; and (V) means the researchers.

The findings of the two tables above, which are the Risk Probability (RP) and Risk Severity (RS) of the IRFs, will be used as inputs for a computer-based risk analysis model, which is developed in Chapter 5: to assess and rank the IRFs with regard to their degree of impact on OGP projects.

The next section uses the results of Table 4.3 and Table 4.4 in order to calculate the degree of impact of the IRFs on OGP projects in Iraq based on the results of the survey. Additionally, the next section shows the differences in analysing the IRFs in OGP projects in Iraq based on the occupations and different perceptions of the stakeholders and participants.

4.4.5 Ranking the IRFs

This research has used the Risk Importance Impact (RII), which has been used by a number of past researchers (e.g. Jamshidi et al. 2013; Julie Pallant, 2001; Yadav et al. 2003 and Yazdani-Chamzini, 2014) in order to calculate the degree of impact of the IRFs on the OGP projects in Iraq based on the results of the survey. The values of RII of the IRFs were calculated based on the results of the Risk Impact Equation (RIE) equation, see equation 4.1.

$$RII = [Risk\ Probability\ (RP) \times Risk\ Severity\ (RS)]/5 \qquad \ldots \quad 4.1$$

Table 4.5 shows the results of calculating the RII values of the IRFs using the RII.

Table 4.5: The results of calculating the impact values of the IRFs using the RII.

IRFs	Risk Type	RII (The results of RII)					
		Total	I	II	III	IV	V
Terrorism & sabotage	S&S	3.587*	3.021	3.579	3.909	3.405	3.669
Corruption	R&R	3.441	3.314	3.537	3.254	3.314	3.677
Insecure areas	PL	3.053	2.722	2.928	3.267	3.035	3.222
Low public legal & moral awareness	S&S	3.023	2.812	3.210	2.583	3.211	3.056
Theft	S&S	3.013	2.388	3.206	2.998	2.906	3.029
Corrosion & lack of protection against it	OR	2.942	2.498	2.918	2.696	3.172	3.222
Improper safety regulations	HSE	2.912	2.810	2.899	2.797	2.958	3.070
Exposed pipelines	HSE	2.870	2.755	2.742	2.829	3.015	3.078
Shortage of IT services & modern equipment	OR	2.865	3.086	2.934	2.588	2.738	3.127
Improper inspection & maintenance	HSE	2.832	2.551	2.802	2.831	2.878	2.961
Lack of appropriate training	R&R	2.796	2.629	2.972	2.583	2.716	2.855
Weak ability to identify & monitor the threats	OR	2.751	2.551	2.807	2.634	2.574	3.080
The pipeline is easy to access	PL	2.700	2.253	2.498	2.820	3.118	2.710
Limited warning signs	HSE	2.678	2.446	2.641	2.641	2.633	2.958
Little research on this topic	R&R	2.656	2.057	2.672	2.396	3.057	2.754
Lawlessness	R&R	2.648	2.245	2.550	2.858	2.613	2.824
Lack of risk registration	R&R	2.636	2.112	2.692	2.381	2.725	2.984
Stakeholders are not paying appropriate attention	R&R	2.586	2.057	2.796	2.348	2.343	2.983
Conflicts over land ownership	PL	2.566	1.839	2.410	2.538	2.760	3.033
Public’s poverty & education level	S&S	2.524	2.398	2.586	2.641	2.670	2.139
Design, construction & material defects	OR	2.481	1.900	2.687	2.312	2.518	2.468
Threats to staff	S&S	2.352	2.398	2.500	2.332	2.071	2.384
Inadequate risk management	HSE	2.240	1.837	2.185	2.008	2.482	2.556
Operational errors	OR	2.194	2.050	2.170	1.843	2.343	2.599
Leakage of sensitive information	S&S	2.089	1.774	2.171	1.756	2.117	2.462
Geological risks	PL	1.748	1.551	1.605	1.670	1.749	2.273
Natural disasters & weather conditions	HSE	1.626	1.388	1.585	1.448	1.657	2.031
Vehicle accidents	PL	1.337	1.010	1.274	1.275	1.328	1.707
Hacker attacks on the operating or control system	OR	1.329	0.964	1.380	1.195	1.308	1.582
Animal accidents	PL	0.765	0.661	0.856	0.609	0.728	0.860
*for example the RI of the Terrorism & sabotage = [3.99 X 4.49]/5=3.58							
Note: Total means the overall results of the survey, (I) means the consultants, planners and designers; (II) means the construction workers; (III) means the operators; (IV) means the owners and clients; and (V) means the researchers.							

The IRFs were ranked based on their degree of impact on the projects, which was calculated in table above, as shown in Table 4.6.

Table 4.6: The ranking of the IRFs based on their degree of impact on OGP projects in Iraq.

IRFs	Risk Type*	The ranking of the IRFs					
		Total	I	II	III	IV	V
Terrorism & sabotage	S&S	1	3	1	1	1	2
Corrosion & lack of protection against it	OR	2	1	2	3	2	1
Theft	S&S	3	7	7	2	7	4
Lawlessness	R&R	4	4	3	16	3	9
Shortage of IT services & modern equipment	OR	5	15	4	4	10	11
Hacker attacks on the operating or control system	OR	6	11	8	10	4	3
Natural disasters & weather conditions	HSE	7	5	9	9	9	8
Threats to staff	S&S	8	6	13	7	8	7
Inadequate risk management	HSE	9	2	6	14	13	5
Insecure areas	PL	10	10	11	6	11	14
Limited warning signs	HSE	11	8	5	15	15	16
Operational errors	OR	12	9	10	13	19	6
Improper inspection & maintenance	HSE	13	16	21	8	5	19
Low public legal & moral awareness	S&S	14	12	17	12	17	15
Leakage of sensitive information	S&S	15	20	16	18	6	18
Design, construction & material defects	OR	16	17	19	5	18	17
Corruption	R&R	17	18	14	19	14	12
Improper safety regulations	HSE	18	19	12	20	23	13
Geological risks	PL	19	23	22	17	12	10
Little research on this topic	R&R	20	14	18	11	16	26
Lack of risk registration	R&R	21	22	15	22	20	22
Lack of appropriate training	R&R	22	13	20	21	25	24
Exposed pipelines	HSE	23	24	23	23	21	21
Vehicle accidents	PL	24	21	25	24	22	20
The pipeline is easy to access	PL	25	25	24	25	24	23
Weak ability to identify & monitor the threats	OR	26	26	26	26	26	25
Public's poverty & education level	S&S	27	27	27	27	27	27
Conflicts over land ownership	PL	28	28	29	28	28	28
Animal accidents	PL	29	29	28	29	29	29
Stakeholders are not paying appropriate attention	R&R	30	30	30	30	30	30

*The classification of the IRFs was done in section 2.4.5 of Chapter 2:. The ranking of the IRFs by their types is presented in section 4.4.5
Note: Total means the overall results of the survey, (I) means the consultants, planners and designers; (II) means the construction workers; (III) means the operators; (IV) means the owners and clients; and (V) means the researchers.

4.4.5.1 Ranking the IRFs based on the occupation of the project stakeholders

As shown in the table above, the overall results of the survey show the most influencing RFs on OGP projects, which are terrorism & sabotage, corrosion & lack of protection against it, theft, lawlessness, and shortage of IT services & modern equipment. On the other hand, weak ability to identify & monitor the threats, public's poverty & education level, conflicts over land ownership, animal accidents, and stakeholders are not paying appropriate attention are the IRFs that have less impact on the projects.

The ranking of the IRFs is quite varied, depending on the occupations of the stakeholders, as shown in Table 4.6. For example, three groups (construction workers, operators, and owners and clients) ranked terrorism & sabotage actions first, whilst the consultants, planners and designers group ranked it third, and the academic group ranked it second, with both of these groups ranking corruption first. The construction workers and owners and clients ranked corruption second, while the operators ranked it third. The consultants, planners and designers, construction workers and owners and clients ranked the insecure areas seventh, while it was ranked second and fourth from the operators' and researchers' point of view, respectively. Lawlessness was ranked third based on construction workers', and owners' and clients' perceptions. It ranked fourth, ninth and 16th regarding consultants, planners and designers', researchers', and operators' perceptions, respectively. Thefts were ranked fourth by both the construction workers and operators, 10th by owners and clients, 11th by researchers, and 15th by consultants, planners and designers. Regarding the less influential RFs, researchers ranked the leakage of sensitive information 23rd, construction workers and owners and clients ranked it 24th, and the consultants, planners and designers, and operators ranked it 25th. All the stakeholders ranked the geological risk 26th, apart from researchers, who ranked it 25th. All the stakeholders ranked natural disasters and weather conditions 27th and vehicle accidents 28th, apart from construction workers, who ranked vehicle accidents 29th. The ranking of IRFs indicated that the hacker attack on the operating or control system and animal accidents were ranked 29th and 30th, respectively. Only the construction worker group ranked hacker attack on the operating system differently, at 28th.

At the same time, to highlight the top five IRFs by each group of stakeholders (as highlighted in yellow in Table 4.6), it is worth noting that the lawlessness and corrosion were the first and second-highest IRFs from the consultants, planners and designers' point of view. Corrosion and lawlessness were the top IRFs from the construction workers' point of view. From the perception of the operators, the top IRFs were terrorism & sabotage, and improper inspection & maintenance. Corruption and terrorism & sabotage were the top IRFs according to the perceptions of the owners and clients in the projects. Terrorism & sabotage and corruption were the main IRFs in OGP projects according to the researchers who participated in the survey.

Form the previous discussion and results in Table 4.3,Table 4.4, and Table 4.6, it is obvious that the analysis and the ranking of the IRFs is significantly influenced by the occupations of the stakeholders in OGP projects. The staff who are working on-site considered terrorism & sabotage as the most severe IRF. This consideration might be because they are the people who are suffering from these threats directly, while this kind of risk is only threatening other staff such as consultants, planners and designers, and researchers in an indirect way, as these people are office-based workers and might not work at the site. Thus, the staff who are working on-site see that terrorism & sabotage is the IRF that has the most effect. However, office-based staff (i.e. consultants, planners and designers, and researchers) considered corruption to be the most severe IRF, as these people usually check the work procedures (e.g. welding) and the quality of the final work. This might give them a chance to compare the designs and work procedures developed in the design offices with the real work being carried out at the project site. If they identify a difference between the project on research and on-site, they may conclude that the final check and acceptance of the work has been affected by some kind of corruption; so they are the ones who perceive that corruption is the IRF that has the most effect.

4.4.5.2 Ranking the IRFs based on their types

As shown in Table 4.6 above, ranking the IRFs based on their types was as follows.

1- With regard to ranking the S&S IRFs terrorism & sabotage has come first followed by theft, threats to staff, low public legal & moral awareness, leakage of sensitive information and public’s poverty & education level.
2- The ranking of the CR IRFs was as follows: corrosion & lack of protection against it, shortage of IT services & modern equipment, hacker attacks on the operating or control system, operational errors, design, construction & material defects, and weak ability to identify & monitor the threats.
3- Natural disasters & weather conditions was the first HSE IRF, followed by inadequate risk management, limited warning signs, improper inspection & maintenance, improper safety regulations and exposed pipelines.
4- Lawlessness was the first IRF related to R&R, followed by corruption, little research on this topic, lack of risk registration, lack of appropriate training, and stakeholders are not paying appropriate attention.
5- The ranking of the IRFs related to PL was as follows: insecure areas, geological risks, vehicle accidents, the pipeline is easy to access, conflicts over land ownership, and animal accidents.

The next section shows the ranking of the five groups of IRFs with regard to their degree of impact on OGP projects in Iraq based on the survey.

4.4.6 The Results of Ranking the Five Groups of IRFs

According to the survey results, the five types of IRFs have been ranked as follows. S&S type of IRF is the most critical factor followed by PL, HSE, R&R and OR. Table 4.7 shows the difference in ranking the IRFs by participants' occupation. In the survey, rank 1 was represented as the highest impact and 5 the lowest impact amongst IRF types. Therefore, the lowest value in the table means the highest tank.

Table 4.7: The ranking of IRF types by participants' occupation.

The groups of the IRFs	**Total**		**I**		**II**		**III**		**IV**		**V**	
	Mean	**R***	**Mean**	**R***	**Mean**	**R***	**Mean**	**R***	**Mean**	**R***	**Mean**	**R***
S&S	2.155	1	1.857	1	2.014	1	2.244	1	2.359	1	2.273	1
PL	2.634	2	2.929	2	2.465	2	2.780	2	2.410	2	2.939	2
OR	3.134	3	4.000	5	3.676	5	3.561	5	3.538	4	3.091	3
HSE	3.536	4	3.143	4	3.254	3	2.854	3	3.051	3	3.182	4
R&R	3.541	5	3.071	3	3.592	4	3.561	4	3.641	5	3.515	5

Note: Total means the overall results of the survey, (I) means the consultants, planners and designers; (II) means the construction workers; (III) means the operators; (IV) means the owners and clients; and (V) means the researchers.
R* means Ranking

From the table above, it is clear that all the groups of participants were agreed that S&S IRFs are the most influential groups or risks that affect the OGP projects in Iraq, followed by the IRFs related to the location of the pipelines (PL). The rest of the groups were ranked as follows. The planners and designers said the HSE, R&R and OR are the third, fourth and fifth groups of IRFs, respectively. The HSE, R&R and OR IRFs were the third, fourth and fifth groups of IRFs, respectively, as per the construction workers and operators. With regard to the ranking of the groups of the IRFs based on the perspective of the owners and clients, the HSE IRFs come third, the OR IRFs come fourth and the R&R come fifth. The academics said the third, fourth and fifth groups of the IRFs are OR, HSE, and R&R, respectively. The next section discusses the participants' comments with regard to adding additional risk factors to the survey.

4.4.7 Participant Responses with Regard to Addition of New IRFs

In question 7, which was an open-ended question, the participants wrote several comments with regard to adding IRFs to the survey. A summary of these comments is provided in Table 4.1

Table 4.8: The summary of the participants' comments about adding IRFs to the survey.

IRFs	**Type of the IRFs**
Not taking into account the future of urban planning.	PL & R&R
External oil spots that negatively affect the pipes.	PL & HSE
The internal corrosion due to the transported products (e.g. pumping more than one type of petroleum product and crude oil from different fields in the same pipe).	Product type
Salt and metal contents in the transported products such as silver.	Product type
The pipes are older than the design age.	Material
Unqualified, less experienced and not well-educated staff with regard to risk management.	Labour
Poor quality pipes and material defects.	Material
Construction defects (e.g. welding defects and damage to the pipes during the construction of new ones).	Construction Defects

Table B.1 and Table B.2 in APPENDIX B: explain all the participants' comments about adding IRFs to the survey. As these IRFs were not mentioned in the literature review, the highlighted IRFs in the table above expand the knowledge of the risks that affect the safety of the pipeline projects in Iraq. This could be counted as one of the contributions of this research with regard to identifying a list of the IRFs that reflects the problems in OGP projects more realistically and specifically in Iraq. The results of this section will be used in the future work of this research, as discussed in the future work section in the last chapter of this thesis. The next section evaluates the effectiveness degree of the RMMs with regard to managing the IRFs in the OGP projects based on the survey in Iraq.

4.4.8 Evaluating the Risk Mitigation Methods (RMMs)

As explained earlier, in section 4.2, part of the survey conducted in this research is to analyse and evaluate the RMMs with regard to their degree of effectiveness in managing the IRFs in OGPs in Iraq based on the perceptions of the stakeholders in these projects. Question 8 and 9, therefore, asked about the usability and effectiveness degree of these RMMs, respectively (see item number III in section 4.2.2, and items 3.1 and 3.2 in point number 3 in section 4.4).

In other words, in order to make useful suggestions about risk management, the RMMs were evaluated based on (I) their chance of being used in OGP project in Iraq, i.e. "their usability degree", and (II) their effectiveness degree with regard to managing the IRFs in these projects, i.e. "their effectiveness degree". Below are the two tables that show the results of the survey with regard to evaluating the usability and the effectiveness of the RMMs.

A descriptive statistical analysis method is used to analyse the RMMs in the survey. The mean of the five-point Likert scale was calculated to determine the numerical values of usability and effectiveness degrees of the RMMs in OGP projects in Iraq. The results of analysing the RMMs in the survey are presented in Table 4.9, which shows the results of the survey with regard to evaluating the usability degree of the RMMs, and

Table 4.10, which shows the results of the survey with regard to evaluating the effectiveness degree of the RMMs.

Table 4.9: The usability degree of each RMM by participants' occupation (from the survey).

RMMs	**Usability**					
	Total	**I**	**II**	**III**	**IV**	**V**
Avoid 'Insecure Zones'	3.652	2.929	3.789	3.829	3.385	3.758
Anti-terrorism design	3.475	2.643	3.676	3.268	3.564	3.545
Avoid the registered risks and threats	3.616	3.357	3.662	3.634	3.513	3.727
Proper training	3.768	3.643	3.634	3.854	3.769	4.000
Move to an underground pipeline	4.051	3.857	4.085	4.390	3.846	3.879
Anti-corrosion such as isolation and cathodic protection	4.247	4.000	4.282	4.512	4.103	4.121
Protective barriers and perimeter fencing	3.783	3.214	3.732	3.878	3.872	3.909
Warning signs and marker tape above the pipeline	3.727	3.143	3.732	3.683	3.846	3.879
Foot and vehicle patrols	3.606	3.143	3.648	3.683	3.590	3.636
High technology and professional remote monitoring	3.480	2.643	3.606	3.415	3.359	3.788
Government-public cooperation	3.278	3.000	3.183	3.463	3.205	3.455
Proper inspection, tests and maintenance	3.677	3.429	3.549	3.805	3.769	3.788
Note: Total means the overall results of the survey, (I) means the consultants, planners and designers; (II) means the construction workers; (III) means the operators; (IV) means the owners and clients; and (V) means the researchers.						

As shown in the table above, the overall results of the survey indicate anti-corrosion measures (such as isolation and cathodic protection), moving to an underground pipeline, and protective barriers and perimeter fencing are the RMMs with the highest chance of being used in OGP projects in Iraq. The stakeholders have a similar point of view, which is that anti-corrosion measures such as isolation and cathodic protection is the RMM with the highest chance of usability. The second-highest RMM, according to the planners, consultants and designers, construction members and operators, is moving the pipelines underground. However, this method was only third highest for owners and clients. Protective barriers and perimeter fencing was the method with the second-highest chance of usability according to owners and clients, and third highest according to operators and researchers. Appropriate training was second highest for researchers, and third for consultants, planners and designers, while avoiding 'Insecure Zones' was third highest according to construction members.

Table 4.10 shows the results of the survey with regard to evaluating the effectiveness degree of the RMMs.

Table 4.10. The effectiveness degree of each RMM by participants' occupation.

RMMs	Effectiveness					
	Total	I	II	III	IV	V
Anti-corrosion such as isolation & cathodic protection	4.232	3.857	4.113	4.415	4.513	4.091
Move to an underground pipeline	4.066	3.929	4.000	4.220	4.333	3.758
High technology & professional remote monitoring	3.995	3.643	4.070	3.878	4.000	4.121
Proper inspection, tests & maintenance	3.828	3.429	3.887	3.829	3.872	3.818
Proper training	3.793	3.857	3.662	3.780	3.897	3.939
Avoid "Hot-Zones	3.778	3.214	4.014	3.659	3.744	3.697
Anti-terrorism design	3.778	3.143	3.986	3.341	4.179	3.667
Avoid the registered risks & threats	3.773	3.500	3.817	3.683	4.000	3.636
Protective barriers & perimeter fencing	3.682	3.214	3.577	3.756	3.872	3.788
Warning signs & marker tape above the pipeline	3.571	2.929	3.577	3.439	3.923	3.576
Government-public cooperation	3.545	3.214	3.563	3.561	3.564	3.606
Foot & vehicle patrols	3.530	3.429	3.563	3.634	3.615	3.273
Note: Total means the overall results of the survey, (I) means the consultants, planners and designers; (II) means the construction workers; (III) means the operators; (IV) means the owners and clients; and (V) means the researchers.						

As shown in the table above, based on the perceptions of the stakeholders in OGP projects that were collected from the survey, the results of evaluating the effectiveness degree of the RMMs show that anti-corrosion measures (such as isolation and cathodic protection), moving to an underground pipeline, and the use of high technology and professional remote monitoring are the most effective RMMs. The RMM anti-corrosion measures (such as isolation and cathodic protection) is the most effective RMM based on the perceptions from construction team members, operators, and owners and clients, while this method is the second most effective according to consultants, planners and designers, and researchers. Laying the pipelines underground is the most effective RMM for consultants, planners and designers, while this method is the second most effective according to operators, and owners and clients. Using high technology and professional remote monitoring is the most effective RMM according to researchers, the second for construction workers, and the third for consultants, planners and designers, and operators. Appropriate training to mitigate the IRFs is the third most effective RMM according to consultants, planners and designers, and researchers. Meanwhile, the third most effective RMMs for construction workers, and owners and clients were avoiding insecure areas and anti-terrorism design, respectively.

Although the overall results indicated that anti-corrosion measures and laying the pipelines underground were the RMMs that had the best chance of being used and were the most effective methods in the projects, the stakeholders' jobs in OGP projects might affect their evaluation of the RMMs. This can be seen in some examples: consultants, planners and designers said that training the staff is the RMM with the highest rate of usability to mitigate the IRFs. However, the construction teams and operators said avoiding insecure areas and having protective barriers and perimeter fencing are the methods with the highest rate of usability and effectiveness, as they are facing the risk of terrorism & sabotage directly. Additionally, using high technology and professional remote monitoring was evaluated as an effective RMM because such methods could cover wide areas in less time (compared to foot and/or vehicle patrols) to identify any threats to the pipelines.

The results presented in the two tables above will be used later in this research to make useful recommendations for identifying effective risk mitigation methods in OGP projects in Iraq, see Chapter 7:. The next section discusses the participants' comments with regard to adding more RMMs to the survey.

4.4.9 The Comments of the Participants about Additional RMMs

In question 10, which is an open-ended question, the participants wrote several comments with regard to adding RMMs to the survey use. A summary of these comments is provided in Table 4.11.

Table 4.11: The summary of the participations' comments about adding RMMs to the survey.

type	frequency (total comments = 29)	percentage (100%)
Advanced IT System	7	24.138
Anti-Corrosion	5	17.241
Barriers	4	13.793
Pipe Brand	2	6.897
Product Type	2	6.897
Geographical Location	2	6.897
Government and Public cooperation	2	6.897
Maintenance	1	3.448
Experts	1	3.448
Grads	1	3.448
Risk registration	1	3.448
Rules and regulation	1	3.448

Table B.3 and Table B.4 in APPENDIX B: provide all the participants' comments about adding RMMs to the survey. As these RMMs were not mentioned in the survey, the highlighted RMMs in the table above expand the knowledge of managing the IRFs in OGP project in Iraq. These RMMs could be used to manage the IRFs in OGPs in Iraq and minimise the problems of risk in these projects, as suggested by the survey participants. The results of this section will be used in the future work of this research, as discussed in the future work section in the last chapter of this thesis.

The next section shows the priority of applying the RMMs to manage the IRFs in OGPs during the different stages of the projects.

4.4.10 Application of RMM at Different Project Stages

The project stages were ranked regarding the priority in applying the RMMs in OGP projects in Iraq by calculating the average response rate in question 10 of the survey, as shown in Table 4.12.

Table 4.12: The priority of the project stage regarding applying the RMMs to mitigate the IRFs in OGP projects.

The stage of the project	Total		I		II		III		IV		V	
	Mean	R*	Mean	R*	Mean	R*	Mean	R*	Mean	R*	Mean	R*
Planning and Design Stage	1.52	1	1.857	1	1.423	1	1.439	1	1.385	1	1.848	1
Construction Stage	2.045	2	2.071	2	2.085	2	1.951	2	2.051	2	2.061	2
Operation Stage	2.434	3	2.071	3	2.493	3	2.610	3	2.564	3	2.091	3

Note: Total means the overall results of the survey, (I) means the consultants, planners and designers; (II) means the construction workers; (III) means the operators; (IV) means the owners and clients; and (V) means the researchers.
R* means Ranking

As shown in the table above, all the groups of participants were agreed that the management of the IRFs in the projects must be started during the project planning stage. The construction and operation stages were the second and third stages with regard to this ranking.

The next section makes a comparison between the above and underground pipelines based on the subjected risk factors in each type of these pipelines.

4.4.11 Comparing the Aboveground and Underground OGPs

The table below shows the results of comparing the above ground and underground pipelines based on the stakeholders' perceptions.

Table 4.13: A comparison between the above ground and underground pipelines based on the stakeholders' perceptions.

Above ground and underground pipes	Total	I	II	III	IV	V
A	71%	21.4%	35.2%	22.0%	17.9%	42.2%
B	29%	78.6%	64.8%	78.0%	82.1%	57.6%

A- The above ground pipelines are safer than the underground pipelines, despite them being exposed, and providing sabotage and theft opportunities.
B- The underground pipelines are safer than the above ground pipelines, despite the corrosion, geological, construction and maintenance risks.

Note: Total means the overall results of the survey, (I) means the consultants, planners and designers; (II) means the construction workers; (III) means the operators; (IV) means the owners and clients; and (V) means the researchers.

As shown in the table above, the majority of participants (71%) agreed that extending the pipelines underground is a safer option than extending them above ground, even though they will be subject to corrosion, and the added cost and time factors which should be considered when digging the trenches and laying the pipelines. This is because underground pipelines are not as easy to access as above ground ones. Thus, they are less subject to terrorism & sabotage, thieves, and vehicular and animal accident IRFs, which are the most influential risk factors in Iraq. Additionally, there is no need for an early warning system of signs along with the pipelines when the pipes are underground.

4.5 Summary

In this chapter:

- A questionnaire survey has been designed to analyse the IRFs and RMMs in OGP projects in Iraq, which were identified from the literature review.
- The survey design has gone through two stages, which are the pilot-like survey that provided the feedback to design the final draft of the survey, see section 4.2.
- An online questionnaire survey with a snowball sampling technique is utilised in this research to ensure widespread distribution of the survey, section 4.3.

The survey findings:

- The response rate of the survey was high, section 4.4.1. And, the sampling of the targeted population was good, section 4.4.2.
- Based on the results of the reliability testing of the survey, the survey was found to be reliable, section 4.4.3.
- Based on the perceptions of the stakeholders in different occupations in OGP projects in Iraq, the survey was used to analyse the probability (RP) and severity (RS) of the IRFs that influence the safety of these projects in Iraq, section 4.4.4. Additionally, it was used to rank the IRFs with regard to their degree of impact on the projects, section 4.4.5.
- The findings of the survey (e.g. the RP and RS of the IRFs) will be used as inputs for a computer-based risk analysis model that uses fuzzy theory to analyse and rank the IRFs with regard to their degree of impact on the projects, see Chapter 5:.
- This chapter has shown the ranking of the five groups of the IRFs (S&S, PL, OR, HSE and R&R) with regard to their degree of influence on the projects, section 4.4.6.

- The survey has evaluated some of the RMMs that could be used to manage the IRFs in OGP projects in Iraq, based on the perceptions of the stakeholders about their degree of usability and effectiveness degrees in their projects, section 4.4.8.
- The results of the survey regarding evaluating the RMM (e.g. their degrees of usability and effectiveness in OGP projects in Iraq) will be helpful to make useful suggestions and recommendations about identifying effective risk mitigation methods in OGP projects in Iraq. In other words, based on their degree of effectiveness, some of the RMMs will be suggested to manage the IRFs in Iraq, as will be discussed in Chapter 6: and Chapter 7:.
- This chapter has shown the IRFs and RMMs added to the survey based on the comments of the participants, as per sections 4.4.7 and 4.4.9, respectively. This helps in providing lists of IRFs and RMMs that reflect the situation of risk management in pipeline projects in Iraq more realistically.
- The added IRFs and RMMs will be used in the future work of this research, as discussed in the future work section in the last chapter of this thesis.
- This chapter has shown the ranking of the project stages with regard to their priority in terms of managing the IRFs in the projects, section 4.4.10.
- This chapter has shown that the majority of the stakeholders in OGP projects in Iraq prefer the above ground pipeline network, section 4.4.11.

The statistical analysis of the opinions collected from the survey could provide a good understanding and meaningful results about the IRFs and RMMs in OGP projects in Iraq based on the perceptions of a larger and diverse group of stakeholders in these projects, which is one of the advantages of the survey. A big population participating in the survey enhances the chance of collecting more answers from them. This is one of the advantages of using an industry-wide questionnaire survey to analyse the IRFs and RMMs in OGP projects in Iraq. In other words, collecting stakeholders' perceptions, i.e. government agencies, academic organisations and professionals (i.e. consultants, planners, designers, operators and researchers) about OGPs' IRFs and RMMs could reduce the time and the cost of investigations into OGP issues. Additionally, it ensures more verified analysis results of OGP IRFs and RMMs as the information has been gathered from field-experienced individuals. However, this method relies on their willingness to cooperate with the researchers, which is one of its disadvantages.

CHAPTER 5: RISK MODELLING AND RANKING

5.1 Introduction

This chapter provides an overview of the modelling and the ranking methodology of the Influencing Risk Factors (IRFs) associated with the Oil and Gas Pipeline (OGP) projects. In this study, the theory of fuzzy logic is used for modelling the IRFs and ranking them in order of their degree of impact on the projects. In the previous chapter, the ranking of the IRFs was based on their values of probability and severity levels that were calculated from the survey, which directly depends on the people's personal judgements. This means that ranking the IRFs based on the results of the survey is uncertain and biased due to the uncertainty and biases of the judgements. Hence, the theory of fuzzy logic was used to rank the IRFs since fuzzy logic has been widely used to reduce the uncertainty and the biases associated with the judgement of the participants in a survey.

This chapter is organised under four sections as follows. Section 5.2 describes the background of fuzzy theory and its applications while ranking the IRFs. Section 5.3 presents the computer-based risk modelling based on the results of analysing the IRFs through the industry survey (Chapter 4:) in order to rank them. The values of Risk Probability (RP) and Risk Severity (RS) calculated from the survey are used as key inputs for risk modelling and ranking. Section 5.4 discusses the results of risk modelling and section 5.5 explains the difference in the results of the survey and the fuzzy theory. Section 5.6 summarises this chapter.

5.2 Background of Fuzzy Theory

5.2.1 Overview and Definitions

The fuzzy set was introduced by Zadeh in 1965 and it is defined as a generalised characteristic function; that is, one which varies uniformly between zero and one rather than merely assuming the two values of zero and one (Zadeh, 1965). The fuzzy set is defined as a set of elements (*X*) that belong to a group called universe (*U*) with a membership degree between 0 and 1 (i.e. $X \in U$, [0-1]) (Pawlak, 1985). The definition of fuzzy logic is stated as follows. A fuzzy set (*X)* of a universe of (*U*) is represented by a collection of ordered pairs of a generic element X ∈ U and its grade of membership function, as described below (Li et al. 2005).

$$X = \sum_{1}^{N} \frac{\mu_{(X_1)}}{X_1}, \frac{\mu_{(X_2)}}{X_2}, \ldots., \frac{\mu_{(X_N)}}{X_N}$$

Where N is the number of elements in *X*. Note that the symbol ∑ here denotes the collection of discrete elements. The corresponding notation for a continuous universe of discourse *U* is

$$U = \int_{1}^{U} \frac{\mu_{U(X)}}{X}$$

Fuzzy logic uses intermediate values that give the grades of membership of various points in the fuzzy set. Higher values imply a higher grade of membership, and vice versa. Typical examples of fuzzy sets are the set of children around five years old or the set of young men. However, there still appears to be no satisfactory axiomatic theory to describe fuzziness (Nahmias, 1978). On the other side, on many occasions, the values of [0 or 1] are used to describe a certain phenomenon. For example, describing the colour of a number of cars in a car park to see how many black or white cars there are, where 1 means a black car and 0 means a white car. In this situation, we are not expecting to see any values rather than 0 or 1. Such a concept, therefore, is defined as a restriction concept. However, using fuzzy theory to describe the cars' colours in that car park, we might see the value of 0.7 for example, as the colour of that car is not white or black, but nearly black. In such a case about how the colour of the car is near to the black colour, some of the observers might say it is 0.6, 0.65 or 0.7, which depends on their personal perspective. The personal perspective and the personal judgement lead to a range of differences in the results, which is called uncertainty. In that case, the numbers between 0 and 1 are called membership degrees, in which the element belongs to the group (i.e. the universe). In another definition of the fuzzy theory, Marinos (1969) thought it was quite possible that certain situations might have values other than falsehood and truth. In another situation, the approach uses many variables with values between 0 to 1 called fuzzy set" to describe the degree of a person – is he/she young or old – and is called fuzzy logic (Marinos, 1969). Fuzzy logic – the logic underlying approximate, rather than exact, modes of reasoning – is finding applications that range from process control to medical diagnosis (Zadeh, 1988). The fuzzy logic system has different functions and three different stages, which are (i) fuzzification, (ii) model engine and knowledge base, and (iii) defuzzification, as will be explained in section 5.3. The next section explains the application of fuzzy theory in risk analysis.

5.2.2 Applications of Fuzzy Theory in Risk Analysis

The IRFs in the OGP projects are complicated, uncertain and subjective due to the unique characteristics of the projects and the different types of work activities in them (Taylan et al. 2014). The absence of enough information, the inaccurate values about the probability and severity levels of the IRFs 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 assessment (Cheng and Lu, 2015). De Almeida et al. (2017) made a comparison between the multi-criteria and multi-objective models applied in risk management. This study has confirmed that fuzzy theory helps decision-makers to deal with the uncertainties and partially known facts while making decisions. A comprehensive review was conducted by Islam et al. (2017) about the application of fuzzy theory in the risk assessment of construction projects. Fuzzy theory was found to be an active alternative way of handling the uncertainty and vagueness associated with using document analysis, questionnaire survey and Analytic Hierarchy Process (AHP) risk analysis methods. AHP works by directly comparing two risk factors with regard to their degree of impact on the projects, as explained below.

The IRFs	IRF_1										IRF_2								
The impact	9	8	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9
The answer																			

However, using AHP under an uncertain environment is still an open issue. This is because the weights of the main and sub-criteria in the tables imply that there exists variation between the priorities of the main and sub-criteria mentioned in the model (Azadeh et al. 2013).

Gentile et al, (2003) as cited by Khan et al. (2015), p. 131 made a comparison between the methods and models used in risk management, explaining that: "*Similar to any other quantification, quantification associated with inherent safety assessment may also contain a certain extent of uncertainty. A fuzzy logic based method was developed to produce a more realistic estimation reducing the uncertainty associated with subjective analysis*". The next paragraph focuses on reviewing a number of past studies that used fuzzy theory to analyse the Third-Party Disruption (TPD) IRFs in the oil and gas industry because they are related to the scope of this research.

Akyuz and Celik (2015) used fuzzy theory to enhance the results of analysing the potential hazards and accidents associated with transporting Liquefied Natural Gas (LNG) using cargo tanks. Yoon et al. (2013) used fuzzy theory to develop a risk assessment system to analyse the IRFs in gas refinery plants. However, the IRFs in OGPs are different from those in cargo tanks and refinery plants because these projects run for thousands of kilometres, which makes them more exposed to the risk factors. This means that the methodology of these two papers cannot be applied to effectively analyse the operational IRFs in similar industry fields.

Urbina and Aoyama (2017) used fuzzy theory to reduce the uncertainty associated with determining the cost of risk management activities in pipeline projects and the probability and the severity levels of the hazards events in these projects. Nevertheless, this study did not allocate the IRFs to the project activities to develop a risk optimisation model, which could help the project stakeholders in making sound decisions related to the safety domain of the projects. Innal et al. (2016) tried to reduce the uncertainty in safety-instrumented systems using fuzzy theory and Monte Carlo analysis. Keprate and Ratnayake (2016) used fuzzy theory to select the best locations for fatigue-critical piping locations for inspection of offshore pipelines. However, the last two studies did not consider the location of the pipelines.

Lu et al. (2015) study used fuzzy theory to calculate the probability of failure for underwater gas pipeline projects undertaken by the China National Petroleum Corporation (CNPC). Peng et al. (2016a) used fuzzy theory to assess the TPD in OGP projects in Petro-China Gang-Zao. Fuzzy theory has enhanced the results of analysing the probability of accidents and the IRFs. Nonetheless, the last two studies did not analyse the severity levels of the IRFs, which is one of their limitations.

Guo et al. (2018) analysed some of the leakage accidents occurring in OGPs in China. This study used fuzzy theory and Bayesian theory to overcome the problem of defining the boundaries of the IRFs while analysing them in the pipeline projects. Jamshidi et al. (2013) provided a systematic risk assessment framework to analyse the IRFs in gas pipeline projects in Iran. This study used fuzzy theory as a rational way of coming up with precise and robust results of risk analysis. In these two studies, the detection of the probability and severity levels of the IRFs was not accurate, which is one of their limitations. The authors suggested performing more quantitative analyses about the IRFs (e.g. questionnaire survey and experts' judgements) in order to provide accurate inputs for their study before using fuzzy theory to analyse the IRFs. In doing so, fuzzy theory will provide a better prediction about the probability and severity levels of the IRFs in the projects.

Zhang et al. (2016) developed a framework in order to evaluate the performance of a petroleum transportation system. The framework identified and evaluated the IRFs via the literature review and a questionnaire survey. It used linguistic evaluation and fuzzy theory to reduce the complexity and uncertainty involved with risk analyses using experts' judgements. However, this study evaluated the IRFs based on ambiguous features and subjective perception, which means this study needs further research with regard to providing dynamic data and effective mathematical algorithms and calculations to provide more trusted inputs for the study.

Fuzzy theory, therefore, has been increasingly used to analyse the IRFs in projects in the conditions of poor data and information about the IRFs (Chan et al. 2009). Still, all of the above-mentioned studies are limited to analysing the IRFs during the operational stage of the projects. Meanwhile, the pipeline projects are vulnerable to a massive number of risks during the planning and construction stages as well. Moreover, the above-mentioned studies are limited to analysing the IRFs in their countries, which means they would not be effective to analyse the IRFs in OGP projects elsewhere. This is because OGP projects are subjected to different IRFs in different countries and different situations. Fuzzy theory cannot be used to draw and analyse the failure scenarios in pipeline projects, which is one of the disadvantages of using fuzzy theory for analysing the IRFs in the projects.

The next section provides the assessment and the ranking of the IRFs in OGP projects using a computer-based risk assessment model integrated with fuzzy theory.

5.3 Computer-based Risk Modelling

As explained in section 5.2 above, fuzzy theory is useful to reduce the uncertainty caused by the lack of data about the IRFs and the biases associated with human judgements about their level of impact. The uncertainty associated with analysing the IRFs comes from the lack of data about the IRFs, which leads to stakeholder judgements being used to analyse the IRFs in the projects. Therefore, both the lack of data and the biases associated with the judgements about the IRFs make the results of risk analyses uncertain. Figure 5.1 shows a flowchart of a computer-based risk model that was developed in this study with the aim of ranking the IRFs based on their degree of the probability and severity impact in the OGP projects.

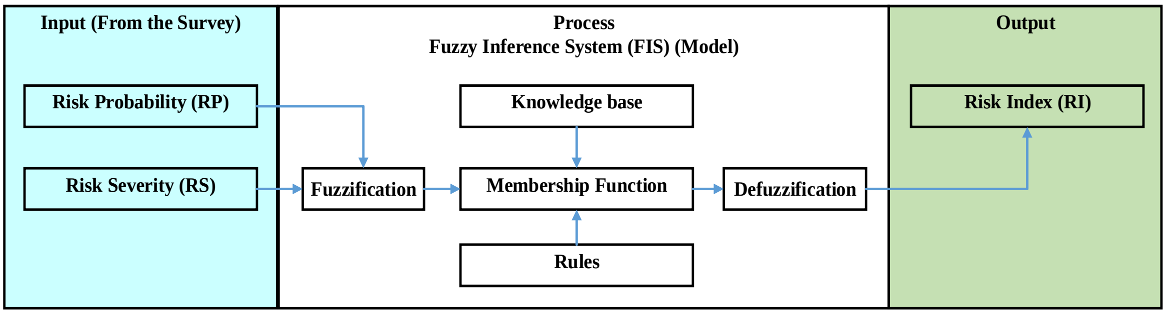

Figure 5.1: The data flowchart used in risk modelling.

The model uses the fuzzy logic tool provided by the Fuzzy Inference System (FIS) toolbox within MATLAB software to calculate the Risk Index (RI) of IRFs. Following are the steps involved as inputs, process and outputs of the computer-based risk model.

1- The findings of the survey, which are the Risk Probability (RP) and Risk Severity (RS) levels of the IRFs, were used as **inputs** of the FIS.
2- As shown in Figure 5.1, using the FIS to analyse the IRFs in the projects has three stages, which are (I) fuzzification (section 5.3.1), (II) the engine of the FIS (e.g. the knowledge base, the controlling rules and the membership functions) (section 5.3.2) and (III) defuzzification (section 5.3.3) (Jamshidi et al. 2013; Li et al. 2010 and Sa'idi et al. 2014).
3- **The outputs** of the model are the value Risk Index (RI) of the IRFs.

5.3.1 Step I: Fuzzification

Fuzzification is about providing crisp inputs for the FIS by generating sets of membership functions. The inputs of the system were the RP and RS of the IRFs, which were calculated via the survey. The Min-Max membership function, which is explained in Figure 5.2, was used to generate the inputs of the FIS (Sa'idi et al. 2014).

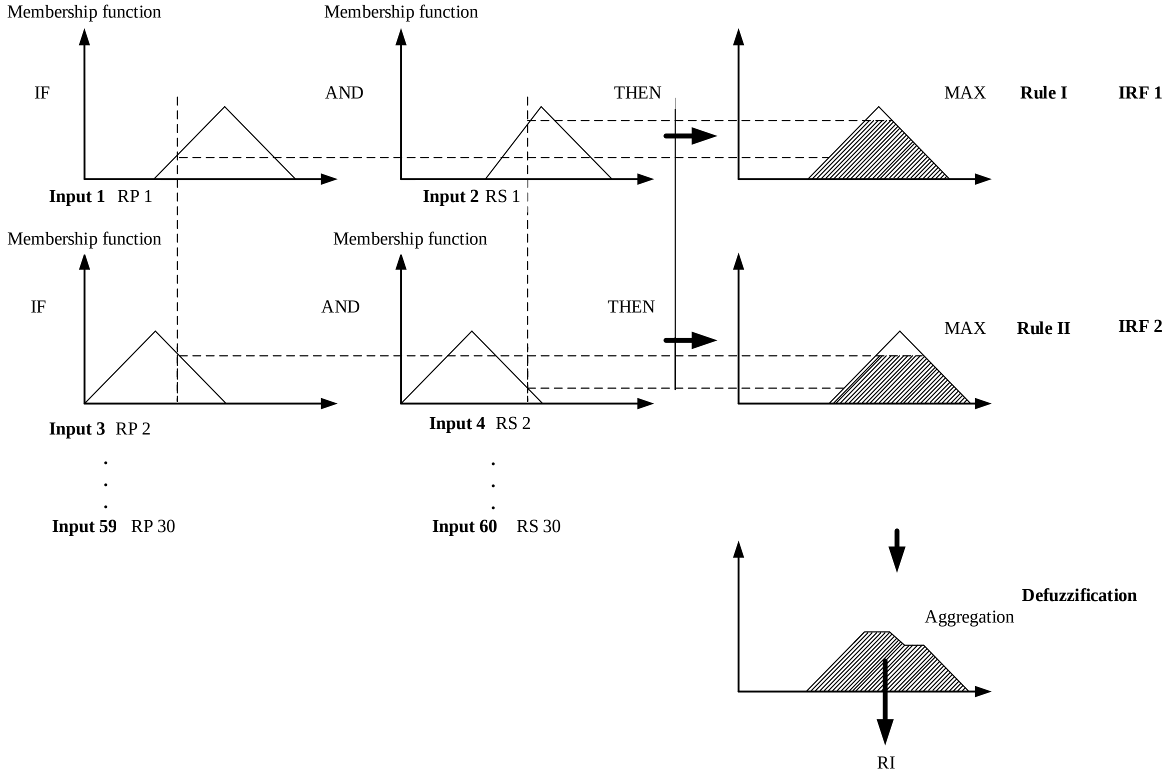

Figure 5.2: The Min-Max membership function of the fuzzy theory.

The model uses the fuzzy logic functions provided by the Fuzzy Inference System (FIS) toolbox within MATLAB software to calculate the Risk Index (RI) of IRFs. Two types of membership functions proposed by the Mamdani mathematical algorithm were applied in this research, which are the triangular and the trapezoidal membership functions. In the triangular membership function, full compliance is only attained at the maximum score of RI, see Figure 5.3 and equations 5.1 to 5.5.

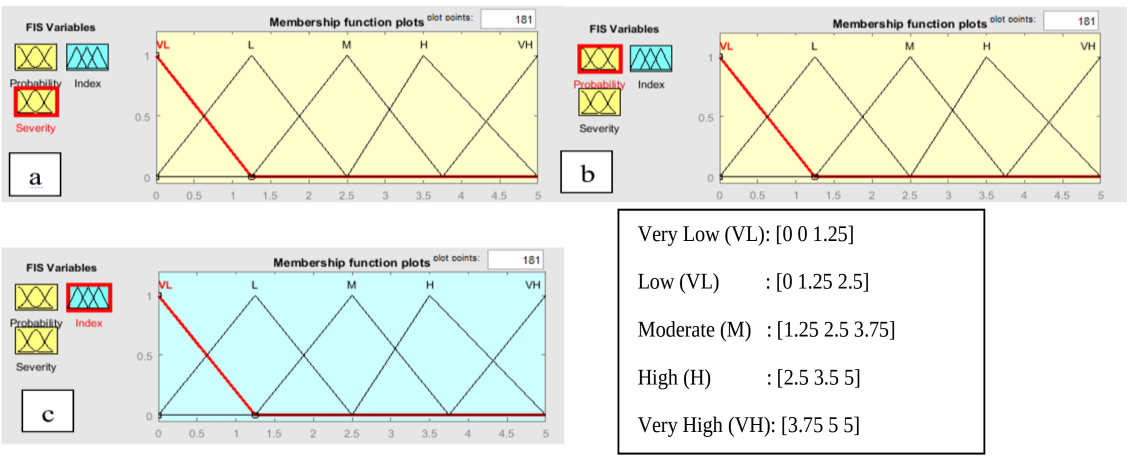

Figure 5.3: Fuzzy triangular membership functions for (a) RP, (b) RS, and (c) RI.

$$f(VL)x=\begin{cases} 5 & 0<x<0.5 \\ (1.25-x)/(1.25-0.5) & 0.5<x<1.25 \\ 0 & Otherwise \end{cases}$$ Very Low (VL) =[0 0 1.25] ...(5.1)

$$f(L)x=\begin{cases} (1.25-x)/(1.25-0.0) & 0.0<x<1.25 \\ (2.5-x)/(2.5-1.25) & 1.25<x<2.5 \\ 0 & Otherwise \end{cases}$$ Low (L) =[0 1.25 2.5] ...(5.2)

$$f(M)x=\begin{cases} (x-1.25)/(2.5-2) & 1.25<x<2.5 \\ (3.75-x)/(3.75-2.5) & 2.5<x<3.75 \\ 0 & Otherwise \end{cases}$$ Moderate (M) = [1.25 2.5 3.75] ...(5.3)

$$f(H)x=\begin{cases} (x-2.5)/(3.5-3) & 2.5<x<3.5 \\ (2.5-x)/(5-3.5) & 5<x<3.5 \\ 0 & Otherwise \end{cases}$$ High (H) = [2.5 3.5 5] ...(5.4)

$$f(VH)x=\begin{cases} (x-4)/(4.5-4) & 4<x<4.5 \\ (4.5-x)/(5-4.5) & 4.5<x<5 \\ 0 & Otherwise \end{cases}$$ Very High (VH) = [3.75 5 5] ...(5.5)

The trapezoidal membership function has used both an upper and a lower limit. This means that the RI score is considered fully compliant once it hits the upper limit, see Figure 5.4 and equations 5.6 to 5.10.

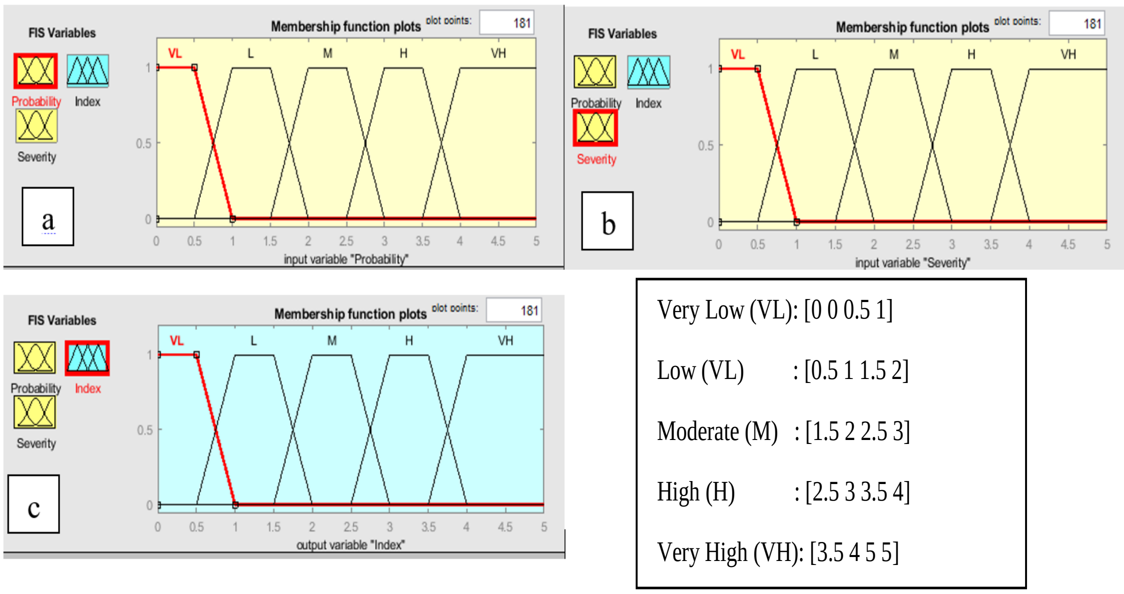

Figure 5.4: Fuzzy trapezoidal membership functions for (a) RP, (b) RS, and (c) RI.

$$f(A)x=\begin{cases} 5 & 0<x<0.5 \\ (1-x)/(1-0.5) & 0.5<x<1 \\ 0 & Otherwise \end{cases}$$

Very Low = [0 0 0.5 1] ...(5.6)

$$f(A)x=\begin{cases} (x-1)/(1.5-1) & 0.5<x<1 \\ 5 & 1<x<1.5 \\ (2-x)/(2-1.5) & 1.5<x<2 \\ 0 & Otherwise \end{cases}$$

Low = [0.5 1 1.5 2] ...(5.7)

$$f(A)x=\begin{cases} (x-2)/(2.5-2) & 1.5<x<2 \\ 5 & 2<x<2.5 \\ (3-x)/(3-2.5) & 2.5<x<3 \\ 0 & Otherwise \end{cases}$$

Moderate = [1.5 2 2.5 3] ...(5.8)

$$f(A)x=\begin{cases} (x-3)/(3.5-3) & 2.5<x<3 \\ 5 & 3<x<3.5 \\ (4-x)/(4-3.5) & 3.5<x<4 \\ 0 & Otherwise \end{cases}$$

High = [2.5 3 3.5 4] …(5.9)

$$f(A)x=\begin{cases} (x-4)/(4.5-4) & 3.5<x<4 \\ 5 & 4<x<4.5 \\ (4.5-x)/(5-4.5) & 4.5<x<5 \\ 0 & Otherwise \end{cases}$$

Very High = [4 4.5 5 5] …(5.10)

The next section details the knowledge base and the controlling rules of the model.

5.3.2 Step II: The Knowledgebase and If-Then Rules

The knowledge base is about defining the rules controlling the behaviour of the FIS, i.e. the "If-Then rules" (Guzman Urbina and Aoyama, 2017). The following 25 rules were used to control the model. The rule weight was one. The rules are presented below.

1. Rule 1: If RP is Very Low and RS is Very Low, Then RI is Very Low
2. Rule 2: If RP is Very Low and RS is Low, Then RI is Very Low
3. Rule 2: If RP is Very Low and RS is Medium, Then RI is Very Low

4. Rule 4: If RP is Very Low and RS is High, Then RI is Medium
5. Rule 5: If RP is Very Low and RS is Very High, Then RI is Medium
6. Rule 6: If RP is Low and RS is Very Low, Then RI is Very Low
7. Rule 7: If RP is Low and RS is Low, Then RI is Low
8. Rule 8: If RP is Low and RS is Medium, Then RI is Low
9. Rule 9: If RP is Low and RS is High, Then RI is Medium
10. Rule 10: If RP is Low and RS is Very High, Then RI is High
11. Rule 11: If RP is Medium and RS is Very Low, Then RI is Low
12. Rule 12: If RP is Medium and RS is Low, Then RI is Low
13. Rule 13: If RP is Medium and RS is Medium, Then RI is Medium
14. Rule 14: If RP is Medium and RS is High, Then RI is High
15. Rule 15: If RP is Medium and RS is Very High, Then RI is High
16. Rule 16: If RP is High and RS is Very Low, Then RI is Low
17. Rule 17: If RP is High and RS is Low, Then RI is Very Medium
18. Rule 18: If RP is High and RS is Medium, Then RI is High
19. Rule 19: If RP is High and RS is High, Then RI is High
20. Rule 20: If RP is High and RS is Very High, Then RI is Very High
21. Rule 21: If RP is Very High and RS is Very Low, Then RI is Medium
22. Rule 22: If RP is Very High and RS is Low, Then RI is Very Medium
23. Rule 23: If RP is Very High and RS is Medium, Then RI is High
24. Rule 24: If RP is Very High and RS is High, Then RI is Very High
25. Rule 25: If RP is Very High and RS is Very High, Then RI is Very High

The next section details the defuzzification step and the outputs of the risk model.

5.3.3 Step III: Defuzzification

The defuzzification step is about providing the outputs of the model, which were the RI for each IRF. The defuzzification could be done in different methods such as centroid, the centre of an area, mean max membership, weighted average, max membership principle, the centre of sums, IRF weighted valuation function and first (or last) of maxima methods. This thesis has used the centre of the area to calculate the RI of the IRFs because this method of defuzzification is a more reasonable and reliable method. Most of the past studies that used fuzzy theory to analyse the IRFs in projects have used the centre of the area to calculate the RI of the IRFs. For example, these include Beriha et al. (2012), Elsayed (2009), Innal et al.

(2016), Jamshidi et al. (2013), Kabir et al. (2015), Keprate and Ratnayake (2016), Li et al. (2010), Markowski and Mannan (2008), Mokhtari et al. (2012), Sa'idi et al. (2014) and Tabesh et al. 2018. The FIS provides a powerful rule viewer tool, which displays the RP and RS of the IRFs, controlling rules, and the RI of the IRFs. The rule viewer and the three-dimension risk matrix are shown in Figure 5.5.

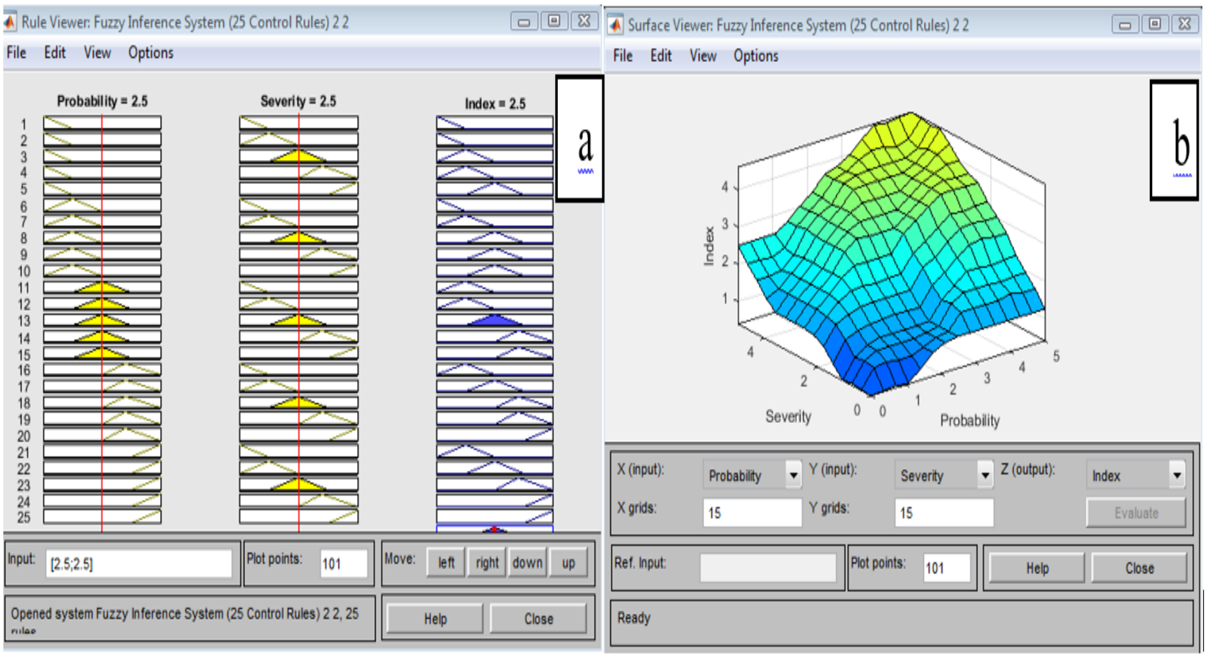

Figure 5.5: (a) Rule viewer, and (b) 3D risk matrix in FIS.

The results of analysing the IRFs using the FIS are shown in the next section.

5.4 Results

Table 5.1 presents the key output of the risk model which are the results of analysing the IRFs using the FIS.

Table 5.1: The results of assessing the IRFs using FIS.

IRFs	The outputs of the FIS, which are the values of RI for the IRFs				Rank
	RI (1)*	**Risk Range**	**RI (2)^**	**Risk Range**	
Terrorism & sabotage	3.99	H	4.38	VH	1
Corruption	3.87	H	4.38	VH	2
Low public legal & moral awareness	3.8	H	4.36	VH	3
Insecure areas	3.76	H	4.34	VH	4
Theft	3.75	H	4.33	VH	5
Corrosion & lack of protection against it	3.72	H	4.31	VH	6
Lack of appropriate training	3.71	H	4.29	VH	7
Improper safety regulations	3.7	H	4.2	VH	8
Exposed pipelines	3.7	H	4.15	VH	9
Improper inspection & maintenance	3.69	H	4.13	VH	10
Shortage of modern IT services	3.68	H	4.01	VH	11
Conflicts over land ownership	3.68	H	4.04	VH	12
Weak ability to identify & monitor the risks	3.67	H	3.87	H	13
Design, construction & material defects	3.64	H	3.78	H	14
Lack of risk registration	3.6	H	3.72	H	15
Easy access to pipeline	3.57	H	3.67	H	16
Limited warning signs	3.56	H	3.65	H	17
Little research on this topic	3.55	H	3.63	H	18
Lawlessness	3.54	H	3.61	H	19
Stakeholders not paying appropriate attention	3.51	H	3.54		20
Public poverty & education level	3.49	H	3.52	H	21
Inadequate risk management	3.48	H	3.52	H	22
Leakage of sensitive information	3.38	H	3.28	H	23
Threats to staff	3.35	H	3.25	H	24
Operational errors	3.3	H	3.25	H	25
Geological risks	3.17	H	3.25	H	26
Natural disasters & weather conditions	3.1	H	3.25	H	27
Hacker attacks on the operating or control systems	3.03	H	3.18	H	28
Vehicular accidents	2.8	M	2.68	M	29
Animal accidents	1.95	L	2.5	M	30
*RI(1): RI using triangular membership function. ^ RI(2): RI using trapezoidal membership function.					

In this research, the IRFs were ranked with regard to their degree of impact on OGP projects in Iraq based on their values of RI, which were the results of the FIS. The table above shows the top five IRFs in OGP projects in Iraq, which are terrorism & sabotage, corruption, low public legal & moral awareness, insecure areas and theft. And the IRFs with less impact in these projects are geological risks, natural disasters & weather conditions, hacker attacks on the operating or control systems, vehicular accidents and animal accidents.

The results of Table 5.1 above (e.g. the RI of the IRFs) will be used in Chapter 6: to optimise the pipeline routes/alignments based on identified IRFs to build a new pipeline project. This analysis involves selecting safest routes/alignments for a pipeline project. Additionally, the RI values of each IRF will be used in Chapter 7: to select the optimum safest routes/alignments for the new pipeline project, and in Chapter 8: and Chapter 9: to quantify the delay impact from IRFs on the project duration of a pipeline construction project.

Using the fuzzy theory to analyse the IRFs in the project could be improved by paying more attention towards the fact that the fuzzy theory-based expert system applies an imprecise term that could lead to poor performance in many situations, where identifying risk level of OGP stations includes many overlapping variables changing over time. This does not really assess the risk level in such big projects, and can affect decision-making as well as the validity and reliability of decisions made by such systems. Consequently, we recommend taking a step forward and considering sophisticated, intelligent approaches to identify the risk levels of such big projects. In our upcoming study that will be available online soon, we are applying a set of machine-learning methods for the same purpose.

5.5 Difference between the Results of the Risk Importance Index and the FIS

Table 5.2 shows the difference in ranking the IRFs using the Risk Importance Index (RII) of the IRFs (i.e. equation 4.1 in Chapter 4:) and fuzzy theory via the FIS toolbox in MATLAB software.

Table 5.2: The ranking of the IRFs using equation 4.1 and the FIS.

IRFs	Risk Type	Risk Rank using RII	Risk Rank using FIS
Terrorism & sabotage	S&S	1	1
Corruption	R&R	2	2
Low public legal & moral awareness	S&S	9	3
Insecure areas	PL	3	4
Theft	S&S	5	5
Corrosion & lack of protection against it	OR	6	6
Lack of appropriate training	R&R	12	7
Improper safety regulations	HSE	7	8
Exposed pipelines	HSE	13	9
Improper inspection & maintenance	HSE	8	10
Shortage of modern IT services	OR	14	12
Conflicts over land ownership	PL	20	11
Weak ability to identify & monitor the risks	OR	10	13
Design, construction & material defects	OR	19	14
Lack of risk registration	R&R	17	15
Easy access to pipeline	PL	16	16
Limited warning signs	HSE	15	17
Little research on this topic	R&R	18	18
Lawlessness	R&R	4	19
Stakeholders not paying appropriate attention	R&R	11	20
Public poverty & education level	S&S	22	21
Inadequate risk management	HSE	24	22
Leakage of sensitive information	S&S	25	23
Threats to staff	S&S	21	24
Operational errors	OR	23	25
Geological risks	PL	26	26
Natural disasters & weather conditions	HSE	27	27
Hacker attacks on the operating or control systems	OR	29	28
Vehicle accidents	PL	28	29
Animal accidents	PL	30	30

In addition to the uncertainty associated with analysing the IRFs based on the traditional risk assessment and ranking methods using the RII, as explained earlier in the study (see section 1.3), ranking the IRFs regarding their RI values might not reflect their criticality. When comparing the ranking of the IRFs using the results of RII and the FIS, it was found that the five most critical IRFs and the five least critical ones barely changed, with a slight change between the 3rd and the 4th and the 28th and the 29th IRFs.

The FIS assists in overcoming the limitations in ranking the IRFs using the traditional assessment methods via the RII (Kraidi et al. 2020). The difference in the ranking of the IRFs using the two different methods is because the FIS uses the class of linguistic summaries 'VL, L, M, H and VH' and the If-Then to analyse the IRFs. For example, the probability of the IRF 'little research on this topic' is = 3.62 and its severity = 3.7. The rank of this IRF was 18th with RI = 3.55. However, the probability of the IRF 'lack of risk registration' = 3.57 and its severity = 3.66, which are lower than the probability and severity levels of ‘lack of risk registration’, but ‘lack of risk registration’ was ranked higher as the 15th IRF with RI = 3.6.

5.6 Summary

This chapter has defined the fuzzy theory and explained its applications in analysing the IRFs in the projects, see section 5.2. The main points in this chapter are:

- The findings of the survey were used as inputs for a computer-based risk analysis model, section 5.3.1.
- This model has used fuzzy theory to assess and rank the IRFs in OGP projects in Iraq, section 5.3.2.
- The FIS in MATLAB was used to apply the fuzzy theory for assessing, ranking and calculating the RI values of the IRFs in OGP projects in Iraq.
- The results of the survey and the FIS highlighted the most critical IRFs in OGP projects in Iraq, which are: terrorism & sabotage, corruption, low public legal & moral awareness, insecure areas and theft, see Table 5.1.
- The IRFs that have the least impact on OGP projects in Iraq are: geological risks, natural disasters & weather conditions, hacker attacks on the operating or control systems, vehicular accidents and animal accidents, see Table 5.1.
- The fuzzy theory has helped in providing more accurate results of assessing and ranking the IRFs in OGP projects by reducing the uncertainty and biases in analysing them, based on the results of the survey only. When comparing the ranking of the IRFs using the results of RII and the FIS, it was found that the five most critical IRFs and the five least critical ones barely changed, see section 5.4.
- The results of the risk analysis will be used in the next chapter in order to select safe routes/alignments for the new OGP projects in Iraq (Chapter 7:) and quantify the impact of the IRFs on the duration of these projects (Chapter 8: and Chapter 9:).

CHAPTER 6: DESIGN OF THE RISK MANAGEMENT FRAMEWORK

6.1 Introduction

This chapter describes the design details and specifications of a Risk Management Framework (RMF), which is one of the key goals of this study. The RMF is applicable to analyse and manage the Influencing Risk Factors (IRFs) in Oil and Gas Pipeline (OGP) projects. In addition, the RMF has three main functionalities: (i) optimise the safest pipeline routes/alignments for laying new projects, (ii) make recommendations of a suitable risk mitigation method in the projects, and (iii) quantify the impact of delay caused by the IRFs in the OGP projects.

The RMF is structured under three main components: inputs, process and outputs. The key information in this study that is used to design the RMF are the IRFs and the list of existing Risk Mitigation Methods (RMMs). The potential list of existing RMMs was identified through an extensive review of the literature (in Chapter 2:). The IRFs and RMMs were analysed with regard to their impact on the OGP projects based on the industrial survey (in Chapter 4:) and the application of fuzzy theory (in Chapter 5:). The key modules integrated in the RMF are risk optimisation, identification of RMMs and quantification of the impact of delay caused by the associated IRFs in the OGP project. The key outputs of the RMF are (i) the safest pipeline routes/alignments based on risk level in the suggested routes; (ii) the effective RMMs, which could be used to mitigate the IRFs; and (iii) the amount of construction delay in the projects caused by the IRFs in the OGP projects. Section 6.2 presents the overall structure of the RMF and its design procedure. The details of key components of the framework that are integrated within the framework, which are the inputs (section 6.3), the processes (section 6.4) and the outputs (section 6.5), are discussed below. Section 6.6 presents the summary of this chapter.

6.2 Design a Risk Management Framework (RMF)

This section explains the design specification of the RMF and the key components of the framework that include inputs, the process and the outputs. The research study designed a concept and developed a risk management framework in order to analyse and manage the risk factors associated with the OGP projects. According to the justification presented in

Chapter 3:, the pragmatist paradigm philosophy is adopted in this study to design the RMF. Both qualitative and quantitative approaches were used to collect and analyse the information required to design and evaluate the RMF, as explained below.

- The findings of the qualitative part of this research that were used to develop the RMF were the IRFs and RMMs in OGP projects, which were identified based on the literature review. In addition, the investigations of the literature review were extended to understand the limitations and the strengths of the existing RMFs in the OGP projects. Moreover, the literature review was used to analyse the past studies about selecting safest routes for the new pipeline projects and to analyse the impact of the construction delay in these projects.
- The findings of the quantitative part of this research used to develop the RMF included the results of analysing the probability and severity levels of the IRFs, the usability and the effectiveness degrees of the RMMs (Chapter 4:) and the values of the Risk Index (RI) of the IRFs (Chapter 5:).

Based on the findings mentioned above, the following steps are followed to design the risk management framework.

- Step 1: **Identify, assess and document the potential IRFs in OGP projects**.

This step involves investigating the past studies about risk management in OGP projects worldwide. The findings of this step are the potential IRFs in the projects which could obstruct the safety of their projects. This step will help the stakeholders in looking at the problems in their projects and considering the causes of the problems they might face. The sources of the IRFs 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: **Establish the context of the risk management plans**.

The qualitative part of the research was extended to review the past studies about managing the IRFs in the projects (section 2.5). Additionally, the literature review was used to examine the prior studies about selecting safest routes for the new pipeline projects (section 2.5.2) and to analyse the construction delay in these projects (section 2.5.3). The findings of this step have helped to understand the existing management system and identify the strengths and limitations of the existing RMFs in OGP projects.

- Step 3: **Risk assessment**.

The IRFs were assessed with regard to their degree of impact on the projects based on the results of

1- An industrial survey that tested the Risk Probability (RP) and Risk Severity (RS) of the IRFs (section 2.4.4, 2.4.5); and
2- The results of the fuzzy theory used to calculate the IRFs' degree of impact on the projects (section 5.3.3).

This step has helped in ranking the IRFs with regard to their degree of impact on the projects.

- Step 4: **Potential risk treatments – how will the risk will be managed**?

This step involved identifying the RMMs used to manage the IRFs in the projects based on the literature review (section 2.4.6) and analysing their effectiveness degree in the projects based on the results of the survey (section 4.4.8). The findings of this step could make the RMFs able to be used for recommending some of the effective RMMs in OGP projects.

- Step 5: **Create a risk management plan**, **implementation and evaluation**.

Selecting an appropriate **risk management and controlling plan** is a vital part of risk management. This step involves using the findings of the four steps above to measure and control each risk factor in the projects. In this research, the findings of this step will be flowchart diagrams about the inputs, process and outputs used to assess and manage the IRFs in OGP projects in Iraq. The risk management plan of this research involves designing an integrated RMF, which could be **implemented** to optimise and manage the IRFs in the new pipeline projects. Additionally, it includes analysing the construction delay in the projects, which is caused by the associated IRFs. Meanwhile, the **evaluation** process of the developed RMF involves testing its functionality by using it for analysing and managing the IRFs in a real case study project selected from Iraq.

This section, therefore, is about providing the explanations about designing and evaluating the RMF which will be used to manage the IRFs in OGP projects. The key information about inputs, process and outputs of the proposed RMF is presented in Figure 6.1.

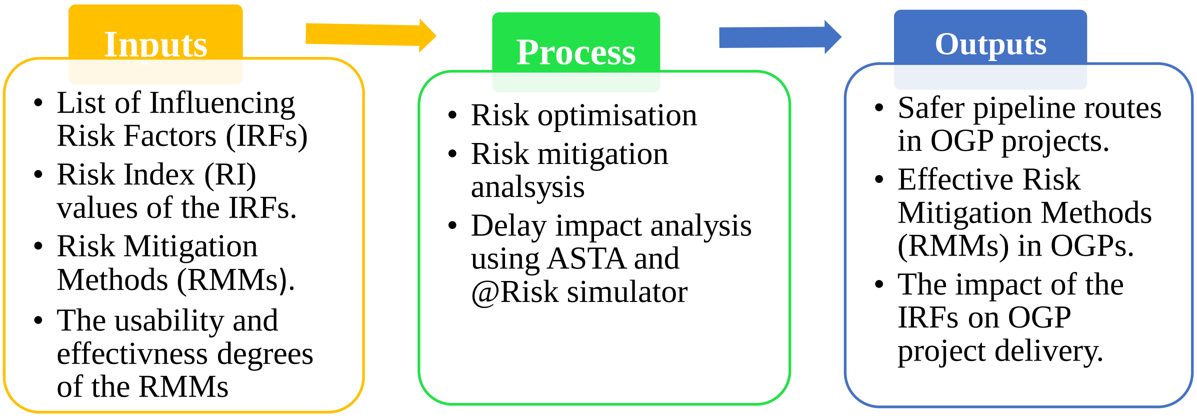

Figure 6.1: Specifications of the Risk Management Framework (RMF).

As shown in Figure 6.1 above, the RMF has been developed using three main components (input, process and outputs), which are explained below:

1- **Inputs**: The main sources of inputs used in the RMF are the list of IRFs and their degree of impact in terms of probability and severity in the OGP projects, which is analysed and expressed as the risk index (RI) of each risk factor. The values of RI of the IRFs were calculated using fuzzy logic (for details see Chapter 5:).
2- **Process**: Three main functionalities/modules were used in this RMF, which are
   A. Optimising the safest pipeline route/alignment for the OGP projects,
   B. Recommending suitable risk mitigation methods in the OGP projects, and
   C. Quantifying the impact of delay caused by the IRFs in the OGP projects.
3- **Outputs**: The main outputs of the framework are
   A. Identification of safest pipeline route/alignment based on risk level in the suggested routes;
   B. Identification of suitable RMMs for particular risk factors in OGP projects; and
   C. Quantification of delay impacting the OGP project's delivery, which could be caused by the associated IRFs.

The RMF will be used to analyse the IRFs in a real case study pipeline project. The case study used in this research is aimed to analyse the IRFs associated with a new gas/oil export pipeline project, which will be built in the south of Iraq. This project belongs to the Gazprom Neft Badra company. The length of the pipe is 164 km, and, when constructed, the pipe will transport the extracted gas from Badra gas field to the shipping point on the Gulf in Basra. A detailed data flowchart of the RMF is shown in Figure 6.2.

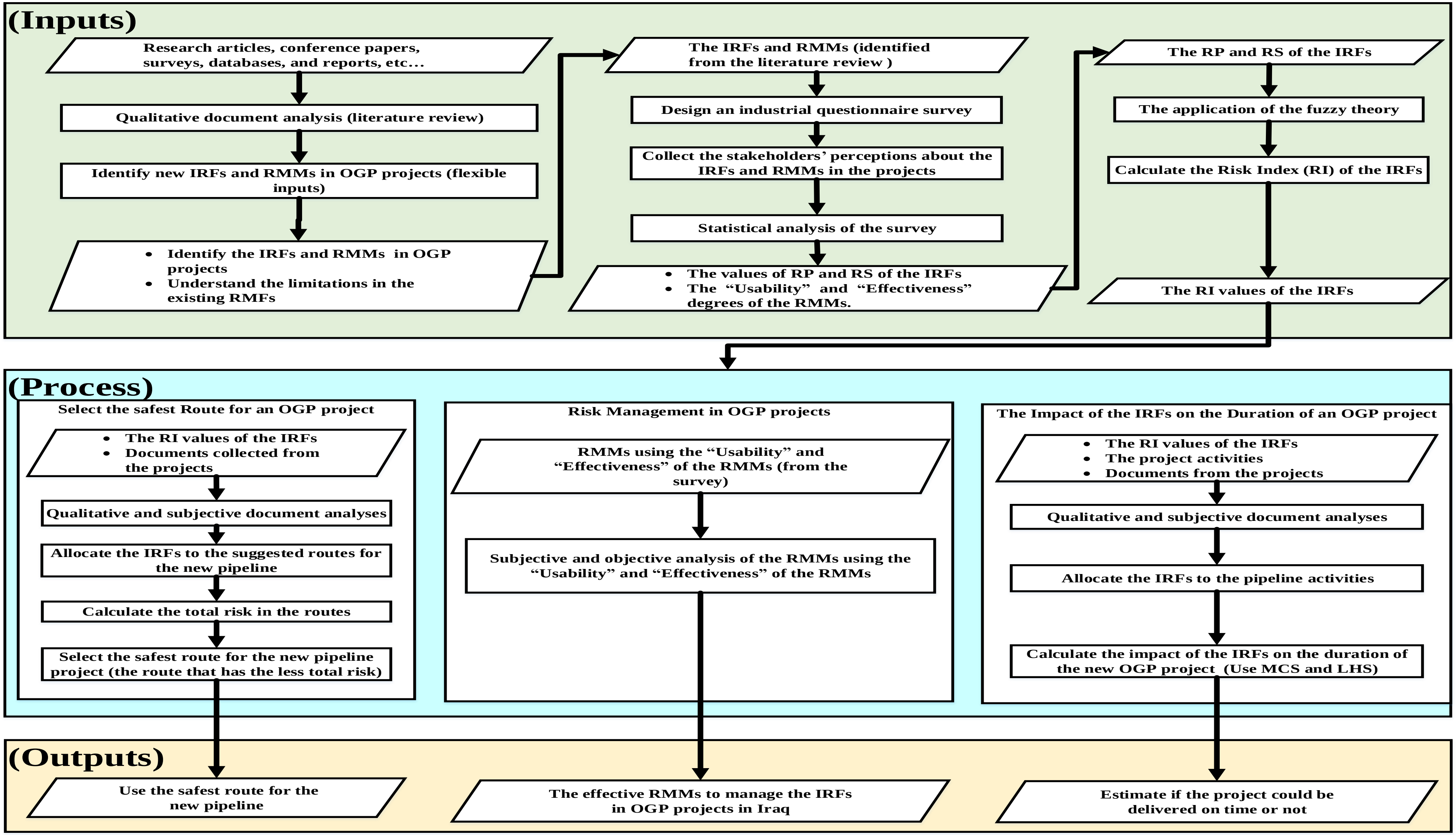

Figure 6.2: A detailed view of the inputs, process and outputs used in the Risk Management Framework (RMF).

Below is a detailed explanation of the preparation of the inputs of the RMF, the three functional processes modules and the outputs of the framework.

6.3 Inputs

This section explains the inputs used in the RMF and the preparations for collecting them, as shown in Figure 6.3.

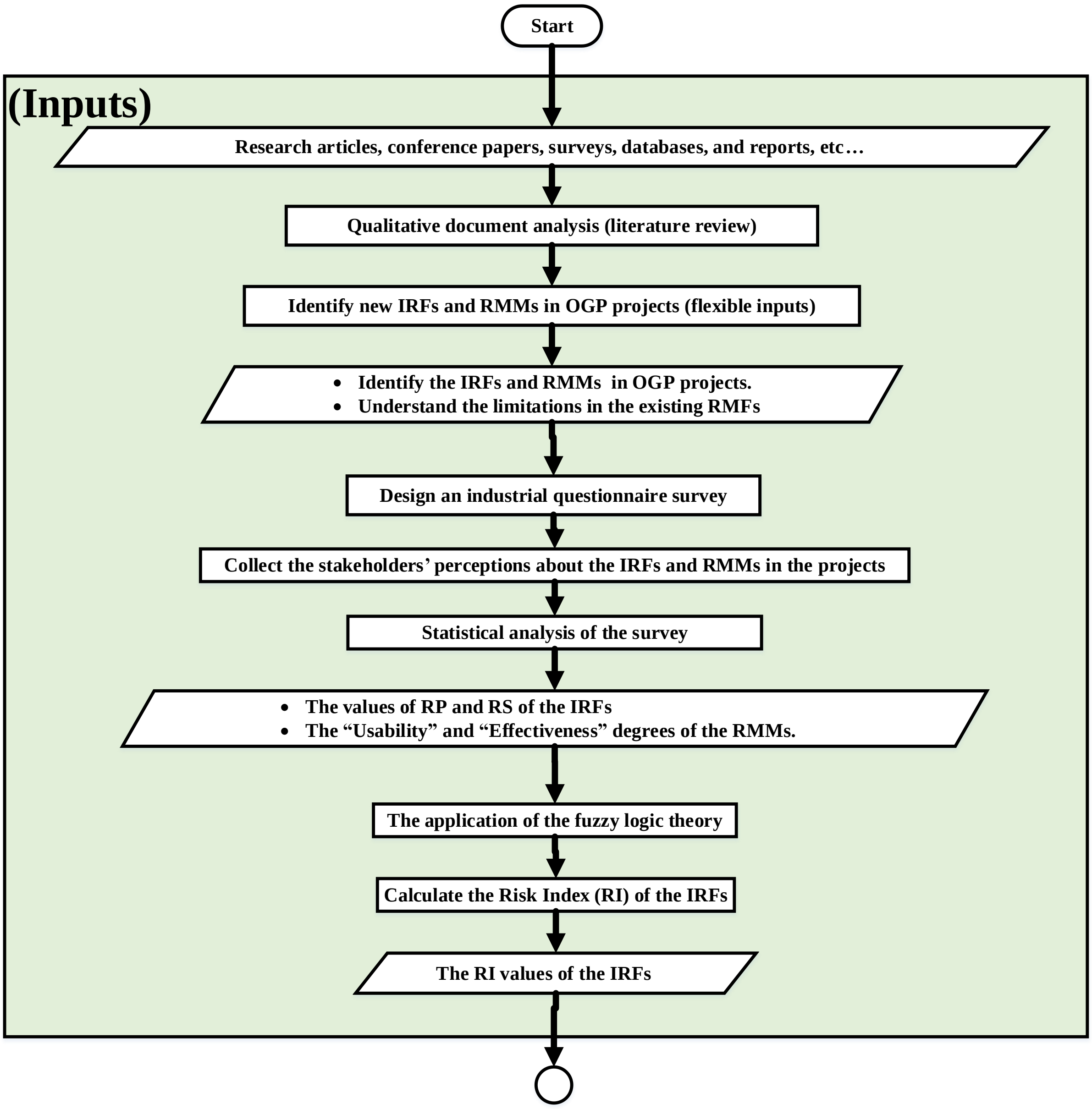

Figure 6.3: The inputs of the RMF.

As shown in Figure 6.3 above, the main inputs of the RMF are the values of the RI of the IRFs, which were calculated as follows.

1- The research started by identifying the IRFs associated with OGP projects based on an extensive literature review about them in OGP projects worldwide (details in Chapter 2:, section 2.4.4 and 2.4.5).
2- The IRFs were analysed based on the findings from an industrial survey conducted in Iraq. The perceptions of the stakeholders about the RP and RS levels of the IRFs were collected and analysed in order to assess the IRFs (details in Chapter 4:, section 4.4.4
3- The values of RP and RS of the IRFs have been used as inputs for the Fuzzy Inference System (FIS) in MATLAB, which was used to calculate the RI values of the IRFs (details in Chapter 5:).
4- Moreover, in order to make useful suggestions for risk management in the OGPs, this research has identified some of the RMMs via a literature review (section 2.4.6) which could be used to manage the IRFs in the projects. The RMMs were evaluated regarding their degree of effectiveness in managing the risk factors in the projects, which were calculated based on the results of the industrial survey (details in Chapter 4:, section 4.4.8).
5- Further and above, a qualitative and subjective analysis of the documents collected from the projects is used within the process of risk analysis in order to allocate the identified IRFs to the routes and activities of the pipeline projects, as will be explained in the process section.

In this research, the main inputs of the developed RMF are the common IRFs and RMMs in the OGP projects, which were identified based on the literature review. However, for other studies about analysing the IRFs and RMMs in different projects and/or in different geographical regions, the researchers might use a different list of IRFs and/or RMMs that fit the situations of their studies. In other words, this research designed an RMF that uses flexible lists of inputs based on the situations of the projects, which means that the application of the framework is not limited to certain projects or geographical regions; it will be applicable to manage the IRFs in OGP projects in different security and geographical situations. Additionally, if the researchers or the stakeholders have identified newly arising IRFs and RMMs in their project which should be considered in the risk management of the project, the RMF will also be applicable in future studies about analysing these new IRFs.

Moreover, the impact of the IRFs and RMMs in the projects might change as time passes. Nevertheless, the RMF has the ability to reanalyse the impact of the IRFs (i.e. the RP and RS levels of the IRFs) and the RMMs (i.e. the effectiveness and usability degrees of the RMMS) in the future. The next section details the process components of the RMF.

6.4 Process

This section describes the process of the RMF, which includes three modules. Module 1 is risk optimisation, module 2 is identification of risk mitigation methods, and module 3 is the quantification of the impact of delay in the construction of pipeline projects caused by the associated IRFs. The processes of each are explained below:

1- **Module 1: Optimisation of safest pipeline route/alignment for the new projects**, which helps to identify the safest pipeline route/alignment in the OGP projects from the aspects of the risk level associated within the projects. The steps and algorithm for selecting the safest pipeline route/alignment for the new pipeline project are explained in section 6.4.1.

2- **Module 2: Identification of risk mitigation methods in the projects** by suggesting some of the effective RMMs that could be used to manage the IRFs in the projects. The detailed process of how to identify suitable risk mitigation methods in the OGP project is explained in section 6.4.2.

3- **Module 3: Quantification of the impact of delay in the new pipeline projects delivery**, which is caused by the associated IRFs in these projects. The process of quantifying the delay during the construction stage of the project is explained in section 6.4.3.

6.4.1 Optimisation of OGP Pipeline Route/Alignment

This section explains how the RMF could be used to select a safe pipeline route for the new OGP project, i.e. the case study project. Selecting safe pipeline routes for the new projects during the planning and design stage helps in improving the safety level of these pipelines during the construction and operation stages. The process details of this module are presented in Figure 6.4.

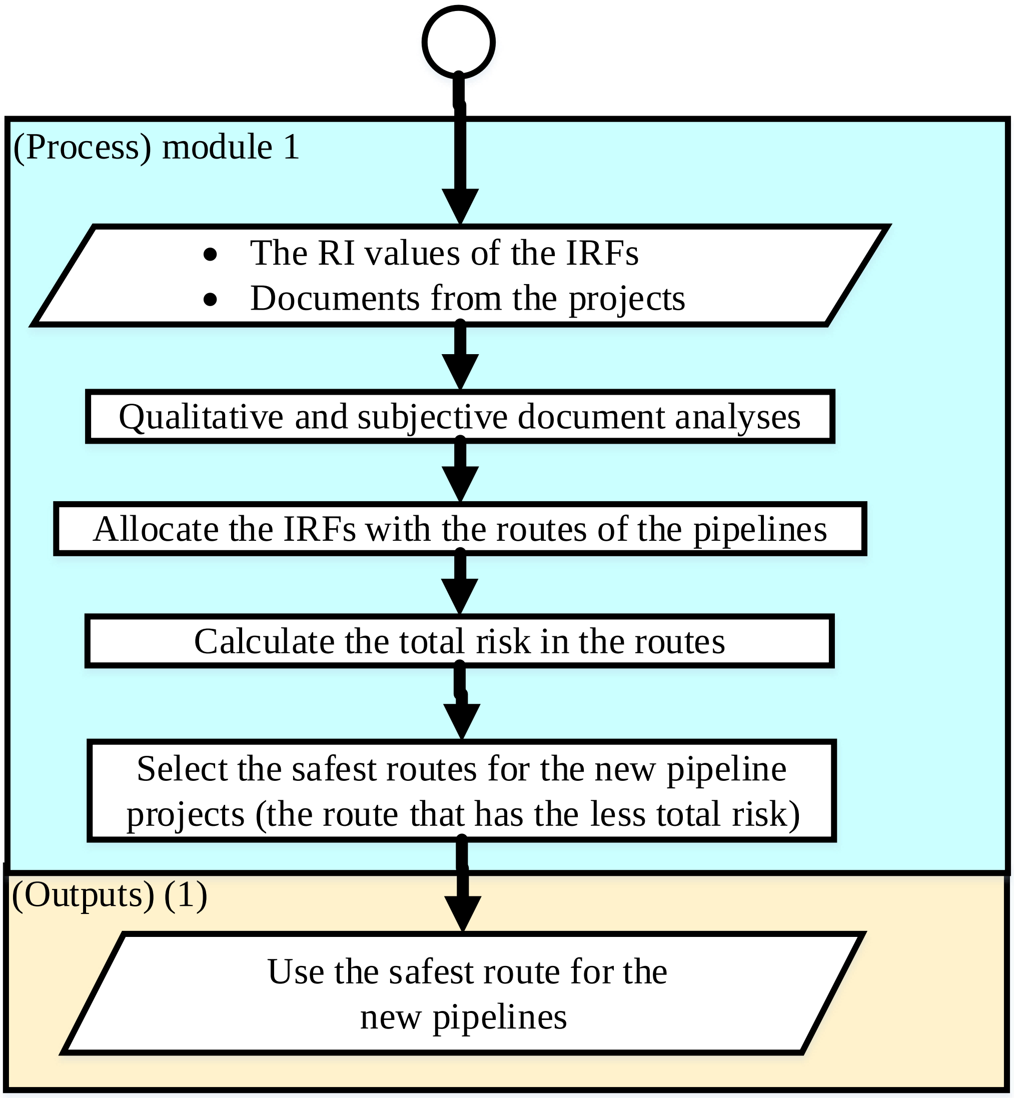

Figure 6.4: Process module 1 and output 1, select the safest pipeline route for the new project.

As explained in the figure above, the RMF will use the values of the RI of the IRFs to analyse the impact of the IRFs on the pipeline routes in order to optimise the safest pipeline route for the new project. Figure 6.5 shows the algorithm used in this research to optimise safest pipeline routes for the new OGP projects.

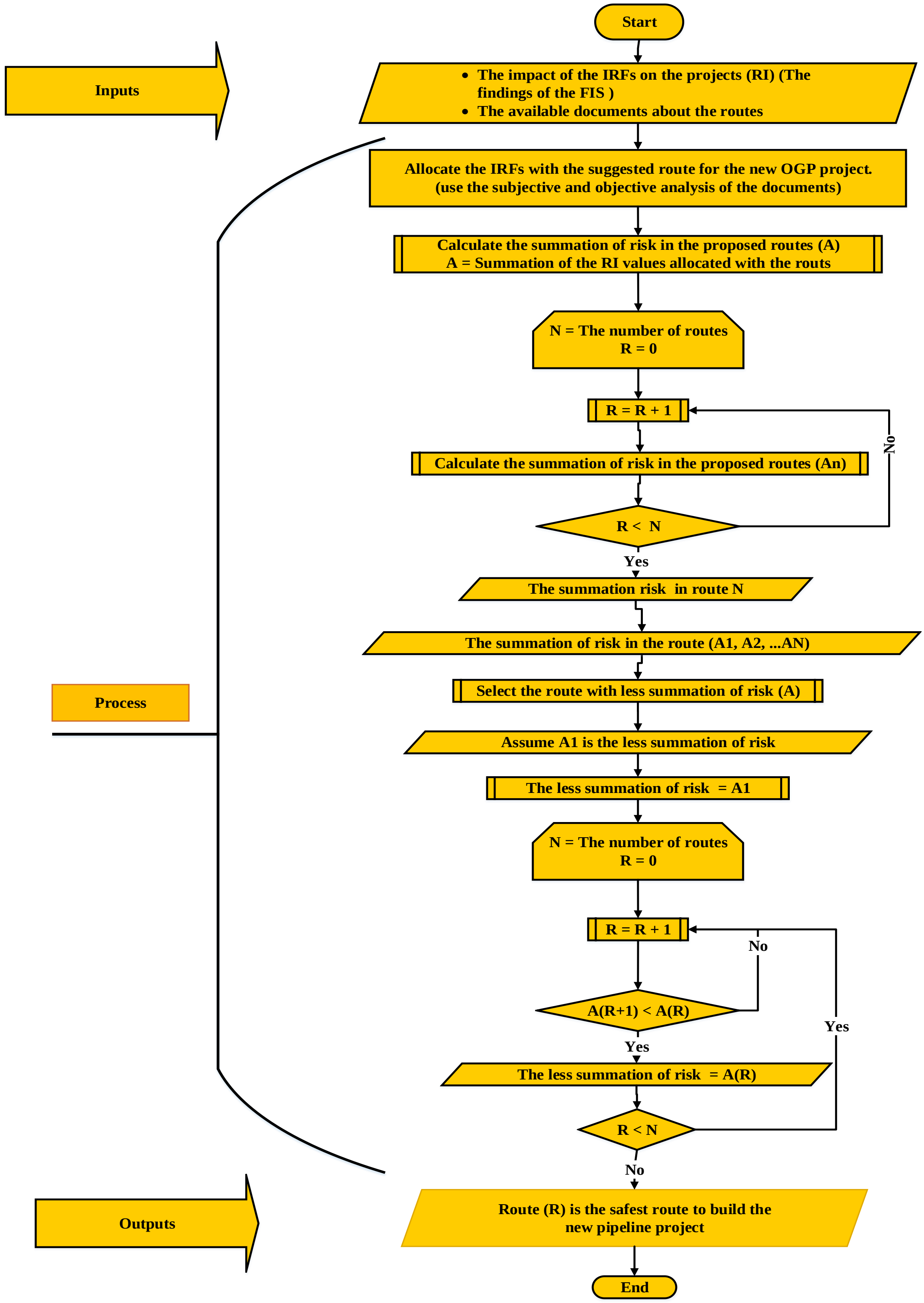

Figure 6.5: The algorithm for selecting safe pipeline routes for the new OGP projects.

As shown in Figure 6.5 above, **the inputs** used by the RMF to select the optimum safe pipeline routes of the new pipeline project were a list of the IRFs that may affect the safety of the pipelines in these routes. The IRFs were identified from the literature review, the questionnaire survey and the documents collected from the project. The IRFs were evaluated based on the results of the survey and their degrees of impact on the project were calculated using the FIS in MATLAB. **The process** of calculating the impact of the IRFs in the pipeline routes and identifying safest pipeline routes for the new projects includes (i) subjective and qualitative document analyses, (ii) risk allocation and (iii) risk calculation in the project's pipeline routes, as explained below.

1- **Allocation of the IRFs to a pipeline route/alignment**. In this study, the routes were evaluated based on analysing the available/existing documents provided by the companies who are working on this project. The provided documents (such as design documents; maps; reports; time schedules; laboratories' reports; work procedures and specifications; construction and insulation of the pipeline; functional specifications; field development report and similar documents) provide information about the pipeline routes based on site surveys and inspections, which were carried out along the routes suggested for the new pipeline project. The collected documents show useful information about the project. For instance, the topography of the pipeline routes; roads, rivers, lake and water channel crossings; seismic and flood hazard perceptions; geological risk in the routes (e.g. groundwater, the chemical and physical properties of the soil); weather conditions (e.g. rain, temperature and sand storms); population density; maps and GPS coordinates; the general conditions in the pipeline routes; and other supportive documents. Subjective and objective analyses of the documents and the professional knowledge in OGP projects were carried out to allocate the IRFs to the pipeline's routes. The IRFs were allocated to the pipeline's routes by adding the RI values of these IRFs to these routes. The documents are presented in Table C.1 of APPENDIX C:.
2- Calculate (A), which is the summation of risk impact caused by the IRFs associated with the pipeline routes, using equation 6.1. In other words, (A) is the summation of the values of the RI of the IRFs associated with the suggested route.

$$A = \sum RI \ values \ of \ the \ allocated \ IRFs \ to \ the \ pipeline \ routes \qquad \ldots \quad 6.1$$

3- Select the optimum safe pipeline route to build the new oil and gas pipeline, which is the route that has the lowest value of (A), which is the summation of the impact of the associated IRFs with the routes.

The next chapter (see section 7.2) presents the results of using the RMF to optimise the pipeline routes for building the new pipeline project.

6.4.2 Identification of Effective Risk Mitigation Methods (RMMs)

This section illustrates the process of making recommendations about risk management in OGP projects. Risk management is a continuous process of identifying and analysing the IRFs, risk response and risk control actions. Therefore, identifying and analysing effective RMMs to manage the IRFs in OGP projects in Iraq is a part of the process of the RMF developed in the research. The steps to make recommendations for risk management to manage the IRFs in OGP projects in Iraq are explained in Figure 6.6.

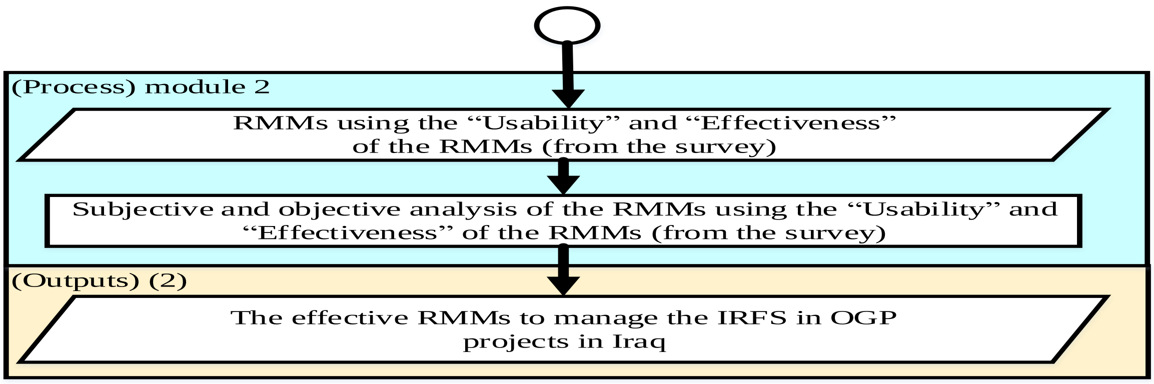

Figure 6.6: Process module 2 and output 2, effective RMMs in the OGP projects.

As explained in the figure above, the inputs used by the RMF to make useful suggestions regarding risk management in OGP projects in Iraq were a list of RMMs (which was identified based on the literature review) and their degrees of effectiveness in managing the IRFs (which were calculated based on the results of the survey). Depending on the character of the risk factor, a number of RMMs were suggested to manage each one of the IRFs. For example, avoiding insecure areas, using an anti-terrorism design, having protective barriers and patrols could mitigate the risk of terrorism & sabotage by direct action. Meanwhile, laying the pipelines underground can help with minimising the opportunities for terrorists and saboteurs to attack them. However, terrorists and vandals still have an opportunity to damage the pipelines. Educating government/public corporations about managing the safety of OGPs and reporting any case of vandalism could reduce pipeline attacks, but the government cannot entirely stop terrorists and vandals from attacking the pipelines. From these examples, the RMMs were classified into direct and indirect RMMs in the way that the RMM(s) will mitigate the IRFs. In a case where the IRF has more than one RMM to manage it, the RMMs were ranked based on their degrees of effectiveness that were collected via the survey. Section 7.3 of Chapter 7: describes how to identify or recommend an effective RMM(s) to mitigate the IRFs in the OGP projects.

6.4.3 Quantification of Impact Caused by IRFs in the OGP Project Delivery

This section explains the procedure of analysing the level of impact of the IRFs on the duration of the project's work activities. The steps of analysing and quantifying the delay in the construction duration of the project caused by the associated IRFs are explained in Figure 6.7.

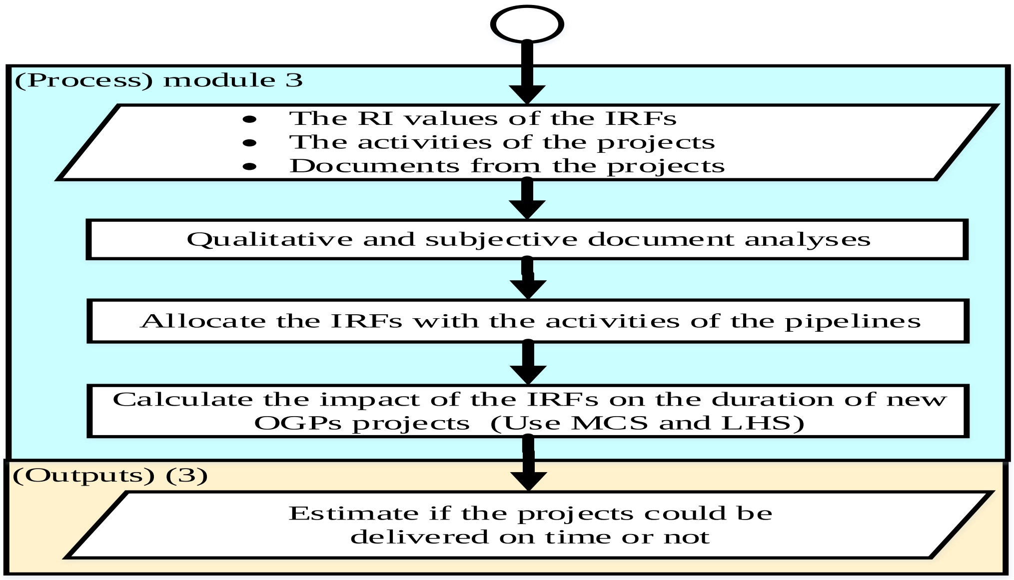

Figure 6.7: Process module 3 and output 3, delay analysis in the new OGP projects.

As shown in the figure above, the inputs used to analyse the delay in the projects are (i) the IRFs, (ii) their values of RI (iii), the activities of the projects and (iv) their duration. Figure

6.8 shows the flowchart and the algorithm of analysing the level of impact of the IRFs on the duration of the work activities of the projects.

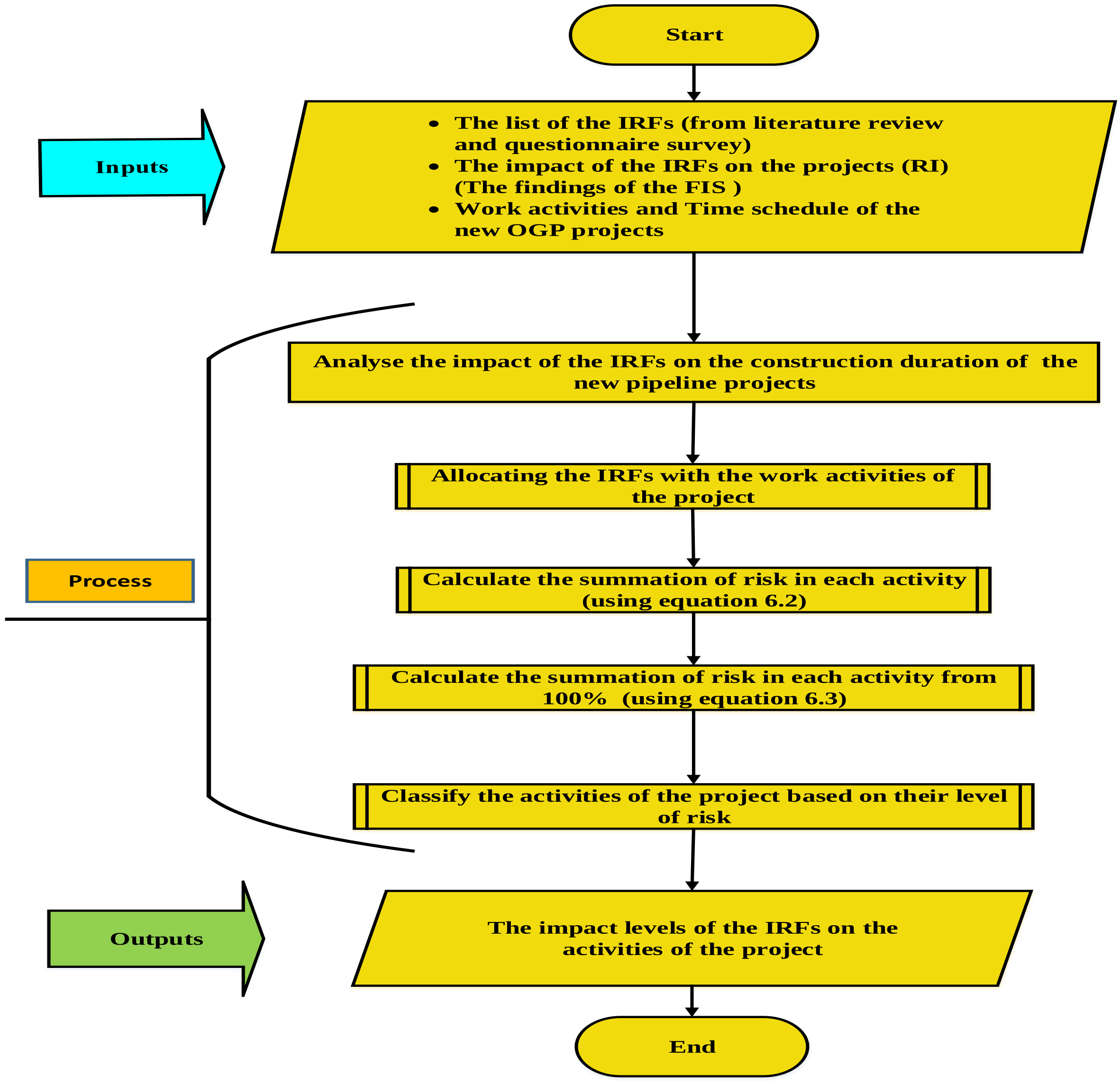

Figure 6.8: The algorithm for analysing the level of impact of the IRFs on the duration of the projects' work activities.

As shown in Figure 6.8 above, analysing the level of impact of the IRFs on the duration of the projects' work activities includes the following steps.

A- **Inputs:** the inputs used by the RMF to analyse the level of impact of the IRFs on the duration of the projects' work activities were (i) a list of the IRFs that affect the safety of OGPs in Iraq (which was identified from the literature review); (ii) their degree of impact on the projects (which was calculated using the survey and the FIS in

MATLAB), and (iii) the activities and the time schedule of the projects, see Figure 6.8.

The case study project of this research is a new gas export pipeline project, which belongs to the Gazprom Neft Badra company. This project has been under planning since May 21, 2019, and the targeted delivery date is January 13, 2023. This means the duration of the project is estimated as three years and 238 days (1334 days).

B- Process, which includes the following steps.

1- Allocating the IRFs to the work activities of the projects. The IRFs were allocated to the work activities of the project depending on the type of risk factor and the nature of the activity. Professional knowledge was used to achieve this task. The subjective and objective analysis of technical reports, practical guides and studies such as CEPA Foundation Inc. and INGAA Foundation Inc (2016), E.E.P.A. (2016), F.T.A. (2019);, Folga (2007), Nandagopal (2007), Stanton and Stanton (2019) and Williams Companies (2019) were 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 IRFs that could affect that activity based on vast experience and a review of the construction process in OGP projects worldwide.

For example, the IRFs such as terrorism; sabotage; Threats to staff; leakage of sensitive information; lack of appropriatetraining; lack of records about the IRFs; little research about the IRFs; 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.) because such kinds of IRFs could affect the safety of the project during the trenching activities and cause delay in the project. The results of allocating the IRFs to the project's work activities are shown in APPENDIX D:.

This research has analysed the IRFs that affect the safety of the pipelines during the planning and design, construction and operation stages of the projects. In other words, this research has analysed the IRFs in OGP projects during the entire life of these projects. For some IRFs, such as corruption, which were assumed to affect the new pipeline projects, the activity or the location of the project does not matter, because such a risk factor does not only affect a specific project or a specific activity; it affects the OGP projects in the whole country and during their entire work stages. Additionally, some relationships between the IRFs have been considered in this research. For instance, similar types of IRFs, such as sabotage and thefts, which are related to the security situation, might threaten a number of different pipelines together if the security level of a specific area is low. The case is similar to the pipelines in areas that are easy to access, which means the chance of vehicle and similar accidents is high in these areas. Meanwhile, it was assumed that some of the IRFs would not affect the new pipeline projects in Iraq. For example, hacker attacks on the system, as the stakeholders in OGP projects in Iraq are not using an advanced management system, yet.

2- Calculate the summation of the impact of the IRFs associated with each project activity using equation 6.2, which calculates the summation of the RI values of the IRFs allocated to these activities.

$$The\ summation\ of\ risk\ of\ an\ activity\ = \sum RI\ values\ of\ the\ IRFs\ related\ to\ that\ activity \qquad \ldots(6.2)$$

For example, the summation of risk in the trenching activities; temporary erosion control and side support activities; pipe set-up and welding activities; and fabrication and installing pipe activities was 54.05, 57.48, 43.84 and 36.28, respectively.

3- Calculate the summation of risk for the project activities from 100% using equation 6.3.

$$The\ summation\ of\ risk\ of\ an\ activity\ (from\ 10\%) = \frac{\sum risk\ in\ the\ activity}{\sum risk\ in\ the\ project} \ldots(6.3)$$

For example, the summation of risk from 100% for the above-mentioned activities was 2.567, 2.78, 2.082, and 1.723, respectively.

4- 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. For example, the level of risk for the above-mentioned activities was medium risk, medium risk medium risk and low risk, respectively.

C- **Outputs**: Chapter 8: and Chapter 9: show the results of the above-mentioned steps in analysing the construction delay in the new pipeline projects. In other words, these chapters present the amount of delay in the new pipeline projects during the construction stage of these projects.

6.5 Risk Management Framework Outputs

This section explains the key outputs of the RMF, which was developed to analyse the IRFs in the OGP projects, which are:

1- The summation of the impact of the IRFs associated with the pipeline routes that are suggested to build the case pipeline project. Section 7.2 in Chapter 7: explains the final outputs of the summation of risk for the project's pipeline routes. Additionally, this section explains the optimum safe route that could be used to build the project.
2- The effective RMMs that could be used to manage the IRFs in OGP projects in Iraq. Section 7.3 shows the final outputs of this step, which are the suggested RMMs that could be used to manage the IRFs in OGP projects in Iraq.
3- The level of impact of the IRFs on the duration of the project. The amount of construction delay in the project is presented in Chapter 8: and Chapter 9:.

6.6 Summary

This chapter presented the design and specification of the developed risk management framework, which will be used for assessing and managing the IRFs in OGP projects in addition to quantifying the delay impact in the OGP projects in Iraq. The RMF is useful to analyse the IRFs associated with OGP projects at the planning, design and execution stages. This chapter has also discussed details of inputs and algorithms used in the processes and key outputs of the framework:

1- The inputs that were used to design the RMF in this research, which were the IRFs, the RI values and the RMMs in OGP projects, see section 6.3.
2- The three process modules of the RMF, which are risk optimisation and select safest routes for the new pipeline projects; making recommendations about risk management in the projects; and analysing the delay caused by the associated IRFs, see sections 6.4.1, 6.4.2 and 6.4.3, respectively.
3- The outputs of this RMF will be the optimum safest routes for the new pipeline projects; the effective RMMs that could be used to manage the IRFs in the project and the amount of construction delay in the new projects caused by the IRFs, see section 6.5.

CHAPTER 7: RISK OPTIMISATION IN OGP PROJECTS

This chapter aims to evaluate two functionalities of the Risk Management Framework (RMF) developed in this study and presented in the previous chapter. The chapter explains how to optimise risk factors to identify the safest route/alignment considering the risk level available in each route/alignment in the OGP project, which is the first functionality of the framework. The second functionality of the framework focuses on how to identify the effective/suitable Risk Mitigation Methods (RMMs) to mitigate the risk factors in the OGP projects. This chapter also presents the background and introduction to a case study used to evaluate the functionality of the framework, as explained in section 7.1.

This chapter also discusses two key outputs of the RMF developed in this research. The first output is risk optimisation and identification of the safest pipeline route/alignment based on risk levels. The second output is the identification of the suitable RMMs which could be used to mitigate/control the IRFs in OGP projects. The case study selected in this research is a new oil and gas export pipeline, which will be built in the south of Iraq. This project belongs to the Gazprom Neft Badra Company. The key inputs are the IRF associated within the case study project in Iraq and their degree of impact on the project. Section 7.2 explains the functionality of the RMF with regard to how to use it to optimise risk and identify safest routes/alignments for the OGP projects. Section 7.3 explains the second functionality of the RMF for identifying and recommending suitable risk mitigation methods in the OGP projects. Section 7.4 summarises the chapter.

7.1 Introduction to the Case Study Project

The case study of this research is to analyse the IRFs associated with a new oil and gas export pipeline, which is going to be built in the south of Iraq. This project belongs to the Gazprom Neft Badra Company. The length of the pipe is 164 km, and, when constructed, the pipe will transport the extracted oil and gas from Badra field to the shipping point on the Gulf in Basra. The export pipeline runs between the Central Processing Facility (CPF) of Badra field to the third-party pipeline system at Gharraf–An Nassiriyah. The expected operating gas flowrate of this pipeline is 110 Million standard cubic feet per day (MMSCF/day) and the design flowrate is 156 MMSCF/day. This project has been under planning since May 21, 2019 and the targeted delivery date is January 13, 2023. This means the duration of the project is estimated as three years and 238 days (1334 days). The information mentioned in this paragraph was taken from Gulf Oil & Gas (2020a, 2020b) and Mehdi (2018). This section analyses the information collected from the project, which was provided by Gazprom company. Gazprom is a global energy company focused on geological exploration, production, transportation, storage, processing and sales of gas, gas condensate and oil, sales of gas as a vehicle fuel, as well as generation and marketing of heat and electric power (Gazprom, 2020). Gazprom is an international company working on the project, which is responsible for making investigations about the routes for the new gas pipeline (Iraq - Gazprom, 2020). In order to provide a general view of the OGP projects in the country, the two figures below show the Iraqi oil and gas infrastructure units on the map.

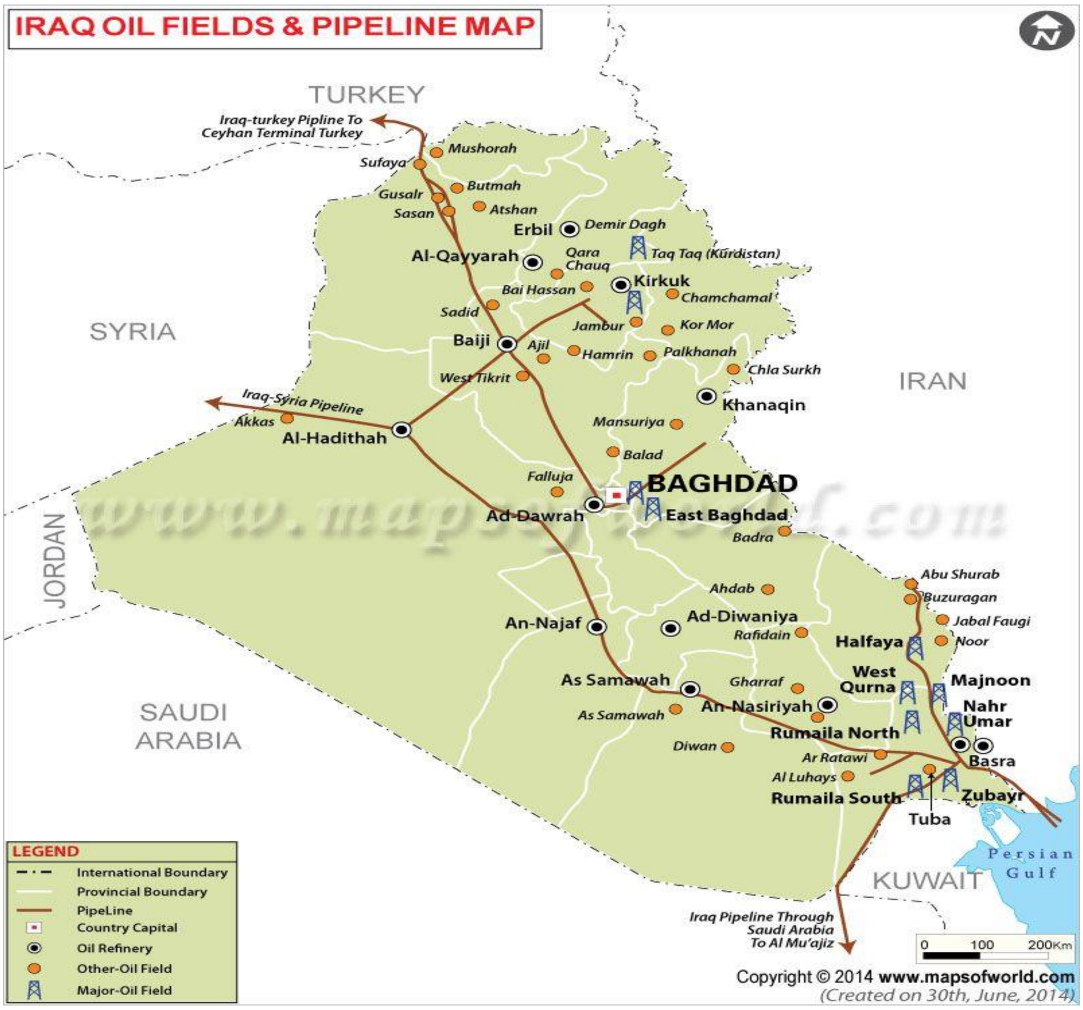

Figure 7.1 Iraq oil fields and pipelines (World Map, 2014).

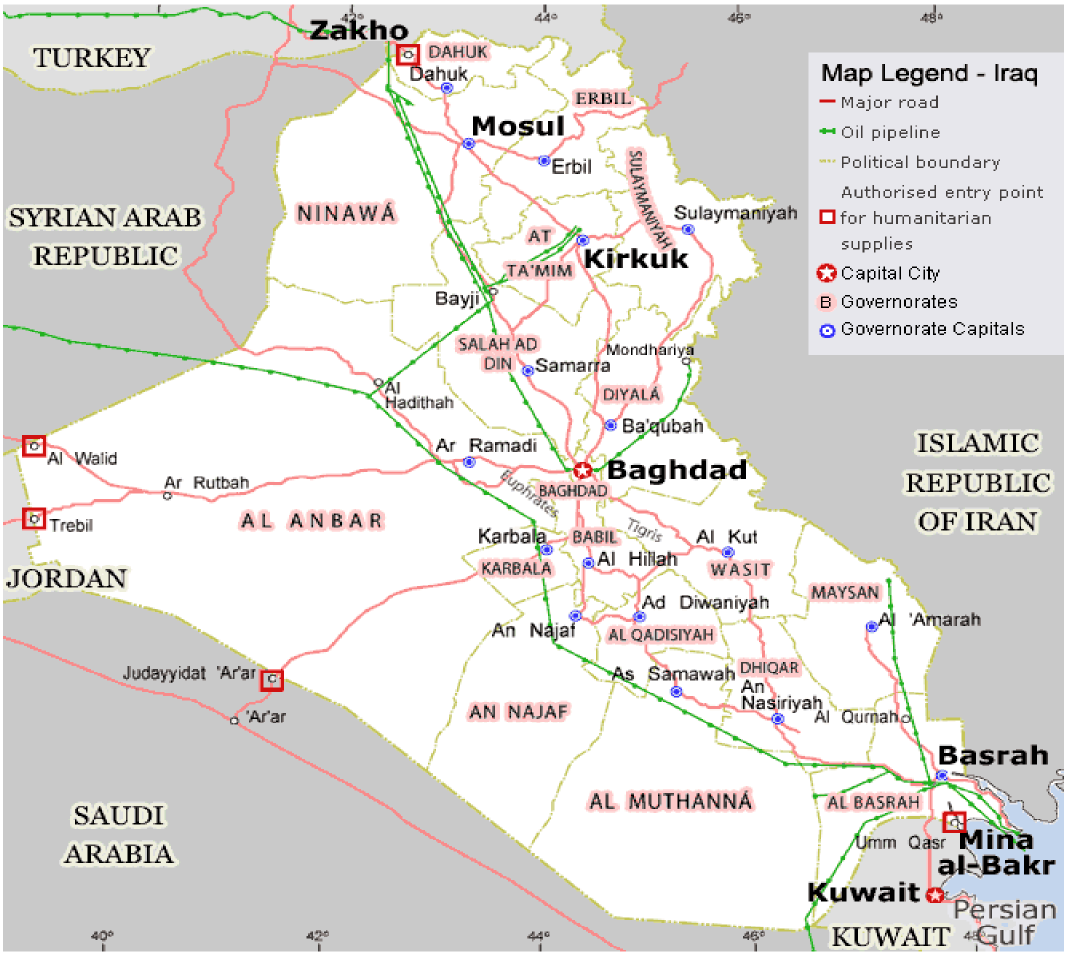

Figure 7.2: Iraq oil fields and pipelines (Energy Security, 2008).

Moreover, the figure below shows the oil and gas infrastructure units in the south of Iraq (the research area study) on the map.

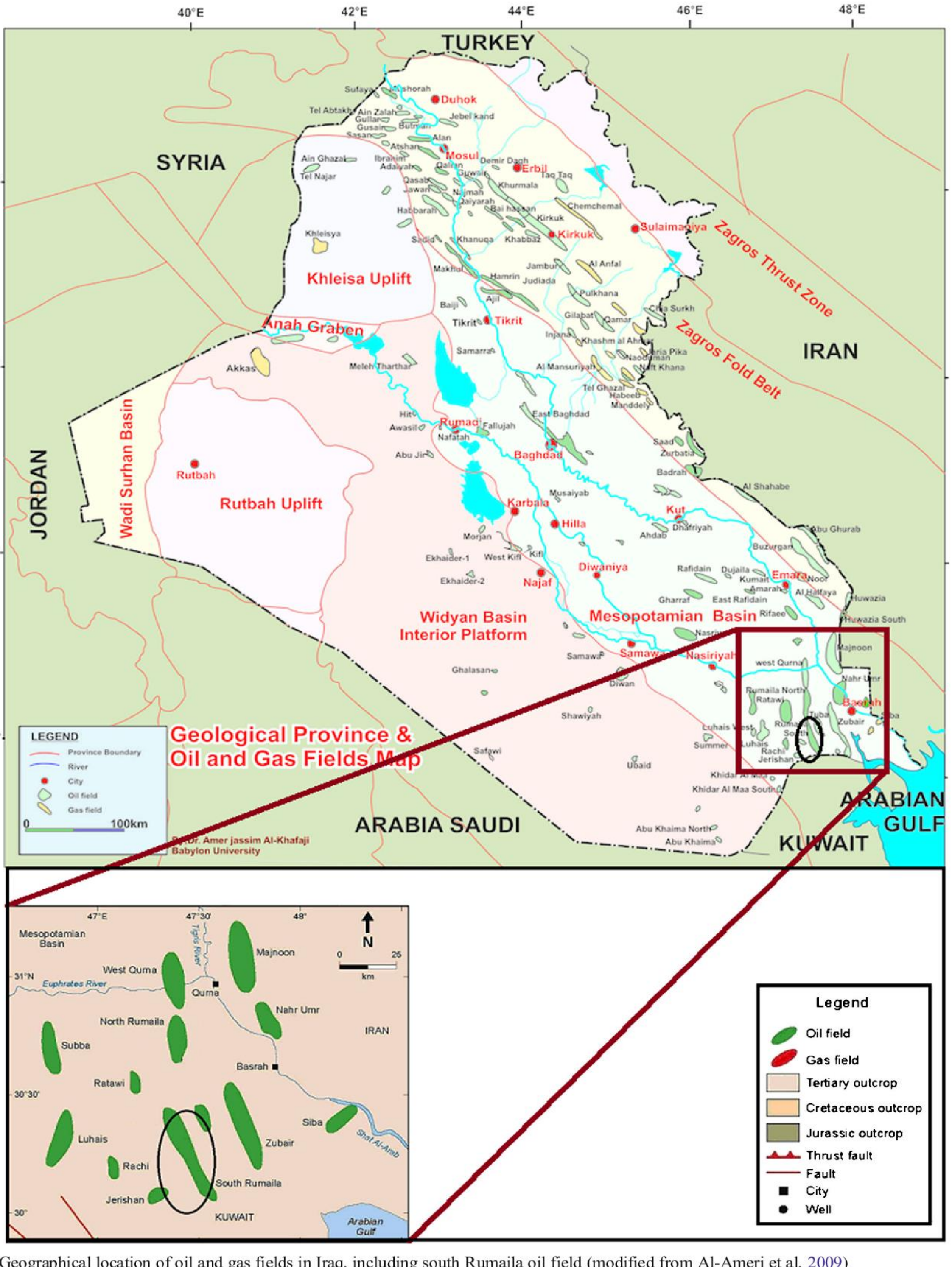

Figure 7.3: The pipelines in the south of Iraq (Al-Mudhafar, 2017).

The new pipeline will be built between Badra and Zubair, as explained in the two figures below.

Figure 7.4: Badra and Zubair areas on the map (2B1st Consulting, 2012).

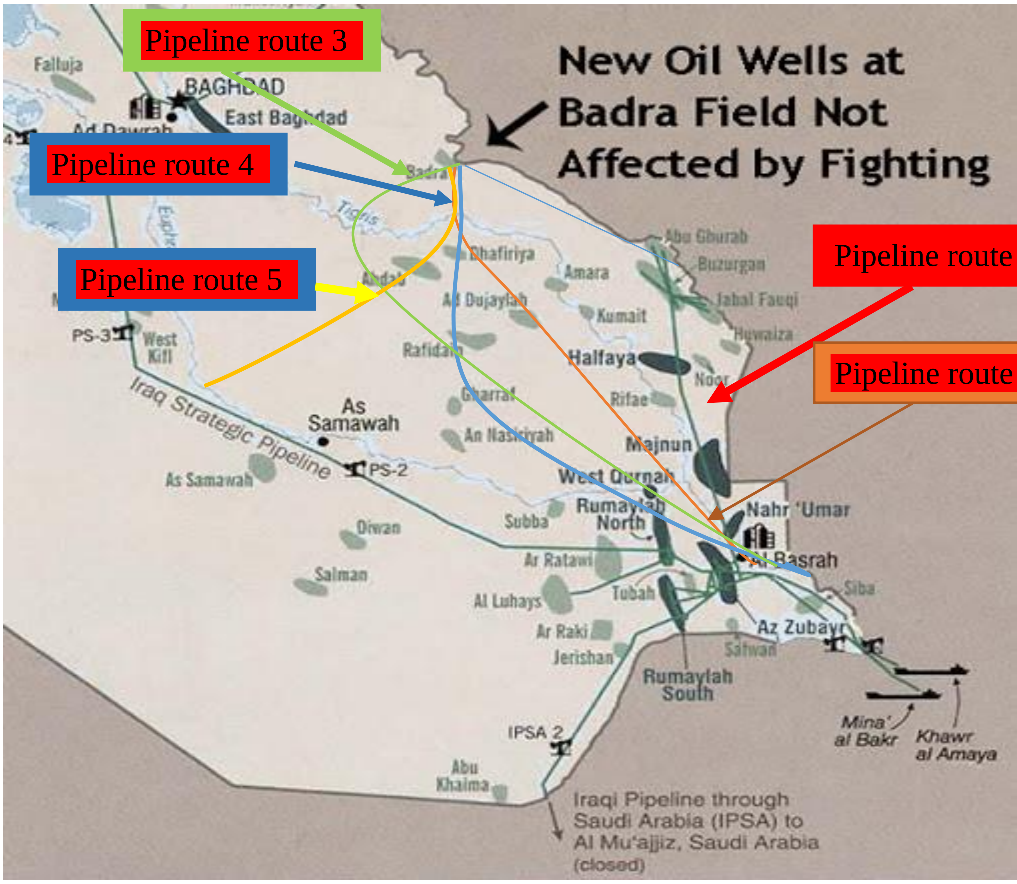

Figure 7.5: The pipelines between Badra and Zubair areas on the map (Global Resources News, 2016).

Five different routes are suggested for the new gas export pipeline. This section will describe route 1 of the gas pipeline project. The figures below were taken from the Iraq-Gazprom company.

Route 1 of the pipeline project is divided into three sections. The figures and text below provide more detail about section 1 of route 1 of the pipeline project. The approximate length of this section is 48 km, see Figure 7.6.

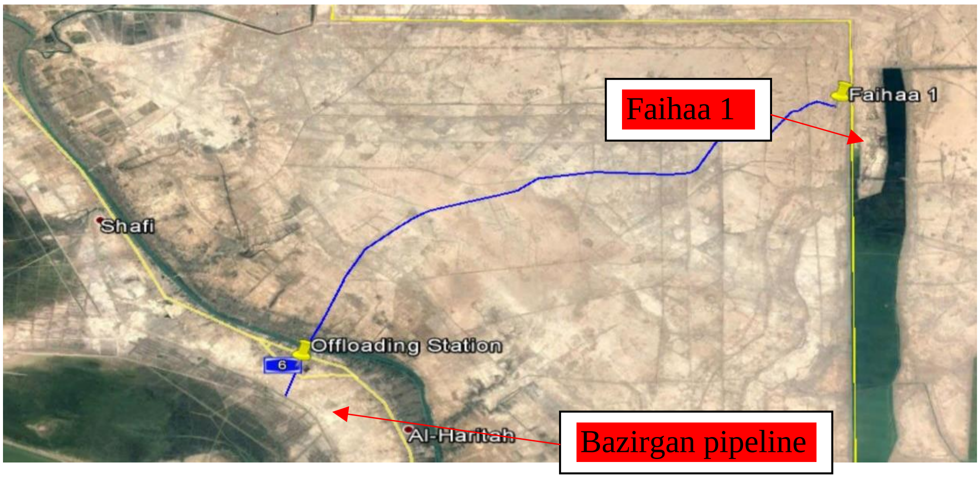

Figure 7.6: The join between Faihaa 1 with the Bazirgan pipeline near the current offloading station.

After analysing the documents collected from the project, the following IRFs were identified in route 1 of the pipeline project, as shown in the table below.

Table 7.1: The Influencing Risk Factors (IRFs) identified in route 1 of the pipeline project.

IRFs	**IRF types**
Terrorism, sabotage and the security risk	Social and Security (S&S)
Theft of the products	S&S
Public awareness	S&S
Leakage of sensitive information	S&S
Corruption	Rules & Regulations (R&R)
The absence of the law on TPD	R&R
Lack of risk management practice	R&R
Lack of appropriate training	R&R
Lack of risk registration	R&R
Little research on this topic	R&R
The pipeline is easy to access	Pipeline Location (PL)
Land ownership conflicts	PL
Improper safety regulations	Health Safety and Environment (HSE)
Improper inspection and maintenance	HSE
The risk related to the above ground pipeline	HSE
Inadequate risk management	HSE
Natural disasters	HSE
The weak ability to manage the risk	Operational Risk (OR)
Shortage of modern equipment	OR
Design, construction and material defects	Design and construction risk

The figures below show information about the first section of the pipeline (48 km out of 164 km). These figures show the IRFs associated with the project pipeline route 1. For example, the route elevation profile of the pipeline area was almost flat, as shown in Figure 7.7.

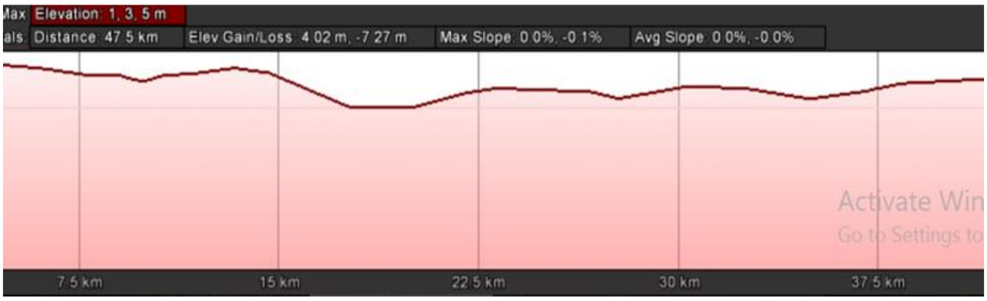

Figure 7.7: The route elevation profile of the crossing area.

The figure below shows the Horizontal Directional Drilling line of the pipeline.

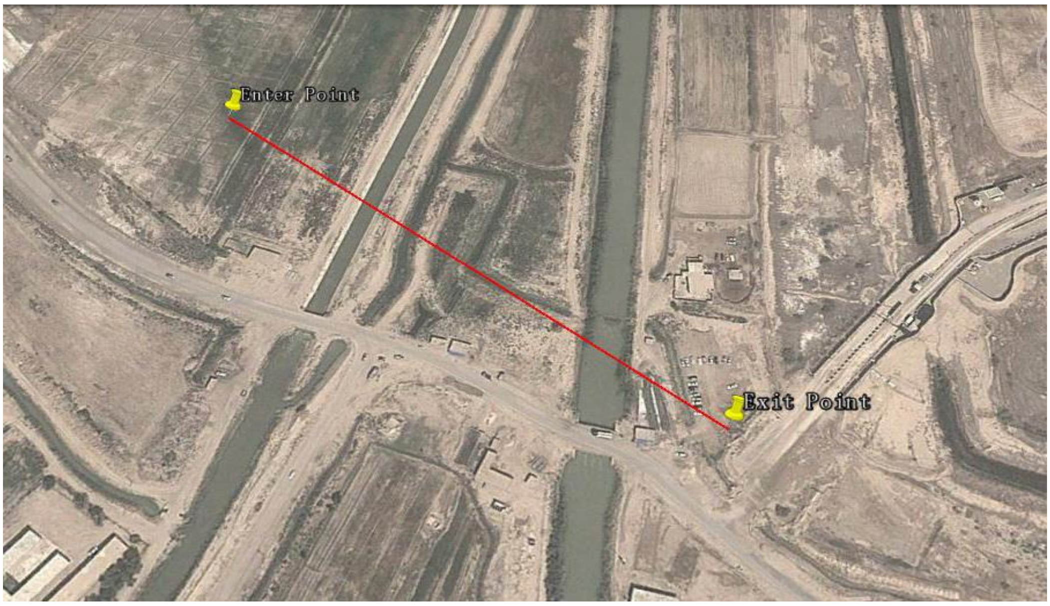

Figure 7.8: Satellite map of HDD crossing for Al Mzaak and Al Rahma canals.

This initial route can cross the Bin Omran river near Bin Omran oil and gas field, to minimise its effect on nearby farmers. The river's width at that area is approximately 200 m, with the north bank fully occupied by farms and houses, see Figure 7.9 to Figure 7.14. These figures show how the new pipeline project crosses the river, farms, roads and bridges in the area.

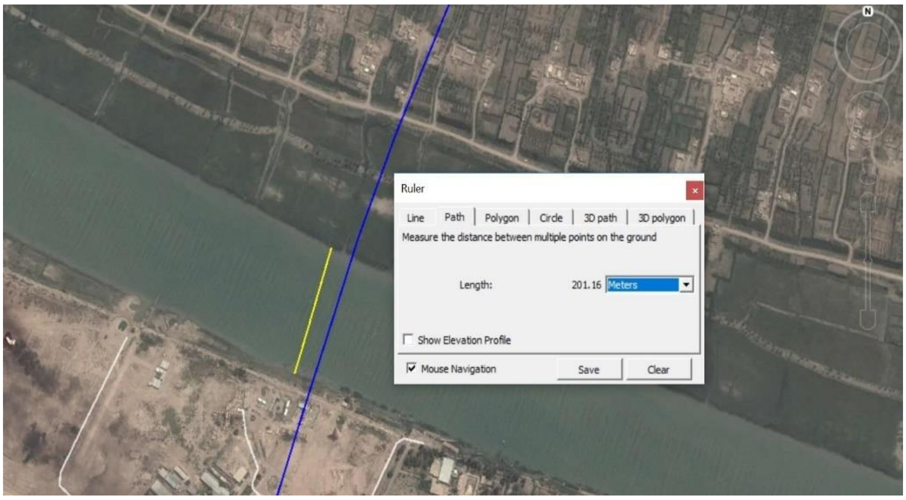

Figure 7.9: This initial route can cross the Bin Omran river near Bin Omran oil and gas field. The river's width at that area is approximately 200 m.

Figure 7.10: River crossing; the river's width in that area is approximately 200 m.

Figure 7.11: Green area crossing of section 1 of route 1 of the pipeline.

Figure 7.12: Green area crossing of section 1 of route 1 of the pipeline

Figure 7.13: Green area and road crossing of section 1 of route 1 of the pipeline

Figure 7.14: Bridge crossing of section 1 of route 1 of the pipeline (there is a floating bridge near the offloading station with a weight capacity of 5 tons).

The figures below show some photos of the surrounding area (between Yamama and Junction) of the pipeline project.

Figure 7.15: Some photos of the area between the river and Yamama Junction and street.

Figure 7.16: The area surrounding the pipelines.

Figure 7.17: The area surrounding the pipelines.

Figure 7.18: The area surrounding the pipelines.

Figure 7.19: The area surrounding the pipelines.

The figures below show some of the risks on section 1 of route 1 of the project, for example, Figure 7.20 shows oil contamination on that route, Figure 7.21 shows the flooding risk, Figure 7.22 shows illegal housing on the route and Figure 7.23 shows the risk of crude oil near to the surface on the pipeline route.

Figure 7.20: Oil contamination on the pipeline route.

Figure 7.21: A flooded area due to the seasonal rain.

Figure 7.22: Illegal housing on the pipeline route.

Figure 7.23: Crude oil near the surface on the pipeline route.

The second section of route 1 of the pipeline project covers 103 km out of 164 km, which will be used to transport the natural gas extracted from Bazirgan to Zubair. When constructed, the third section of the pipeline is going to transport the extracted oil and gas from Zubair to the export point on the Gulf. **To keep this chapter short, APPENDIX C:**

explains the details of routes two, three, four and five of the pipeline on the map, see Figure C.1.

The next section explains how the RMF will be used to select safest routes by optimising the risk level for the new OGP projects.

7.2 Optimisation of Risk Factors in Pipeline Routes/Alignments

This section tests the functionality of the RMF with regard to selecting a safe pipeline route/alignment for the new OGP project, i.e. the case study project. The section presents the results of section 6.4.1 in Chapter 6:, which explained the process of selecting safest pipeline routes/alignments for new pipeline projects using the developed RMF. The summary of the process steps is as follows:

1- Identify the IRFs in the projects via literature review, analyse the RP and RS levels of the IRFs via the survey, and calculate the RI of these risk factors using fuzzy theory.
   The RI values are the standard values of the degree of impact of the IRFs in OGP projects in the whole of Iraq.
2- Analyse the documents collected from the project to allocate the IRFs with the routes suggested to build the pipeline by adding the values of RI of the IRFs to the routes.
3- Calculate the summation of risk in each route.
4- Select the optimum safe routes for the OGP project by selecting the route that has the lowest summation of risk (A).

Table 7.2 shows the results (the outputs) of using the steps above to analyse the IRFs in five routes that were suggested for building the new gas pipeline in the south of Iraq.

Table 7.2: The allocation of the IRFs to the activities of the project.

IRFs by type	**RI***	**Route 1**	**Route 2**	**Route 3**	**Route 4**	**Route 5**
Terrorism, sabotage and the security risk (S&S)	3.99*	3.99*	3.99*	3.99*	3.99*	3.99*
Theft of the products (S&S)	3.75	3.75	3.75	3.75		
Public awareness (S&S)	3.8	3.8	3.8	3.8	3.8	3.8
Threats to staff (S&S)	3.35		3.35		3.35	
Socio-political effects (S&S)	3.49		3.49	3.49	3.49	
Leakage of sensitive information (S&S)	3.38	3.38		3.38		3.38
Corruption (R&R)	3.87	3.87	3.87	3.87	3.87	3.87
The absence of the law on TPD (R&R)	3.54	3.54	3.54	3.54	3.54	
Lack of risk management practice (R&R)	3.51	3.51	3.51	3.51	3.51	3.51
Lack of appropriate training (R&R)	3.71	3.71	3.71	3.71	3.71	3.71
Lack of risk registration (R&R)	3.6	3.6	3.6	3.6	3.6	3.6
Little research on this topic (R&R)	3.55	3.55	3.55	3.55	3.55	3.55
The geographical location (PL)	3.76		3.76	3.76		
The pipeline is easy to access (PL)	3.57	3.57	3.57	3.57		3.57
Land ownership conflicts (PL)	3.68	3.68	3.68	0	3.68	3.68
Geological risks (PL)	3.17		3.17	3.17		3.17
Vehicle accidents (PL)	2.8		2.8	2.8		2.8
Animal accidents (PL)	1.95					
Improper safety regulations (HSE)	3.7	3.7	3.7	3.7	3.7	3.7
Improper inspection and maintenance (HSE)	3.69	3.69	3.69			3.69
The risk related to the above ground pipeline (HSE)	3.7	3.7	3.7		3.7	3.7
Limited warning signs (HSE)	3.56		3.56	3.56		3.56
Inadequate risk management (HSE)	3.48	3.48	3.48	3.48	3.48	3.48
Natural disasters (HSE)	3.1	3.1		3.1		3.1
Corrosion (OC)	3.72		3.72	3.72	3.72	
The weak ability to manage the risk (OC)	3.67	3.67	3.67	3.67	3.67	3.67
Shortage of modern equipment (OC)	3.68	3.68	3.68	3.68	3.68	3.68
Design, construction and material defects (OC)	3.64	3.64	0	3.64		3.64
Operational errors (OC)	3.3	3.3	3.3	3.3		3.3
Hacker attacks on the system (OC)	3.03					
The summation of RI in the each route (A)=		75.91^	89.64^	85.34^	62.04^	78.15^
*The value of the RI of each IRF (from the FIS). **The RI values are the standard values of the degree of impact of the IRFs in OGP projects in the whole Iraq.** ^ The summation of the column.						

With regard to calculating the summation of the impact of the IRFs associated with the pipeline routes, it was found in the table above that the pipeline route number 4 is the route that has the lowest summation of risk and pipeline route number 2 is the route that has the highest summation of risk. This means that pipeline **route number 4** is the safest route for the new pipeline project, and pipeline route number 2 is the riskiest route for this project.

The routes/alignments suggested for the new pipeline project are tested further by analysing the level of risk in each route depending on the types of associated IRFs. Table 7.3 shows the analysis of the IRFs in the pipeline routes based on the types of IRFs that affect the project.

Table 7.3: The summation of risk in the five routes by the type of risk in each route.

The type of IRFs	**Route 1**	**Route 2**	**Route 3**	**Route 4**	**Route 5**
Safety and Security (S&S)	14.92	18.38	18.41^	14.63	11.17*
Rules and Regulations (R&R)	21.78^	21.78^	21.78^	21.78^	18.24*
Pipeline Location (PL)	7.25	16.98^	13.3	3.68*	13.22
Health, Safety and Environment (HSE)	17.67	18.13	13.84	10.88*	21.23^
Operation Risks (OR)	14.29	14.37	18.01^	11.07*	14.29
*means the lowest total risk and ^means the highest total risk.					

As shown in the table above, considering the impact of different types of IRFs on the project, it was found that pipeline route number 4 is the safest route with regard to the PL, HSE and OR IRFs, and pipeline route number 5 is the safest route with regard to the S&S and PL IRFs. These results also testify that route number 4 is the safest route for the new pipeline project as it appears to be the safest route three out of five times, see the table above.

On the other side, pipeline route number 1 is the riskiest route considering the impact of the R&R IRFs; pipeline route number 2 is the riskiest route considering the impact of the R&R and PL IRFs; pipeline route number 3 is the riskiest route considering the impact of the S&S R&R and OR IRFs; pipeline route 4 is the riskiest route considering the impact of the R&R IRFs; and pipeline route number 5 is the riskiest route considering the impact of the HSE IRFs. It was found that the IRFs related to the R&R in the pipeline projects were found to be the riskiest type of risk factors in most of the routes, see Table 7.3.

This research has investigated and ranked the IRFs associated with the pipeline projects in the whole of Iraq. These investigations provide wide knowledge about the IRFs and their impact on OGP projects across the country. Additionally, this research 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 of the IRFs on the pipeline routes in Iraq, particularly in the south of Iraq.

However, the IRFs might have a slightly different impact on the OGPs in different regions in the country. Also, the analysis and allocation of the IRFs to the pipeline routes were performed based on analysing the documents collected from these projects. This means that collecting more documents and carrying out targeted questionnaires, focus group survey and/or interviews with the stakeholders in these projects will enhance the process of analysing the IRFs that affect the pipelines along these routes.

The next section explains the second functionality of the RMF that helps to identify an effective way or a suitable risk mitigation method to mitigate/control the risk factors in the OGP projects.

7.3 Identification of Effective Risk Mitigation Methods (RMMs)

This section illustrates the process of evaluating the functionality of the RMF with regard to using it to manage the IRFs in the projects. Risk management is a continuous process of identifying and analysing the IRFs, risk response and risk control actions. Therefore, identifying and analysing effective RMMs to manage the IRFs in OGP projects in Iraq is a part of the process of the RMF developed in this research. This section present the results of section 6.4.2 in Chapter 6:. The summary of the process steps for making recommendations about risk management in OGP projects is as follows.

1- Identify the RMMs in the projects via literature review and analyse their usability and effectiveness degrees in the projects via the survey.
2- Classify the RMMs by their actions in managing the IRFs as direct and indirect RMMs.
3- Allocate the RMMs to the IRFs in the project depending on the nature and the character of the IRFs and RMMs.

Table 7.4 shows the RMMs recommended/suggested to mitigate the IRFs in OGP projects in Iraq.

Table 7.4: The RMMs suggested to mitigate the IRFs in OGP projects in Iraq (Kraidi et al. 2018a).

IRFs	**The suggested RMMs**	
	The RMMs that have a direct action to manage the IRFs	**The RMMs that have an indirect action to manage the IRFs**
• Terrorism, sabotage and the security • Theft of the products • Insecure areas	1. Avoid the insecure areas. 2. Anti-terrorism design. 3. Use protective barriers and perimeter fencing 4. Use a high technology and advanced risk-monitoring system. 5. Government-public cooperation. 6. Foot and vehicle patrols. 7. Use the rivers and lakes to extend the pipelines in the insecure areas despite the construction cost and the risk of corrosion.	1. Use underground pipeline. 2. Expand the protection zones along with the pipelines and remove the random buildings and unauthorised activities in the pipeline production zones.
Public's low legal and moral awareness	Government-public cooperation.	1. Use protective barriers and perimeter fencing. 2. Expand the protection zones along with the pipelines and remove the random buildings and unauthorised activities in the pipeline production zones.
Threats to staff	1. Avoid insecure areas. 2. Foot and vehicle patrols.	Government-public cooperation.
The pipeline is easy to access	1. Use underground pipeline. 2. Use a high-technology and advanced risk-monitoring system. 3. Use protective barriers and perimeter fencing. 4. Foot and vehicle patrols. 5. Expand the protection zones along with the pipelines. 6. Use the rivers and lakes to extend the pipelines in the insecure areas.	Avoid insecure areas.
Geological risks such as groundwater and landslides	1. Anti-corrosion such as isolation and cathodic protection. 2. Extend the pipes inside concrete pipes.	Proper inspection, tests and maintenance.
Vehicle accidents	1. Use underground pipeline. 2. Use protective barriers and perimeter fencing. 3. Warning signs. 4. Choose the pipeline routes accurately to avoid the traffic areas.	Expand the protection zones.
Animal accidents on the pipeline	1. Use underground pipeline. 2. Use protective barriers and perimeter fencing.	Expand the protection zones.
Corrosion and lack of protection against it	1. Anti-corrosion such as isolation & cathodic protection. 2. Extend the pipes inside concrete pipes. 3. Use optimisers and remove the salts and metals before pumping the petroleum products. 4. Pump only one type of product in the pipeline and use a different pipeline for each oil field.	1. Proper inspection, tests and maintenance. 2. Use high-quality pipes and spare parts. 3. Do not use pipes older than the design age.
The weak ability to identify and monitor the threats	1. Use a high-technology and advanced risk-monitoring system. 2. Proper inspection, tests and maintenance. 3. Proper training. 4. Record pipeline accidents and risks in order to avoid them in the future.	All of the RMMs could be used to improve the ability to identify and monitor the IRFs in OGP projects.
Shortage of the IT services and modern equipment	Use a high-technology and advanced risk-monitoring system.	
Design, construction and material defects	1. Proper training. 2. Make studies about the safety of the pipelines and follow the new research about risk management. 3. Use high-quality pipes and spare parts. 4. Choose well-known design companies to minimise design errors. 5. Choose well-known construction companies to minimise construction defects.	Do not use pipes older than the design age.
Operational errors	1. Choose well-known construction companies to minimise construction defects. 2. Commit to the operating standards. (e.g. do not pass the design capacity).	All of the RMMs could be used to manage the IRFs in OGP projects during the operation stage.

	3. Use optimisers and remove the salts and metals before pumping the petroleum products. 4. Pump only one type of product in the pipeline and use a different pipeline for each oil field.	
Lack of appropriatetraining	Proper training.	Record pipeline accidents and risks in order to avoid them in the future.
Conflicts over land ownership	1. Choose the pipeline routes accurately to avoid conflicts over land ownership. 2. Taking future urban planning into account.	
Salt and metal contents in the transported products such as silver	Use optimisers and remove the salts and metals before pumping the petroleum products.	
The pipes are older than the design age	Do not use pipes older than the design age.	
Not taking the future urban planning into account	Taking future urban planning into account.	
Poor quality pipes	Use high-quality pipes and spare parts.	
Natural disasters and weather conditions	Choose the pipeline routes accurately to avoid natural disasters.	
Few researchers are dealing with this problem	Make studies about the safety of the pipelines and follow the new research about risk management.	
Lack of risk registration	Record pipeline accidents and risks in order to avoid them in the future.	
Not paying appropriate attention to risk management (e.g. not following scheduled programmes to solve problems)	1. The stakeholders in different levels should pay the appropriate attention to the risk management in their projects. 2. Follow and commit to the operating standards (e.g. do not pass the design capacity).	
Improper inspection and maintenance	1. Proper inspection, tests and maintenance.	
Improper safety regulations	1. All the methods.	
The aboveground pipelines increase sabotage and theft opportunities, as they are easy to access	1. Move to an underground pipeline. 2. Foot and vehicle patrols. 3. Use the rivers and lakes to extend the pipelines in the insecure areas despite the construction cost and the risk of corrosion.	1. Use a high technology and advanced risk-monitoring system. 2. Use protective barriers and perimeter fencing. 3. Warning signs and marker tape above the pipeline 4. Expand the protection zones along with the pipelines and remove the random buildings and unauthorised activities in the production zones of the pipeline.
Limited warning signs	Warning signs and marker tape above the pipeline.	
Inadequate risk management	All the methods.	
Pumping more than one type of petroleum product and crude oil from different fields in the same pipe	Pump only one type of product in the pipeline and use a different pipeline for each oil field.	

Managing and mitigating the risk factors in these OGP projects is not limited to one stage of the project. Therefore, different risk mitigation methods were suggested to mitigate the risk factors during the project's entirety. Based on the survey results, anti-corrosion measures such as isolation and cathodic protection were rated as effective RMMs. Corrosion could be protected against by providing the pipelines with an external coating, using isolation layers, a cathodic protection system, or a combination of these methods. However, these methods are not perfect. Therefore, the condition of the coating, the isolation layers, and the system of cathodic protection must be periodically checked for any issues (Hopkins et al. 1999). The main disadvantage of this method is the added cost to the projects, and it might slow down pipeline construction and installation processes as certain protections need to be applied.

Regular risk monitoring and surveys by using advanced technological and professional remote monitoring (e.g. aerial and satellite surveillance, remotely controlled vehicles, Global Positioning System (GPS), and smart camera systems) can help to investigate any unauthorised activities in OGP project zones such as terrorism, sabotage, thievery, illegal excavation, and construction activities near to the pipeline. Using these methods has a number of advantages, for example, surveying a large network of pipelines in a short period of time. The presence of these methods could serve as a deterrent against intentional TPD and provide quick risk prediction and alerts. These methods also enable photographs of pipelines to be shared between the project partners. However, they also have disadvantages including high capital investment for equipment and machinery, operational costs, and additional training for personnel on new software.

Based on the survey results, foot and vehicle patrols are not effective RMMs as they are time-consuming, do not cover large areas of the OGP network, and need to be carried out at frequent intervals to be effective. That said, this method has some advantages such as requiring a moderate capital investment for equipment and machinery, and it is effective against intentional or unintentional TPD during inspection periods.

Proper operational practices, inspections and maintenance reduce operative IRFs and mechanical failure for the pipeline. Most operators in OGP projects control operational IRFs by limiting the operational stress (operating pressure) and following the regulations and codes. However, Hopkins et al. (1999) noticed some problems with such a procedure: (i) the regulations and codes are different in different areas and companies; therefore, they are not applicable to OGPs everywhere; (ii) this procedure might potentially miss new IRFs if IRF identification and registration are not up to date; and (iii) this procedure creates an inflexible practice of risk management that restricts the stakeholders in applying new methods of identifying and mitigating the IRFs.

The landowners and construction workers should monitor pipelines in their areas to avoid carrying out farming or construction work that could damage the pipes. Providing communication facilities for the local population such as emergency contact (emails and phone numbers) and phone lines, mailboxes, and so forth) could help people to report any threat to a pipeline. Iraq's OGP network is above ground, which means that the pipelines are susceptible to IRFs mainly related to TPD.

The majority of participants agreed that moving pipelines underground is safer than having exposed ones, despite the corrosion and geological IRFs, and the construction and maintenance difficulties.

This research's findings and recommendations are suitable and applicable for OGPs in Iraq and many other countries under similar situations. OGP stakeholders could use this research's findings to improve risk management during the pipeline projects' stages. Moreover, the RMF could be applied to mitigate the IRFs for other critical infrastructures such as water supply network; transportation system (e.g. railway, highways, fuel supply, etc.); energy supply infrastructure (e.g. transmission and distribution lines, nuclear power generators, etc.); telecommunication and communication facilities; etc. The IRFs may be different in these projects, but insecure situations cause similar types of risks. Therefore, the methodology for identifying and evaluating the IRFs and RMMs could also be similar.

Suggesting, recommending and/or identifying effective RMMs to manage the risk factors in the projects should be done based on an extensive review though the project stages. In other words, the perceptions of the manufacturers, the designers, the inspections and the operators should be collected and analysed in order to enhance the safety levels of the pipelines continually. This is because: (i) the impact of the risk factors changes as time passes, (ii) there are always new risk factors arising in the projects and (iii) the methods of risk management are continually improved. This means that the stakeholders and researchers should be prepared and updated about: (i) analysing and reanalysing the existing risk factors, (ii) revaluating the existing RMMs with regard to their effectiveness degree in the projects, (iii) analysing the newly arising risk factors, and (iv) using modern and new RMMs. Therefore, continuous extensive interviews and focus group studies with experts with high experience levels in the projects should be conducted to recommend a robust system of risk management in the OGP projects.

7.3.1 Evaluating the Recommendations for Identifying Effective RMMs (Stage I)

This section explains the process of evaluating the functionality of the RMF with regard to identifying and recommending some of the effective RMMs which could be used to manage the IRFs in OGP projects in Iraq. The process for evaluating the identified and recommended RMMs involves creating a targeted questionnaire asking several experts in the field about their perceptions of the recommended RMMs. The survey was conducted using a Google Forms survey. The survey link was sent to the potential participants via email or private message on Facebook. The survey was sent to 35 participants, and 20 participants answered the survey questions, which means the survey response rate was 57.14%.

The experience levels of the participants in OGP projects were as follows: 5% (1 out of 20) of the participants had between 5 and 10 years of experience; 55% (11 out of 20) had between 10 and 15 years; and 40% (8 out of 20) had more than 15 years of experience, as shown in the figure below.

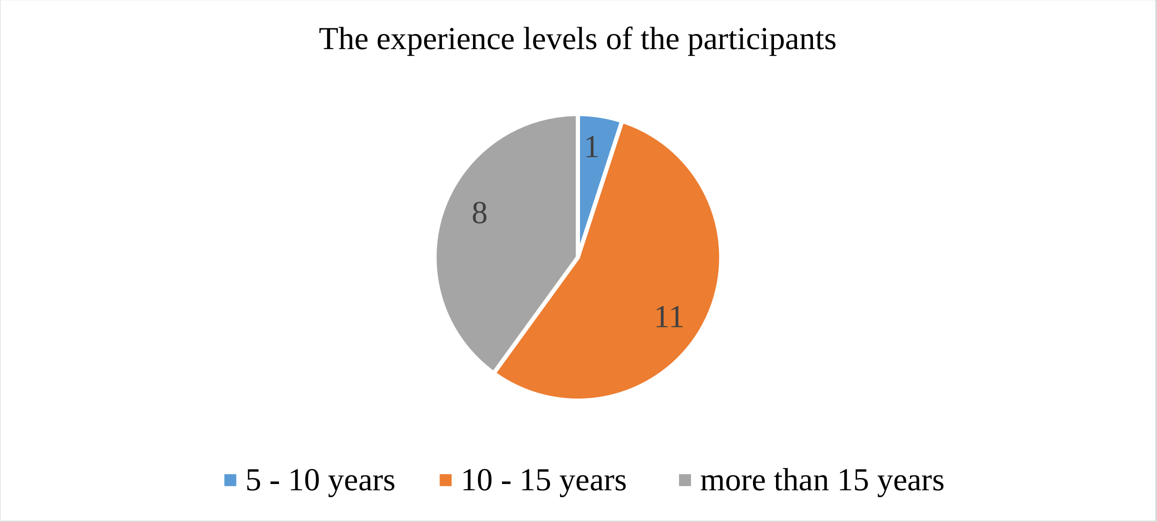

Figure 7.24: The experience levels of the participants, evaluation survey stage I.

The participants' occupations were as follows: 40% (8 out of 20) of the participants were clients or owners; 35% (7 out of 20) were operators; 20% (4 out of 20) were members of a construction teams; and 5% (1 out of 20) were consultants, planners or designers, as explained in the figure below.

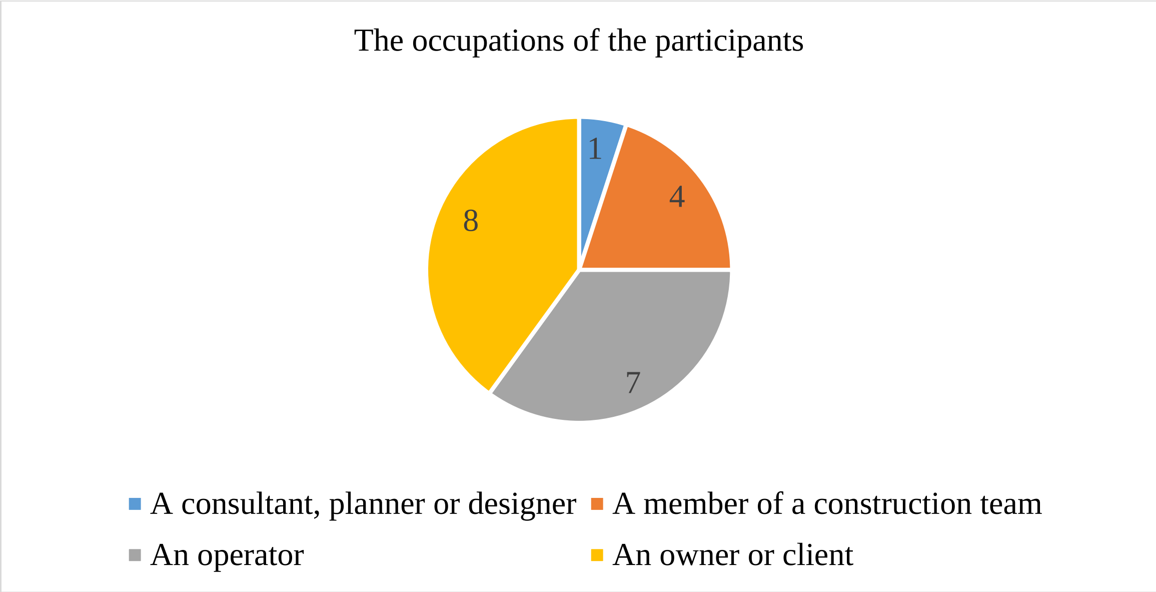

Figure 7.25: The occupations of the participants, evaluation survey stage I.

As shown in the two figures above, most of the participants had more than 11 years of experience in OGP projects. Additionally, the appropriate sampling of people representing all the roles in OGP projects enhances the results of the survey. This means that the results of the targeted questionnaire reflect valid and trusted perceptions about the recommended RMMs which have been collected by surveying people from all the roles in OGP projects in Iraq.

The results of the survey show that the majority of the participants agreed about the results, which evaluated the RMF with regard to using it to identify effective RMMs to manage the IRFs in the OGP projects in Iraq. The figure below shows an example of the survey results.

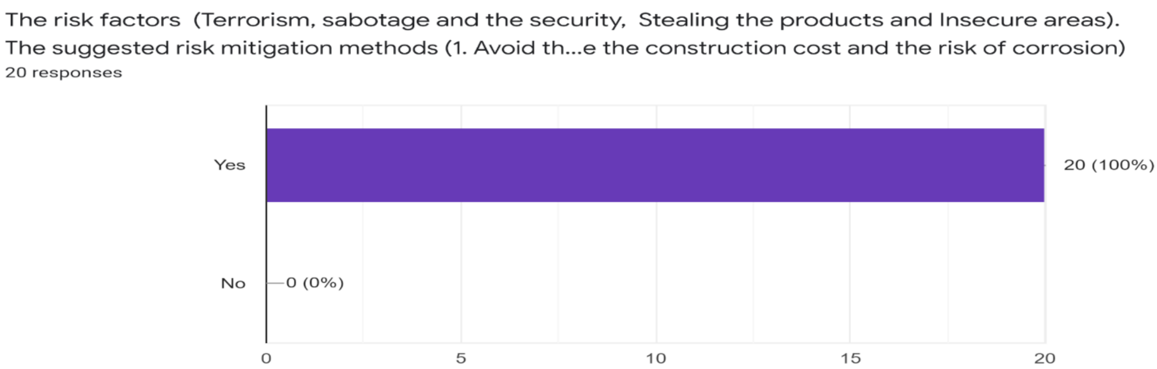

Figure 7.26: The results of evaluating the identified RMMs to mitigate terrorism, sabotage and the security, theft of the products and insecure areas, evaluation survey stage I.

As the size of the figure above was not big enough to explain the full details, the recommended RMM to manage the Terrorism, sabotage and the security, Theft of the products and Insecure areas IRFs, were (I) Avoid the insecure areas. (II) Anti-terrorism design. (III) Use protective barriers and perimeter fencing. (IV) Use a high technology and advanced risk-monitoring system. (V) Government-public cooperation. (VI) Foot and vehicle patrols. (VII) Use the rivers and lakes to extend the pipelines in the insecure areas despite the construction cost and the risk of corrosion.

The responses to most of the questions were 100% yes. This is because the types and characteristics of the identified and recommended risk mitigation methods are suitable to manage the risk factors. To justify these answers, this research has been based on an extensive literature review about the IRFs and risk mitigation methods in OGP projects. The findings of the literature review have helped to identity most of the common risk mitigation methods in the projects. Additionally, the data collected from the initial survey (in Chapter 4:) have helped in identifying at least one risk mitigation method for the IRFs mentioned in the survey. Moreover, the results from using the RMF to identify and recommend effective risk mitigation methods to manage the IRFs in Iraq have been presented at a prestigious conference (Kraidi et al. 2018a). The reviewers' comments helped to reduce the chance of identifying and recommending unsuitable risk mitigation methods for the IRFs in the projects.

Furthermore, as the technology and the risk mitigation methods are continuously developing with time, the participants in the targeted survey have added more risk mitigation methods to the worklist. This means that risk management in oil and gas pipeline projects is dynamic and always being updated. In other words, there are always new risk mitigation methods arising in the projects which could be used by the stakeholders to manage the IRFs in their projects. For example, an advanced monitoring system such as SAP software, or new chemical materials that prevent the internal and external corrosion of the pipelines, were added by the participants in the targeted survey as risk mitigation methods that could be used to manage the risk factors in OGP projects. These methods were not found in the literature review when this research started. Therefore, these methods were not involved in the first survey, which was about analysing the IRFs and RMMs in OGP projects in Iraq. One of the recommendations of the future work of this research, therefore, is to be up to date with the new risk mitigation methods, as will be explained in Chapter 10:. To keep this chapter short, the results of the targeted survey and the participants' comments (i.e. the added risk mitigation methods) are explained in APPENDIX E:.

7.3.2 Evaluating the Recommendations for Identifying Effective RMMs (Stage II)

As explained and justified in the section above, the responses to most of the questions were 100% yes. This is because the types and characteristics of the identified RMMs are suitable to manage the risk factors. Therefore, the research distributed another targeted survey to evaluate the findings of the RMF with regard to identifying and recommending RMMs to manage the IRFs in OGP projects in Iraq.

In this targeted survey, which has been considered as stage II of evaluating the findings of the RMF, the researcher has used a five-point Likert scale to collect the perceptions of the participants regarding the identified and recommended RMMs where 5 means strongly agree and 1 means strongly disagree. This is because such a scale is useful to understand to what extent the participants accept/agree or not on the recommended RMMs rather than accept/agree or not on these methods, rather than if they just accept/ agree about them by answering to yes or no questions.

Nine participants responded to the targeted survey (stage II). These participants also responded to stage I of the evaluation survey. The experience levels of the participants in OGP projects were as follows: 11.1% (one out of nine) of the participants had between five and 10 years of experience; 33.3% (three out of nine) had between 10 and 15 years; and 455.6% (five out of nine) had more than 15 years of experience, as shown in the figure below.

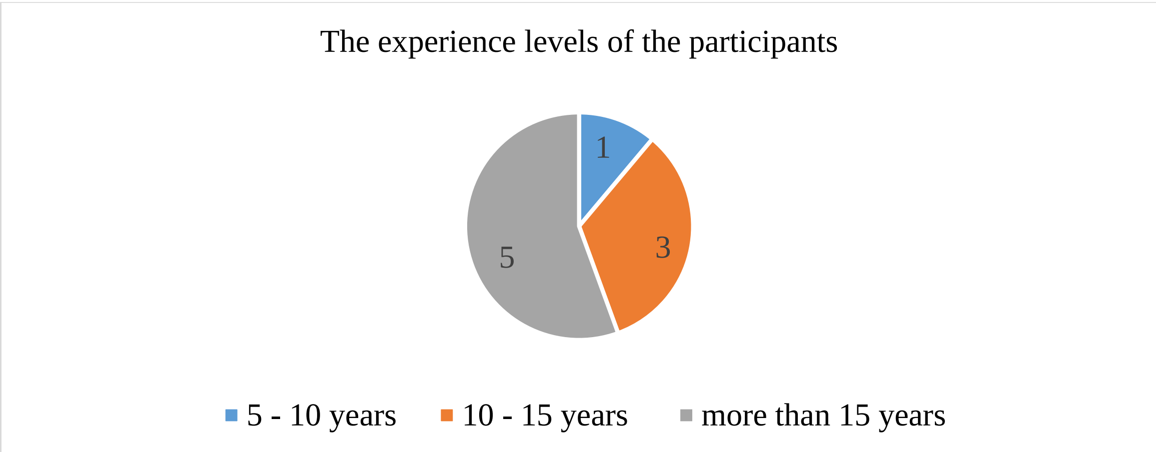

Figure 7.27: The experience levels of the participants, evaluation survey stage II.

The results of stage II of the survey show that the majority of the participants agreed about the results, which evaluated the RMF with regard to using it to identify effective RMMs to manage the IRFs in the OGP projects in Iraq, as shown in the figure below.

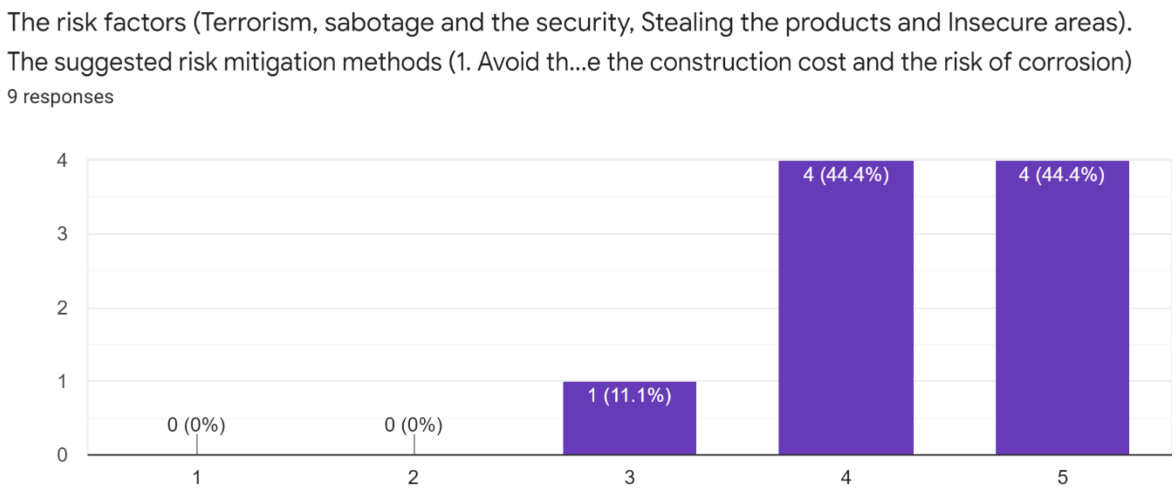

Figure 7.28: The results of evaluating the identified RMMs to mitigate terrorism, sabotage and the security, theft of the products and insecure areas, evaluation survey stage II.

As the figure above is not big enough to explain the full details, the RMMs recommended to manage the Terrorism, sabotage and the security, Theft of the products and Insecure areas IRFs, were (I) Avoid the insecure areas. (II) Anti-terrorism design. (III) Use protective barriers and perimeter fencing. (IV) Use a high technology and advanced risk-monitoring system. (V) Government-public cooperation. (VI) Foot and vehicle patrols. (VII) Use the rivers and lakes to extend the pipelines in the insecure areas despite the construction cost and the risk of corrosion.

To keep this chapter short, the results of the targeted survey and the participants' comments (i.e. the added risk mitigation methods) are explained in APPENDIX D:.

7.4 Summary

The new oil and gas pipeline projects must be planned, designed, installed, operated and maintained after detailed analysis of risk factors including safety requirements and regulations in order to transport the petroleum products safely. Building an OGP project without analysing safest routes based on risk levels could result in serious consequences in the future of such projects where the selected pipeline route is influenced by a number of risk factors. On the other side, the safest pipeline route provides a safe means of transport for oil and gas products as well as reducing the associated risk factors in the projects. Moreover, it is important to understand the RMMs that could be used to manage the IRFs in the projects and estimate their degree of effectiveness in the projects to take suitable risk management actions if a risky event occurs. The developed RMF is useful to satisfy the following functionalities.

1. The developed framework will help in identifying the safest pipeline route amongst others while developing a new gas and oil pipeline, see section 7.2.
2. The developed framework also helps to suggest some effective RMMs which could be used to mitigate the risk factors in the OGP projects, see section 7.3.

CHAPTER 8: RISK IMPACT QUANTIFICATION USING ASTA RISK SIMULATOR

8.1 Introduction

This chapter describes the process of evaluating the functionality of the Risk Management Framework (RMF) developed in this study. The third functionality of the RMF focuses on the quantification of delay impacts caused by the risk factors associated with Oil and Gas Pipeline (OGP) projects. This chapter also illustrates how to perform the quantification of the delay impact in an OGP project caused by the associated IRFs using a real case study project. The key inputs in the RMF are the summation of the impact in terms of the Risk Index (RI) of each IRF on the project's work activities and their level of probability and consequence, as shown in section 8.2.

The first process in quantifying the delay impact on the construction project is the allocation of the potential Influencing Risk Factors (IRFs) that influence the work activities in the OGP project. Then the delay impact of the risk factors will be quantified using the risk simulation algorithm integrated within the ASTA risk simulator programme. The key outputs of the RMF are the amount of delay impact caused by the IRFs in the construction project in the OGP and the sensitivity levels of risk factors. Figure 8.1 explains the layout when analysing the delay impact of the IRFs in the OGP project delivery.

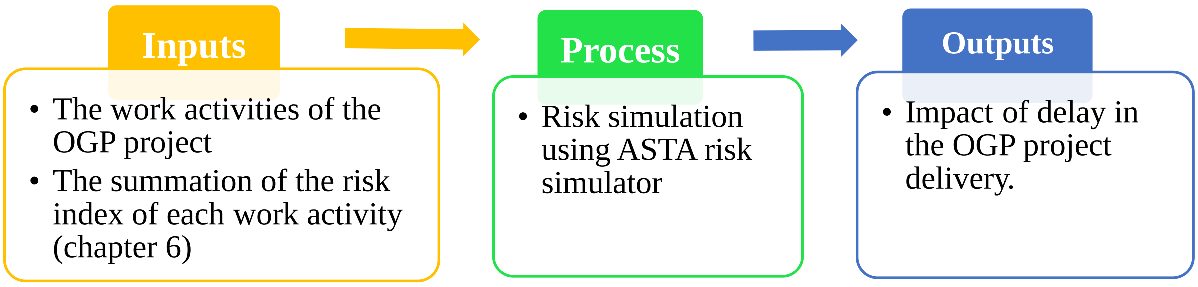

Figure 8.1: The layout when analysing the delay impact of the IRFs in the OGP project delivery.

This chapter is organised in six sections including the introduction. Section 8.2 presents the systematic steps of calculating the summation of risk level in terms of RI caused by IRFs on the work activities of the OGP project. Section 8.3 describes the details of the quantification of the impact on the OGP project delivery caused by IRFs in each work activity. The quantification processes are presented under inputs, process and outputs, which are integrated within the developed RMF. Section 8.4 analyses the delay impact of the IRFs on the duration of the OGP project. Section 8.5 analyses the project activities in order to understand their degree of impact and their likelihood of affecting the duration of the project. Section 8.6 analyses the activities on the critical path of the project time schedule to understand their degree of impact on the project duration. Finally, section 8.7 summarises the key outputs and results of the case study used for the evaluation process of the RMF's functionality with regard to using it to quantify project delay.

8.2 Analysis of Risk Impact Caused by IRF in Each Project Activity

This section explains the algorithm and systematic procedure of analysing the impact of the IRFs **on the work activities associated with an OGP project**. As shown in Figure 6.8 in Chapter 6:, this section presents the results after analysing the risk impact caused by the IRFs on the duration of each work activity. The summation processes of the risk impact are presented under three steps, inputs, process and outputs, as shown in Figure 8.2.

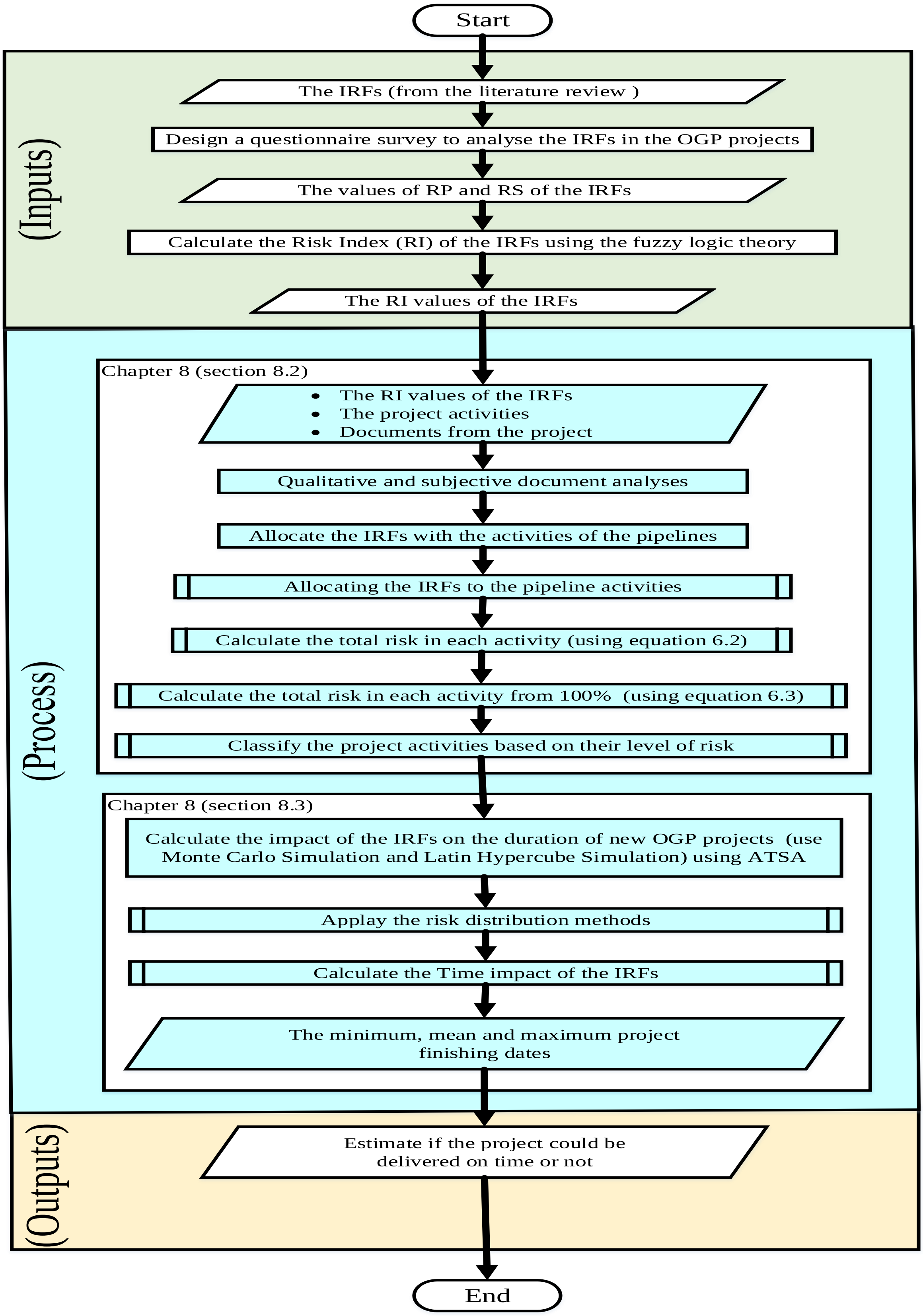

Figure 8.2: A detailed flowchart of calculating the delay impact in the case study project.

A- **Inputs:** the inputs used by the RMF to analyse the level of impact of the IRFs on the duration of the project work activities were (i) a list of the IRFs that affect the safety of OGPs in Iraq (which were identified from the literature review); (ii) their degree of impact on the project (which was calculated using the survey and the FIS in MATLAB), and (iii) the activities and the time schedule of the project. This case study project belongs to the Gazprom Neft Badra company. Figure 7.5 presents the case study project, which is route 1 of the oil and gas export pipeline.

At the time of this research, the project was under the planning phase, with a starting date of May 21, 2019, and the targeted delivery date is January 13, 2023. This means that the duration of the project is estimated at around three years and 238 days (1334 days).

In this step, the data collected from the project were the project work activities, the duration of these activities (including the activities' start and finish dates), the logical link between the activities, and the project construction programme. These data are presented at the end of APPENDIX D:.

B- Process: algorithms for analysing the impact of IRFs.

1- Allocating the IRFs to the project work activities. The IRFs were allocated to the project work activities depending on the type of IRF and the nature of the activity. Professional knowledge was used to achieve this task. The subjective and objective analysis of technical reports, practical guides and studies such as CEPA Foundation Inc. and INGAA Foundation Inc (2016), E.E.P.A. (2016), F.T.A. (2019), Folga (2007), Nandagopal (2007), Stanton and Stanton (2019) and Williams Companies (2019) were 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 IRFs that could affect that activity based on vast experience and a review of the construction process in OGP projects worldwide.

For example, IRFs such as terrorism; sabotage; threats to staff; leakage of sensitive information; lack of appropriate training; lack of records about the IRFs; little research about the IRFs; insecure areas; conflict over land ownership; improper safety regulations; natural disasters; weather conditions; weak ability to identify and monitor the threats; shortage of IT services; and construction defects were allocated to the trenching work activities (e.g. digging the trench, laying the pipelines, backfill, etc.) because such kinds of IRFs could affect the safety of the project during the trenching activities and cause delay in the project. The results of allocating the IRFs to the project work activities are shown in APPENDIX D:.

This research has analysed the IRFs that affect the safety of the pipelines during the planning and design, construction and operation stages of projects. In other words, this research has analysed the IRFs in OGP projects during the entire lifetime of these projects. Some of the IRFs such as corruption were assumed to affect the new pipeline projects no matter the project activity or location, because such a risk factor is not only affecting a specific project or a specific activity, it affects the OGP projects in the whole country and during all their work stages. Additionally, there are some relationships between the IRFs which have been considered in this research. For instance, similar IRFs such as sabotage and thefts, which are related to the security situation, might threaten the pipelines together if the security level of a specific area is low. In the areas with easy access to the piplines, the piplines are subject tp the vehicle and similar accidents. Meanwhile, it was assumed that some of the IRFs would not affect the new pipeline projects in Iraq. For example, hacker attacks on the system, as the stakeholders in OGP projects in Iraq are not using an advanced management system, yet.

2- Calculate the summation of the impact of the IRFs associated with each activity of the project using equation 8.4, which calculates the summation of the RI values of the IRFs allocated to these activities.

The summation of risk in an activity= ∑RI values of the IFRs relevant to that activity …(8.1)

For example, the summation of risk in the trenching activities; temporary erosion control and side support activities; pipe set-up and welding activities; and fabrication and installing pipe activities was 54.05, 57.48, 43.84 and 36.28, respectively. For example, 54.05 was the summation of the RI values of the IRFs associated with trenching activities, see Table D.1 and Table D.2 in APPENDIX D:.

3- Calculate the summation of risk for project work activities from 100% using equation 8.2.

$$The\ summation\ of\ risk\ in\ an\ activity\ (from\ 100\%) = \frac{\sum of\ risk\ of\ that\ activity}{\sum of\ risk\ in\ the\ project} \quad \ldots(8.2)$$

For example, the summation of risk from 100% for the above-mentioned activities was 2.567, 2.78, 2.082 and 1.723, respectively. For example, 2.567 was the summation of the RI values of the IRFs associated with trenching activities from 100%, see see Table D.1 and Table D.2 in APPENDIX D:.

4- 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. For example, the level of risk for the above-mentioned activities was medium risk, medium risk, medium risk and low risk, respectively.

C- **Outputs**: Table 8.1 shows the results of the risk summation of the project's main work activities and the level of risk of these activities

Table 8.1: The summation of the impact of the IRFs on the project's main work activities and the level of risk of these activities.

Activities	**Equation 8.1**	**Equation 8.2**	**Risk Level**
Concept and definitions	18.11^	0.86¬	VL
Life-cycle plan	71.8	3.41	H
Choosing the route	76.65	3.64	H
Route approval	73.14	3.47	H
Design and development	43.44	2.06	M
Installation procedure	29.28	1.39	L
Risk assessment	49.67	2.36	M
Time schedule	22.08	1.05	L
Cost estimation	22.08	1.05	L
Communications	25.43	1.21	L
Materials order	18.41	0.87	VL
Survey, staking and setting out	75.77	3.60	H
Clearing and grading the right-of-way	73.46	3.49	H
Topsoil stripping	57.88	2.75	M
Buildings, roads and river crossings	76.63	3.64	H
Pipe transportation to site	59.02	2.80	M
Temporary fencing and signage	51.09	2.43	M
Trenching	54.05	2.57	M
Temporary erosion control and side support	57.48	2.73	M
Pipe set-up	43.84	2.08	M
NDT tests	32.77	1.56	L
Welding, fabrication and installing	36.28	1.72	L
Sandblast	32.82	1.56	L
Painting	32.81	1.56	L
Coating	54.69	2.60	M
Lowering pipe and backfilling	46.71	2.22	M
Cathodic protection of the pipe	68.64	3.26	H
Final fitting	32.61	1.55	L
As-built survey	32.48	1.54	L
Hydro, pressure test	29.1	1.38	L
Backfilling	36.16	1.72	L
Fencing and signage	61.49	2.92	M
Final clean-up	40.11	1.90	L
Right of way reclamation	54.03	2.57	M
Safety barriers	55.53	2.64	M
Operation within design limits	97.54	4.63	VH
Commissioning operation value	97.54	4.63	VH
Measure the performance and efficiency	29.26	1.39	L
Enhanced performance and efficiency	97.54	4.63	VH
Monitoring and inspection	42.57	2.02	M
Maintenance	59.54	2.83	H
Risk control	36.31	1.72	L

*See Table D.1 and f in APPENDIX D:. ^For example, 54.05 was the summation of the RI values of the IRFs associated with trenching activities. ¬ For example, 2.567 was the summation of the RI values of the IRFs associated with trenching activities from 100%,

The findings shown in Table 8.1 above will be used to quantify the delay impact in the selected case study OGP project using Monte Carlo Simulation (MCS) and Latin Hypercube Simulation (LHS) algorithms, which are integrated within the ASTA risk simulator. This is explained in the next section.

8.3 Quantifying the Delay Impact of IRFs in the OGP Project Delivery

As shown in Figure 8.2, section 8.2 was about allocating the IRFs to the work activities of the case study project and analysing the impact levels of the IRFs on the duration of these activities. This section shows the steps of using the ASTA risk simulator to analyse the delay impact in the OGP project. In this research, the risk simulation method that is integrated within the ASTA risk simulator is used to calculate the delay impact of the IRFs on the duration of the OGP case study project. Calculating the time impact and the delay in the project includes three main components, which are inputs, process and outputs.

Figure 8.2 shows the key inputs, process and outputs used by the ASTA risk simulator to quantify the impact of the IRFs on **the duration of the case study project**. These steps are explained as follows.

1- **The inputs** used in this process were a list of the IRFs (from the literature review) and their degree of impact on the project (from the Fuzzy Inference System (FIS)). The construction programme of the project is explained in section G.5 of APPENDIX G:.

2- **The processing steps** of using these inputs were as follows. (I) Allocate the IRFs to the project activities. (II) Calculate the summation of risk in each activity. (III) Calculate the summation of risk of the project activities from 100%. And (IV) Classify the level of risk in the project activities. These steps are carried out in section 8.2, see Table 8.1.

   In this section, the ASTA risk simulator was used to allocate the time schedule of the project and the risk levels of these activities to the risk simulation and distribution methods in order to quantify the delay in the case study project. The ASTA risk simulator has two types of risk simulation methods, which are MCS and LHS, and four types of risk distribution methods, which are Uniform, Normal, Skewed Normal and Skewed Triangular. Figure 8.3 shows the risk simulation and distribution methods in the ASTA risk simulator.

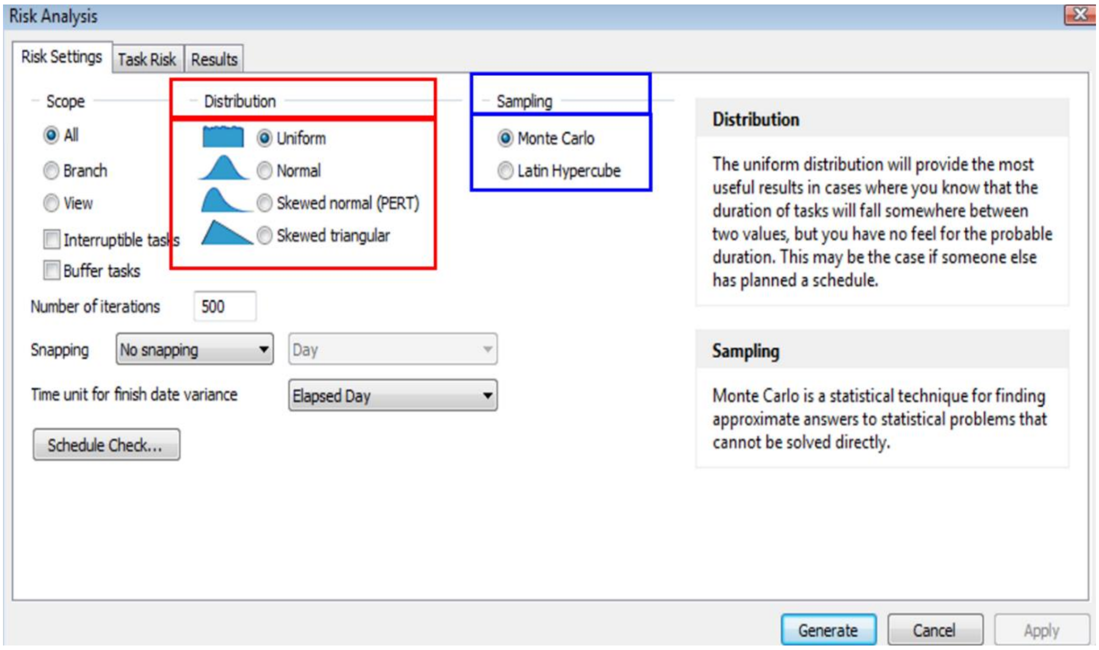

Figure 8.3: Data sampling and distribution methods in the ASTA risk simulator.

As shown in the figure above, this research has used two risk simulation methods to analyse the delay impact of the IRFs in the case study project. The reason for using two simulation methods in this research is to produce trusted research findings by comparing the results of these methods. The differences between the two data sampling methods of the ASTA risk simulator are as follows.

1- **Monte Carlo Simulation (MCS):** Figure 8.4 displays an example of how MCS works. The example is as follows. If there was a semi-circle drawn inside a square, and someone dropped rice over the square, some of the rice would fall inside the semi-circle and some would fall outside it. If this action was carried out 100 times, and 60 grains fell inside the circle, it means the chance that every single grain of rice has of falling inside the semi-circle is 60%.

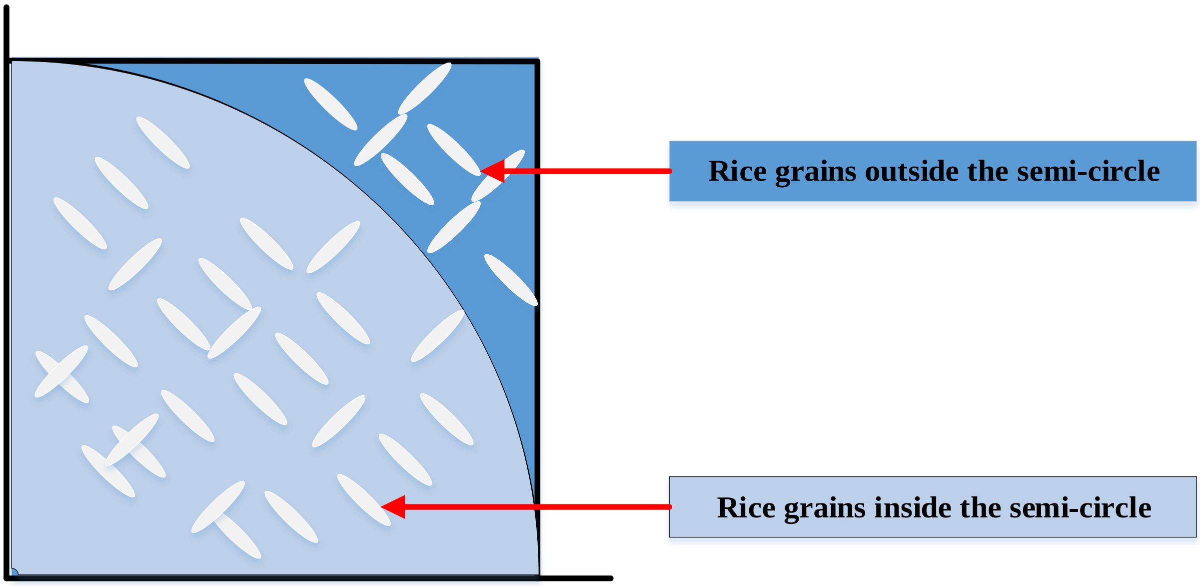

Figure 8.4: An example of the Monte Carlo simulation (MCS) method.

The process of dropping the rice grains is called iteration, which means that, the more times the rice is dropped over the square, the predictions about the probability of the rice falling in the semi-circle become more accurate. Therefore, increasing the number of iterations provides a sample which is big enough to produce the desired level of prediction in research studies. With regard to the application of MCS to analyse the impact of the IRFs on the duration of the project activities, Grinstead and Snell (2012), Keramat and Kielbasa (1997) and Rutherford et al. (2006) assumed that, if an activity has a minimum duration of 10 days and a maximum duration of 15 days, the duration of that activity produced by MCS after considering the impact of the IRFs would be 15 days, with a probability of 90%.

2- **Latin Hypercube Simulation (LHS):** LHS will produce better results with less iteration. This is because it reduces the element of randomness by using the full range of possible results (Keramat and Kielbasa, 1997; Rutherford et al. 2006).

The differences between the four data distribution methods of the ASTA risk simulator are as follows.

1- **Uniform distribution**: In uniform distribution, the elements have the same probability, but they are discrete and not continuous. In other words, the probability values fall between the minimum and maximum duration and have equal likelihood (Castrup, 2009; Mun, 2015), see Figure 8.5. Uniform distribution is useful when the results will fall between two values, but there is no indication as to which duration is most likely.

2- **Normal distribution**: Triangular distribution is a continuous probability distribution. In this kind of data distribution, there will be three parameters, which are the minimum, the peak and the maximum values. If the peak value comes in the middle of the distribution, it means the distribution is normal (Castrup, 2009; Karagoz and Altunay, 2015), see Figure 8.5.
3- **Skewed Normal**: Skewed normal distribution refers to a parametric class of probability distributions. It is similar to normal distribution, but it is extended by an additional shape parameter, which regulates the skewness and allows for a continuous variation from normality to non-normality (Ashour and Abdel-hameed, 2010; Kumar and Anusree, 2015), see Figure 8.5.
4- **Skewed Triangular**: Skewed triangular distribution is similar to skewed normal, but the results are most likely to fall on specified durations. This means that the results will move further and further from the predicted results and become less likely (Bhunya et al. 2004), see Figure 8.5.

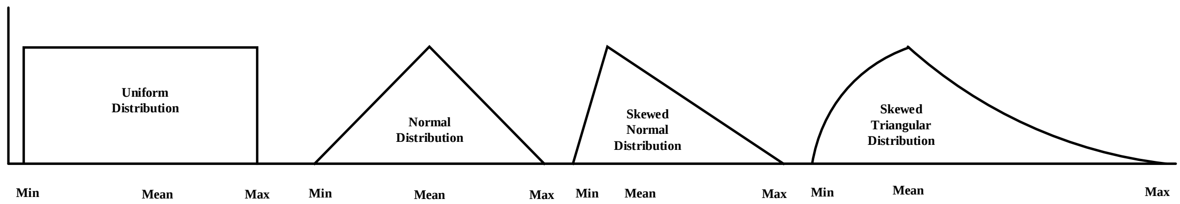

Figure 8.5: Uniform, Normal, Skewed Normal and Skewed Triangular risk simulation.

After selecting the risk simulation and distribution methods, the ASTA risk simulator will apply the iterations between the minimum and maximum duration for each activity using the selected risk simulation and risk distribution methods to analyse the impact of the IRFs in the project. Increasing the number of iterations of the simulation enhances the accuracy of the results, but it takes a longer time. Therefore, this research has used 10,000 iterations, rather than 500 iterations, which is the software default.

3- The **key output of** the ASTA risk simulator will be the amount of time delay caused by the IRFs in the project. Table D.1 and Table D.2 in APPENDIX D: show the IRFs allocated to the project activities.

The next section provides the results from using the ASTA risk simulator to analyse the time impact of the IRFs on the case study project.

8.4 The Output of the RMFs with Regard to Using the ASTA Risk Simulator to Analyse the Delay in the Project

This section presents the results of using the ASTA risk simulator to analyse the delay in the case study project. The project's initial planned (original) duration was three years and 238 days (1334 days). Table 8.2 shows the results of using the ASTA risk simulator to recalculate the duration of the project considering the impact of the associated IRFs.

Table 8.2: The duration of the project after analysing the impact of the IRFs on it using the ASTA risk simulator.

Simulation	Distribution	Finishing date	Mean Duration (days) *	Delay (days)	Std	Mean duration ± Std. (days)		Mean duration ± (2*Std.) (days)		Max hits
MCS	Uniform	January 31, 2023	1352 (Figure 8.7)	18	18	1334	1370	1316	1388	353
	Normal	January 29, 2023	1350 (Figure G.2)	16	18	1334	1370	1316	1388	367
	Skewed Normal	January 29, 2023	1350 (Figure G.3)	16	18	1334	1370	1316	1388	382
	Skewed Triangular	January 28, 2023	1349 (Figure G.4)	15	22	1330	1374	1308	1396	310
LHS	Uniform	January 30, 2023	1351 (Figure 8.8)	17	21	1330	1372	1309	1393	299
	Normal	January 29, 2023	1350 (Figure G.6)	16	22	1328	1372	1306	1394	300
	Skewed Normal	January 28, 2023	1349 (Figure G.7)	15	22	1328	1371	1307	1391	322
	Skewed Triangular	January 28, 2023	1349 (Figure G.8)	15	22	1328	1371	1307	1391	311

Before considering the impact of the IRFs, the expected finishing date of the project was January 13, 2023.

*The difference between the finishing dates after and before considering the impact of the IRFs, i.e. it is the difference between the original duration of the project and the duration after considering the impact of the IRFs.

After analysing the impact of the associated IRFs that affect the duration of the project work activities, it was found that the average delay in the project varied using different risk simulation and distribution methods, as shown in the table above. The figure below presents the results of using the ASTA risk simulator to quantify the delay impact in the project using different risk simulation and distribution methods.

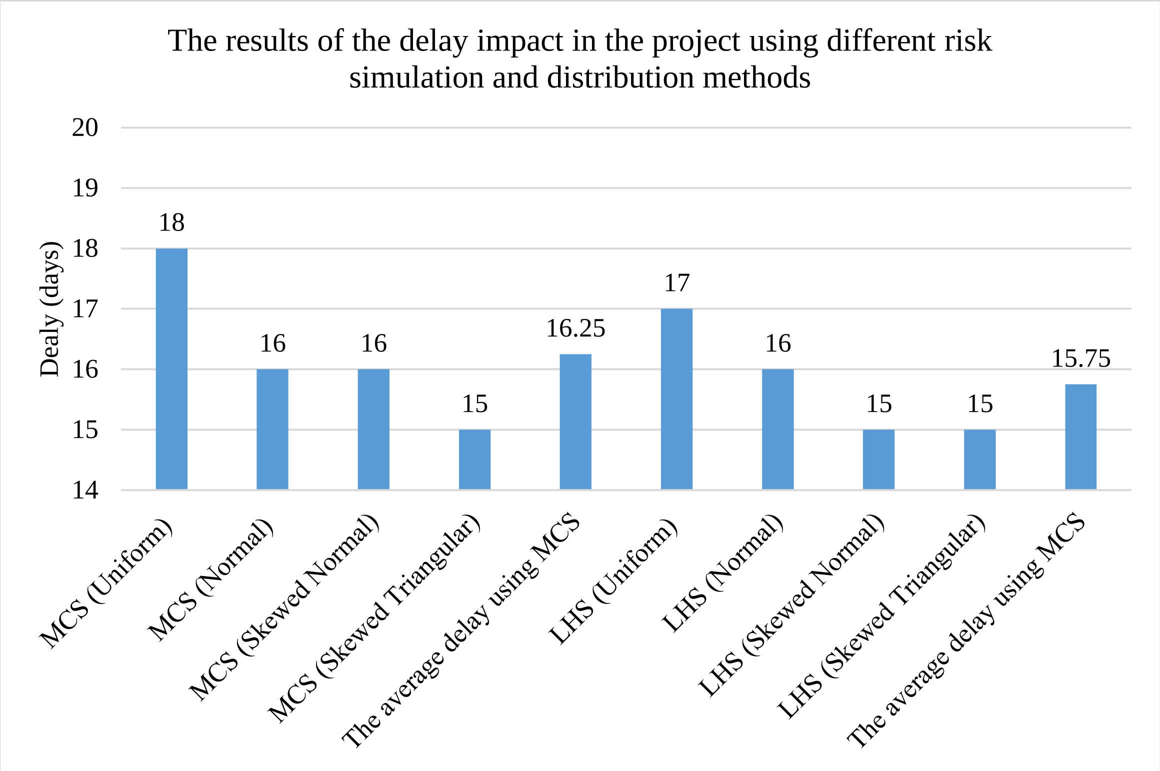

Figure 8.6: The results from using the ASTA risk simulator to quantify the delay impact in the project using different risk simulation and distribution methods.

Details of the results of these risk simulation and distribution methods are provided below.

This section details the results of using the risk simulation methods (e.g. MCS and LHS) and the risk distribution methods (e.g. Uniform, Normal, Skewed Normal and Skewed Triangular), which are integrated into the ASTA risk simulator. The results of using these distribution methods are as follows.

For example, **when considering using MCS and Uniform risk distribution**, it was found that the project needed 1,352 days to be completed rather than 1,334 days, which was the initial duration of the project. This means that the project will have a longer duration due to the impact of the IRFs associated with it. It was found that the project is expected to be completed on January 31, 2023, rather than January 14, 2023, which means the average delay in the project is 18 days with 50% probability, see Figure 8.7.

Additionally, the ASTA risk simulator shows the maximum hits for each sample, which is the date that had the highest frequency as a project finishing date during the simulation process. The maximum hits rate from using the Uniform risk distribution method is 353, which reflects the mean value of the project duration. Moreover, the ASTA risk simulator shows the Standard Deviation (Std) of each sample. The Std measures the dispersion of the data from the mean, which shows the variability within the sample. In other words, the Std characterises the average distance of the data from the mean of the distribution value of the sample, which means that the sample with a low Std is the more significant sample. The Std of this distribution method is 18 days. This means that there is a 68% probability that the project will be finished in between 1,334 and 1,370 days, whereas there is a 95% probability that it will be finished in between 1,316 and 1,388 days, see Figure 8.7.

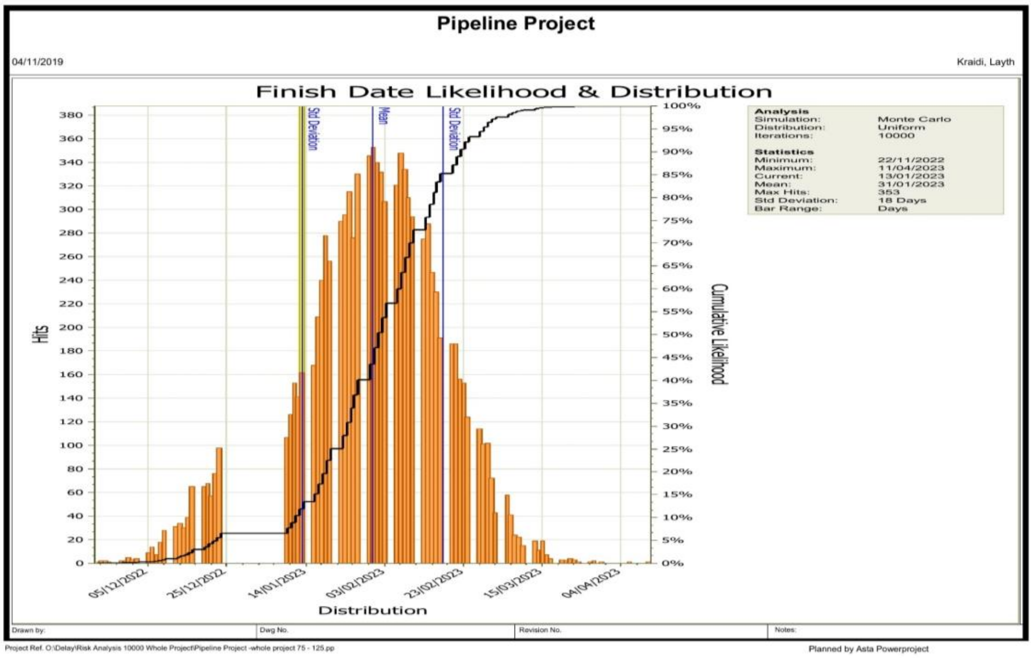

Figure 8.7: Finish date likelihood and distribution using the **Uniform data distribution method, using MCS**.

As another example of the results of the ASTA risk simulators when **considering LHC** and **Uniform risk distribution**, it was found that the average delay in the project was 17 days, which means that it is expected that the project will be completed on January 30, 2023, with 50% probability, see Figure 8.8. The maximum hits rate of this distribution method is 299, which reflects the mean value of the project duration. The Std of this distribution method is

18 days. This means that there is a 68% probability that the project will be finished in between 1,330 and 1,372 days, whereas there is a 95% probability that it will be finished in between 1,309 and 1,393 days, see Figure 8.8.

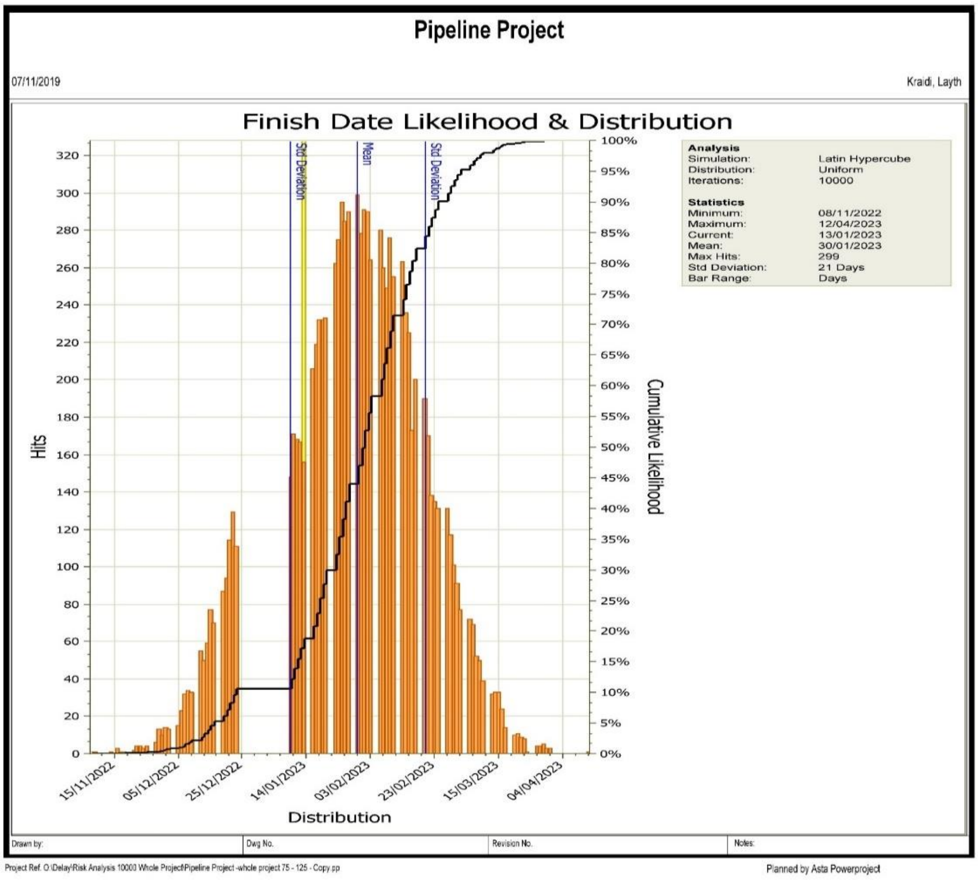

Figure 8.8: Finish date likelihood and distribution using the **Uniform data distribution method, using LHS**.

The rest of the results from using the ASTA risk simulator to quantify the delay impact in the project using different risk simulation and distribution methods are presented in APPENDIX G:.

As shown in Table 8.2, the difference between the risk simulation and data distribution methods in this case study is minimal, which means that making a comparison between the methods to choose the one that gives a better result is challenging. The project programmers could use these dates to estimate and/or reanimate the project schedule. For example, if they found that is it definite that the project will be running late then they could either change the project time schedule, take the IRFs into consideration to develop suitable risk management strategies, or even accept that the project is going to be delivered late, and then they can deal with the consequences.

The next section details the task and activities of the project that affect its duration.

8.5 Results of Project Duration Sensitivity

This section provides the results from using the ASTA risk simulator to analyse the sensitivity index of the project activities and analyse their degree of impact on the duration of the project. The ASTA risk simulator shows the sensitivity analysis of the project activities that are most likely to affect the project duration if their duration changes. In other words, the ASTA risk simulator ranks these tasks in terms of their likelihood of delaying the project finishing date. Table 8.3 shows the top two activities affecting the project duration with either a positive or a negative impact on the duration.

Table 8.3: The activities most likely to affect the project duration if their duration changes.

Simulation	Distribution	Top 2 activities with positive impact	Top 2 activities with negative impact
MCS	Uniform	Right of way (42%) Design and development (40%)	Trenching (-23%) Manufacturing and installation (-21%)
	Normal	Right of way (42%) Design and development (40%)	Trenching (-24%) Manufacturing and installation (-20%)
	Skewed Normal	Design and development (65%) Right of way (58%)	Manufacturing and installation (-53%) Trenching (-33%)
	Skewed Triangular	Design and development (64%) Right of way (56%)	Manufacturing and installation (-51%) Trenching (-35%)
LHS	Uniform	Design and development (64%) Right of way (57%)	Manufacturing and installation (-52%) Trenching (-34%)
	Normal	Design and development (63%) Right of way (57%)	Manufacturing and installation (-52%) Trenching (-32%)
	Skewed Normal	Design and development (64%) Right of way (57%)	Manufacturing and installation (-52%) Trenching (-33%)
	Skewed Triangular	Design and development (63%) Right of way (57%)	Manufacturing and installation (-52%) Trenching (-33%)

As shown in the table above, using different simulation and distribution methods to analyse the sensitivity index of the project activities has confirmed the two top activities that have a positive impact on the project duration, which are as follows. (i) The right of way, which is top twice; and (ii) the design and development, which is top six times. Similarly, the two top activities that have a negative impact on the duration of the project are (i) the trenching activities, which come top twice; and (ii) manufacturing and installation, which come top six times.

For example, with regard to analysing the duration sensitivity index of the project activities using **MCS and Uniform** methods, it was found that the right of way, design and development, final fitting, safety barriers, choosing routes, route approval and survey are the activities most likely to affect the duration of the project, see Figure 8.9.

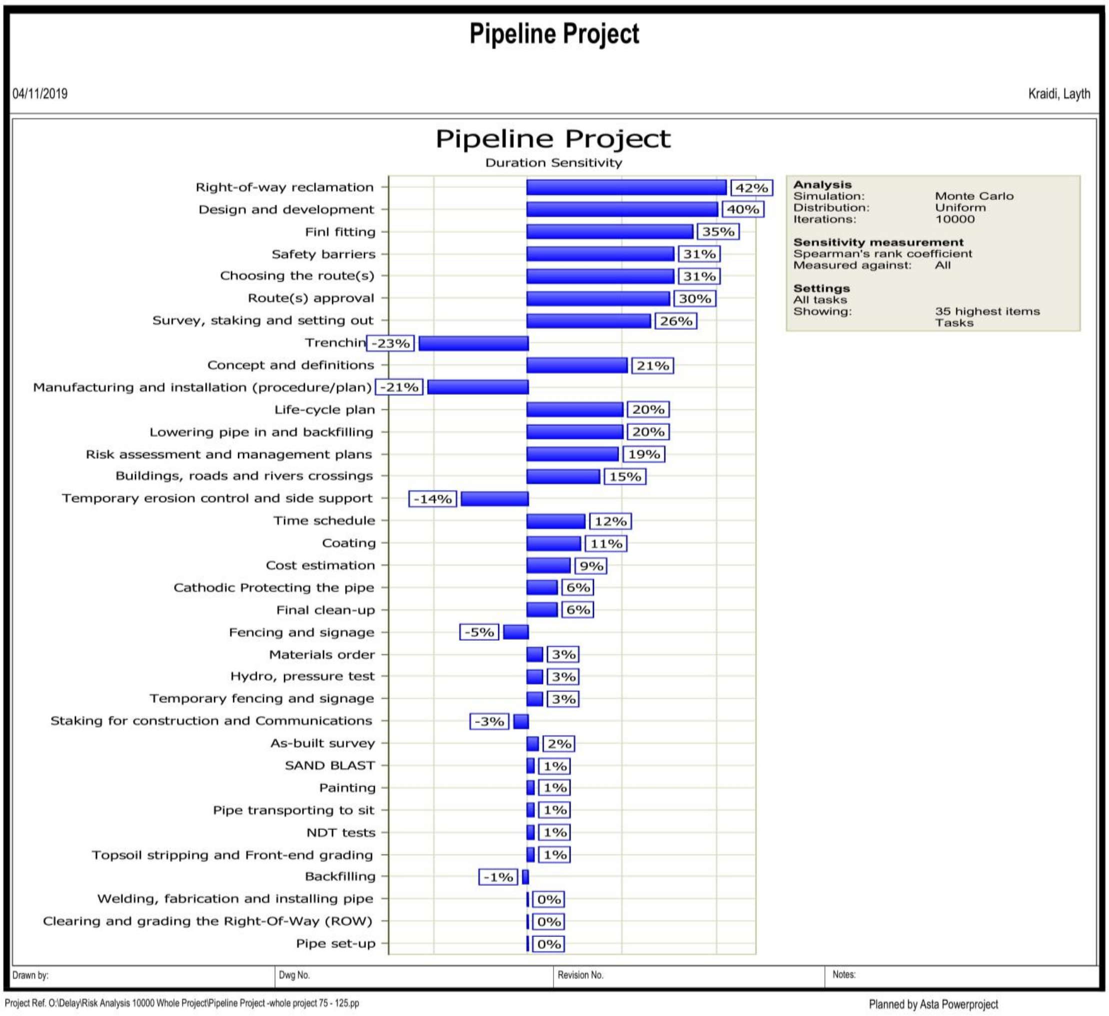

Figure 8.9: The duration sensitivity using the **MCS method and Uniform** data distribution method.

To keep this chapter short, APPENDIX D: provides the detailed ranking of the project's activities using different simulation and distribution methods.

8.6 The Results of Criticality Index Sensitivity

This section provides the results from using the ASTA risk simulator to analyse the criticality index of the activities that appear on the critical path of the project and their degree of impact on changing the project duration if their duration changes. The ASTA risk simulator identifies the tasks that have the highest iterations as the activities that might change the duration of the project. After running thousands of simulations (depending on the number of iterations), the ASTA risk simulator generates a report to rank the project activities from highest to lowest impact in terms of their degrees of criticality impact on the project duration. The activities with the higher criticality index are the activities that are more likely to affect the project finishing date. Some activities may appear as critical activities using a certain simulation or distribution method, but they might not appear as critical activities using different methods.

Table 8.4 shows the results of using the ASTA risk simulator to analyse the criticality sensitivity index of the activities of the case study project. This table highlights the activities that have a different impact on the project using different risk simulation and distribution methods.

Table 8.4: The ranking of the project activities with regard to their degree of impact on project duration using the ASTA risk simulator.

MCS				LHS	
Uniform and Normal distribution		Skewed Normal and Skewed Triangular distribution		All distribution methods	Impact
Activity	Impact	Activity	Impact		
Concept and definitions	100%	Concept and definitions	100%	Concept and definitions	100%
Choosing the route(s)	100%	Choosing the route(s)	100%	Choosing the route(s)	100%
Route(s) approval	100%	Route(s) approval	100%	Route(s) approval	100%
Life-cycle plan	100%	Life-cycle plan	100%	Life-cycle plan	100%
Design and development	100%	Design and development	100%	Design and development	100%
Manufacturing and installation (procedure/plan)	100%	Manufacturing and installation (procedure/plan)	100%	Manufacturing and installation (procedure/plan)	100%
Risk assessment and management plans	100%	Risk assessment and management plans	100%	Risk assessment and management plans	100%
Staking for construction and Communications	100%	Staking for construction and Communications	100%	Staking for construction and Communications	100%
Pipe set-up	100%	Survey, staking and setting out	100%	Survey, staking and setting out	100%
Welding, fabrication and installing pipe	100%	Clearing and grading the Right of way (ROW)	100%	Clearing and grading the Right of way (ROW)	100%
NDT tests	100%	Topsoil stripping and Front-end grading	100%	Topsoil stripping and Front-end grading	100%
Sand blast	100%	Pipe transporting to sit	100%	Pipe transporting to sit	100%
Backfilling	100%	Pipe set-up	100%	Pipe set-up	100%

Final clean-up	100%	Welding, fabrication and installing pipe	100%	Welding, fabrication and installing pipe	100%
Safety barriers	100%	NDT tests	100%	NDT tests	100%
Fencing and signage	100%	SAND BLAST	100%	SAND BLAST	100%
Pipe transporting to site	99%	Painting	100%	Painting	100%
Painting	98%	Coating	100%	Coating	100%
Coating	92%	Backfilling	100%	Backfilling	100%
Hydro, pressure test	85%	Final clean-up	100%	Final clean-up	100%
Survey, staking and setting out	80%	Safety barriers	100%	Safety barriers	100%
Clearing and grading the Right of way (ROW)	80%	Fencing and signage	100%	Fencing and signage	100%
Topsoil stripping and Front-end grading	79%	Hydro, pressure test	83%	Hydro, pressure test	83%
Time schedule	73%	Lowering pipe in and backfilling	72%	Lowering pipe in and backfilling	72%
Lowering pipe in and backfilling	63%	Time schedule	62%	Time schedule	63%
Right of way reclamation	57%	Right of way reclamation	52%	Cost estimation	37%
Cost estimation	42%	Cost estimation	38%	Right of way reclamation	37%
Final fitting	38%	Final fitting	36%	Final fitting	36%
Materials order	27%	Cathodic protecting the pipe	17%	Cathodic protecting the pipe	17%
Cathodic protecting the pipe	16%	As-built survey	17%	As-built survey	17%
As-built survey	16%	Materials order	0%	Materials order	0%
Buildings, roads and river crossings	1%	Buildings, roads and river crossings	0%	Buildings, roads and river crossings	0%
Temporary fencing and signage	1%	Temporary fencing and signage	0%	Temporary fencing and signage	0%
Trenching	1%	Trenching	0%	Trenching	0%
Temporary erosion control and side support	1%	Temporary erosion control and side support	0%	Temporary erosion control and side support	0%

As shown in the table above, most of the activities have stayed in the same ranking positions using different simulation and distribution methods. However, the percentage of the criticality index sensitivity of the activities is slightly different for a few activities using different simulation and distribution methods, as highlighted in yellow in the table. In the table above, the activities with different percentages of impact on the duration of the project are highlighted in yellow if the difference is 8% or higher.

With regard to using **MCS** to analyse the criticality sensitivity index of the project activities, the activities stayed in the same ranking position using Uniform and Normal distribution or Skewed Normal and Skewed Triangular distribution. However, the ranking positions of these activities are slightly different using Uniform and Normal distribution comparing to Skewed Normal and Skewed Triangular distribution. In the meanwhile, the ranking positions of the project activities were not changed using the four different risk distribution methods along with **LHS**. Nevertheless, the ranking positions were slightly changed comparing the results of MCS to LHS.

For example, the results of analysing the criticality sensitivity index of the project activities using **MCS and Uniform** distribution are shown in the figure below.

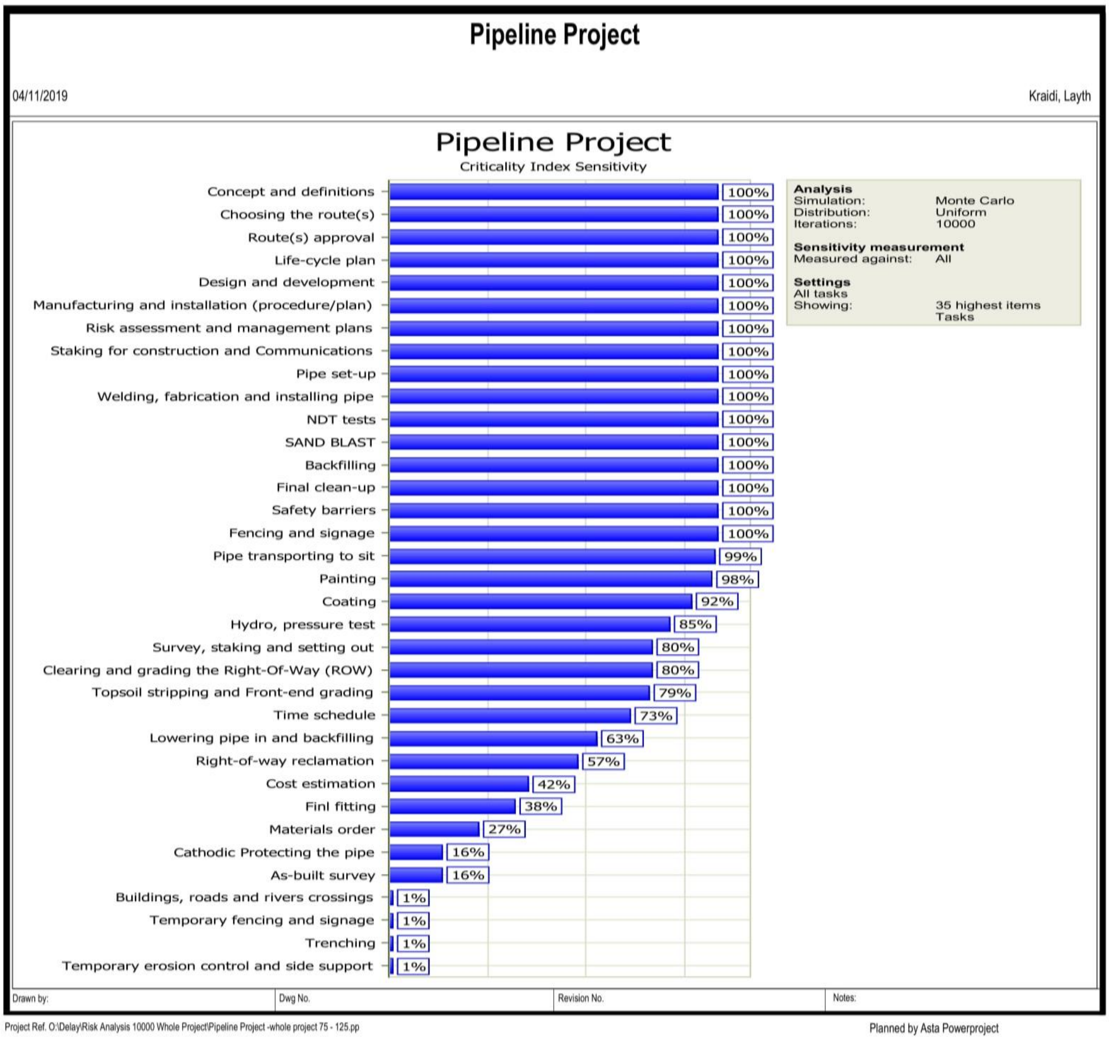

Figure 8.10: Results of criticality index sensitivity using **MCS and Uniform** distribution.

APPENDIX D: provides the detailed results of the critical index sensitivity analysis.

8.7 Summary

Having good analysis results for the IRFs that affect the duration of new projects as well as a good estimation about the delay in the projects before they start (as performed in this chapter), helps project stakeholders, decision-makers and policy-makers to develop suitable policies and take the correct actions related to risk management. Therefore, this chapter has used the RMF designed and developed in Chapter 6: to analyse the delay in the case study project using ASTA risk simulator software. The list of the IRFs in OGP projects identified via the literature review (see Chapter 2:), their degree of impact on the projects (i.e. the RI values of the IRFs) (see Chapter 5:), and the activities of the projects were the inputs for the ASTA risk simulator. The ASTA risk simulator has integrated these inputs with MCS and LHS to analyse the project delay caused by the associated IRFs. The ASTA risk simulator was used in this research to do the following.

- Show the results of the time impact and the delay caused by the IRFs associated with the project activities, see Table 8.2.
- Show the results of the sensitivity index of the project activities and their likelihoods of influencing the project duration, see section Table 8.3.
- Show the results of the criticality sensitivity index for the critical activities of the project and their degree of impact on the project duration, see Table 8.4.

The difference between the results of the MCS and LHS is minimal, which enhances the results of this research. However, the ASTA risk simulator has only four methods of risk distribution, and only one distribution method could be applied at a time during the process of risk simulation, which means the process of risk simulation was carried out four times. This is one of the limitations of using the ASTA risk simulator to analyse the IRFs in the projects. Thus, there is a need to use risk analysis software that helps to apply different distribution methods for each IRF and activity at the same time, which will enhance the risk simulation results and add more confidence with regard to estimating the probability of the project completion dates. The @Risk simulator, therefore, will be used to analyse the impact of the IRFs on the duration of the new OGP projects, see Chapter 9:.

CHAPTER 9: ANALYSIS OF RISK IMPACT USING @RISK

9.1 Introduction

This chapter presents the systematic procedure and the results of the delay analysis considering the impact of the Influencing Risk Factors (IRFs) IRFs on the project's delivery. The @Risk simulator is used in this study to quantify the delay impact of the case study project. This pipeline will be built in the south of Iraq to link between the Badra oil field and the export point on the Gulf, the length of the pipeline is 164 KMs, see Figure 7.5. The key inputs used in the risk simulator are the Risk Index (RI) (see Chapter 5:) caused by relevant IRFs that influence the duration of each work activity in the Oil and Gas Pipeline (OGP) project and the work activities of the project and their durations (see section 8.2 of Chapter 8:). The results found by the @Risk simulator in terms of project delay in days have been compared with the results from the ASTA risk simulator to evaluate the functionality of the developed RMF. The comparison of the results from the ASTA risk simulator and the @Risk simulator is presented in this chapter.

This chapter is organised under six sections. Section 9.2 provides the impact of the IRFs on the project duration using the @Risk Simulator. Section 9.3 presents the sensitivity analysis of the IRFs on the project work activities and their impact on the project duration. Section 9.4 details the real-life case study with potential delay in the project. Section 9.5 provides a discussion of the results and differences in the results of quantifying the time impact of the IRFs using the ASTA risk simulator and @Risk program. Finally, section 9.6 summarises the chapter.

9.2 Delay Impact of the IRFs on the OGP Project Delivery

With reference to the collected data explained in section 7.1 of Chapter 7: and section 8.2 of Chapter 8:, the planned (original) duration of the project was 1,334 days. The inputs for the @Risk simulator include the following four steps. (I) Allocate the IRFs to the project activities, (II) calculate the total risk in each activity, (III) calculate the total risk of the activity from 100%, and (IV) classify the level of risk in the project activities. The results of these steps are presented in Table 8.1 and section 8.2 in Chapter 8:.

This chapter is focused on applying the findings of the above four steps using the @Risk simulation program to analyse the delay impact of the IRFs on the project delivery. The delay was analysed in (1) the overall duration of the project, (2) the planning and design stage of the project, (3) the pre-construction stage of the project, (4) the construction stage of the project and (5) the post-construction stage of the project. Additionally, this chapter also presents the quantification of delay caused by these IRFs using the @Risk simulator.

After allocating the IRFs to the project activities, the researchers should assign the risk distribution methods suitable for the nature of the IRFs and the project activities. For example, the Risk Gamma (0.9,1) distribution risk method has been chosen for terrorism, sabotage and security. This is because the impact of such a risk factor is really high in the project and, when it occurs, the chance of it stopping the project is really high. The Excel sheet in APPENDIX H: shows the detailed results of the @Risk simulator, including the IRFs allocated to the project work activities and the assigned risk distribution methods. Please note that the reader needs to install the @Risk simulator on his/her device to be able to read the results in the Excel sheet. However, without installing the @Risk simulator, the reader can read the written notes to understand the risk distribution methods assigned to the IRFs and the project work activities.

This section presents an example with regard to the result of quantifying the delay in the project using the @Risk simulator. For example, with regard to the delay in the overall duration of the project, the risk simulation results show the minimum and maximum duration of the project are 1,329.30 days and 1,441.84 days, respectively. The project has a 5% chance of being completed in between 1,329.30 and 1,349.1 days or between 1,404.5 days and 1,441.84 days. The project has a 90% probability of being finished in between 1,349.1 days and 1,404.5 days. The results are explained in Figure 9.1.

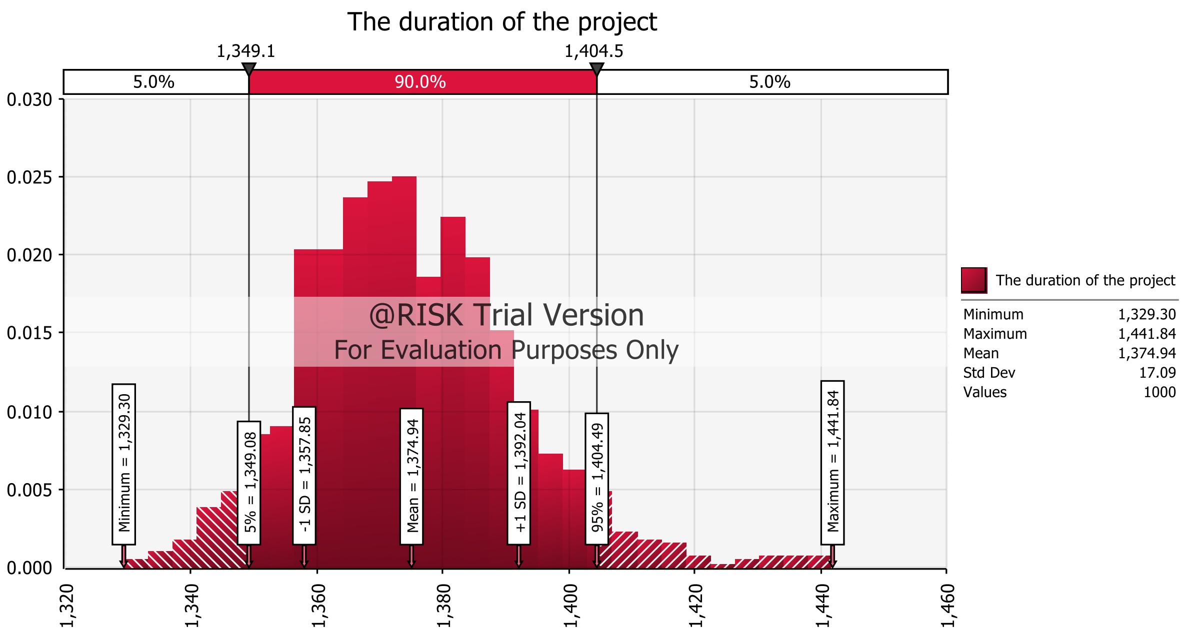

Figure 9.1: The results of simulating the duration of the project using @Risk.

The mean duration of the project is 1,374.94 days, which means that the project has a 50% probability of being completed in this duration, see Figure 9.2.

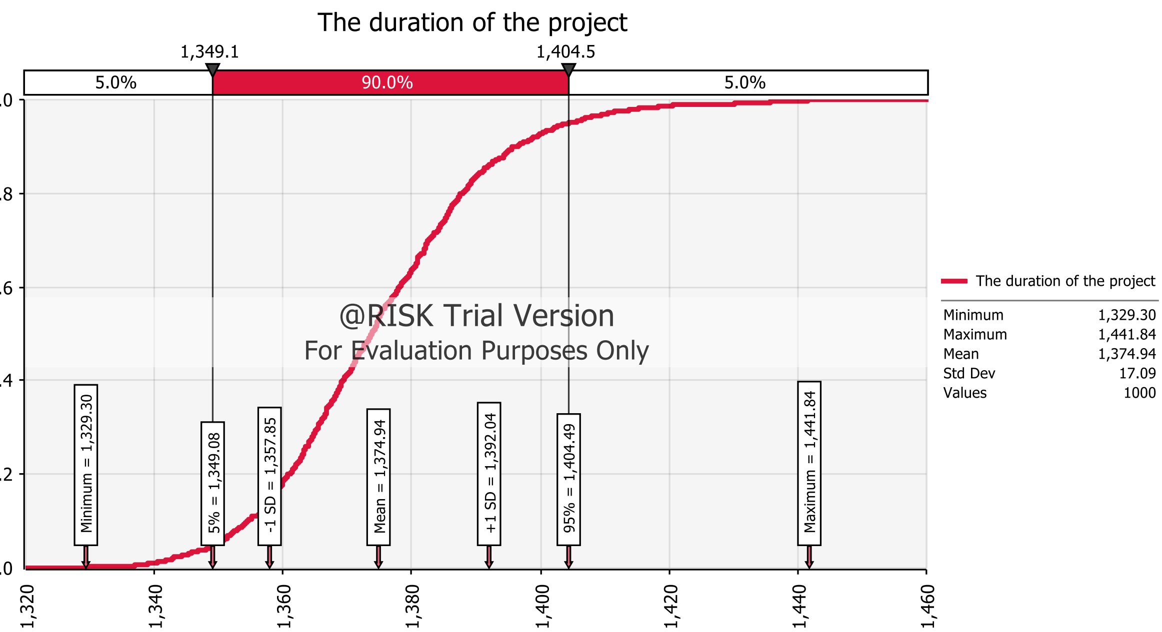

Figure 9.2: The results of the accumulative duration of the project using @Risk.

The minimum delay and maximum delay in the project are -0.703 days and 111.84 days. The project has a 5% probability of being delayed between -0.703 and 19.1 days or between 74.5 and 111.84 days. The project has a 90% probability of being delayed between 19.1 days and 74.5 days, see Figure 9.3.

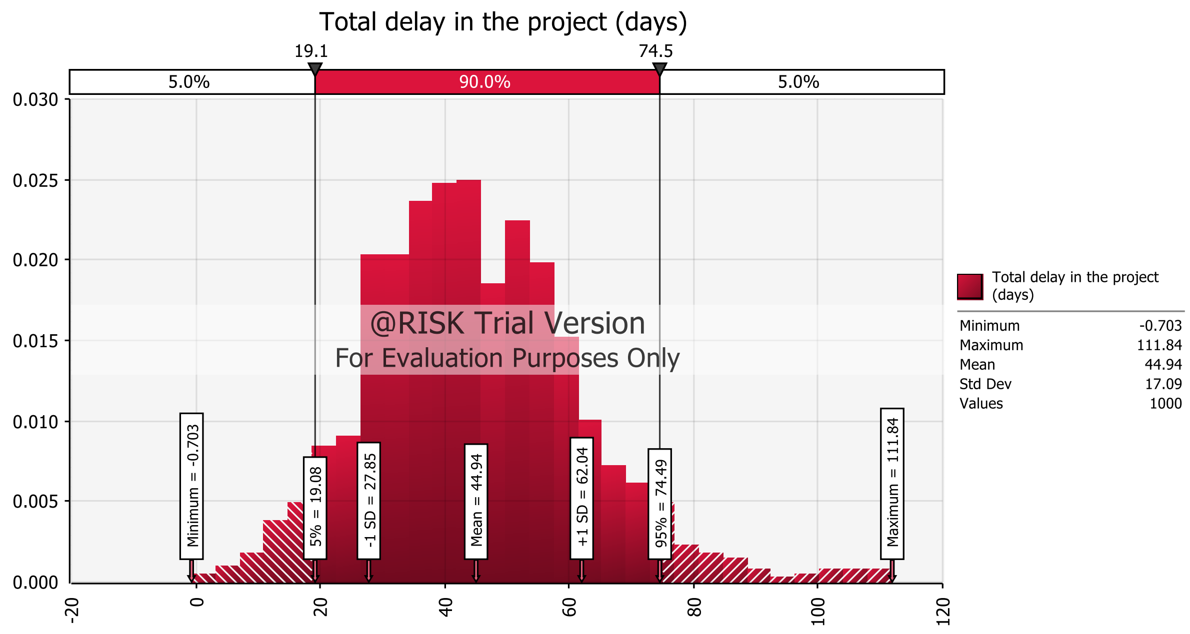

Figure 9.3: The delay in the project using @Risk.

The mean delay in the duration of the project is 44.94 days, with a probability of 50%, see Figure 9.4.

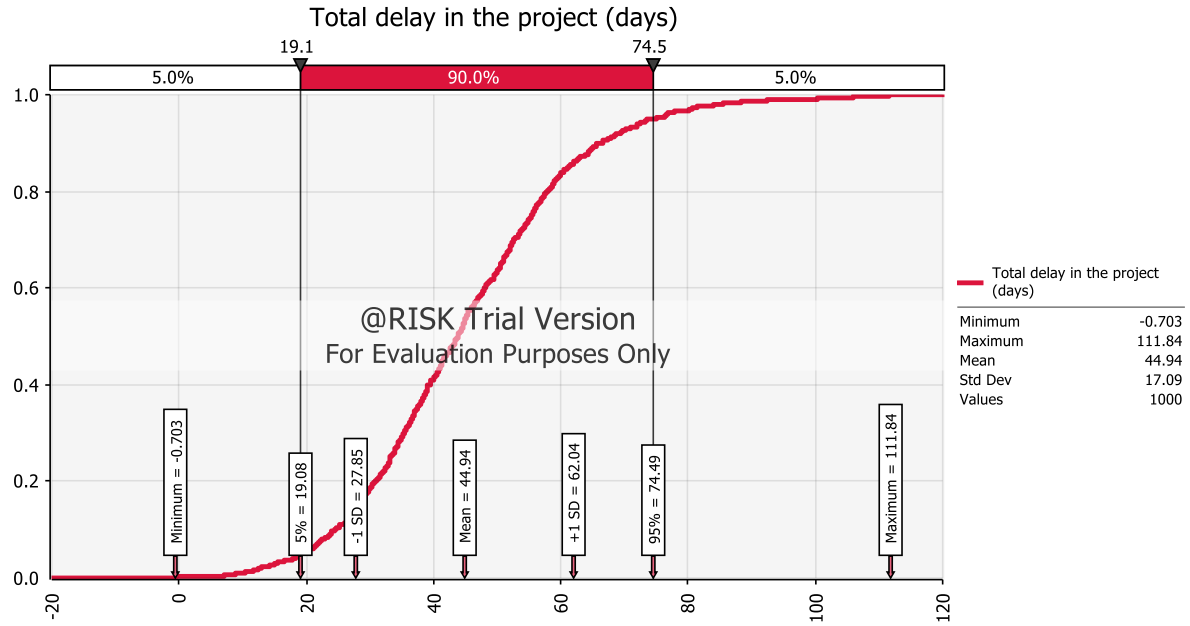

Figure 9.4: The accumulative delay in the project using @Risk.

To keep this chapter short, Table 9.1 summarises the results of estimating the duration of the project using @Risk.

Table 9.1: The project duration after allocating the IRFs in the project's listed work activities using @Risk.

Section	Planned duration	Duration after allocating the IRFs (days)	Delay (days)
The total duration of the project	1330 days	1374.94 (see Figure 9.1 and Figure 9.2)	44.944* (see Figure 9.3 and Figure 9.4)
The duration of the planning stage	812 days	796.84 (see Figure H.5 and Figure H.6)	-15.156 (see Figure H.7 and Figure H.8)
The duration of the pre-construction stage	200 days	242.12 (see Figure H.9 and Figure H.10)	42.130 (see Figure H.11 and Figure H.12)
The duration of the construction stage	213 days	224.45 (see Figure H.13 and Figure H.14)	11.444 (see Figure H.15 and Figure H.16)
The duration of the post-construction stage	105 days	111.52 (see Figure H.17 and Figure H.18)	6.526 (see Figure H.19 and Figure H.20)
*44.944 = -15.156+42.130+11.444+6.526			

The details of the results with regard to analysing the delay in the duration of the planning, pre-construction, construction and post-construction stages are explained in APPENDIX H:. In this appendix, Figure H.5 and Figure H.6 show the duration of the planning stage, while Figure H.7 and Figure H.8 show the results in this stage. Figure H.9 and Figure H.10 show the duration of the pre-construction stage, and Figure H.11 and Figure H.12 show the delay in this stage. The duration of the construction stage is shown in Figure H.13 and Figure H.14, while Figure H.15 and Figure H.16 show the delay in this stage. Finally, Figure H.17 and Figure H.18 show the results of analysing the duration of the post-construction stage, and Figure H.19 and Figure H.20 show the results of analysing the potential delay in this stage of the project.

The next section provides the results for the sensitivity analysis of the IRFs and their impact on project duration.

9.3 Results for Project Duration Sensitivity

In this section, the research has used different methods and tests in order to test the sensitivity analysis of the IRFs and their impact on project duration. The tests were Tornado-Change in output mean, Tornado-Regression coefficients, Tornado-Correlation coefficients, Tornado-

Regression mapped values, and Tornado-Contribution to variance tests. The results of the sensitivity tests were shown by the stages of the project as follows. For example, with regard to IRFs that affect the overall duration of the project, it was found that the different types of sensitivity tests have confirmed the IRFs that have the highest impact on project duration. These IRFs are limited warning signs; animal accidents; terrorism, sabotage and security; corruption; inadequate risk management; little research about risk management; and the weak ability to identify and monitor the threats and the IRFs, see Figure 9.5 and Figure 9.6.

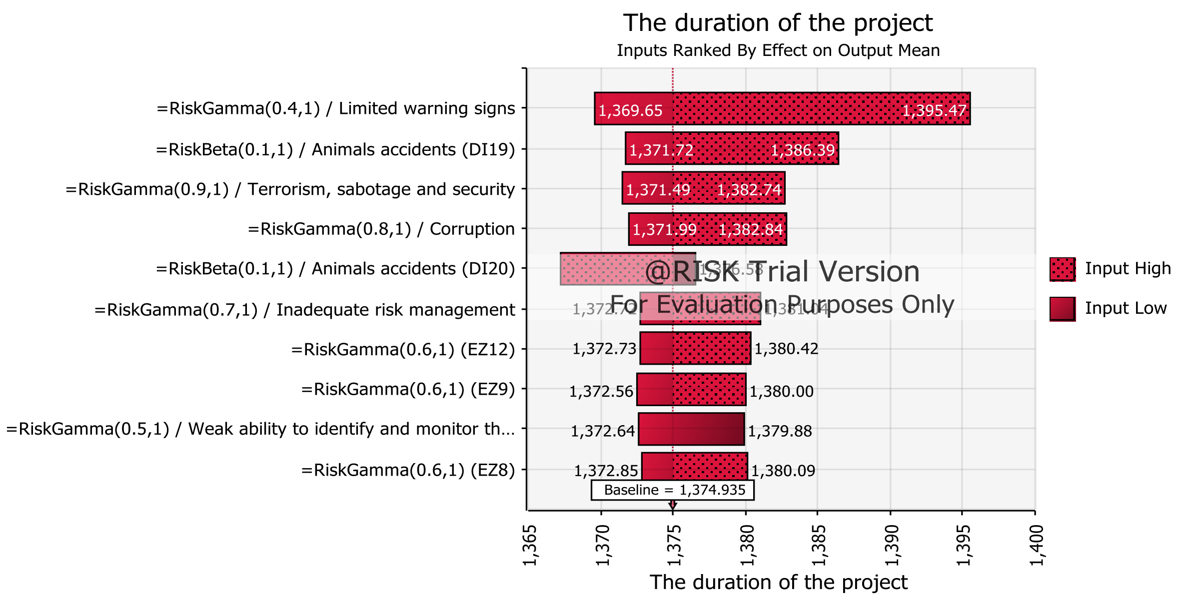

Figure 9.5: Tornado-Change in output mean (the overall project).

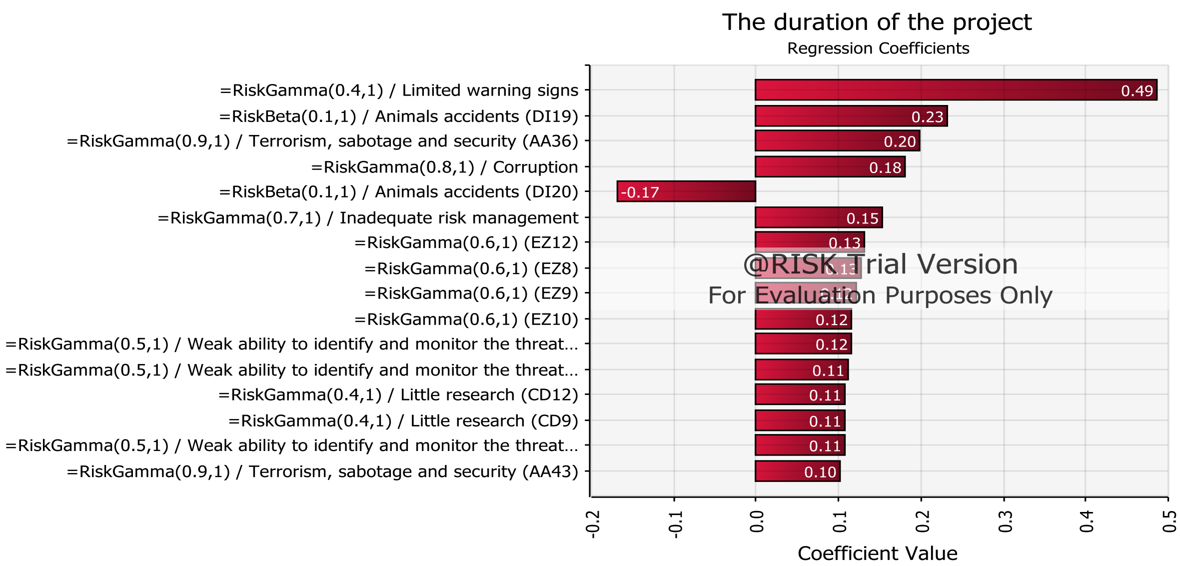

Figure 9.6: Tornado-Regression coefficients (the overall project).

APPENDIX H: explains the details of the results with regard to analysing the duration sensitivity of the planning, pre-construction, construction and post-construction stages of the project. The next section presents the calculation of real-life delay in the project.

9.4 Potential Delay in the Case Study OGP Project

The previous sections have shown the potential and/or the expected delay that could be caused by the IRFs. However, in addition to the mentioned IRFs, the project might be subjected to other types of problems that could cause delay. Such problems are reflecting the situation from the real life of the project. In other words, this section will analyse the reality of the problem of delay in the project, not only the estimated delay. The construction of the project commenced on May 21, 2019 instead of April 1, 2019 due to the delay in signing the contract between the government and the construction company. Consequently, the project started later than the original plan, which caused 51 days of delay in real life. In other words, the 51 days delay is the project starting delay, which has been calculated using ASTA or @Risk. Such IRFs are beyond the author's knowledge and need to be managed from very high levels of government. Therefore, such an exceptional delay has not been included in the simulation model with the case study. Table 9.2 presents a real-life project delay in addition to the delay caused by IRFs in the OGPs project below.

Table 9.2: The comparison of project delay between the research findings and real-life delay in the project.

<table>
<tr><th>Program</th><th>Impact delay in project</th><th>Real-life project</th><th>Case study results</th><th>Delay</th></tr>
<tr><td rowspan="3">Using ASTA</td><td>Research findings</td><td>1334 days¬</td><td>1349 (from Table 8.2)</td><td>15 days (+) (from ASTA, see Table 8.2)</td></tr>
<tr><td>Actual delay in project</td><td>1385 days¬¬ (=1334+51^)</td><td>1385 + 15 (from Table 8.2) =1400 days</td><td>66 days (+)*</td></tr>
<tr><td colspan="4">¬The initial duration of the project.
¬¬ The delay caused by the late start of the project.
^ The 51 days delay is the project staring delay, which has been calculated using ASTA.
*The real life delay = 15 days (Table 8.2) + 51 (days) the delay that cause by late start of the project = 66 days.</td></tr>
<tr><td rowspan="3">Using @Risk</td><td>Research findings</td><td>1330 days¬</td><td>1375 (from Table 9.1)</td><td>45 day (+) (from @Risk, see Table 9.1)</td></tr>
<tr><td>Actual delay in project</td><td>1381 days¬¬ (=1330+51^)</td><td>1381 + 45 (from Table 9.1) = 1426 days</td><td>96 days (+)*</td></tr>
<tr><td colspan="4">¬The initial duration of the project.
¬¬ The delay caused by the late start of the project.
^ The 51 days delay is the project staring delay, which has been calculated using @Risk.
*The real life delay = 15 days (Table 9.1) + 51 (days) the delay that cause by late start of the project = 96 days.</td></tr>
</table>

Correspondingly, the real delay in the project was 51 days (real-life delay). In addition to the real-life delay, the expected delay in the project due to the impact of the IRFs is 15 days using ASTA and 45 days using @Risk (case study results).

9.5 Difference in Using ASTA Risk Simulator and @Risk to Analyse the Delay Impact of the IRFs on the Project Delivery

The Risk Management Framework (RMF) has applied different risk simulation programs (which are ASTA risk simulator and @Risk simulator) to quantify the delay impact of the IRFs on project delivery. The comparison made between the results of the ASTA risk simulator and the @Risk simulator was to validate the findings of this research. Applying different risk simulation methods for risk simulation makes the results of risk analysis different. For example, the overall delay in the project was between 15 and 18 days using the ASTA risk simulator and 45 days using @Risk simulator. See Table 8.2 and Table 9.1 to understand the difference in the results caused by using the ASTA risk simulator and @Risk simulator. The table below summarises the results of the ASTA risk simulator and the @Risk simulator.

Table 9.3: The difference in using the ASTA risk simulator and the @Risk simulator to analyse the delay in the project.

Program	Results (delay)	Cross reference
ASTA risk simulator	15 – 18 days (using two different simulation methods and four different distribution methods)	Table 8.2
@Risk simulator	45 days	Table 9.1

The reasons behind comparing the results of the ASTA risk simulator and the @Risk simulator are to highlight the limitations of each program and validate the findings of this research. For instance:

1- ASTA risk simulator has only four methods of risk distribution, but only one distribution method could be applied at a time during the process of risk simulation, which means the process of risk simulation was carried out four times, for each method of risk simulation. This is one of the limitations of using ASTA to quantify the impact of the IRFs on project duration. Meanwhile, the @Risk simulator helps to apply different distribution methods for each IRF and activity at the same time, which will enhance the risk simulation results and add more confidence regarding the project completion probability.

2- @Risk helps to analyse the delay in the project overall as well as by the project stages, which cannot be done using the ASTA risk simulator. In other words, @Risk could show the stage of the project that has the longest delay and the stage could be finished earlier. This is one of the advantages of @Risk.

3- Moreover, @Risk could be used to analyse the delay in the duration of the individual activities (see APPENDIX D:). However, the ASTA Risk simulator cannot be used to analyse the delay in the project in such a way.

4- One of the differences between the ASTA risk simulator and @Risk simulator is that ASTA could only be used to analyse the sensitivity impact of the project activities in order to calculate their impact on project duration. On the other side, @Risk simulator could be used to analyse the sensitivity impact of both the IRFs and the project activities in order to calculate their degree of impact on the duration of the project.

5- The difference in the results from using the two risk simulation methods (which are Monte Caro Simulation and Latin Hypercube Simulation) and the four risk distribution methods (which are Uniform, Normal, Triangular and Skewed Triangular) integrated with the ASTA risk simulator was minimum, which enhances the results of the ASTA risk simulator as well as the findings of this research. The case is similar to the low values of standard deviation (Std) that result from using the ASTA risk simulator, which also enhances the results of the ASTA risk simulator and the research. The Std value for @Risk simulator was low too, which also enhances the results of the @Risk simulator and the research.

In summary, compared to the ASTA risk simulator, @Risk simulator is a more useful and powerful tool to analyse the IRFs and the project delay. This is because @Risk can use more and different risk distribution methods than ASTA. It could be used to analyse the delay in the duration of the individual activities, by the stages of the projects and by the overall duration of the projects. Meanwhile, the ASTA risk simulator is useful to analyse the delay that affects the overall duration of the projects only. @Risk provides more detailed graphs than ASTA. And it can analyse the sensitivity of both the IRFs and the project activities and calculate their degree of impact on project duration. In contrast, ASTA can only analyse the sensitivity of the project activities and calculate their degree of impact on project duration.

The difference in the results of ASTA and @Risk is because the ASTA risk simulator applies one risk distribution method for all RFs and project activities at a time, which makes the RFs and the project activities give the same impact regarding the duration of the project, which is not accurate. On the other side, the @Risk simulator applies different risk distribution methods for the RFs and the project activities, 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 of 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, as done in ASTA. Assigning different risk distribution methods for the RFs and the project activities with a degree of impact on the duration of the project was the reason behind the difference in the results of ASTA and @Risk. Therefore, the @Risk simulator gives more trusted results than the ASTA simulator.

Furthermore, the RMF has used only one case study project with regard to analysing the delay in OGP projects. However, the IRFs might have a slightly different impact on the OGPs in different regions in the country. Additionally, the analysis and allocation of the IRFs to the work activities of the pipeline project were performed based on analysing the documents collected from these projects. This means that collecting more documents and conducting targeted questionnaires, focus group survey and/or interviews with the stakeholders in these projects will enhance the process of analysing the IRFs that affect the pipelines along these routes.

9.6 Summary

This chapter has used the @Risk simulator to analyse the delay in the project caused by the IRFs associated with the project. @Risk has helped in overcoming the limitations in using the ASTA Risk simulator to analyse the IRFs and their impact on the project. For example, the @Risk Simulator has helped in using different types of risk distribution rather than the Uniform, Normal, Skewed Normal and Skewed Triangular risk simulation which are available in the ASTA Risk simulator. @Risk helped in using different types of risk distribution methods at the time and it helped in analysing the delay by the overall duration of the project and by the stages of the project as well, which could not have been done using the ASTA risk simulator, such as:

- Analyse the delay caused by the IRFs in the overall duration of the project and during the stages of the project, see section 9.2.
- Analyse the sensitivity analysis of the IRFs and their impact on the overall duration of the project and during the stages of the project, see section 9.3.
- Analyse real-life delay in the project, see section 9.4.
- Analyse the difference in using the ASTA Risk simulator and the @Risk Simulator to analyse the delay impact caused by the IRFs in the project, see section 9.5.
- The advantage of using the @Risk simulator rather than the ASTA risk simulator is that the @Risk simulator has more flexibility in applying different risk distribution methods for the same IRFs and work activities at the same time. Additionally, the @Risk simulator could help the researchers to analyse the delay by the stages of the project, which could not have been done using the ASTA risk simulator.

The next chapter will discuss the findings of the research. Additionally, the chapter provides the conclusion, the limitations and the future work of this research.

CHAPTER 10: CONCLUSIONS AND RECOMMENDATIONS

This chapter summarises the conclusions and recommendations, which are drawn from this research study. The chapter presents the potential benefits of the computer-based risk management model (see Chapter 5:) and the developed Risk Management Framework (RMF) (see Chapter 6:, Chapter 7:, Chapter 8:, and Chapter 9:). This chapter also explains the key contributions of knowledge and highlights the limitations of the developed RMF while evaluating its functionalities as well as the practical applications of the developed risk management framework particularly in Oil and Gas Pipeline (OGP) projects. Finally, the chapter provides recommendations for further study and research developments.

10.1. Summary of the Research Conclusions

The conclusions drawn from the research study are summarised under different sections to satisfy the research objectives and research questions listed in this research study. These sections include literature review, industry survey in Iraq, development of RMF, and evaluation of the functionalities of the computer-based risk management model and RMF. The key functionalities of the model include risk optimisation for identification of safest routes/alignments for OGP projects based on risk level, identification of Risk Mitigation Methods (RMMs), and the quantification of delay impact caused by relevant Influencing Risk Factors (IRFs) associated with OGP projects.

10.1.1 Literature Review

A comprehensive literature review was carried out to investigate the existing practices and limitations associated with risk management techniques in OGP projects, and RMMs and quantification of risk impact in these projects. The conclusions from the literature review are summarised below:

- List of thirty risk factors and twelve RMMs 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.

- It was found that the existing RMFs are not effectively applicable in OGP projects elsewhere, and also, they are not active in managing the IRFs in OGP projects when the data and records about them are scarce. Moreover, there is a lack of studies about evaluating the RMMs with regard to their degree of effectiveness in OGP projects, which might make the responses to the IRFs not utilised, which is one of the limitations of existing risk management methods and frameworks in the projects.
- It was found that there is a need for a logical evaluation of IRFs in OGP projects, specifically regarding the issue of Third-Party Disruption (TPD) because these factors have not been accurately evaluated in the past.
- Moreover, the prior studies of risk management in OGP projects are mainly focused on managing the IRFs that affect the safety and the performance of the pipelines during the operation stage of these projects. However, different RMMs were suggested to mitigate the IRFs during the whole project.
- The findings of the literature review have been used to conduct a questionnaire survey to analyse the impact of the IRFs and RMMs in OGP projects in Iraq. They have also been used to design an integrated RMF, which has been used in this research to assess and manage the IRFs in these projects.

The findings of the literature review provide the answers for the first and second research questions and satisfy the first objective of the study.

10.1.1 Industry Survey of OGP Projects

A questionnaire survey has been designed to analyse the IRFs and RMMs in OGP projects in Iraq. The response rate of the survey was 49.5%, which is considered a good rate since the snowball sampling method was used to collect data amongst a large number of the targeted population in OPG projects in Iraq. The data was collected using a superstructure questionnaire survey, which was distributed using an online survey portal. The work experience of the researcher within OGP projects and the good networking of professionals working in the OPG industry helped to improve the survey response rate. The results of the survey were found to be reliable because the Cronbach's alpha correlation coefficient (α) was above the minimum level of 0.7. The findings from the survey are summarised below.

- The levels of Risk Probability (RP) and Risk Severity (RS) of the IRFs that influence the safety of OGP projects in Iraq.

- The values of the RP and RS of the IRFs were used to calculate the Risk Importance Index (RII) for each IRF. Then, the IRFs were ranked based on their degree of influence on the projects and algebraic values of the calculated RII.
- Based on the results of the survey, it was found that TPD IRFs such as terrorism & sabotage, insecure areas, and theft were the IRFs that have the most influence on OGP projects in Iraq in addition to the corruption, low public legal and moral awareness, and corrosion IRFs. This shows a need to be explicit about exactly what motivates intentional TPD and makes pipelines more vulnerable.
- Based on the ranking of the IRFs with regard to their degree of impact on the projects, it was found that the safety and security IRFs are the ones that have the most influence on OGP projects in Iraq.
- The survey has helped to identify the potential RMMs. Also, it helped to assess the RMMs with regard to their degree of effectiveness in managing the IRFs in the projects. Anti-corrosion measures (such as isolation and cathodic protection), moving to an underground pipeline, and protective barriers and perimeter fencing were found to be the most effective RMMs in OGP projects in Iraq.
- Based on the results of the survey, it was found that the planning stage of the OGP projects has the highest priority with regard to managing the IRFs in these projects.
- The majority of the respondents (71%) suggested that underground pipelines' supply of oil and gas is safer than the aboveground ones. This means the IRFs relevant to construction and geological factors that result from moving the pipelines underground have less influence compared to the IRFs that affect the pipelines that are above ground in Iraq.
- Based on the participants' comments, the survey has identified some of the unique IRFs in OGP projects in Iraq. For example, not taking into account the future of urban planning, as well as pumping more than one type of petroleum product in the same pipe and the salt and metal contents in the transported products, which cause internal corrosion. These risk factors have not been stated in the existing literature.

The results of the survey address the second objective of this study.

10.1.2 Analyse the IRFs in the Projects Using Fuzzy Theory

In this study, the fuzzy theory integrated within MATLAB software was used for calculating the Risk Index (RI) of the IRFs and ranking them with regard to their degree of impact on the projects based on their values of RI.

- Using the fuzzy theory in the process of the risk assessment remedies the problems relating to the uncertainty of analysing and ranking the IRFs based on the results of the survey only.
- The values of the RP and RS of the IRFs, which were calculated from the survey, were used as inputs to calculate the values of RI of the IRFs.
- Based on the values of RI of the IRFs, it was found that the most critical IRFs in OGP projects in Iraq are terrorism & sabotage; corruption; low public legal and moral awareness; insecure areas; and theft. The IRFs that have the least impact on the OGP projects in Iraq are geological risks; natural disasters and weather conditions; hacker attacks on the operating or control systems; vehicular accidents; and animal accidents.

The results of the FIS provide answers for the third research question and address the third objective of this study.

10.1.3 The Conclusions of the Findings of the RMF

The integrated RMF designed in this research has been used to (i) select the safest route for a new oil and gas export pipeline project which will be built in the south of Iraq, (ii) recommend effective RMMs to OGP projects in Iraq, and (iii) quantify the delay impact on the delivery time of the export pipeline project which is caused by the associated IRFs. The outcomes of the three main functions of the RMF are as follows.

10.1.3.1 Select Safest pipeline Routes/Alignments for the New OGP Projects

The developed RMF has been used to select the safest pipeline route/alignment for the new pipeline projects based on the risk levels in the alternative routes/alignments that were suggested to build this project.

The inputs used by the RMF to select the optimum safe pipeline routes for the new pipeline project were a list of the IRFs that may affect the safety of the pipelines along these routes, which were identified from the literature review and the documents collected from the projects. The IRFs were evaluated based on the results of the FIS (see section 10.1.2). The process of calculating the impact of the IRFs on the pipeline routes and identifying safest pipeline routes for the new projects includes: (i) subjective and qualitative document analyses, (ii) risk allocation and (iii) risk calculation on the pipeline routes. Following the results of the RMF, it was found that pipeline route number 4 is the safer route to build a new export oil and gas pipeline in the south of Iraq and pipeline route number 2 is the risky route for this project.

This pipeline will be built in the south of Iraq to link between the Badra oil field and the export point on the Gulf in Basra. The total length of the pipeline is 164 km. It will start from the Central Processing Facility (CPF) of Badra field (Faihaa 1), then cross the Bin Omran river to make a link with the Bazirgan pipeline. After that, the pipeline will be extended between Bazirgan and Gharraf to make a link with the third-party pipeline system at Gharraf–An Nassiriyah. Then it goes to the export point on the Gulf via Zubair.

Using the RMF to select the safest pipeline routes/alignments for the new OGP projects provides an answer for the fourth research question and addresses the fourth objective of this research.

10.1.3.2 Identification of Effective Risk Mitigation Methods (RMMs) in OGP Projects

The RMF has been used to identify, analyse and recommend effective RMMs which could be used to manage the IRFs in OGP projects in Iraq. The RMMs were identified based on the findings of the literature review, and their degrees of effectiveness in managing the IRFs that were calculated based on the results of the survey. The RMF has been used to (i) classify the RMMs by their actions in managing the IRFs as direct and indirect RMMs and (ii) allocate the RMMs to the IRFs in the project depending on the nature and the character of the IRFs and RMMs.

In summary, managing the IRFs in OGP projects is not limited to one project stage. Therefore, different RMMs were suggested to mitigate the IRFs during the whole project. Based on the survey, the planning and design stage is the stage with higher priority to apply the RMMs and mitigate the IRFs. At the same time, the results revealed that the anti-corrosion efforts are the most effective RMMs, and the stakeholders who participated in this research stated that the underground OGPs are safer than the above ground ones in relation to their susceptibility to the IRFs. This means that the stakeholders assumed that the construction and geological IRFs that result from moving the pipelines underground have less influence compared to the TPD that results from having exposed pipelines.

Using the RMF to suggest some effective RMMs has helped in answering the fifth research question and achieving the fifth objective of this research.

10.1.3.3 Analysing the Delay Impact of the IRFs on Project Delivery

The RMF has applied different programs, which are ASTA risk simulator and @Risk simulator to quantify the delay impact of the IRFs on project delivery. The overall delay in the project was between 15 and 18 days using the ASTA Risk simulator and 45 days using the @Risk simulator.

Using the RMF to quantify the delay impact in OGP project delivery which is caused by the associated IRFs has helped in answering the sixth research question and achieving the sixth objective of this research.

In conclusion, this research has delivered a useful risk assessment system about identifying, analysing and mitigating the IRFs in OGP projects. The developed RMF provides a comprehensive and systematic approach to the risk management system in OGP for the organisations that have just begun to mitigate IRFs in their projects more effectively, which is the case in OGP projects in Iraq. Concerning OGP projects in Iraq, while the results identified various problems and risks, which cause pipeline failure, TPD is recognised as one of the prevailing issues obstructing the OGP projects. Moreover, the RMF developed in this research provides a systematic approach to selecting safe routes/alignments for OGP projects, recommends effective RMMs in the projects and quantifies the impact of the associated IRFs on the duration of the projects and their delivery time. Scientifically, OGP stakeholders (e.g. the decision-makers, policymakers and researchers) could use this research's discoveries (i.e. the developed database) for monitoring and prioritising risks during design, re-design, construction, operation, and inspection and maintenance activities. The findings and recommendations of this research are more applicable to manage the IRFs in OGP projects in Iraq and other countries that have similar circumstances.

10.2 Research Contributions

The research contributions to the knowledge, the practice (theoretical and practical contributions) from this research study and the answer of research questions are summarised as follows.

10.2.1 Theoretical Contributions

The findings of the literature review about identifying the common IRFs and RMMs in OGP projects have helped in overcoming the problem of the shortage of data required for risk management in these projects, which is one of the contributions of the literature review.

Moreover, this research has engaged with the stakeholders in OGP projects in order to collect real perspectives about the IRFs and RMMs in the projects. This is because the data were collected from 198 participants who have real experience about the problems and close work experience within OGP projects in Iraq. The survey helped to assess the RP and RS levels of the IRFs, which is one of the contributions of the survey. Additionally, the survey has helped in analysing some of the RMMs with regard to their degree of effectiveness in managing the IRFs in the projects. The results of the survey were used to make the useful recommendations for identifying effective RMMs in OGP projects in Iraq, which is the second contribution of this research.

The values of RP and RS of the IRFs were used as inputs for a computer model that uses fuzzy theory to assess the Risk Index (RI) of the risk factors. The results of the fuzzy theory were used to rank the IRFs with regard to their degree of impact on the projects using their values of RI. The fuzzy theory has helped in reducing the uncertainty and bias associated with analysing the IRFs in the project, which is another contribution of this research.

Even though risk management cannot protect pipelines from all the associated risk factors, it should recognise the best way to manage and mitigate these factors. This research, therefore, has developed a systematic and an integrated risk management framework, which could be used for assessing and mitigating the IRFs in OGP projects. In addition, the developed framework is also useful to quantify the delay impact in the OGP projects. Hence, it is concluded that the RMF is a useful tool to analyse the IRFs associated with OGP projects at the planning, design and execution stages. The key practical applications of the developed RMF are selecting optimum safest routes/alignments for the new pipeline projects, identifying the effective RMMs that could be used to mitigate the IRFs in the project and quantifying the amount of construction delay in the new projects caused by the IRFs.

10.2.2 Practical Contributions

This study is the first research related to making a comprehensive study of the OGP projects in Iraq to develop an integrated RMF. The stakeholders and academic researchers in the country could use the findings of this research in order to identify, understand and analyse the IRFs in their respective projects. This research used a comprehensive and integrated way of identifying, understanding and analysing the IRFs in the OGP projects, which is the first and fundamental step for risk management-related studies particularly in OGP projects in Iraq. This research, therefore, will help the oil and gas industry in Iraq to mitigate the associated IRFs more effectively. The midstream projects (i.e. the transported pipelines) will be benefited by the outcome of this study, which will be useful in achieving the target of increasing the oil export demand until 2035 suggested by the government after 2003. As the oil export activities are the backbone of Iraq's economy but the slow development in increasing the capacity of the midstream section is obstructing the increase of the oil export rate, the findings of this research will help the economic growth of the country.

The RMF designed in this study has been used in a number of ways/applications, as follows.

1- The RMF provides a wide range of knowledge about identifying and analysing the IRFs. The way of analysing the IRFs is an integrated and more accurate way used while ranking the potential risk factors and effectively mitigating them in the projects.
2- The RMF is useful to select the safe pipeline routes/alignments with regard to total risk level for the new projects.
3- The RMF is useful to make recommendations about identifying effective risk mitigation methods in OGP projects in Iraq by suggesting some of the effective RMMs to manage the IRFs in these projects. This step could help in reducing the pipeline accidents and failure rate in the country.
4- Analyse the construction delay in the new projects. This step includes analysing the potential impact of the IRFs on the duration of the projects during their planning and design stage.

5- Ten research publications were published from this research including three journal articles and seven conference papers. These publications have delivered most of the findings of this research and presented the research contributions in knowledge.

10.3 The Answers of Research Questions and the Achieved Objectives

This section summarises the answers of the research questions and the achieved objectives of this research. The main question of the research study was "Can this research provide a comprehensive and accurate way of assessing and managing the RFs in OGP projects, particularly in insecure and developing countries?" And, the aim of this research is to develop an integrated and systematic RMF to manage the RFs in OGP projects, particularly in insecure and developing countries. The RMF was used to identify, assess and rank the RFs and RMMs in OGP projects in Iraq. Also, the RMF was used to select the safest route for a new OGP project, which will be built in the south of Iraq and quantify the delay in the project caused by the associated IRFs in the project. Moreover, the RMF was used to make suggestions of effective RMMS to manage the IRFs in OGP project in Iraq. Table 10.1 shows the sub-research that addressed the main research question and the objectives that addressed these sub-questions and achieved the main aim of this research.

Table 10.1: Research questions and objectives.

Research questions	Research objectives
Question 1: What are the limitations of the existing risk assessment and management methods that make them inapplicable in assessing the RFs in OGP projects?	1. Conduct a comprehensive literature review to examine the strengths and the limitations of the existing risk management system, the RFs and the RMMs applicable in OGP projects.
Question 2: What are the RFs and RMMs associated with OGP projects?	
Question 3: Can this research help in reducing the uncertainty while assessing the RFs and ranking them when the data about risk factors in OGP projects is insufficient?	2. Explore the perceptions of the stakeholders about the impact of the RFs and RMMs in OGP projects to provide trusted data/inputs for the process of risk assessment in this research.
	3. Use the fuzzy theory integrated with MATLAB software to assess and rank the RFs in the projects using the findings from items 1 and 2 above.
Question 4: Can this research help with the optimisation of selecting the safest pipeline route/alignment for new OGP projects?	4. Optimise the pipeline transmission paths/routes/alignments considering the identified influential risk factors in OGP projects.
Question 5: What are the effective RMMs that could be used to manage the RFs in OGP projects?	5. Provide recommendations for identifying effective risk mitigation methods in OGP projects.
Question 6: What is the impact of the RFs on the project duration of OGP projects?	6. Quantify the delay impact caused by relevant IRFs on the duration of OGP projects using ASTA risk simulator and @Risk simulator.

As explained in the table above, objective 1 provides answers for research questions 1 and 2; objectives 2 and 3 provide the answers for research question 3; objective 4 provides the answers for research question 4; objective 5 provides the answers for research question 5; and objective 6 provides the answers for research question 6, as follows.

- **The answer for the first and second research question** was based on the findings of the literature review about the risk factors RMMs in OGP projects. A list of thirty risk factors (Table 2.3) and twelve RMMs (Table 2.5) in OGP projects have been identified based on a comprehensive review of the pipeline failure causes and risk management in OGP projects worldwide. Also, it was found that the existing RMFs are not effectively applicable in OGP projects elsewhere, and they are not active in managing the IRFs in OGP projects when the data and records about them are scarce. Moreover, there is a lack of studies about evaluating the RMMs with regard to their degree of effectiveness in OGP projects, which might make the responses to the IRFs not utilised, which is one of the limitations of existing risk management methods and frameworks in the projects. The findings of the literature review and the survey provide the answers for the first and second research questions and satisfy the first objective of the study.

- **The answer for the third research question.** A questionnaire survey was conducted to analyse the IRFs and RMMs in OGP projects based on the perceptions of the stakeholders. The findings of the literature review have been used to conduct a questionnaire survey to analyse the impact of the IRFs and RMMs in OGP projects in Iraq. The results of the survey have provided information about the probability (RP) (Table 4.3) and severity (RS) (Table 4.4) of the IRFs and the usability (Table 4.9) and the effectiveness (Table 4.10) degrees of the RMMs in OGP projects in Iraq. This research has used the fuzzy theory to assess and rank the IRFs in OGP projects in Iraq, using the findings of the survey as inputs. The fuzzy theory has helped in providing more accurate results of assessing and ranking the IRFs in OGP projects by reducing the uncertainty and biases in analysing them based on the results of the survey only. The results of the survey and the fuzzy theory have highlighted the most critical IRFs in OGP projects in Iraq, which are: terrorism & sabotage, corruption, low public legal & moral awareness, insecure areas and theft. On the other side, the IRFs that have the least impact on OGP projects in Iraq are: geological risks, natural disasters & weather conditions, hacker attacks on the operating or control systems, vehicular accidents and animal accidents (Table 5.1).

Moreover, the results of the survey regarding evaluating the RMMs (e.g. their degrees of usability and effectiveness in OGP projects in Iraq) were used to make useful suggestions and recommendations about identifying effective risk mitigation methods in OGP projects in Iraq. Also, the results of the survey and the application of fuzzy theory were used in this research in order to select safe routes/alignments for the new OGP projects in Iraq, make suggestions of effective RMMs in the projects (Chapter 7:) and quantify the impact of the IRFs on the duration of these projects (Chapter 8: and Chapter 9:).

The results of the survey address the second objective and the results of the fuzzy theory address the third objective of this study.

- **The answer for the fourth, fifth and sixth research questions.** The integrated RMF designed in this research has been used to (i) select the safest route for a new oil and gas export pipeline project which will be built in the south of Iraq, (ii) recommend effective RMMs to OGP projects in Iraq, and (iii) quantify the delay impact on the delivery time of the export pipeline project which is caused by the associated IRFs.

    - The developed RMF has been used to select the safest pipeline route/alignment for the new pipeline projects based on the risk levels in the alternative routes/alignments that were suggested to build this project. Following the results of the RMF, it was found that pipeline route number 4 is the safer route to build a new export oil and gas pipeline in the south of Iraq and pipeline route number 2 is the risky route for this project. Using the RMF to select the safest pipeline routes/alignments for the new OGP projects provides an answer for the fourth research question and addresses the fourth objective of this research.

    - The RMF has been used to identify, analyse and recommend effective RMMs which could be used to manage the IRFs in OGP projects in Iraq. Based on the survey, the planning and design stage is the stage with higher priority to apply the RMMs and mitigate the IRFs. At the same time, the results revealed that the anti-corrosion efforts are the most effective RMMs, and the stakeholders who participated in this research stated that the underground OGPs are safer than the above ground ones in relation to their susceptibility to the IRFs. This means that the stakeholders assumed that the construction and geological IRFs that result from moving the pipelines underground have less influence compared to the TPD that results from having exposed pipelines. Using the RMF to suggest some effective RMMs has helped in answering the fifth research question and achieving the fifth objective of this research.

- The RMF has applied different programs, which are ASTA risk simulator (which used Monte Carlo and Latin Hypercube simulation) and @Risk simulator (which used Monte Carlo simulation) to quantify the delay impact of the IRFs on project delivery. The overall delay in the project was between 15 and 18 days using the ASTA Risk simulator and 45 days using the @Risk simulator. Using the RMF to quantify the delay impact in OGP project delivery which is caused by the associated IRFs has helped in answering the sixth research question and achieving the sixth objective of this research.

10.4 The Generalisability, Limitations of the Research Study

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 RFs in OGP projects is limited to Iraq only. The RMF was designed based on an extensive and worldwide literature review about risk management approaches in OGP 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.

The developed RMF might be used to identify, classify and assess the IRFs and RMMs in OGP projects in a systematic and integrated way. The RMF could be used to select the optimum safest pipeline routes/alignments, recommend some of the effective RMMs and analyse the construction delay in OGP projects. However, the RMF has the following limitations.

- The developed RMF cannot link the IRFs or draw failure scenarios to calculate the consequences of any hazardous event. Also, it does not provide a decision support tool that has an automated system to analyse the information (e.g. IRFs, RP, RS, the RMMs and the effectiveness of RMMs).

- The RMF was designed to assess and manage the IRFs in OGP projects. Howsoever, it was evaluated via a case study project and interviews carried out in OGP projects in Iraq. Therefore, the recommendations and findings of the RMF will be more applicable for OGP projects in Iraq than elsewhere. In this study, the functionalities of the RMF were tested and evaluated within an OGP project in Iraq. This means that the RMF developed in this research could be used to assess and mitigate the IRFs relevant to OGP projects in different geographical regions. Nevertheless, it will be better to carry out more experiments and validate the findings of the RMF before using it in OGP projects in different regions/areas with different characters and variations.
- The IRFs associated with the OGPs projects all over Iraq were investigated and ranked. This provides wide knowledge about the IRFs and their impact on OGP projects across the country. The IRFs might have a slightly different impact on the OGPs in different regions in the country. However, the findings of this research were limited to one case study project, which is an oil and gas export pipeline project in the south of the country.
- 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. Also, 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.

10.5 Recommendations and Future Works

The future work of this research includes the following:

- Compare the degree of influence of the IRFs using Analytic Hierarchy Process (AHP) to provide more verified ranking of the IRFs. This is because making a direct comparison between the IRFs with regard to their degree of impact on the project will provide a more accurate ranking list of them.
- Estimate the consequences of the hazardous events: we will use a neural network analysis tool to draw some pipe failure scenarios.

- Develop an automated decision-support method that can analyse the inputs (e.g. IRFs, RP, RS, RMMs, the effectiveness degrees of RMMs) in an automated way.
- Develop a scenario-based model, to find the optimum/best schedule for developing and building OGP projects in Iraq. The model could help the stakeholders to show the inter-related various challenges and aspects, provide a graphic picture of the interdependence of these components and outline processes for the future.
- The IRFs might have a slightly different impact on the OGPs in different regions in the country. The future work, therefore, will analyse the IRFs in other new projects when they appear.
- Analysis of the cost-effects that result from applying the RMMs in OGP projects will be carried out by conducting some interviews with experts in these projects.
- Development of a new database to store the findings of the research and make it accessible for stakeholders and researchers to use this data in studies related to risk management in OGP projects.

REFERENCES

2B1st Consulting, (2012) *The Gazprom Neft (Gazprom) Badra oil field is located in the Wasit Province at the Southeast of Iraq*. [online] One day - One Project. Available at: https://www.2b1stconsulting.com/gazprom-continues-to-award-packages-for-2-billion-badra-oil-field/.

Aarseth, W., Rolstadås, A. and Andersen, B., (2013) Managing organizational challenges in global projects. *International Journal of Managing Projects in Business*, [online] 71, pp.103–132. Available at: https://www.emerald.com/insight/content/doi/10.1108/IJMPB-02-2011-0008/full/html.

Abudu, D. and Williams, M., (2015) GIS-based optimal route selection for oil and gas pipelines in Uganda. *Advances in Computer Science: an International Journal*, 44, pp.93–104.

Acharya, A.S., Prakash, A., Saxena, P. and Nigam, A., (2013) Sampling: Why and how of it. *Indian Journal of Medical Specialties*, 42, pp.330–333.

Adebayo, W.A. and Adeniyi, A.O., (2019) Utilitarianism and the Challenges of Insecurity in Nigeria from 2015 to 2019. *JL Pol'y & Globalization*, 86, p.68.

Adel, S., (2013) *Iraq wants to resume pumping via Saudi pipeline [Onlin]*. [online] Available at: http://www.iraqenergy.org/news/?detailof=6606&content=Iraq-wants-to-resume-pumping-via-Saudi-pipeline.

Adishi, E. and Hunga, M.O., (2017) Oil Theft, Illegal Bunkering and Pipeline Vandalism: It's Impact on Nigeria Economy, 2015-2016. *International Journal of Economics and Business Management*, 32, pp.47–65.

Adunbi, O., (2017) Reviewed Work: Oil Wealth and Insurgency in Nigeria. *Africa Today*, 633, pp.116–118.

Ahmad Fuad, A.F., Said, M.H., Samo, K., Rahman, M.A.A., Mohd, M.H. and Zainol, I., (2020) Risk Assessment of Fishing Trawl Activities to Subsea Pipelines of Sabah and Labuan Waters. *The Scientific World Journal*, 2020, pp.1–9.

Ahmed, A., Kayis, B. and Amornsawadwatana, S., (2007) A review of techniques for risk management in projects. *Benchmarking: An International Journal*, [online] 141, pp.22–36. Available at: http://www.emeraldinsight.com/doi/10.1108/14635770710730919.

Ahmed, S.M., Azhar, S., Kappagntula, P. and Gollapudil, D., (2003) Delays in construction: a brief study of the Florida construction industry. In: *Proceedings of the 39th Annual ASC Conference, Clemson University, Clemson, SC*. p.66.

Ai, C., Zhao, H., Ma, R. and Dong, X., (2006) Pipeline damage and leak detection based on sound spectrum LPCC and HMM. In: *Sixth International Conference on Intelligent Systems Design and Applications*. IEEE, pp.829–833.

Akyuz, E. and Celik, E., (2015) A fuzzy DEMATEL method to evaluate critical operational hazards during gas freeing process in crude oil tankers. *Journal of Loss Prevention in the Process Industries*, [online] 38, pp.243–253. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0950423015300498.

Al-Bahar, J.F., Crandall, K.C., Al-Bahar, J.F. and Crandall, K.C., (1990) Systematic Risk Management Approach for Construction Projects. *Journal of Construction Engineering and Management*, [online] 1163, pp.533–546. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9364%281990%29116%3A3%28533%29.

AL-Kadi, T., AL-Tuwaijri, Z. and AL-Omran, A., (2013) Wireless Sensor Networks for Leakage Detection in Underground Pipelines: A Survey Paper. *Procedia Computer Science*, [online] 21, pp.491–498. Available at: https://linkinghub.elsevier.com/retrieve/pii/S1877050913008600.

Al-Mudhafar, W.J., (2017) Geostatistical lithofacies modeling of the upper sandstone member/Zubair formation in south Rumaila oil field, Iraq. *Arabian Journal of Geosciences*, 10, pp.1–14.

Al-Rashed, Y. and León, J., (2015) Energy efficiency in OPEC member countries: analysis of historical trends through the energy coefficient approach. *OPEC Energy Review*, 391, pp.77–102.

Alaghbari, W., Razali A. Kadir, M., Salim, A. and Ernawati, (2007) The significant factors causing delay of building construction projects in Malaysia. *Engineering, Construction and Architectural Management*, [online] 142, pp.192–206. Available at: http://www.emeraldinsight.com/doi/10.1108/09699980710731308.

Alali, B., (2010) *Post-Project Risk Perception and Systems Management Reaction*. OLD DOMINION UNIVERSITY.

Alex W Dawotola, P.H.A.J.M. Van Gelder and Vrijling, J.K., (2010) Multi Criteria Decision Analysis framework for risk management of oil and gas pipelines. *RELIABILITY, Risk and Safety. London: Taylor & Francis Group*, pp.307–314.

Ali, K., (2015) *Associated Petroleum Gas management in the south of Iraq*. LAP LAMBERT Academic Publishing.

Allen, D., (2018) *An Exploration of Entrepreneurial Anxiety in the Context of Small and Medium Sized Enterprises (SMEs)*. University of Gloucestershire.

Almadhlouh, A.A., (2019) *Risk Management Approaches in Oil and Gas Industry Projects: A Qualitative Study*. Colorado Technical University.

de Almeida, A.T., Alencar, M.H., Garcez, T.V. and Ferreira, R.J.P., (2017) A systematic literature review of multicriteria and multi-objective models applied in risk management. *IMA Journal of Management Mathematics*, [online] 282, pp.153–184. Available at: http://academic.oup.com/imaman/article/28/2/153/2447883.

Amaratunga, D., Baldry, D., Sarshar, M. and Newton, R., (2002) Quantitative and qualitative research in the built environment: application of “mixed” research approach. *Work Study*, [online] 511, pp.17–31. Available at: https://www.emerald.com/insight/content/doi/10.1108/00438020210415488/full/html.

Anifowose, B., Lawler, D.M., van der Horst, D. and Chapman, L., (2012) Attacks on oil transport pipelines in Nigeria: A quantitative exploration and possible explanation of observed patterns. *Applied Geography*, 322, pp.636–651.

Antoniades, S., Christodoulakis, N., Delias, P. and Matsatsinis, N., (2018) Applying the Disaggregation-Aggregation Paradigm for Crude Oil Pipeline Risk Management. pp.147–162.

Arzaghi, E., Abaei, M.M., Abbassi, R., Garaniya, V., Binns, J., Chin, C. and Khan, F., (2018) A hierarchical Bayesian approach to modelling fate and transport of oil released from subsea pipelines. *Process Safety and Environmental Protection*, 118, pp.307–315.

Aseeri, A., Gorman, P. and Bagajewicz, M.J., (2004) Financial Risk Management in Offshore Oil Infrastructure Planning and Scheduling. *Industrial & Engineering Chemistry Research*, [online] 4312, pp.3063–3072. Available at: https://pubs.acs.org/doi/10.1021/ie034098c.

Ashour, S.K. and Abdel-hameed, M.A., (2010) Approximate skew normal distribution. *Journal of Advanced Research*, [online] 14, pp.341–350. Available at: https://linkinghub.elsevier.com/retrieve/pii/S209012321000069X.

Azadeh, A., Saberi, M., Atashbar, N.Z., Chang, E. and Pazhoheshfar, P., (2013) Z-AHP: A Z-number extension of fuzzy analytical hierarchy process. In: *2013 7th IEEE International Conference on Digital Ecosystems and Technologies (DEST)*. [online] IEEE, pp.141–147. Available at: http://ieeexplore.ieee.org/document/6611344/.

Babbie, E.R., (2016) *The practice of social research*. Fourteenth ed. Boston, MA, USA: Boston, MA, USA : Cengage Learning.

Badida, P., Balasubramaniam, Y. and Jayaprakash, J., (2019) Risk evaluation of oil and natural gas pipelines due to natural hazards using fuzzy fault tree analysis. *Journal of Natural Gas Science and Engineering*, 66, pp.284–292.

Bai, Y. and Bai, Q., (2017) Safety of Risers, Pipelines, and Subsea Facilities. In: *Encyclopedia of Maritime and Offshore Engineering*. Chichester, UK: John Wiley & Sons, Ltd, pp.1–14.

Balfe, N., Leva, M.C., McAleer, B. and Rocke, M., (2014) Safety risk registers: Challenges and guidance. *Chemical Engineering Transactions*, 36, pp.571–576.

Ballentine, A.J., Watson, M., Fagan, J., Flugrad, G. and Olenchuk, S., (2019) Report Of The Natural Gas Committee. *Energy Law Journal*, 402, pp.1–53.

Balogun, A.-L., Matori, A.-N., Hamid-Mosaku, A.I., Umar Lawal, D. and Ahmed Chandio, I., (2017) Fuzzy MCDM-based GIS model for subsea oil pipeline route optimization: An integrated approach. *Marine Georesources & Geotechnology*, [online] 357, pp.961–969.

Available at: https://www.tandfonline.com/doi/full/10.1080/1064119X.2016.1269247.

Balogun, A., Matori, A., Lawal, D.U. and Chandio, I., (2012) Optimal oil pipeline route selection using GIS: community participation in weight derivation and disaster mitigation. In: *proc International Conference on Future Environment and Energy 2012*. pp.100–104.

Bennett, L. and Nair, C.S., (2010) A recipe for effective participation rates for web-based surveys. *Assessment & Evaluation in Higher Education*, [online] 354, pp.357–365. Available at: http://www.tandfonline.com/doi/abs/10.1080/02602930802687752.

Beriha, G.S., Patnaik, B., Mahapatra, S.S. and Padhee, S., (2012) Assessment of safety performance in Indian industries using fuzzy approach. *Expert Systems with Applications*, [online] 393, pp.3311–3323. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0957417411013273.

Bernard, H.R. and Bernard, H.R., (2013) *Social research methods: Qualitative and quantitative approaches*. Sage.

Bertot, J.C., (2009) Web-Based Surveys Not Your Basic Survey Anymore. *The University of Chicago Press Journal*, [online] 791, pp.119–124. Available at: http://www.jstor.org/stable/10.1086/593960.

Bhate, V., (2014) A Pilot Study for Monograph on Stock Market Investor-behaviour. *Journal of Commerce and Management Thought*, 54, p.676.

Bhunya, P.K., Mishra, S.K., Ojha, C.S.P. and Berndtsson, R., (2004) Parameter Estimation of Beta Distribution for Unit Hydrograph Derivation. *Journal of Hydrologic Engineering*, [online] 94, pp.325–332. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%291084-0699%282004%299%3A4%28325%29.

Blaikie, N. and Priest, J., (2019) *Designing social research: The logic of anticipation*. John Wiley & Sons.

Blaxter, L., (2010) *How to research*. McGraw-Hill Education (UK).

Bloomberg, L. and Volpe, M., (2008) *Completing Your Qualitative Dissertation: A Roadmap from Beginning to End*. [online] 2455 Teller Road, Thousand Oaks California

91320 United States: SAGE Publications, Inc. Available at: http://methods.sagepub.com/book/completing-your-qualitative-dissertation.

Bloomberg, L.D. and Volpe, M., (2018) *Completing your qualitative dissertation: A road map from beginning to end*. 4th Editio ed. [online] Sage Publications. Available at: https://books.google.co.uk/books?hl=en&lr=&id=v_pyDwAAQBAJ&oi=fnd&pg=PP1&dq=Bloomberg,+L.+D.,+%26+Volpe,+M.+F.+(2008).+Completing+your+qualitative+dissertation:+A+roadmap+from+beginning+to+end.+Thousand+Oaks,+CA:+Sage.&ots=ULn1RJp_Wq&sig=deP_Jwg3-_HksMB4r.

Bowers, J. and Khorakian, A., (2014) Integrating risk management in the innovation project. *European Journal of Innovation Management*, [online] 171, pp.25–40. Available at: https://www.emerald.com/insight/content/doi/10.1108/EJIM-01-2013-0010/full/html.

Brierley, J.A., (2017) The role of a pragmatist paradigm when adopting mixed methods in behavioural accounting research. *International Journal of Behavioural Accounting and Finance*, [online] 62, p.140. Available at: http://www.inderscience.com/link.php?id=10007499.

Briggs, C.A., (2010) *Risk assessment in the upstream crude oil supply chain: Leveraging analytic hierarchy process*. North Dakota State University.

Brooks, J., Reed, D.M. and Savage, B., (2016) Taking off with a pilot: the importance of testing research instruments. In: *ECRM2016-Proceedings of the 15th European Conference on Research Methodology for Business Management": ECRM2016. Academic Conferences and publishing limited*. pp.51–59.

Burns, N. and Grove, S.K., (2010) *Understanding nursing research-eBook: Building an evidence-based practice*. United Stat of Americaa: Elsevier Health Sciences.

Carbone, T.A. and Tippett, D.D., (2004) Project Risk Management Using the Project Risk FMEA. *Engineering Management Journal*, [online] 164, pp.28–35. Available at: http://www.tandfonline.com/doi/full/10.1080/10429247.2004.11415263.

Carroll, F. and Hayes, J., (2018) Effective Risk Management for In Service Pipelines: Achieving ALARP by Pressure Management and Slab Protection. In: *Volume 2: Pipeline Safety Management Systems; Project Management, Design, Construction, and*

Environmental Issues; Strain Based Design; Risk and Reliability; Northern Offshore and Production Pipelines. American Society of Mechanical Engineers, p.V002T07A005.

Center Point Enrgy, (2019) *Pipeline Design & Construction For Enable Midstream and it's subsidiaries*. [online] Enable Midstrem Partners. Available at: http://projects.enablemidstream.com/wp-content/uploads/2016/12/Enable_Pipeline-Design-and-Construction_v2.pdf.

CEPA; and INGAA, (2016) *A Practical Guide for Pipeline Construction Inspectors*. [online] Available at: ingaa.org/File.aspx?id=29692&v=ca234b81.

Cervone, H.F., (2006) Project risk management. *OCLC Systems & Services: International digital library perspectives*, [online] 224, pp.256–262. Available at: https://www.emerald.com/insight/content/doi/10.1108/10650750610706970/full/html.

Çetin Demirel, N., Demirel, T., Deveci, M. and Vardar, G., (2017) Location selection for underground natural gas storage using Choquet integral. *Journal of Natural Gas Science and Engineering*, [online] 45, pp.368–379. Available at: https://linkinghub.elsevier.com/retrieve/pii/S1875510017302238.

Chakrabarti, S., (2005) *Handbook of Offshore Engineering (2-volume set)*. Elsevier.

Chalabi, F.J., (2000) Iraq and the Future of World Oil. *Middle East Policy*, [online] 74, pp.163–173. Available at: http://doi.wiley.com/10.1111/j.1475-4967.2000.tb00189.x.

Chan, A.P.C., Chan, D.W.M. and Yeung, J.F.Y., (2009) Overview of the Application of "Fuzzy Techniques" in Construction Management Research. *Journal of Construction Engineering and Management*, [online] 13511, pp.1241–1252. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%29CO.1943-7862.0000099.

Cheliyan, A.S. and Bhattacharyya, S.K., (2018) Fuzzy fault tree analysis of oil and gas leakage in subsea production systems. *Journal of Ocean Engineering and Science*, 31, pp.38–48.

Chen, C., Li, C., Reniers, G. and Yang, F., (2020) Safety and security of oil and gas pipeline transportation: A systematic analysis of research trends and future needs using WoS. *Journal of Cleaner Production*, p.123583.

Chen, X., Wu, Z., Chen, W., Kang, R., He, X. and Miao, Y., (2019) Selection of key indicators for reputation loss in oil and gas pipeline failure event. *Engineering Failure Analysis*, 99, pp.69–84.

Cheng, M. and Lu, Y., (2015) Developing a risk assessment method for complex pipe jacking construction projects. *Automation in Construction*, [online] 58, pp.48–59. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0926580515001545.

Chiu, B.W.Y. and Lai, J.H.K., (2017) PROJECT DELAY: KEY ELECTRICAL CONSTRUCTION FACTORS IN HONG KONG. *Journal of Civil Engineering and Management*, [online] 237, pp.847–857. Available at: http://journals.vgtu.lt/index.php/JCEM/article/view/1192.

Choong Kog, Y., (2018) Major Construction Delay Factors in Portugal, the UK, and the US. *Practice Periodical on Structural Design and Construction*, [online] 234, p.04018024. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%29SC.1943-5576.0000389.

Chu, H., (2015) Research methods in library and information science: A content analysis. *Library & Information Science Research*, [online] 371, pp.36–41. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0740818815000109.

Chua, D.K.H., Wang, Y. and Tan, W.T., (2003) Impacts of Obstacles in East Asian Cross-Border Construction. *Journal of Construction Engineering and Management*, [online] 1292, pp.131–141. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%290733-9364%282003%29129%3A2%28131%29.

Cole, F.L., (1988) Content analysis: process and application. *Clinical nurse specialist*, 21, pp.53–57.

Collis, J. and Hussey, R., (2013) *Business research: A practical guide for undergraduate and postgraduate students*. 3rd editio ed. Basingstoke, UK; Gordonsville, VA, USA; and South Yarra, VIC, Australia: Macmillan International Higher Education.

Content Creation Agency, (2016) *HOW TO CONDUCT A SURVEY? DEFINITION, TYPES AND METHODS USED*. [online] Write a Writing. Available at: https://www.writeawriting.com/research/how-to-conduct-survey-types-methods/ [Accessed 24 Apr. 2020].

Creswell, J.W., (2009) Editorial: Mapping the Field of Mixed Methods Research. *Journal of Mixed Methods Research*, [online] 32, pp.95–108. Available at: http://journals.sagepub.com/doi/10.1177/1558689808330883.

Creswell, J.W. and Creswell, J.D., (2017) *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Creswell, J.W. and Poth, C.N., (2016) *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Crocker, B., (2004) Reconstructing Iraq's economy. *The Washington Quarterly*, [online] 274, pp.73–93. Available at: https://www.tandfonline.com/doi/full/10.1162/wash.2004.27.4.73.

Cronbach, L.J., (1951) Coefficient alpha and the internal structure of tests. psychometrika. 163, pp.297–334.

Crowther, D. and Lancaster, G., (2012) *Research methods A concise introduction to research in management and business consultancy*. Second Edi ed. [online] AMSTERDAM ● BOSTON ● HEIDELBERG ● LONDON ● NEWYORK ● OXFORD ● PARIS ● SAN DIEGO ● SAN FRANCISCO ● SINGAPORE ● SYDNEY ● TOKYO: Routledge. Available at: file:///C:/Users/buelkrai/Downloads/9780080943442_googlepreview.pdf.

Cummins, R.A. and Gullone, E., (2000) No Title. In: *Cummins, R.A. and Gullone, E., 2000, March. Why we should not use 5-point Likert scales: The case for subjective quality of life measurement.* In Proceedings, second international conference on quality of life in cities, pp.74–93.

Czaja, R. and Blair, J., (2005) *Designing surveys: A guide to decisions and procedures*. [online] Pine Forge Press. Available at: https://books.google.co.uk/books?id=GCWZVZXEf2gC&pg=PA185&lpg=PA185&dq=Designing+surveys:+A+guide+to+decisions+and+procedures+%22Czaja%3B+Blair%22&source=bl&ots=dHpNfFNvE3&sig=eTJ-U1N6Oky526WF_j7Ua_-rRG8&hl=en&sa=X&redir_esc=y#v=onepage&q=Designing survey.

Daniel, J., (2012) *Sampling Essentials: Practical Guidelines for Making Sampling Choices*. [online] *Sampling essentials*. 2455 Teller Road, Thousand Oaks California 91320 United

States: SAGE Publications, Inc. Available at: http://methods.sagepub.com/book/sampling-essentials.

Danielsen, A.L., (2015) *OPEC MULTINATIONAL ORGANIZATION*. [online] Available at: https://www.britannica.com/topic/OPEC [Accessed 18 Nov. 2019].

Danylov, O. V, Hloba, R.M., Korneienko, S. V and Hloba, Y.M., (2017) Geophysical and engineering methods in the study of the Ukrainian pipeline systems. *Науковий вісник Національного гірничого університету*, 1, pp.5–11.

Davey, L., (1991) The application of case study evaluations. *Practical Assessment, Research & Evaluation*, 29, p.1.

Dawotola, A.W., Gelder, P. Van and Vrijling, J.K., (2009) *Risk Assessment of Petroleum Pipelines using a com-bined Analytical Hierarchy Process-Fault Tree Analysis (AHP-FTA). Proceedings of the 7th international probabilistic workshop*.

Day, N.B., (1998) *Pipeline route selection for rural and cross-country pipelines*. Reston, Virginia, Virginia: American Society of Civil Engineers ASCE.

Devold, H., (2006) *Oil and gas production handbook*. ABB Oil & Gas.

Dionne, G., (2013) Risk Management: History, Definition, and Critique. *Risk Management and Insurance Review*, 162, pp.147–166.

Dolatabadi, A.B., Dehshiri, M.R. and Kashkoiyeh, H.A., (2017) Recent Developments in Geopolitics of Energy and their Effects on the Political and Economic Future of the Middle East Countries. *International Journal of Economic Perspectives*, 112.

Dowling, M., (2007) From Husserl to van Manen. A review of different phenomenological approaches. *International Journal of Nursing Studies*, [online] 441, pp.131–142. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0020748905002506.

Duch-Brown, N. and Costa-Campi, M.T., (2015) The diffusion of patented oil and gas technology with environmental uses: A forward patent citation analysis. *Energy Policy*, [online] 83, pp.267–276. Available at: https://linkinghub.elsevier.com/retrieve/pii/S030142151500107X.

Durney, C.P. and Donnelly, R.G., (2015) Managing the Effects of Rapid Technological

Change on Complex Information Technology Projects. *Journal of the Knowledge Economy*, [online] 64, pp.641–664. Available at: http://link.springer.com/10.1007/s13132-012-0099-2.

Dzudie, G.B., (2013) *Effectiveness framework for project management information systems used in United States oil and gas exploration*. [online] University of Phoenix. Available at: https://search.proquest.com/docview/1666829239?pq-origsite=gscholar.

E.E.P.A., (Energy East Project Application), (2016) *Construction - Component - Specific Information*. [online] Available at: file:///C:/Users/buelkrai/Downloads/C363-38-29 - Attachment 11 to Response to National Energy Board IRs (00286128xC6E53) - A4W5F2.pdf.

EIA, (2015) *Country Analysis Executive Summary: Iraq*. [online] Available at: https://www.eia.gov/beta/international/analysis.php?iso=IRQ.

EIA, (2016) *International Energy Outlook 2016*. [online] Available at: https://www.eia.gov/outlooks/ieo/pdf/0484(2016).pdf.

Eizakshiri, F., Chan, P.W. and Emsley, M.W., (2015) Where is intentionality in studying project delays? *International Journal of Managing Projects in Business*, [online] 82, pp.349–367. Available at: https://www.emerald.com/insight/content/doi/10.1108/IJMPB-05-2014-0048/full/html.

El-Abbasy, M.S., El Chanati, H., Mosleh, F., Senouci, A., Zayed, T. and Al-Derham, H., (2016a) Integrated performance assessment model for water distribution networks. *Structure and Infrastructure Engineering*, pp.1–20.

El-Abbasy, M.S., Senouci, A., Zayed, T., Mirahadi, F. and Parvizsedghy, L., (2014) Artificial neural network models for predicting condition of offshore oil and gas pipelines. *Automation in Construction*, 45, pp.50–65.

El-Abbasy, M.S., Senouci, A., Zayed, T. and Mosleh, F., (2015) A condition assessment model for oil and gas pipelines using integrated simulation and analytic network process. *Structure and Infrastructure Engineering*, [online] 113, pp.263–281. Available at: http://www.tandfonline.com/doi/abs/10.1080/15732479.2013.873471.

El-Abbasy, M.S., Senouci, A., Zayed, T., Parvizsedghy, L. and Mirahadi, F., (2016b)

Unpiggable Oil and Gas Pipeline Condition Forecasting Models. *Journal of Performance of Constructed Facilities*, [online] 301, p.04014202. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%29CF.1943-5509.0000716.

Elsawah, H., Bakry, I. and Moselhi, O., (2016) Decision Support Model for Integrated Risk Assessment and Prioritization of Intervention Plans of Municipal Infrastructure. *Journal of Pipeline Systems Engineering and Practice*, [online] 74, p.04016010. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%29PS.1949-1204.0000245.

Elsayed, T., (2009) Fuzzy inference system for the risk assessment of liquefied natural gas carriers during loading/offloading at terminals. *Applied Ocean Research*, [online] 313, pp.179–185. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0141118709000716.

Energy HQ logo, (2020) *UPSTREAM? MIDSTREAM? DOWNSTREAM? WHAT'S THE DIFFERENCE?* [online] Available at: https://energyhq.com/2017/04/upstream-midstream-downstream-whats-the-difference/ [Accessed 7 Jan. 2020].

Energy Security, (2008) *Iraq Pipeline Watch*. [online] Available at: http://www.iags.org/iraqpipelinewatch.htm [Accessed 4 Aug. 2020].

Enshassi, A., Al-Najjar, J. and Kumaraswamy, M., (2009) Delays and cost overruns in the construction projects in the Gaza Strip. *Journal of Financial Management of Property and Construction*, [online] 142, pp.126–151. Available at: http://www.emeraldinsight.com/doi/10.1108/13664380910977592.

Epstein, P.R., Selber, J., Borasin, S., Foster, S., Jobarteh, K., Link, N., Miranda, J., Pomeranse, E., Rabke-Verani, J. and Reyes, D., (2002) *A life cycle analysis of its health and environmental impacts*. [online] *The Center for Health and the Global Environment. Harvard Medial School. EUA.* Available at: http://oneplanetfellows.pbworks.com/f/Oil_Impacts_full+report.pdf.

EZE, T.C., (2019) AN APPRAISAL OF THE LEGAL DISPENSATION FOR OIL SPILL COMPENSATION IN NIGERIA. *INTERNATIONAL REVIEW OF LAW AND JURISPRUDENCE (IRLJ)*, 13, pp.179–183.

F.T.A., (FracTracker Alliance), (2019) *PIPELINE CONSTRUCTION: STEP BY STEP*

GUIDE. [online] Pipeline Construction: Step by Step. Available at: https://www.fractracker.org/resources/oil-and-gas-101/pipeline-construction/.

Fallahnejad, M.H., (2013) Delay causes in Iran gas pipeline projects. *International Journal of Project Management*, [online] 311, pp.136–146. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0263786312000683.

Fang, C. and Marle, F., (2012) A simulation-based risk network model for decision support in project risk management. *Decision Support Systems*, [online] 523, pp.635–644. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0167923611002016.

Feibleman, J.K., (1954) On the theory of induction. *Philosophy and Phenomenological Research*, [online] 143, pp.332–342. Available at: https://www.jstor.org/stable/2104105.

Feldman, S.C., Pelletier, R.E., Walser, E., Smoot, J.C. and Ahl, D., (1995) A prototype for pipeline routing using remotely sensed data and geographic information system analysis. *Remote Sensing of Environment*, 532, pp.123–131.

Filippina, K. (Kate) and Dreherb, L., (2004) Major Hazard Risk Assessment for Existing and New Facilities. *American Institute of Chemical Engineers*, 234, pp.237–243.

Fischer, C.T., (2005) *Qualitative research methods for psychologists: Introduction through empirical studies*. Academic Press.

Fishburn, P.C., (1984) Foundations of risk measurement. I. Risk as probable loss. *Management Science*, 304, pp.396–406.

Folga, S.M., (2007) *Natural Gas Pipeline Technology Overview*. Oak Ridg.

Fowler Jr, F.J. and Cosenza, C., (2009) Design and evaluation of survey questions. In: *The SAGE handbook of applied social research methods*. United Stat of Americaa: SAGE Publications, Inc Thousand Oaks, California, pp.375–412.

Gabrielson, G., (2015) *Upstream, Midstream, and Downstream… What's the difference?* [online] lLnetree. Available at: https://lonetreeusa.com/upstream-midstream-downstream-whats-difference/.

Galli, B.J. and Khizar, A., (2019) Risk Assessment of Incidents Response for Downstate New York Natural Gas Distribution Infrastructure. *International Journal of Risk and*

Contingency Management, 82, pp.31–65.

Gazprom, (2020) *About Gazprom*. [online] Available at: https://www.gazprom.com/about/ [Accessed 26 Apr. 2020].

Ge, D., Lin, M., Yang, Y., Zhang, R. and Chou, Q., (2015) Reliability analysis of complex dynamic fault trees based on an adapted K.D. Heidtmann algorithm. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, 2296, pp.576–586.

Gentile, M., Rogers, W.J. and Mannan, M.S., (2003) Development of a Fuzzy Logic-Based Inherent Safety Index. *Process Safety and Environmental Protection*, [online] 816, pp.444–456. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0957582003711227.

Giacobbi, P.R., Poczwardowski, A. and Hager, P., (2005) A Pragmatic Research Philosophy for Sport and Exercise Psychology. *The Sport Psychologist*, 191, pp.18–31.

Global Resources News, (2016) *Global Resources News Map: MENA - Iraq oil fields in south Badra*. [online] Available at: http://globalresourcesnews.com/getmap.php?ineedle=MENA/Iraq/iraq-oil-fields-in-south-Badra.jpg [Accessed 4 Aug. 2020].

Gosling, L. and Edwards, M., (1995) *Toolkits: A practical guide to assessment, monitoring, review and evaluation*. Save the Children London.

De Graaff, N., (2011) A global energy network? The expansion and integration of non-triad national oil companies. *Global Networks*, 112, pp.262–283.

DE GRAAFF, N., (2011) A global energy network? The expansion and integration of non-triad national oil companies. *Global Networks*, [online] 112, pp.262–283. Available at: http://doi.wiley.com/10.1111/j.1471-0374.2011.00320.x.

Greene, J.C., (2007) *Mixed methods in social inquiry*. San Francisco, CA, United Stat of Americaa: John Wiley & Sons.

Grinstead, C.M. and Snell, J.L., (2012) *Introduction to Probability*. American Mathematical Society.

Grüger, J. and Schneider, G., (2019) Automated Analysis of Job Requirements for Computer

Scientists in Online Job Advertisements. In: *Proceedings of the 15th International Conference on Web Information Systems and Technologies*. SCITEPRESS - Science and Technology Publications, pp.226–233.

Gulf Oil & Gas, (2020a) *Gazprom Connects Badra Field to Main Iraqi Pipeline. Source: www.gulfoilandgas.com 3/5/2014, Location: Middle East*. Gulf Oil & Gas.

Gulf Oil & Gas, (2020b) *Pipe Lines Installations News in Iraq. CPP Wins EPC Oil Export Pipeline at Badra Oilfield. (Source: www.gulfoilandgas.com 8/15/2012, Location: Middle East)*. Gulf Oil & Gas.

Gundersen, H.J.G., Bagger, P., Bendtsen, T.F., Evans, S.M., Korbo, L., Marcussen, N., MØLler, A., Nielsen, K., Nyengaard, J.R., Pakkenberg, B., SØRensen, F.B., Vesterby, A. and West, M.J., (1988) The new stereological tools: Disector, fractionator, nucleator and point sampled intercepts and their use in pathological research and diagnosis. *APMIS*, [online] 967–12, pp.857–881. Available at: http://doi.wiley.com/10.1111/j.1699-0463.1988.tb00954.x.

Gunes, E.F., (2013) *Optimal design of a gas transmission network: A case study of the Turkish natural gas pipeline network system*.

Gunter, F., (2013) Challenges facing the reconstruction of Iraq's infrastructure. *Lehigh University. October*, 28.

Guo, B.H., Yiu, T.W. and Gonzalez, V.A., (2015) Identifying behaviour patterns of construction safety using system archetypes. *Accid Anal Prev*, [online] 80, pp.125–141. Available at: http://www.ncbi.nlm.nih.gov/pubmed/25909389.

Guo, X., Zhang, L., Liang, W. and Haugen, S., (2018) Risk identification of third-party damage on oil and gas pipelines through the Bayesian network. *Journal of Loss Prevention in the Process Industries*, [online] 54, pp.163–178. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0950423017310719.

Guo, Y., Meng, X., Wang, D., Meng, T., Liu, S. and He, R., (2016) Comprehensive risk evaluation of long-distance oil and gas transportation pipelines using a fuzzy Petri net model. *Journal of Natural Gas Science and Engineering*, [online] 33, pp.18–29. Available at: http://linkinghub.elsevier.com/retrieve/pii/S187551001630275X.

Guzman Urbina, A. and Aoyama, A., (2017) Measuring the benefit of investing in pipeline safety using fuzzy risk assessment. *Journal of Loss Prevention in the Process Industries*, 45, pp.116–132.

Haimes, Y.Y., (2009) On the Complex Definition of Risk: A Systems-Based Approach. *Risk Analysis*, 2912, pp.1647–1654.

Hair, J.F., (2007) *Research methods for business*. West Sussex, England: John Wiley and Sons.

Hameed, H., Bai, Y. and Ali, L., (2020) A risk-based inspection planning methodology for integrity management of subsea oil and gas pipelines. *Ships and Offshore Structures*, pp.1–13.

Hillson, D., (2002) Extending the risk process to manage opportunities. *International Journal of Project Management*, [online] 203, pp.235–240. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0263786301000746.

Holden, R.R., (2010) Face Validity. In: *The Corsini Encyclopedia of Psychology*. [online] Hoboken, NJ, USA: John Wiley & Sons, Inc. Available at: http://doi.wiley.com/10.1002/9780470479216.corpsy0341.

Holdsworth, S., Sandri, O. and Hayes, J., (2021) Planning, gas pipelines and community safety: What is the role for local planning authorities in managing risk in the neoliberal era? *Land Use Policy*, 100, p.104890.

Hopkins, P., Fletcher, R. and Palmer-Jones, R., (1999) A method for the monitoring and management of Pipeline risk - A Simple Pipeline Risk Audit (SPRA). In: *3rd Annual Conferences on Advances in Pipeline Technologies & Rehabilitation*. In 3rd Annual Conference on ‘Advances in Pipeline Technologies & Rehabilitation ‘99’, Abu Dhabi., Abu Dhabi., pp.0–24.

Hou, L., Chi, H.-L., Tarng, W., Chai, J., Panuwatwanich, K. and Wang, X., (2017) A framework of innovative learning for skill development in complex operational tasks. *Automation in Construction*, 83, pp.29–40.

Howard Castrup, (2009) Error Distribution Variances and Other Statistics. *Integrated Sciences Group*, 1, p.15.

Hutson, A.C., (2006) A guide to route selection for large diameter pipeline projects. In: *Pipelines 2006: Service to the Owner*. pp.1–11.

IEA, (2012) *Word Enegry Outlook*. [online] Available at: https://www.iea.org/publications/freepublications/publication/English.pdf.

IEA, (2013) *Iraq Energy Outlook, World Energy Outlook Special Report*. Paris, France.

IEA, (2015) *World Energy Outlook 2015*. [online] Available at: https://www.iea.org/newsroom/news/2015/november/world-energy-outlook-2015.html.

Ihuah, P.W. and Eaton, D., (2013) The pragmatic research approach: A framework for sustainable management of public housing estates in Nigeria. *Journal of US-China Public Administration*, 1010, pp.933–944.

Innal, F., Chebila, M. and Dutuit, Y., (2016) Uncertainty handling in safety instrumented systems according to IEC 61508 and new proposal based on coupling Monte Carlo analysis and fuzzy sets. *Journal of Loss Prevention in the Process Industries*, [online] 44, pp.503–514. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0950423016302030.

Iraq - Gazprom, (2020) *Iraq - Gazprom*. [online] Available at: https://www.google.com/search?q=gazprom+iraq&oq=gazprom+iraq&aqs=chrome..69i57j0l7.12461j1j7&sourceid=chrome&ie=UTF-8 [Accessed 26 Apr. 2020].

Irina-Maria Dragan and Isaic-Maniu, A., (2013) Snowball Sampling Completion. *Journal of Studies in Social Sciences*, 52, pp.160–177.

Islam, M.S., Nepal, M.P., Skitmore, M. and Attarzadeh, M., (2017) Current research trends and application areas of fuzzy and hybrid methods to the risk assessment of construction projects. *Advanced Engineering Informatics*, [online] 33, pp.112–131. Available at: https://linkinghub.elsevier.com/retrieve/pii/S1474034617300228.

Ismael, H.M., (2018) *The Geopolitical Challenge of Iraqi-Kurdistan's Natural Gas*.

Jaffe, A.M., (2007) *Iraq's oil sector: past, present and future*. *PREPARED IN CONJUNCTION WITH AN ENERGY STUDY SPONSORED BY JAPAN PETROLEUM ENERGY CENTER AND THE JAMES A. BAKER III INSTITUTE FOR PUBLIC POLICY*.

Jaffe, A.M. and Soligo, R., (2007) *The international oil companies*. [online] James A. Baker

III Institute for Public Policy of Rice University. Available at: https://scholarship.rice.edu/bitstream/handle/1911/91449/NOC_IOCs_Jaffe-Soligo.pdf?sequence=1.

Jamie McDuell, R., (2014) *Map: Iraq's Oil & Gas Infrastructure*. S&S Global Platts Insight.

Jamshidi, A., Yazdani-Chamzini, A., Yakhchali, S.H. and Khaleghi, S., (2013) Developing a new fuzzy inference system for pipeline risk assessment. *Journal of Loss Prevention in the Process Industries*, [online] 261, pp.197–208. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0950423012001696.

Jenkinson, C., Wright, L. and Coulter, A., (1994) Criterion validity and reliability of the SF-36 in a population sample. *Quality of Life Research*, 31, pp.7–12.

Jiang, F. and Dong, S., (2020) Collision failure risk analysis of falling object on subsea pipelines based on machine learning scheme. *Engineering Failure Analysis*, 114, p.104601.

Johnson, C.E., (2017) *Development of a Framework for Integrated Oil and gas Pipeline Monitoring and Incident Mitigation System (IOPMIMS)*. [online] University of Wolverhampton. Available at: file:///C:/Users/buelkrai/Downloads/Eze PhD Thesis.pdf.

Julie Pallant, (2001) *SPSS Survival Manual : Step by Step Guide to Data Analysis Using SPSS for Windows*. New York: McGraw Hill: McGraw-Hill Education.

Kabir, G., Sadiq, R. and Tesfamariam, S., (2015) A fuzzy Bayesian belief network for safety assessment of oil and gas pipelines. *Structure and Infrastructure Engineering*, 128, pp.874–889.

Kadry, M., Osman, H. and Georgy, M., (2017) Causes of Construction Delays in Countries with High Geopolitical Risks. *Journal of Construction Engineering and Management*, [online] 1432, p.04016095. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%29CO.1943-7862.0001222.

Kang, J.Y. and Lee, B.S., (2017) Optimisation of pipeline route in the presence of obstacles based on a least cost path algorithm and laplacian smoothing. *International Journal of Naval Architecture and Ocean Engineering*, [online] 95, pp.492–498. Available at: https://linkinghub.elsevier.com/retrieve/pii/S209267821630694X.

Kaplan, S., (1997) The words of risk analysis. *Risk analysis*, 174, pp.407–417.

Karagoz, D. and Altunay, S.A., (2015) Triangle Distribution for Positively Skewed Data.

Kawsar, M.R.U., Youssef, S.A., Faisal, M., Kumar, A., Seo, J.K. and Paik, J.K., (2015) Assessment of dropped object risk on corroded subsea pipeline. *Ocean Engineering*, 106, pp.329–340.

Keprate, A. and Ratnayake, R.M.C., (2016) Enhancing offshore process safety by selecting fatigue critical piping locations for inspection using Fuzzy-AHP based approach. *Process Safety and Environmental Protection*, [online] 102, pp.71–84. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0957582016000409.

Keramat, M. and Kielbasa, R., (1997) Latin Hypercube Sampling Monte Carlo Estimation of Average Quality Index for Integrated Circuits. *Analog Integrated Circuits and Signal Processing*, [online] 141, pp.131–142. Available at: https://doi.org/10.1023/A:1008207113480.

Khakzad, N., Khan, F. and Amyotte, P., (2011) Safety analysis in process facilities: Comparison of fault tree and Bayesian network approaches. *Reliability Engineering & System Safety*, 968, pp.925–932.

Khakzad, N., Khan, F. and Amyotte, P., (2013) Quantitative risk analysis of offshore drilling operations: A Bayesian approach. *Safety Science*, 57, pp.108–117.

Khan, F., Rathnayaka, S. and Ahmed, S., (2015) Methods and models in process safety and risk management: Past, present and future. *Process Safety and Environmental Protection*, [online] 98, pp.116–147. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0957582015001275.

Kim, Y., Kim, K. and Shin, D., (2005) Delay analysis method using delay section. *Journal of construction engineering and management*, 13111, pp.1155–1164.

Kline, R.B., (1999) Book review: Psychometric theory. *Journal of Psychoeducational Assessment*, 173, pp.275–280.

Koduru, S.D. and Nessim, M.A., (2017) Review of Quantitative Reliability Methods for Onshore Oil and Gas Pipelines. In: *Risk and Reliability Analysis: Theory and Applications*.

Springer, pp.67–95.

Komarov, V.A., Nigrey, N.N., Bronnikov, D.A. and Nigrey, A.A., (2018) Mortise terrorism on the main pipelines. *Journal of Physics: Conference Series*, 944, p.012054.

Kraidi, L., Shah, R., Matipa, W. and Borthwick, F., (2018a) An Analysis of the Critical Risk Factors in Oil and Gas Pipeline Projects Using a Comprehensive Risk Management Framework. In: *This paper was presented as a working paper at the ARCOM 34th Conference, 3-5 September.* Belfast, UK.

Kraidi, L., Shah, R., Matipa, W. and Borthwick, F., (2018b) Analyzing the critical risk factors in oil and gas pipelines projects regarding the perceptions of the stakeholders. In: *Creative Construction Conference 2018 - Proceedings*. [online] Ljubljana, Slovenia.: Budapest University of Technology and Economics, pp.304–311. Available at: https://repozitorium.omikk.bme.hu/handle/10890/5703.

Kraidi, L., Shah, R., Matipa, W. and Borthwick, F., (2018c) The development of a questionnaire survey to investigate the critical risk factors in oil and gas pipelines projects. In: *Creative Construction Conference 2018 - Proceedings*. [online] Ljubljana, Slovenia: Budapest University of Technology and Economics, pp.663–670. Available at: https://repozitorium.omikk.bme.hu/handle/10890/5750.

Kraidi, L., Shah, R., Matipa, W. and Borthwick, F., (2019a) Analyzing Stakeholders' Perceptions of the Critical Risk Factors in Oil and Gas Pipeline Projects. *Periodica Polytechnica Architecture*. [online] Available at: https://pp.bme.hu/ar/article/view/13744.

Kraidi, L., Shah, R., Matipa, W. and Borthwick, F., (2019b) Analyzing the critical risk factors associated with oil and gas pipeline projects in Iraq. *International Journal of Critical Infrastructure Protection,* [online] 24, pp.14–22. Available at: https://linkinghub.elsevier.com/retrieve/pii/S1874548217301208.

Kraidi, L., Shah, R., Matipa, W. and Borthwick, F., (2020) Using stakeholders' judgement and fuzzy logic theory to analyze the risk influencing factors in oil and gas pipeline projects: Case study in Iraq, Stage II. *International Journal of Critical Infrastructure Protection*, [online] 28, p.100337. Available at: https://linkinghub.elsevier.com/retrieve/pii/S1874548220300019.

Kraidi, L., Shah, S., Matipa, W. and Borthwick, F., (2019c) Application of Fuzzy Logic Theory on Risk Assessment in Oil and Gas Pipeline Projects. In: *ASC 2019 International Conference, 10-13 April*. [online] Denver, Colorado, USA. Available at: http://researchonline.ljmu.ac.uk/id/eprint/10178.

Kumar, C.S. and Anusree, M.R., (2015) On an Extended Version of Skew Generalized Normal Distribution and Some of its Properties. *Communications in Statistics - Theory and Methods*, [online] 443, pp.573–586. Available at: http://www.tandfonline.com/doi/abs/10.1080/03610926.2012.739251.

Kumar, R., (2019) *Research methodology: A step-by-step guide for beginners*. Sage Publications Limited.

Kumins, L.C., (2003) *Iraq Oil: Reserves, Production, and Potential Revenues*. Congressional Information Service, Library of Congress.

Labaka, L., Hernantes, J. and Sarriegi, J.M., (2016) A holistic framework for building critical infrastructure resilience. *Technological Forecasting and Social Change*, 103, pp.21–33.

Lambert, D.M. and Stock, J.R., (1993) *Strategic logistics management*. Irwin Homewood, IL.

Lambrechts, D. and Blomquist, L.B., (2017) Political–security risk in the oil and gas industry: the impact of terrorism on risk management and mitigation. *Journal of Risk Research*, 2010, pp.1320–1337.

Lameda, R.L. and Van den Berg, F.G., (2009) Integration Is About People. In: *SPE Digital Energy Conference and Exhibition*. [online] Society of Petroleum Engineers. Available at: http://www.onepetro.org/doi/10.2118/123352-MS.

Laufer, A., Shapira, A. and Telem, D., (2008) Communicating in Dynamic Conditions: How Do On-Site Construction Project Managers Do It? *Journal of Management in Engineering*, [online] 242, pp.75–86. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%290742-597X%282008%2924%3A2%2875%29.

Lavasani, S.M., Ramzali, N., Sabzalipour, F. and Akyuz, E., (2015) Utilisation of Fuzzy Fault Tree Analysis (FFTA) for quantified risk analysis of leakage in abandoned oil and natural-gas wells. *Ocean Engineering*, 108, pp.729–737.

Lee, B., Collier, P.M. and Cullen, J., (2007) Reflections on the use of case studies in the accounting, management and organizational disciplines. *Qualitative Research in Organizations and Management: An International Journal*, [online] 23, pp.169–178. Available at: https://www.emerald.com/insight/content/doi/10.1108/17465640710835337/full/html.

Leedy, P.D. and Ormrod, J.E., (2005) *Practical research*. Pearson Custom, PEARSON.

Leira, B.J., Næss, A. and Brandrud Næss, O.E., (2016) Reliability analysis of corroding pipelines by enhanced Monte Carlo simulation. *International Journal of Pressure Vessels and Piping*, [online] 144, pp.11–17. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0308016116301855.

Li, H., Sun, R., Lee, W.-J., Dong, K. and Guo, R., (2016) Assessing Risk in Chinese Shale Gas Investments Abroad: Modelling and Policy Recommendations. *Sustainability*, 88, p.708.

Li, P., Chen, G., Dai, L. and Li, Z., (2010) Fuzzy logic-based approach for identifying the risk importance of human error. *Safety Science*, [online] 487, pp.902–913. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0925753510000846.

Li, P., Irwin, G.W. and Kruger, U., (2005) A recursive rule base adjustment algorithm for a fuzzy logic controller. *Fuzzy Sets and Systems*, [online] 1562, pp.267–284. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0165011405002939.

Li, X., Chen, G., Khan, F. and Xu, C., (2019) Dynamic risk assessment of subsea pipelines leak using precursor data. *Ocean Engineering*, 178, pp.156–169.

Li, X., Han, Z., Zhang, R., Abbassi, R. and Chang, D., (2020) An integrated methodology to manage risk factors of aging urban oil and gas pipelines. *Journal of Loss Prevention in the Process Industries*, 66, p.104154.

Liu, H., (2003) *Pipeline engineering*. CRC Press.

Lommer, H.A., (2018) *War to peace transition and arms trade regulations-South Sudan´ s relapse into war 2013-2015*. Universidade Nova.

Lu, L., Liang, W., Zhang, L., Zhang, H., Lu, Z. and Shan, J., (2015) A comprehensive risk evaluation method for natural gas pipelines by combining a risk matrix with a bow-tie model. *Journal of Natural Gas Science and Engineering*, [online] 25, pp.124–133. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1875510015001766.

Luft, G., (2005) *Reconstructing Iraq: bringing Iraq's economy back online*. [online] Middle East Quarterly. Available at: https://www.meforum.org/736/reconstructing-iraq-bringing-iraqs-economy-back.

Macdonald, K.A. and Cosham, A., (2005) Best practice for the assessment of defects in pipelines – gouges and dents. *Engineering Failure Analysis*, 125, pp.720–745.

Mai-Bornu, Z., (2017) *Between nonviolence and violence: A comparative analysis on the dynamics of choice in the Ogoni and Ijaw movements in the Niger Delta*. University of Bath.

Malilay, J., Flanders, W.D. and Brogan, D., (1996) A modified cluster-sampling method for post-disaster rapid assessment of needs. *Bulletin of the World Health Organization*, 744, p.399.

Manouchehri, S., (2017) Subsea Pipelines and Flowlines Decommissioning: What We Should Know for a Rational Approach. In: *Volume 5B: Pipelines, Risers, and Subsea Systems*. American Society of Mechanical Engineers, p.V05BT04A009.

Mansour, R., (2018) *Directorate-general for external policies department policies, Study (Rebuilding the Iraqi State: Stabilisation, Governance, and Reconciliation)*. [online] Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2017/603859/EXPO_STU(2017)603859_EN.pdf.

Marcjan, K., Dzikowski, R. and Bilewski, M., (2017) Criteria of Accidental Damage by Ships Anchors of Subsea Gas Pipeline in the Gda?sk Bay Area. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 113, pp.441–446.

Marinos, P.N., (1969) Fuzzy Logic and its Application to Switching Systems. *IEEE Transactions on Computers*, [online] C–184, pp.343–348. Available at: http://ieeexplore.ieee.org/document/1671255/.

Markowski, A.S. and Mannan, M.S., (2008) Fuzzy risk matrix. *Journal of Hazardous*

Materials, [online] 1591, pp.152–157. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0304389408004019.

Marshall, J.B., (2016) Joint operating agreements in oil and gas industry: The consequence of sole risk and non consent clauses to joint operation. *Journal of Asian Business Strategy*, [online] 610, pp.214–220. Available at: http://www.aessweb.com/journals/October2016/5006/3702.

Matell, M.S. and Jacoby, J., (1972) Is there an optimal number of alternatives for Likert-scale items? Effects of testing time and scale properties. *Journal of Applied Psychology*, 566, p.506.

Mather, J., Blackmore, C., Petrie, A. and Treves, C., (2001) *An Assessment of Measures in Use for Gas Pipelines to Mitigate Against Damage Caused by Third Party Activity*. WS Atkins Consultants Ltd for the Health and Safety Executive.

Matori, A.N. and Lee, H.Y., (2009) Suitability analysis of subsea pipeline route using GIS. *PETRONAS Technology Journal*, 21.

Matthews, B. and Ross, L., (2012) *Research Methods: A Practical Guide for the Social Sciences. British Journal of Criminology*, .

Maxwell, J.A., (2012) *A realist approach for qualitative research*. United Stat of Americaa: Sage.

McCaslin, M.L. and Scott, K.W., (2003) The five-question method for framing a qualitative research study. *The qualitative report*, [online] 83, pp.447–461. Available at: http://www.nova.edu/ssss/QR/QR8-3/mccaslin.pdf .

McDonald, J., (2006) Analysing historical data: a justification of the use of quantitative methods. *Accounting History*, [online] 111, pp.73–84. Available at: http://journals.sagepub.com/doi/10.1177/1032373206060085.

Mearns, K. and Yule, S., (2009) The role of national culture in determining safety performance: Challenges for the global oil and gas industry. *Safety Science*, [online] 476, pp.777–785. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0925753508000295.

Mehdi, A., (2018) *Iraqi oil*. Oxford, United Kingdom.

Mikdashi, Z., (1974) Cooperation among oil exporting countries with special reference to Arab countries: a political economy analysis. *International Organization*, 281, pp.1–30.

Miller, R.L. and Brewer, J.D., (2003) *The AZ of social research: a dictionary of key social science research concepts*. Sage.

Minsner, T.O. and Leffler, W.L., (2006) *Oil & Gas Pipelines in nontechnical language*. *PennWell*. tulas, Oklahoma, USA: PennWell Corporation.

Miri Lavasani, S.M., Yang, Z., Finlay, J. and Wang, J., (2011) Fuzzy risk assessment of oil and gas offshore wells. *Process Safety and Environmental Protection*, 895, pp.277–294.

Mokhtari, K., Ren, J., Roberts, C. and Wang, J., (2012) Decision support framework for risk management on sea ports and terminals using fuzzy set theory and evidential reasoning approach. *Expert Systems with Applications*, [online] 395, pp.5087–5103. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0957417411015739.

Monaldi, F.J., (2017) *The Rule of Law and Foreign Investment in Oil: Petroleum Nationalism in Latin America and Its Implications for Mexico*. James A. Baker III Institute for Public Policy of Rice University.

Montemurro, D., Barnett, S. and Gale, T., (1998) GIS-based process helps TransCanada select best route for expansion line. *Oil and Gas Journal*, 9625.

Moosa, N.A., (2013) *Blueprint for Iraqi Oil & Gas Infrastructure Development and Plans for Pipeline Network and Storage in Oil Industry*. [online] The 31st JCCP International Symposium, January. Available at: https://www.jccp.or.jp/international/conference/docs/s2-3_simminar_oil_final1_130307.pdf.

Morano, C.A.R., Martins, C.G. and Ferreira, M.L.R., (2006) Application of techniques for the identification of risk in the E & P ventures Engevista. *vol*, 8, pp.120–133.

Mpofu, B., Ochieng, E.G., Moobela, C. and Pretorius, A., (2017) Profiling causative factors leading to construction project delays in the United Arab Emirates. *Engineering, Construction and Architectural Management*, [online] 242, pp.346–376. Available at: https://www.emerald.com/insight/content/doi/10.1108/ECAM-05-2015-0072/full/html.

Mubin, S. and Manna, A., (2013) Innovative Approach to Risk Analysis and Management of Oil and Gas Sector EPC Contracts from a Contractor’s Perspective. *Journal of Business & Economics*, 52, pp.149–170.

Mubin, S. and Mubin, G., (2008) Risk analysis for construction and operation of gas pipeline projects in Pakistan. *Pak. J. Engg. & Appl. Sci. Vol*, 504, pp.55–60.

Muhlbauer, W.K., (2004) *Pipeline Risk Management Manual: Ideas, Techniques, and Resources*. Third Edit ed. Gulf Professional Publishing, Elsvier Inc.

Mun, J., (2015) Understanding and Choosing the Right Probability Distributions. In: *Advanced Analytical Models: Over 800 Models and 300 Applications from the Basel II Accord to Wall Street and Beyond*. [online] Hoboken, NJ, USA: John Wiley & Sons, Inc., pp.899–917. Available at: http://doi.wiley.com/10.1002/9781119197096.app03.

Mundia, C.N. and Macharia, P.M., (2018) GIS analysis and spatial modelling for optimal oil pipeline route location. A case study of proposed Isiolo Nakuru pipeline route.

Muttitt, G., (2006) Production Sharing Agreements-Mortgaging Iraq’s Oil Wealth. *Arab studies quarterly*, pp.1–17.

Nahmias, S., (1978) Fuzzy variables. *Fuzzy Sets and Systems*, [online] 12, pp.97–110. Available at: https://linkinghub.elsevier.com/retrieve/pii/0165011478900118.

Nair, C.S., (2013) The Effect of Email Notification on Web-based Questionnaire Responses. *The Journal for Quality and Participation;*, 34, pp.19–23.

Nandagopal, N.S., (2007) *Pipeline system- design, construction, maintenance and asset management*. West Perth, Western AUSTRALIA: IDC TECHNOLOGIES Technology Taining that Works.

NFER, (2020) *How to… Develop a questionnaire survey Ask the right questions*. [online] Accessed in 25/02/2020. Available at: https://www.nfer.ac.uk/media/2126/resm06.pdf.

Nieto-Morote, A. and Ruz-Vila, F., (2011) A fuzzy approach to construction project risk assessment. *International Journal of Project Management*, [online] 292, pp.220–231. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0263786310000268.

Nnadi, U., El-Hassan, Z., Smyth, D. and Mooney, J., (2014) Lack of proper safety management systems in Nigeria oil and gas pipelines. *IChemE Institution of Chemical Engineers*, 237, pp.27–34.

Nunnally, J.C., (1994) *Psychometric theory 3E*. Tata McGraw-Hill Education.

Ogulu, C., Njomo, L. and Arnolds, C., (2019) Creating An Environment Conducive To Effective Financial Risk Management In Nigeria's Petroleum Industry. *Archives of Business Research*, 75, pp.1–18.

Okaro, I.A., (2017a) *An integrated model for asset reliability, risk and production efficiency management in subsea oil and gas operations*. [online] Newcastle University. Available at: http://hdl.handle.net/10443/3651.

Okaro, I.A., (2017b) *An Integrated Model for Asset Reliability, Risk and Production Efficiency Management in Subsea Oil and Gas Operations*. [online] Newcastle University, Newcastle upon Tyne, United Kingdom. Available at: https://theses.ncl.ac.uk/jspui/handle/10443/3651.

Olujobi, O.J., (2017) Legal Framework for Combating Corruption in Nigeria -The Upstream Petroleum Sector in Perspective. *Journal of Advanced Research in Law and Economics*, 325, pp.956 – 970.

Onuoha, F.C., (2008) Oil pipeline sabotage in Nigeria: Dimensions, actors and implications for national security. *African Security Review*, 173, pp.99–115.

Onyi-Ogelle, O.H., (2020) Imperatives for the Amendment of the Nigerian Oil Pipelines Act. *Journal of Energy Research and Reviews*, pp.1–9.

OPEC, (2017) *Organization of the Petroleum Exporting Countries, OPEC: Annual Statistical Bulletin*.

P.E.T.C.P., (2020) *THE PITFALLS OF QUESTIONNAIRE SURVEYS*. [online] Practical Education Technology Challenging Povety. Available at: http://www.doc-developpement-durable.org/file/Communications-Relations_Interculturelles/moyens-et-methodes-de-communication/The Pitfalls of Questionnaires.pdf.

Parfomak, P.W., (2008) *Pipeline Safety and Security Federal Programs*. [online] Congressional Research Service. Available at:

http://www.fas.org/sgp/crs/homesec/RL33347.pdf.

Pawlak, Z., (1985) Rough sets and fuzzy sets. *Fuzzy sets and Systems*, 171, pp.99–102.

Peng, X., Yao, D., Liang, G., Yu, J. and He, S., (2016a) Overall reliability analysis on oil/gas pipeline under typical third-party actions based on fragility theory. *Journal of Natural Gas Science and Engineering*, [online] 34, pp.993–1003. Available at: https://linkinghub.elsevier.com/retrieve/pii/S1875510016305327.

Peng, X. yu, Yao, D. chi, Liang, G. chuan, Yu, J. sheng and He, S., (2016b) Overall reliability analysis on oil/gas pipeline under typical third-party actions based on fragility theory. *Journal of Natural Gas Science and Engineering*, [online] 34, pp.993–1003. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1875510016305327.

PMI, P.M.I., (2000) *Guide to the project management book of knowledge (PMBOK guide)*. Newtown Square, Pa, Project Management Institute. .

Polit, D.F. and Beck, C.T., (2008) *Nursing research: Generating and assessing evidence for nursing practice*. Lippincott Williams & Wilkins.

Prasad, K.V., Vasugi, V., Venkatesan, R. and Nikhil, B., (2019) Analysis of causes of delay in Indian construction projects and mitigation measures. *Journal of Financial Management of Property and Construction*, [online] 241, pp.58–78. Available at: https://www.emeraldinsight.com/doi/10.1108/JFMPC-04-2018-0020.

Puomisto, T., (2020) *Building a personal political brand using Facebook and Instagram advertising*. [online] Jyväskylän yliopisto University of Jyväskylä. Available at: https://jyx.jyu.fi/bitstream/handle/123456789/70366/URN%3ANBN%3Afi%3Ajyu-202006244558.pdf?sequence=1&isAllowed=y.

Quan, L., (2015) Daqing Crude Oil Price Forecast Based on the ARIMA Model. *The Open Petroleum Engineering Journal*, 81.

Raz, T., Shenhar, A.J. and Dvir, D., (2002) Risk management, project success, and technological uncertainty. *R&D Management*, 322, pp.101–109.

Rezakhani, P., (2012) Current state of existing project risk modeling and analysis methods with focus on fuzzy risk assessment – Literature Review. *Frattura ed Integrità Strutturale*, [online] 620, pp.17–21. Available at: https://www.fracturae.com/index.php/fis/article/view/133.

Rezazadeh, A., Talarico, L., Reniers, G., Cozzani, V. and Zhang, L., (2018) Applying game theory for securing oil and gas pipelines against terrorism. *Reliability Engineering & System Safety*.

Riegert, S.A.F., (2011) Third-party interference pipeline survey based on risk assessment. *Journal of Pipeline Engineering*, 104, pp.231–236.

Rolstadås, A. and Schiefloe, P.M., (2017) Modelling project complexity. *International Journal of Managing Projects in Business*, [online] 102, pp.295–314. Available at: https://www.emerald.com/insight/content/doi/10.1108/IJMPB-02-2016-0015/full/html.

Rowland, A., (2010) *GIS-based prediction of pipeline third-party interference using hybrid multivariate statistical analysis*. [online] Newcastle University, England, UK. Available at: http://hdl.handle.net/10443/2529%0A.

Rui, Z., Cui, K., Wang, X., Chun, J.-H., Li, Y., Zhang, Z., Lu, J., Chen, G., Zhou, X. and Shirish, P., (2018) A comprehensive investigation on performance of oil and gas development in Nigeria: Technical and non-technical analyses. *Energy*, 1581 September 2018, pp.666–680.

Ruijsscher, T., (2016) *Improving risk identification on large infrastructure projects*. *University of Twente, Faculty of Engineering Technology Enschede*, University of Twente.

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. *Journal of Management in Engineering*, [online] 313, p.05014017. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%29ME.1943-5479.0000248.

Rutherford, A.C., Maupin, R.D. and Hemez François M., (2006) Latin Hypercube Sampling vs. Meta-model Monte Carlo for Propagating Uncertainty Through Transient Dynamics Simulations. In: *In 24th SEM International Modal Analysis Conference.* St. Louis, Missouri, United States: Gale Academic Onefile.

Ruwanpura, J., Ariaratnam, S.T. and El-assaly, A., (2004) Prediction models for sewer infrastructure utilizing rule-based simulation. *Civil Engineering and Environmental Systems*, [online] 213, pp.169–185. Available at: http://www.tandfonline.com/doi/abs/10.1080/10286600410001694192.

Sa'idi, E., Anvaripour, B., Jaderi, F. and Nabhani, N., (2014) Fuzzy risk modeling of process operations in the oil and gas refineries. *Journal of Loss Prevention in the Process Industries*, [online] 30, pp.63–73. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0950423014000540.

Saaty, T.L. and Özdemir, M.S., (2014) How Many Judges Should There Be in a Group ? *Annals of Data Science*, [online] 13–4, pp.359–368. Available at: http://link.springer.com/10.1007/s40745-014-0026-4.

Al Sabah, R., (2014) *Evaluating the Impact of Construction Risks on Project Success in the Arabian Gulf Region (AGR) Construction Industry from the Perspective of Multinational Firms*. The University of Wisconsin-Madison.

Salman, M.D. and Mohammed, A.H., (2020) The Development of the Banking Sector's Contribution to the Iraqi Economy: Subject Review. *Ishtar Journal of Economics and Business Studies (IJEBS)*, 11, pp.1–13.

Santos, J.R.A., (1999) Cronbach's alpha: A tool for assessing the reliability of scales. *Journal of extension*, 372, pp.1–5.

Sara Dolnicar, C. Laesser and Matus, K., (2009) Online versus paper: format effects in tourism surveys. *Journal of Travel Research*, 473, pp.295–316.

Schjølberg, I., Gjersvik, T.B., Transeth, A.A. and Utne, I.B., (2016) Next Generation Subsea Inspection, Maintenance and Repair Operations. *IFAC-PapersOnLine*, 4923, pp.434–439.

Schoonenboom, J., (2019) A Performative Paradigm for Mixed Methods Research. *Journal of Mixed Methods Research*, [online] 133, pp.284–300. Available at: http://journals.sagepub.com/doi/10.1177/1558689817722889.

Schwarz, J. and Sandoval-Wong, J.A., Sánchez, P.., (2015) Implementation of artificial intelligence into risk management decision-making processes in construction projects. pp.361–362.

SCOP (State Company for Oil Projects), (2016) *SCOP*. [online] Available at:

https://www.facebook.com/هيئه-مشاريع-الوسط-scop-1443153842657701/photos/?ref=page_internal [Accessed 22 Apr. 2020].

Shah, R.K., (2011) *Innovative methodology for location-based scheduling and visualisation of earthworks in road construction projects*. [online] Teesside University. Available at: https://pdfs.semanticscholar.org/6d9f/f7619fbf457977e6c0614df881107aadfa71.pdf.

Shah, R.K., (2016) An Exploration of Causes for Delay and Cost Overruns In Construction Projects: Case Study of Australia, Malaysia & Ghana. *Journal of Advanced College of Engineering and Management*, [online] 2, p.41. Available at: http://nepjol.info/index.php/JACEM/article/view/16097.

Shah, R.K. and Dawood, N., (2007) Development of innovative visualisation model in road construction. In: *24th CIB W78 conference" Bringing ICT knowledge to work"*. [online] Maribor, Slovenia, pp.499–504. Available at: https://research.tees.ac.uk/en/publications/development-of-innovative-visualisation-model-in-road-constructio.

Shebob, A., Dawood, N. and Shah, R.K., (2012a) Development of a methodology for analysing and quantifying the impact of delay factors affecting construction projects. *Journal of Construction Engineering and Project Management*, [online] 23, pp.17–29. Available at: http://koreascience.or.kr/journal/view.jsp?kj=E1GAAO&py=2012&vnc=v2n3&sp=17.

Shebob, A., Dawood, N., Shah, R.K.K. and Xu, Q., (2012b) Comparative study of delay factors in Libyan and the UK construction industry. *Engineering, Construction and Architectural Management*, [online] 196, pp.688–712. Available at: http://www.emeraldinsight.com/0969-9988.htm.

Sohrabinejad, A. and Rahimi, M., (2015) Risk Determination, Prioritization, and Classifying in Construction Project Case Study: Gharb Tehran Commercial-Administrative Complex. *Journal of Construction Engineering*, [online] 2015, pp.1–10. Available at: https://www.hindawi.com/archive/2015/203468/.

Spice, A., (2018) Fighting Invasive Infrastructures. *Environment and Society*, 91, pp.40–56.

Squalli, J., (2007) Electricity consumption and economic growth: Bounds and causality analyses of OPEC members. *Energy Economics*, [online] 296, pp.1192–1205. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0140988306001174.

Srivastava, A. and Gupta, J.P.P., (2010) New methodologies for security risk assessment of oil and gas industry. *Process Safety and Environmental Protection*, [online] 886, pp.407–412. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0957582010000674.

SSVSC, (2020) *The Natural Gas Delivery Network*. [online] (SafeSeal Valve Systems Corp). Available at: https://safesealsystems.com/nav4/the-natural-gas-delivery-network/ [Accessed 7 Jan. 2020].

Stanton, W. and Stanton, A., (2019) *Natural Pipeline Construction*. [online] Available at: http://preservethenrv.com/articles/process_build_natural_gas_pipeline.pdf.

Stephan, J. and Badr, Y., (2007) A quantitative and qualitative approach to manage risks in the supply chain operations reference. In: *2007 2nd International Conference on Digital Information Management*. IEEE, pp.410–417.

Style, M.P. and Maglaras, L., (2020) *The Current Posture of Cyber Warfare and Cyber Terrorism*. *Global Foundation for Cyber Studies and Research*.

Sulaiman, N.S. and Tan, H., (2014) Third party damages of offshore pipeline. *Journal of Energy Challenges and Mechanics*, 11, pp.14–19.

Sun, X., Liu, C., Chen, X. and Li, J., (2017) Modeling systemic risk of crude oil imports: Case of China’s global oil supply chain. *Energy*, 121, pp.449–465.

Sweis, R., Moarefi, A., Amiri, M.H., Moarefi, S. and Saleh, R., (2019) Causes of delay in Iranian oil and gas projects: a root cause analysis. *International Journal of Energy Sector Management*, [online] 133, pp.630–650. Available at: https://www.emeraldinsight.com/doi/10.1108/IJESM-04-2018-0014.

Tabesh, M., Roozbahani, A., Roghani, B., Faghihi, N.R. and Heydarzadeh, R., (2018) Risk Assessment of Factors Influencing Non-Revenue Water Using Bayesian Networks and Fuzzy Logic. *Water Resources Management*, [online] 3211, pp.3647–3670. Available at: http://link.springer.com/10.1007/s11269-018-2011-8.

Tang, K.H.D., Md. Dawal, S.Z. and Olugu, E.U., (2018) Generating Safety Performance

Scores of Offshore Oil and Gas Platforms in Malaysia. In: *Proceedings of One Curtin International Postgraduate Conference (OCPC)*. Miri, Sarawak, Malaysia, pp.325–331.

Tashakkori, A. and Teddlie, C., (2010) *SAGE Handbook of Mixed Methods in Social & Behavioral Research*. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc.

Taylan, O., Bafail, A.O., Abdulaal, R.M.S. and Kabli, M.R., (2014) Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies. *Applied Soft Computing*, [online] 17, pp.105–116. Available at: https://linkinghub.elsevier.com/retrieve/pii/S1568494614000040.

Taylor, G.J., Bagby, R.M., Ryan, D.P., Parker, J.D., Doody, K.F. and Keefe, P., (1988) Criterion validity of the Toronto Alexithymia Scale. *Psychosomatic medicine*, 505, pp.500–509.

Taylor, S.J., Bogdan, R. and DeVault, M., (2015) *Introduction to qualitative research methods: A guidebook and resource*. United Stat of Americaa: John Wiley & Sons.

Tchórzewska-Cieślak, B., Pietrucha-Urbanik, K., Urbanik, M. and Rak, J., (2018) Approaches for Safety Analysis of Gas-Pipeline Functionality in Terms of Failure Occurrence: A Case Study. *Energies*, [online] 116, p.1589. Available at: http://www.mdpi.com/1996-1073/11/6/1589.

The Revenue Watch Institute, (2014) *The 2013 resource governance index*. [online] The Hangue Centre for Strategic Studies. Available at: https://www.hcss.nl/news/the_revenue_watch_institute_2013_resource_governance_index_1.

Theophilus Chinonyerem, N., (2017) Economic Implications of Marine Oil Spill to Nigeria: A Case for Improvement in Coastal Pipeline Management and Surveillance Practices. *International Journal of Economy, Energy and Environment*, 23, p.40.

Torabi, S.A., Giahi, R. and Sahebjamnia, N., (2016) An enhanced risk assessment framework for business continuity management systems. *Safety Science*, [online] 89, pp.201–218. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0925753516301266.

Torres, N., Afonso, O. and Soares, I., (2012) Oil Abundance and Economic Growth--A Panel Data Analysis. *The Energy Journal*, [online] 332. Available at: http://www.iaee.org/en/publications/ejarticle.aspx?id=2479.

UN, (2019) *Iraq - Country profile*. [online] Available at: http://data.un.org/en/iso/iq.html [Accessed 24 Apr. 2020].

Urquhart, L. and McAuley, D., (2018) Assessing Information Security Regulations for Domestic and Industrial Cyber-Physical Systems. *TILTing Perspectives*, pp.67–72.

Vaezi, A. and Verma, M., (2018) Railroad transportation of crude oil in Canada: Developing long-term forecasts, and evaluating the impact of proposed pipeline projects. *Journal of Transport Geography*, 69, pp.98–111.

Veilleux, J. and Dinar, S., (2019) A Global Analysis of Water-Related Terrorism, 1970–2016. *Terrorism and Political Violence*, pp.1–26.

Walt, V., (2009) Pump It Up: The Development of Iraq’s Oil Reserves. *Time*. [online] Available at: http://content.time.com/time/magazine/article/0,9171,1943091,00.html.

Wan, C. and Mita, A., (2010) Recognition of potential danger to buried pipelines based on sounds. *Structural Control and Health Monitoring*, 173, pp.317–337.

Wang, M.-T. and Chou, H.-Y., (2003) Risk Allocation and Risk Handling of Highway Projects in Taiwan. *Journal of Management in Engineering*, [online] 192, pp.60–68. Available at: http://ascelibrary.org/doi/10.1061/%28ASCE%290742-597X%282003%2919%3A2%2860%29.

Wang, Y., Wei, N., Wan, D., Wang, S. and Yuan, Z., (2019) Numerical Simulation for Preheating New Submarine Hot Oil Pipelines. *Energies*, 1218, p.3518.

Watts, M., (2008) *Curse of the black gold: 50 years of oil in the Niger Delta*. Powerhouse books.

Webb, N.M., Shavelson, R.J. and Haertel, E.H., (2006) 4 Reliability Coefficients and Generalizability Theory. [online] pp.81–124. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0169716106260048.

Whipple, T. and Pitblado, R., (2009) Applied risk-based process safety: A consolidated risk register and focus on risk communication. *Process Safety Progress*, p.NA-NA.

White, M.D. and Marsh, E.E., (2006) Content Analysis: A Flexible Methodology. *Library Trends*, [online] 551, pp.22–45. Available at: http://muse.jhu.edu/content/crossref/journals/library_trends/v055/55.1white.html.

Whitely, S.E., (1983) Construct validity: Construct representation versus nomothetic span. *Psychological Bulletin*, [online] 931, pp.179–197. Available at: http://doi.apa.org/getdoi.cfm?doi=10.1037/0033-2909.93.1.179.

Williams Companies, (2019) *Pipeline Construction, Williams*. [online] Pipeline Construction. Available at: https://co.williams.com/pipeline-construction/.

Williams, R.C., Walker, J.A. and Dorofee, A.J., (1997) Putting risk management into practice. *IEEE software*, 143, pp.75–82.

WINSTON, (2018) *YOUR MIND IS THE UNIVERSE AND THE WORLD IS THE PLACE OF EXPERIMENT*. [online] UNLOCKED SUCCESS YOUR MIND YOUR SUCCESS. Available at: https://www.unlockedsuccess.com/personal/personal-development/your-mind-is-the-universe-and-the-world-is-the-place-of-experiment/.

Wisdom, J.P., Cavaleri, M.A., Onwuegbuzie, A.J. and Green, C.A., (2012) Methodological Reporting in Qualitative, Quantitative, and Mixed Methods Health Services Research Articles. *Health Services Research*, [online] 472, pp.721–745. Available at: http://doi.wiley.com/10.1111/j.1475-6773.2011.01344.x.

World Map, (2014) *Iraq Oil Pipelines Map*.

Wright, A., Grabsch, H. and Treanor, D., (2015) RandomSpot: A web-based tool for systematic random sampling of virtual slides. *Journal of Pathology Informatics*, [online] 61, p.8. Available at: http://www.jpathinformatics.org/text.asp?2015/6/1/8/151906.

Wu, W.-S., Yang, C.-F., Chang, J.-C., Château, P.-A. and Chang, Y.-C., (2015) Risk assessment by integrating interpretive structural modeling and Bayesian network, case of offshore pipeline project. *Reliability Engineering & System Safety*, 142, pp.515–524.

Xie, M. and Tian, Z., (2018) A review on pipeline integrity management utilizing in-line inspection data. *Engineering Failure Analysis*, 92, pp.222–239.

Yadav, O.P., Singh, N., Chinnam, R.B. and Goel, P.S., (2003) A fuzzy logic based approach to reliability improvement estimation during product development. *Reliability Engineering & System Safety*, 801, pp.63–74.

Yang, Y., Khan, F., Thodi, P. and Abbassi, R., (2017) Corrosion induced failure analysis of subsea pipelines. *Reliability Engineering & System Safety*, 159, pp.214–222.

Yazdani-Chamzini, A., (2014) Proposing a new methodology based on fuzzy logic for tunnelling risk assessment. *Journal of Civil Engineering and Management*, [online] 201, pp.82–94. Available at: http://www.tandfonline.com/doi/abs/10.3846/13923730.2013.843583.

Yin, R.K., (2003) Case study research: Design and methods (Vol. 5).

Yoon, H., Park, J., Lim, W., Lee, K., Choi, N., Lee, C. and Moon, I., (2013) Integration of qualitative and quantitative risk assessment methods for gas refinery plants. *Korean Journal of Chemical Engineering*, [online] 307, pp.1368–1374. Available at: http://link.springer.com/10.1007/s11814-013-0057-0.

Zadeh, L.A., (1965) Fuzzy sets. *Information and Control*, 8, pp.338–353.

Zadeh, L.A., (1988) Fuzzy logic. *Computer*, [online] 214, pp.83–93. Available at: http://ieeexplore.ieee.org/document/53/.

Zafra-Cabeza, A., Ridao, M.A., Camacho, E.F., Kempf, K.G. and Rivera, D.E., (2007) Managing risk in semiconductor manufacturing: A stochastic predictive control approach. *Control Engineering Practice*, [online] 158, pp.969–984. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0967066106002292.

Zarei, E., Azadeh, A., Khakzad, N., Aliabadi, M.M. and Mohammadfam, I., (2017) Dynamic safety assessment of natural gas stations using Bayesian network. *Journal of Hazardous Materials*, 321, pp.830–840.

Zhang, L., Kang, J., Zhang, J. and Gao, J., (2016) An integrated framework of safety performance evaluation for oil and gas production plants: Application to a petroleum transportation station. *Journal of Loss Prevention in the Process Industries*, [online] 43, pp.292–301. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0950423016301504.

Zhao, X. and Singhaputtangkul, N., (2016) Effects of Firm Characteristics on Enterprise Risk Management: Case Study of Chinese Construction Firms Operating in Singapore. *Journal of Management in Engineering*, 324, p.5016008.

Zhirov, A., Boltramovich, S. and Kalygin, M., (2017) Natural factors of potential accidents on oil pipelines within northern plains. In: *International Multidisciplinary Scientific GeoConference: SGEM*. Sofia: Surveying Geology & Mining Ecology Management (SGEM), pp.563–570.

APPENDIX A: ETHICAL APPROVAL FIRST AND FINAL DRAFT OF THE SURVEY

Kraidi, Layth

From:	Williams, Mandy
Sent:	22 February 2017 13:51
To:	Kraidi, Layth
Cc:	Research Ethics Proportionate Review; Shah, Raj; Matipa, Wilfred; Borthwick, Fiona
Subject:	Approved - Kraidi
Attachments:	LAYTH KRAIDI Ethics Application2.pdf

Dear Layth

With reference to your application for Ethical Approval:

The University Research Ethics Committee (UREC) considered the above application by proportionate review. I am pleased to inform you that ethical approval has been granted and the study can now commence.

17/BUE/001 - Layth Kraidi, PGR - Development of a risk assessment framework for oil and gas pipeline projects in Iraq (Raj Shah/Wilfred Matipa/Fiona Borthwick)

Note: Please proofread your application for typos

Approval is given on the understanding that:

- any adverse reactions/events which take place during the course of the project are reported to the Committee immediately;
- any unforeseen ethical issues arising during the course of the project will be reported to the Committee immediately;
- the LJMU logo is used for all documentation relating to participant recruitment and participation e.g. poster, information sheets, consent forms, questionnaires. The LJMU logo can be accessed at http://www.ljmu.ac.uk/corporatecommunications/60486.htm

Where any substantive amendments are proposed to the protocol or study procedures further ethical approval must be sought.

Applicants should note that where relevant appropriate gatekeeper / management permission must be obtained prior to the study commencing at the study site concerned.

For details on how to report adverse events or request ethical approval of major amendments please refer to the information provided at http://www.ljmu.ac.uk/RGSO/93205.htm

Please note that ethical approval is given for a period of five years from the date granted and therefore the expiry date for this project will be February 2022. An application for extension of approval must be submitted if the project continues after this date.

LIVERPOOL JOHN MOORES UNIVERSITY

Mandy Williams, Research Support Officer
(Research Ethics and Governance)
Research and Innovation Services
Kingsway House, Hatton Garden, Liverpool L3 2AJ
t: 01519046467 e: a.f.williams@ljmu.ac.uk

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Figure A.1: The ethical approval of the survey.

Table A.1: The first draft of the questionnaire survey (pilot-like survey).

<table>
<tr><td colspan="3">Section I: Introduction and the Participants' Demographic Information A 200-word introduction about the research and the survey</td></tr>
<tr><td>Introduction</td><td colspan="2">A 200-word introduction about the research and the survey</td></tr>
<tr><td>Question 1: Education Degree</td><td>Question 2: The participants’ occupation in OGPs</td><td>Question 3: The participants’ experience in OGPs</td></tr>
<tr><td colspan="3">Section II: The Critical Risk Factors</td></tr>
<tr><td colspan="3">Question 4: How often are the following factors affecting the third-party disruption?
(Always, Very often, Often, Sometimes, Seldom, Does not happen at all and Undecided) (Seven-Point Likert scale)</td></tr>
<tr><td rowspan="6">Security and social *</td><td colspan="2">Public law legal and moral awareness</td></tr>
<tr><td colspan="2">Public socio-political</td></tr>
<tr><td colspan="2">Thieves</td></tr>
<tr><td colspan="2">Terrorism and sabotage</td></tr>
<tr><td colspan="2">Staff threats, kidnapped and murdered</td></tr>
<tr><td colspan="2">Leakage of sensitive information</td></tr>
<tr><td rowspan="4">Pipe's location (Topography) *</td><td colspan="2">Geographical location such as ‘Hot Zones’</td></tr>
<tr><td colspan="2">Conflicts over land ownership</td></tr>
<tr><td colspan="2">Accessibility to pipelines</td></tr>
<tr><td colspan="2">Geological risks</td></tr>
<tr><td rowspan="6">Occupational safety and environment *</td><td colspan="2">Lack of compliance with the safety regulations</td></tr>
<tr><td colspan="2">Non-availability of warning signs</td></tr>
<tr><td colspan="2">Sabotage opportunities arising due to above-the-ground pipeline</td></tr>
<tr><td colspan="2">Natural disasters and weather conditions</td></tr>
<tr><td colspan="2">Traffic accidents</td></tr>
<tr><td colspan="2">Animal attacks</td></tr>
<tr><td rowspan="7">Technical *</td><td colspan="2">Shortage of IT services</td></tr>
<tr><td colspan="2">Corrosion; lack of cathodic protection</td></tr>
<tr><td colspan="2">Pipe's type, age, diameter and length</td></tr>
<tr><td colspan="2">Hacker attacks on the operating or control system</td></tr>
<tr><td colspan="2">Lack of regular inspection and maintenance</td></tr>
<tr><td colspan="2">Operational errors</td></tr>
<tr><td colspan="2">Design and manufacturing defects</td></tr>
<tr><td rowspan="6">Roles and regulations *</td><td colspan="2">Government roles and the laws are not sound</td></tr>
<tr><td colspan="2">Lack of historical records about accidents’ Lack of accident historical records</td></tr>
<tr><td colspan="2">Lack of appropriatetraining schemes</td></tr>
<tr><td colspan="2">Limited researchers are dealing with this problem</td></tr>
<tr><td colspan="2">Stakeholders are not paying appropriateattention</td></tr>
<tr><td colspan="2">Inadequate risk management methods</td></tr>
</table>

	The weak ability to identify and monitor the threats	
	Corruption	
Question 5: Please, rank the above factors from 1-5 in order of the severity on the pipeline. Where 1 means the most critical and 5 is the least critical.	Security and social	Dropdown list (1, 2, 3, 4, 5)
	Pipe's location (Topography)	Dropdown list (1, 2, 3, 4, 5)
	Occupational safety and environment	Dropdown list (1, 2, 3, 4, 5)
	Technical	Dropdown list (1, 2, 3, 4, 5)
	Roles and regulations	Dropdown list (1, 2, 3, 4, 5)
Question 6: Please, write any other risk factors that have not been mentioned in this survey. **(Open-ended question)**		
Section III: Risk Prevention Methods		
Question 7: How often are the following risk production methods used? (Always, Very often, Often, Sometimes, Seldom, Do not use at all and Undecided) **(Seven-Point Likert scale)**		
Early stages of the projects **(Subtitle)**	Risk registration	
	Threat assessment	
	Anti-terrorism design	
	Avoid 'Hot Zones'	
	Move to an underground pipeline	
	Anti-corrosion isolation and cathodic protection	
Later stages of the projects **(Subtitle)**	Patrols	
	Professional remote monitoring	
	Government-public cooperation	
	Appropriate training	
	Warning signs and marker tape above the pipeline	
	Protective barriers and perimeter fencing	
	Appropriate inspection, tests and maintenance	
Question 8: What do you prefer A or B?	A- The aboveground pipeline, although it can often provide sabotage opportunities.	
	B- The underground pipeline, despite the construction and maintenance difficulties.	
Question 9: Please, rank the stages of the project from 1-3 in order of the priority to mitigate pipeline third-party disruption. Where 1 means the highest priority and 3 is the lowest priority.	Planning & design	
	Construction	
	Operation	
Question 10: Please, write any other risk prevention method in your opinion that has not been mentioned. **(Open-ended question)**		
Question 11: Please, if I need additional information, can I contact you? Please provide any contact information if you agree. **(Open-ended question)**		

Table A.2: The final draft of the questionnaire survey.

<table>
<tr><th colspan="4">Section I: Introduction and the Participants' Demographic Information</th></tr>
<tr><td>Introduction A 200-word introduction about the research and the survey</td><td>Question 1: Education Degree</td><td>Question 2: The participants' occupation in OGP projects</td><td>Question 3: The participants' experience in OGP projects</td></tr>
<tr><td colspan="4">Section II: Analysing the Risk Factors</td></tr>
<tr><td rowspan="30">Please, rank the following risk factors which are facing the oil and gas pipeline projects on the scale of likelihood and severity. Please note, to see the two scales, you may need to move the screen to the right or the left.

Question 4: Risk factor likelihood scale. (Almost certain, Likely, Possible, Unlikely and Rare) (Five-Point Likert scale)
Question 5: Risk factor severity and consequence scale. (Catastrophic, Major, Moderate, Minor and Negligible) (Five-Point Likert scale)</td><td colspan="3">Terrorism & sabotage</td></tr>
<tr><td colspan="3">Corruption</td></tr>
<tr><td colspan="3">Insecure areas</td></tr>
<tr><td colspan="3">Lawlessness</td></tr>
<tr><td colspan="3">Thieves</td></tr>
<tr><td colspan="3">Corrosion & lack of protection against it</td></tr>
<tr><td colspan="3">Improper safety regulations</td></tr>
<tr><td colspan="3">Improper inspection & maintenance</td></tr>
<tr><td colspan="3">Public's legal and moral awareness</td></tr>
<tr><td colspan="3">Weak ability to identify & monitor the threats</td></tr>
<tr><td colspan="3">Stakeholders are not paying appropriateattention</td></tr>
<tr><td colspan="3">Lack of appropriatetraining</td></tr>
<tr><td colspan="3">Exposed pipelines</td></tr>
<tr><td colspan="3">Shortage of IT services & modern equipment</td></tr>
<tr><td colspan="3">Limited warning signs</td></tr>
<tr><td colspan="3">The pipeline is easy to access</td></tr>
<tr><td colspan="3">Lack of risk registration</td></tr>
<tr><td colspan="3">Little research on this topic</td></tr>
<tr><td colspan="3">Design, construction & material defects</td></tr>
<tr><td colspan="3">Conflicts over land ownership</td></tr>
<tr><td colspan="3">Threats to staff</td></tr>
<tr><td colspan="3">The education and poverty levels in OGP areas</td></tr>
<tr><td colspan="3">Operational errors</td></tr>
<tr><td colspan="3">Inadequate risk management</td></tr>
<tr><td colspan="3">Leakage of sensitive information</td></tr>
<tr><td colspan="3">Geological risks</td></tr>
<tr><td colspan="3">Natural disasters & weather conditions</td></tr>
<tr><td colspan="3">Vehicle accidents</td></tr>
<tr><td colspan="3">Hacker attacks on the operating or control system</td></tr>
<tr><td colspan="3">Animal accidents</td></tr>
<tr><td rowspan="2">Question 6: Please, compare the main risk factors overall, and rank them from 1 - 5.</td><td colspan="3">Security & Social (S&S)</td></tr>
<tr><td colspan="3">Pipes' Location (PL)</td></tr>
</table>

Where: 1 means the highest risk factor, and 5 means the lowest risk. **Dropdown list (1, 2, 3, 4, 5)**	Health, Safety and Environments (HSE) Rules and Regulation (R&R) Operational Constraints (OC)
Question 7: Please, write any other risk factor in your opinion that has not been mentioned.	
Section III: Evaluating Risk Mitigations Methods	
Please, rank the following risk protection methods regarding the degree of application and effectiveness. **Question 8**: Protection methods usage scale. (Almost certainly used, Likely used, Possibly used, Unlikely used and Rarely used) **(Five-Point Likert scale)** **Question 9**: Protection methods effectiveness scale. (Extremely effective, Very effective, Moderately effective, Slightly effective and Ineffective) **(Five-Point Likert scale)**	Avoid ‘Insecure Zones’ Anti-terrorism design Avoid the registered risks and threats Appropriate training Move to an underground pipeline Anti-corrosion measures such as isolation and cathodic protection Protective barriers and perimeter fencing Warning signs and marker tape above the pipeline Foot and vehicle patrols High technology and professional remote monitoring Government-public cooperation Appropriate inspection, tests and maintenance
Question 10: Which project stage is the most critical stage to mitigate the pipeline risks? Where 1 means the most critical and 3 is the least critical. **Dropdown list (1, 2, 3)**	During the planning and design stage, for example, avoid the ‘Insecure Zones’ and the registered risks and threats; anti-terrorism design; and appropriatetraining. During the construction stage, for example, move to an underground pipeline, corrosion protection, protective barriers and perimeter fencing, warning signs and marker tape above the pipeline. During the operation stage, for example, patrols; high technology and professional remote monitoring; government-public cooperation; and appropriateinspection and maintenance.
Question 11: Overall, by comparing between the above and underground pipelines, which pipeline has the least chance of third-party risk disruption?	The aboveground pipeline, although it is exposed, and it can provide sabotage and theft opportunities. The underground pipeline, despite the corrosion, geological, construction and maintenance risks.
Question 12: Please, write any other risk prevention method in your opinion that has not been mentioned.	
Please, if I need additional information, could I contact you? Please provide any contact information if you agree.	

APPENDIX B: THE SURVEY PARTICIPANTS' COMMENTS

Table B.1: The comments of the participants about adding IRFs to the survey.

Response No.	Comment
3	The brand of the pipes and their quality
78	The manufacturing defects of the pipes
109	Type of material of the pipe (chemical composition of the metal)
105	We can add the age of the pipe
178	Passing the design capacity and using the non-original spare parts
5	The welding is not following the international standers and the brand of the pipes and the coating materials
6	Executive errors
146	Industrial cheating
29	The construction and operational errors
128	The damages the caused by other construction work during the drilling of new pipes, and also to the aging of the pipes and maintenance, the survival of the pipes immersed in areas containing oil derivatives produced by old damage, which negatively affects the packaging of the new pipe and thus increase the rate of damage and the difficulty of maintenance in the future, Passage of machinery and equipment over pipes.
183	the slackness during the construction and corruption
18	The conflicts between the employers within the oil companies, which do not solve administratively and turn into acts of settling accounts through sabotage and without deterrence
22	The concern of the managers about the corruption to steal public money and lack of attention about the safety of the staff and citizen. The complicity of the weak souls of the local people and the employees of the region with the sabotages and the terrorists.
199	The corruption of the site managers
15	Blasting the pipes for the benefits of the contractor. As well as the security and political factor of the country is the most influence factors over all
87	The lack of guards along the pipelines
39	The lack of border controls of the country engorges the sabotages to damage the pipes to steal the products to sell it outside the country
68	The foreign oil and gas companies tend to prefer countries with stable political systems and a history of granting and enforcing long-term leases. However, some companies simply go where the oil and gas is, even if a particular country doesn't quite match their preferences. Numerous issues may arise from this, including sudden nationalization and/or shifting political winds that change the regulatory environment. Depending on what country the oil is being extracted from, the deal a company starts with is not always the deal it ends up with, as the government may change its mind after the capital is invested, in order to make more profit for itself.
30	Thefts and not punishing the thieves
17	Passing the pipelines via agricultural areas is exposing them directly for damage
79	Choose the pipelines routes accurately and taking the future urban planning into account
81	Moving the dangerous of fire and vapours far from the residence areas
38	Corrosion
198	Misuse of shrinkage and expansion joints for long pipeline fitting. Neglecting the use of cathodic and anodic protection systems and thus not controlling high corrosion rates.
33	The nature of the pumped fluid in special the silver contents
75	Non-stability in the raw specification (change in Apl between one field and another) and the difference of sulphur content of oil between field and another, which negatively affects the alloy pipe and thus the occurrence of cracking in the long term
65	Pump several product in the same pipeline

99	The non-isolation of salts from oil is considered one of the important reasons for the corrosion of oil pipelines
27	The health status of labours
43	Not to choose the right people to work
86	Nepotism
93	Put the unqualified person in the wrong place and nepotism and negligence
97	Non-specialised labours
103	Sagging in the staff and the lack of seriousness in taking responsibilities and duties.
114	The lack of experience in dealing with problems
121	Negative human behaviour
127	Choose the companies that have done successful pipeline projects with sufficient experience to carry out the construction work
197	The stakeholders are not well educated about risk management and fail to provide public safety
57	The lack of teamwork and exchange of experiences and finding solutions. The lack of communications with the researchers and not following the studies about the risk management. There is no platform to receive new ideas and studies about the pipelines' safety. And not turned the ideas into action. There is no schedule timetables to solve the problems. There is a need for new rules that commit the decision makers and managers are to identify the risks and examine their solutions with experts.
62	The organisational cultural and the organisational structure of the companies
44	The high prices of oil products
85	International conventions for the pipelines that crossing the neighbour countries
112	The government and the oil ministry do not consider the pipelines as significance sites and their exposure due to the sovereignty, security and stability of the country
69	The obsession of the parties and the weakness of the government control
82	There is no risk that has not been mentioned
16	No comment
20	No comment
24	No comment
96	No comment
173	No comment
190	No comment

Table B.2: Analysis of the participants' comments about adding IRFs to the survey

comment	The Type of the IRFs in the comment
The brand of the pipes and their quality	Martials quality and type
The manufacturing defects of the pipes	Martials quality and type
Type of material of the pipe (chemical composition of the metal)	Martials quality and type
We can add the age of the pipe	Martials quality and type
Passing the design capacity and using the non-original spare parts	Operational errors
The welding is not following the international standers and the brand of the pipes and the coating materials	Construction Defects
Executive errors	Construction Defects
Industrial cheating	Construction Defects
The construction and operational errors	Construction Defects
The damages the caused by other construction work during the drilling of new pipes, and also to the aging of the pipes and maintenance, the survival of the pipes immersed in areas containing oil derivatives produced by old damage, which negatively affects the packaging of the new pipe and thus increase the rate of damage and the difficulty of maintenance in the future, Passage of machinery and equipment over pipes.	Construction Defects
the slackness during the construction and corruption	Construction Defects
The conflicts between the employers within the oil companies, which do not solve administratively and turn into acts of settling accounts through sabotage and without deterrence	Corruption
The concern of the managers about the corruption to steal public money and lack of attention about the safety of the staff and citizen. The complicity of the weak souls of the local people and the employees of the region with the sabotages and the terrorists.	Corruption
The corruption of the site managers	Corruption
Blasting the pipes for the benefits of the contractor. As well as the security and political factor of the country is the most influence factors over all	Security
The lack of guards along the pipelines	Security
The lack of border controls of the country engorges the sabotages to damage the pipes to steal the products to sell it outside the country	Security
The foreign oil and gas companies tend to prefer countries with stable political systems and a history of granting and enforcing long-term leases. However, some companies simply go where the oil and gas is, even if a particular country doesn't quite match their preferences. Numerous issues may arise from this, including sudden nationalization and/or shifting political winds that change the regulatory environment. Depending on what country the oil is being extracted from, the deal a company starts with is not always the deal it ends up with, as the government may change its mind after the capital is invested, in order to make more profit for itself.	Security
Thefts and not punishing the thieves	Security
Passing the pipelines via agricultural areas is exposing them directly for damage	geographical location "agricultural areas"
Choose the pipelines routes accurately and taking the future urban planning into account	geographical location "urban planning"
Moving the dangerous of fire and vapours far from the residence areas	geographical location
Corrosion	Operational errors
Misuse of shrinkage and expansion joints for long pipeline fitting. Neglecting the use of cathodic and anodic protection systems and thus not controlling high corrosion rates.	Operational errors
The nature of the pumped fluid in special the silver contents	The type of the product
Non-stability in the raw specification (change in Apl between one field and another) and the difference of sulphur content of oil between field and another, which negatively affects the alloy pipe and thus the occurrence of cracking in the long term	The type of the product

Pump several products in the same pipeline	The type of the product
The non-isolation of salts from oil is considered one of the important reasons for the corrosion of oil pipelines	The type of the product
The health status of labours	Labours
Not to choose the right people to work	Labours
Nepotism	Labours
Put the unqualified person in the wrong place and nepotism and negligence	Labours
Non-specialised labours	Labours
Sagging in the staff and the lack of seriousness in taking responsibilities and duties.	Labours
The lack of experience in dealing with problems	Labours
Negative human behaviour	Labours
Choose the companies that have done successful pipeline projects with sufficient experience to carry out the construction work	Labours
The stakeholders are not well educated about risk management and fail to provide public safety	Labours
The lack of teamwork and exchange of experiences and finding solutions. The lack of communications with the researchers and not following the studies about the risk management. There is no platform to receive new ideas and studies about the pipelines' safety. And not turned the ideas into action. There is no schedule timetables to solve the problems. There is a need for new rules that commit the decision makers and managers are to identify the risks and examine their solutions with experts.	Labours
The organisational cultural and the organisational structure of the companies	
The high prices of oil products	Social
International conventions for the pipelines that crossing the neighbour countries	Governmental factors
The government and the oil ministry do not consider the pipelines as significance sites and their exposure due to the sovereignty, security and stability of the country	Governmental factors
The obsession of the parties and the weakness of the government control	Governmental factors
There is no risk that has not been mentioned	
No comment	
No comment	
No comment	
No comment	
No comment	
No comment	

Table B.3: The comments of the participants about adding RMMs to the survey.

Response No	The comments from the survey
5	Construct the B.R.C barriers on the both sides of the tube to reduce the risk of being exposed to the pipe and for easy maintenance
6	Using high technology to monitor the pipelines
18	Periodic maintenance
20	Using different pipes brand that bears the corrosion
22	Evacuation of illegal residents from the areas of pipelines. Expand protection zones along pipelines. Appropriatemonitoring and development of the cathodic protection system.
24	Satellite monitoring for 24 hours
27	CCTV
29	Counting Covers
30	Using high technology
37	The purchase of high-quality pipes based on international companies and the presence of a specialized department and an expert in the engineering examination to ensure the certificates of laboratory examination.
38	Use optimisers
43	Employ people to monitor the pipelines daily using modern technology
50	Monitor the pipelines by aircraft
53	Monitor pipelines with modern technology such as airplanes and marching cameras
55	The most important point in the subject to avoid passing near the people both as a city or outside the city in "rural areas". It has happened one time, that we have a lot of problems in the pipes of Majnoon where there are two breeders buffalo breeders and threatened to give them financial ratios and employ their people.
57	The imposition of fines and strict laws for the relevant bodies, including the public if the agreement between the government and them to protect the pipes
62	Take advantage of previous lessons in the oil sector
79	Constant monitoring and the of deterrence sanctions on transgressors
87	The need to dig security trenches surrounded by warehouses and pipelines
89	The thief and the terrorist do not care if the pipe is open or buried because it is stolen or destroyed. The cost of an exposed pipe is cheaper and its maintenance is easier and may be less costly than protection.
95	Covering the pipes especially the river crossing
109	Use high-quality covering material. With continuous use of cathodic protection.
112	Inform people of the need to report any doubts about the vulnerability of the network and prepare a team ready to receive and verify complaints.
113	The pipes can be extended inside concrete slabs as well as burial
127	Air monitoring of the pipes because it covers large spaces and distances
178	It is possible to reduce the pumping the oil products for the final product from the refinery to the port, ie make the refinery close to the final product line and the possibility of transporting the crude oil or kerosene by train or sea freight buoys
183	Construct the B.R.C barrier

Table B.4: Analysis of the participants' comments about adding RMMs to the survey.

The comments from the survey	Type		Frequency
Construct the B.R.C barriers on the both sides of the tube to reduce the risk of being exposed to the pipe and for easy maintenance	Barriers		1
Using high technology to monitor the pipelines	Advanced IT System		2
Periodic maintenance	Maintenance		3
Using different pipes brand that bears the corrosion	Pipe Brand		4
Evacuation of illegal residents from the areas of pipelines. Expand protection zones along pipelines. Appropriatemonitoring and development of the cathodic protection system.	Barriers	Anti Corrosion	5
Satellite monitoring for 24 hours	Advanced IT System		6
CCTV	Advanced IT System		7
Counting Covers	Anti Corrosion		8
Using high technology	Advanced IT System		9
The purchase of high-quality pipes based on international companies and the presence of a specialized department and an expert in the engineering examination to ensure the certificates of laboratory examination.	Pipe Brand	Experts	10
Use optimisers	Product Type		11
Employ people to monitor the pipelines daily using modern technology	Grads		12
Monitor the pipelines by aircraft	Advanced IT System		13
Monitor pipelines with modern technology such as airplanes and marching cameras	Advanced IT System		14
The most important point in the subject to avoid passing near the people both as a city or outside the city in "rural areas". It has happened one time, that we have a lot of problems in the pipes of Majnoon where there are two breeders buffalo breeders and threatened to give them financial ratios and employ their people.	Geographical Location		15
The imposition of fines and strict laws for the relevant bodies, including the public if the agreement between the government and them to protect the pipes	Government and Public cooperation		16
Take advantage of previous lessons in the oil sector	Risk registration		17
Constant monitoring and the of deterrence sanctions on transgressors	Rules and regulation		18
The need to dig security trenches surrounded by warehouses and pipelines	Barriers		19
The thief and the terrorist do not care if the pipe is open or buried because it is stolen or destroyed. The cost of an exposed pipe is cheaper and its maintenance is easier and may be less costly than protection.			20
Covering the pipes especially the river crossing	Anti Corrosion		21

Use high-quality covering material. With continuous use of cathodic protection.	Anti Corrosion		22
Inform people of the need to report any doubts about the vulnerability of the network and prepare a team ready to receive and verify complaints.	Government and Public cooperation		23
The pipes can be extended inside concrete slabs as well as burial	Anti Corrosion		24
Air monitoring of the pipes because it covers large spaces and distances	Advanced IT System		25
It is possible to reduce the pumping the oil products for the final product from the refinery to the port, ie make the refinery close to the final product line and the possibility of transporting the crude oil or kerosene by train or sea freight buoys	Product Type		26
Construct the B.R.C barrier	Barriers	Geographical Location	27
Comments analysis			
Type	Frequency	Percentage (100%)	
Advanced IT System	7	24.13793103	
Anti-Corrosion	5	17.24137931	
Barriers	4	13.79310345	
Pipe Brand	2	6.896551724	
Product Type	2	6.896551724	
Geographical Location	2	6.896551724	
Government and Public cooperation	2	6.896551724	
Maintenance	1	3.448275862	
Experts	1	3.448275862	
Grads	1	3.448275862	
Risk registration	1	3.448275862	
Rules and regulation	1	3.448275862	
Total	29		

APPENDIX C: DOCUMENTS FROM THE PROJECT

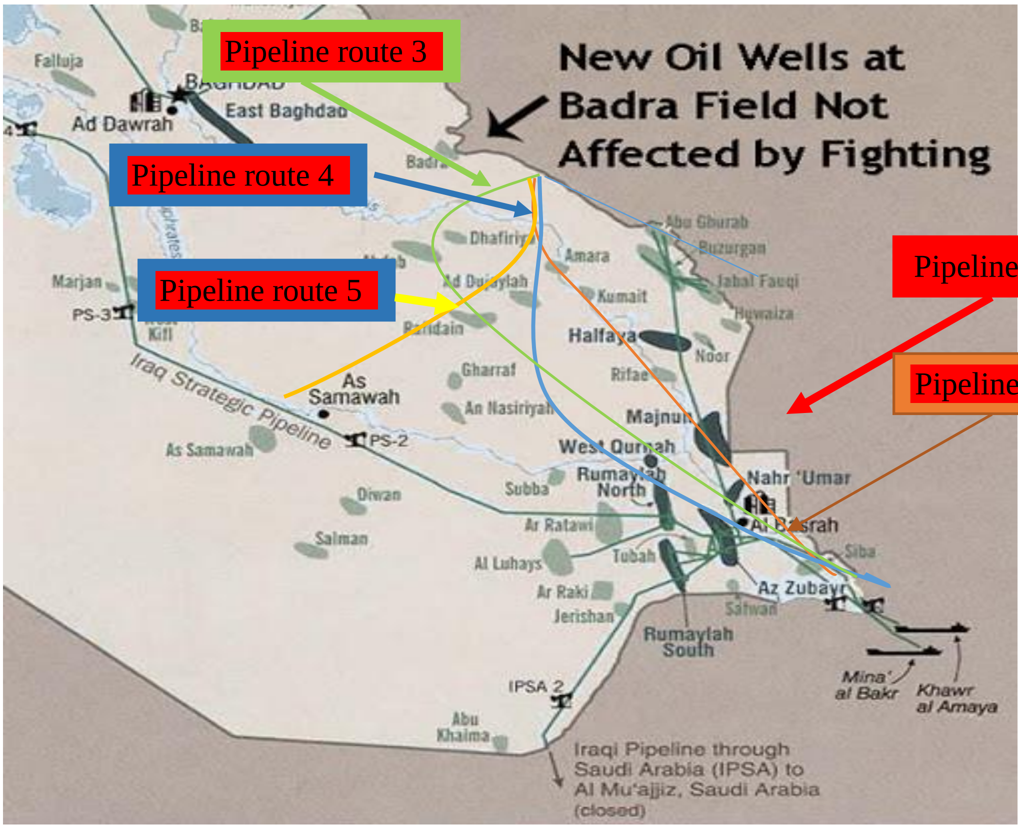


Figure C.1: The five pipeline routes of the project.

Table C.1: The collected documents from the project.

Report No	Report title	Report type	The company(s) generated the report	The company(s) used the report
03516.PLI.MEC.SDS Rev. 1 July 2012	COMPANY SPECIFICATION CONSTRUCTION AND INSTALLATION OF ONSHORE PIPELINE	Company specification	eni spa exploration & production division	The partners involved in the project
Company Identification 250600DBQR7410P Owner Identification IQ022-00-0805-SC-0010	ENI – IRAQ ZUBAIR OIL FIELD DEVELOPMENT PROJECT MULTIPHASE PIPELINES BETWEEN DGS Procedure for	Company specification	eni spa exploration & production division	ZFOD, MOC, eni, SOC, and KOGas

	Pipeline Survey and Setting Out			
IQ022-TZ-2001-SI-003	IRAQ-ZUBAR OIL FIELD DEVELOPMENT PROJECT - SOW FOR 26" MULTIPHASE TRUNKLINES	DOCUMENT TITLE: SOW for 26" Multiphase Trunklines	SICIM	The partners involved in the project
Revision 2	ZUBAR OIL FIELD DEVELOPMENT PROJECT - SOW FOR 26" MULTIPHASE TRUNKLINES	Sit Map	MSK	MSK
Owner Document Identification 2506-GA-E-60910	ENI – IRAQ ZUBAIR OIL FIELD DEVELOPMENT PROJECT PIPELINE GENERAL WELDING SPECIFICATION	PIPELINE GENERAL WELDING SPECIFICATION	eni spa exploration & production division	The partners involved in the project
20550.PIP.COR.FUN Rev.02 –Dec 2015	External Coatings Corrosion Protection Of Steel Pipes and Components	Functional Specification	eni spa exploration & production division	The partners involved in the project
03516.PLI.MEC.SDS Rev. 1 July 2012	CONSTRUCTION AND INSTALLATION OF ONSHORE PIPELINE	COMPANY SPECIFICATION	eni spa exploration & production division	The partners involved in the project
DOC.NO.: HFY3-3682-01-GEN-MPR-0001	HALFAYA PROJECT SURFACE FACILITY PHASE THREE	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-GEN-WPR-0002	Provision of Engineering and Construction of Flow Lines and Trunk Lines (2018-2021)"	WEEKLY PROGRESS REPORT	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
Job No: PRID No: 3682-01	Project Titel: Engineering and Construction of Flow Lines and Trunk Lines (2018-2021)	WELD LOG HISTORY	FUTUREWILL	The partners involved in the project
Project ID (PRID): 3682-01	ENGINEERING AND CONSTRUCTION OF FLOWLINES AND TRUCKLINES (2018-2021)	WELD LOG HISTORY	FUTUREWILL	The partners involved in the project

HFY3-3575-PPL-DWG-001	General drawing and deign	Right of Way	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-014	General drawing and deign	Warning Tape	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-013	General drawing and deign	Masonry slope	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-012	General drawing and deign	Balance Bag	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-011	General drawing and deign	Balance block	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-010	General drawing and deign	Mile Post, Turning Post, Marker Post	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-009	General drawing and deign	River, Channel, Road and HDD Crossing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-008	General drawing and deign	River, Channel, Road and Excavation Crossing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-007	General drawing and deign	River, Channel, Road and Culvert Crossing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-006	General drawing and deign	River, Channel, Road and Jacking Crossing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-005	General drawing and deign	Road Excavation Crossing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-004	General drawing and deign	Underground cable Crossing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-003	General drawing and deign	Underground pipeline Crossing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-DWG-002	General drawing and deign	Pipeline trenching detail	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-PPL-02-DWG-004	General drawing and deign	Pipeline trenching detail and welding joints	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.

HFY3-3575-02-CP-DWG-003	General drawing and deign	Cathodic protection for road crossing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-02-CP-DWG-002	General drawing and deign	Temporary cathodic protection for road crossing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY3-3575-02-CP-DWG-00	General drawing and deign	installation drawing	PetroChina International Iraq FZE Iraq Branch	China Petroleum Engineering Co. Ltd.
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk Lines (2018-2021)”	Procedure for Civil Work Construction	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-PPL-ITP-0003 REV.: B	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Standard ITP & Inspection Checklist Earth-Work	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	PROJECT EXECUTION PLAN	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	PROJECT QUALITY PLAN	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Procedure for handling, processing, evaluation, filling and storage for radiographic film	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Ultrasonic Test Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	MT Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	PT Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project

HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Welding Consumable Control Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/06	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Welding Consumable Control Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/05	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Weld repair procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Procedure Qualification Record - PQR & Welder Performance Qualification Test Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Radiographic Testing Procedures	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Weld Inspection Procedures	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/01	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Weld Inspection Procedures	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY-CON/F&C0869-0893/03	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	HSE Plan	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
HFY3-3682-01-HSE-PD-0009	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Hazard Identification & Risk Assessment Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-HSE-PD-0008	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Driving Safety Guidelines Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project

DOC.NO.: HFY3-3682-01-HSE-PD-0007	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Security Policy & Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-HSE-PD-0006	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Permit to Work Management Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-HSE-PD-0005	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Radiography Safety Guidelines Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-HSE-PD-0004	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Environmental Protection Management Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-HSE-PD-0003	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Safety Training Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-HSE-PD-0002	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Emergency Response Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-HSE-PD-0001	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Lifting Procedure	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-FW-PCH-T-0010	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Halfaya Oil Field Surface Facility Phase 3 Project	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-PLA-SCH-0001	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Project Baseline Schedule	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project
DOC.NO.: HFY3-3682-01-PLA-PMS-0001	Provision of Engineering and Construction of Flow Lines and Trunk lines (2018-2021)	Progress Measurement system	Petrochina (Halfaya) and FUTUREWILL	The partners involved in the project

	RISK MANAGEMENT PROCEDURE		KHAERAT MSK	The partners involved in the project
CLOSED DRAIN DRUM 04-May-19		Time plan	GAZPROM NEFT	The partners involved in the project
	Time Schedule - ZB-266 FL	Time plan	MSK	The partners involved in the project
	Time Schedule - ZB-93 FL	Time plan	MSK	The partners involved in the project
	WEEKLY PLAN FOR TRUNK LINE -3	Time plan	MSK	The partners involved in the project
	Time Schedule Plan For TK03	Time plan	MSK	The partners involved in the project
	Time Schedule - Cluster 01 FL	Time plan	MSK	The partners involved in the project
	Project plan	Time plan	MSK	The partners involved in the project
Project ID (PRID): 3682-01	ENGINEERING AND CONSTRUCTION OF FLOWLINES AND TRUCKLINES (2018-2021)	Time plan	MSK	The partners involved in the project
GB095-BA01-300-PL-DW-007	Typical pipeline Construction in Seismological Critical Areas	Design Drawing	GAZPROM NEFT	The partners involved in the project
095-12-BD-174-00	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	PIPELINE INSTALLATION AND CALCULATION IN SEISMOLOGICALLY CRITICAL AREA	GAZPROM NEFT & CCP	China Petroleum Pipeline Bureau
095-12-BD-174-00	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Specification for Earth Work and Site Preparation	GAZPROM NEFT & CCP	China Petroleum Pipeline Bureau
GB095-BA01-300-CV-SP-002	EPC OIL EXPORT PIPELINE	Specification for Geotechnical Survey and Soil Investigation	GAZPROM NEFT & CCP	China Petroleum

	BADRA-GHARRAF (Phase I) AT BADRA OILFIELD			Pipeline Bureau
095-12-BD-174-00-GB95	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Site Survey Drawing and GPS Coordination	GAZPROM NEFT & CCP	The partners involved in the project
095-12-BD-174-04-GB95	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Typical Site Survey Drawing and GPS Coordination	GAZPROM NEFT & CCP	China The partners involved in the project
GB000-307758-500-CV-TQ-001	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Technical Query-Soil data for Badra	GAZPROM NEFT & CCP	China Petroleum Pipeline Bureau
GB000-307758-500-CV-TQ-011	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Specification for Geotechnical Investigations	GAZPROM NEFT & CCP	China Petroleum Pipeline Bureau
GB000-307758-500-CV-TQ-002	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Geotechnical Basis of Design	GAZPROM NEFT & CCP	China Petroleum Pipeline Bureau
GB000-307758-500-CV-TQ-003	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Specification for Bathymetrical Survey	GAZPROM NEFT & CCP	China Petroleum Pipeline Bureau
GB000-307758-500-CV-TQ-001	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Pipeline Design Basis	GAZPROM NEFT & CCP	China Petroleum Pipeline Bureau
GB000-307758-300-CV-TQ-001	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Civil and Structural Design Basis	GAZPROM NEFT & CCP	China Petroleum Pipeline Bureau

GB000-307758-400-PL-DW-008	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Typical crossing of HV overhead power lines	GAZPROM NEFT	Mott MacDonald
GB000-307758-400-PL-DW-001	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Typical pipeline trenching for different soil types	GAZPROM NEFT	Mott MacDonald
GB000-307758-400-PL-DW-010	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Typical pipeline construction in seismologically critical areas	GAZPROM NEFT	Technip
GB000-7044T-000-DW-3247 001	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Typical pipeline trenching for different soil types	GAZPROM NEFT	Technip
GB000-7044T-000-BOD-1400- 010	FEED of Production Infrastructure for Badra Oilfield	Geotechnical Basis of Design For CPF	GAZPROM NEFT	The partners involved in the project
GB000-307758-400-CV-SP-011	FEED Update for Gas Export pipeline	Specification for Geotechnical Investigation	GAZPROM NEFT	Mott MacDonald
GB000-307758-400-CV-SP-019	FEED Update for Gas Export pipeline	Specification for Pipeline Installation in Seismological Critical Areas	GAZPROM NEFT	Mott MacDonald
GB000-7044T-0000-CN-3231-003	FEED of Production Infrastructure for Badra Oilfield	Pipeline Installation in Seismological Critical Areas	GAZPROM NEFT	Mott MacDonald
GB095-BA01-300-CV-RM-218	EPC OIL EXPORT PIPELINE BADRA-GHARRAF (Phase I) AT BADRA OILFIELD	Geotechnical Survey and Soil Investigation Report for Al Mzaak Canal and Al Rahma Crossing	Gazprom Neft Badra B.V.	China Petroleum Pipeline Bureau

APPENDIX D: THE ALLOCATION OF THE IRFS TO THE PROJECT ACTIVITIES

The IRFs were allocated to the project activites after a careful read and subjective and objective analysis of the following documents:

1- CEPA and INGAA (2016), which is a practical guide for pipeline construction, prepared by two well-known foundations working on pipeline projects.
2- F.T.A. (2019), which is a step-by-step guide for pipeline construction prepared by FracTracker Alliance, which is a support group addressing pressing extraction-related concerns with a lens towards health effects and exposure risks on communities from oil and gas development in the USA.
3- Nandagopal (2007), which is a book about "*Pipeline Systems - Designing, Construction, Maintenance and Asset Management*".
4- Folga (2007), which is a book about "*General and Special Pipeline Construction Procedures*" for "*Aboveground Facility Construction Procedures*" for natural gas pipelines.
5- Center Point Enrgy (2019), which is a brief report about pipeline design and construction.

Table D.1: The allocation of the IRFs to the project activities.

The activities of the project	The IRFs								
Concept and definitions	Terrorism, sabotage and the security risk	Stealing the products	Low public legal and moral awareness	Staff threats	Socio-political effects	Leakage of sensitive information	Corruption	The absence of law on TPD	Lack of risk management practice
Life-cycle plan						3.38	3.87		
Choosing the route(s)	3.99	3.75	3.8		3.49	3.38	3.87		
Route(s) approval	3.99	3.75	3.8		3.49	3.38	3.87		3.51
Design and development	3.99	3.75	3.8		3.49	3.38	3.87		
Manufacturing and installation (procedure/plan)	3.99					3.38	3.87		
Risk assessment and management plans							3.87		3.51
Time schedule						3.38	3.87		3.51
Cost estimation							3.87		

Staking for construction and Communications							3.87		
Materials order						3.38	3.87		
Survey, staking and setting out							3.87		
Clearing and grading the Right-Of-Way (ROW)	3.99		3.8	3.35	3.49	3.38	3.87	3.54	3.51
Topsoil stripping and Front-end grading	3.99		3.8	3.35	3.49		3.87	3.54	3.51
Buildings, roads and rivers crossings	3.99			3.35			3.87		3.51
Pipe transporting to sit	3.99		3.8	3.35	3.49		3.87	3.54	3.51
Temporary fencing and signage	3.99			3.35			3.87	3.54	
Trenching	3.99			3.35			3.87	3.54	
Temporary erosion control and side support	3.99			3.35		3.38	3.87		
Pipe set-up	3.99			3.35			3.87		3.51
Welding, fabrication and installing pipe	3.99			3.35			3.87		3.51
NDT tests				3.35			3.87		3.51
SAND BLAST				3.35			3.87		
Painting				3.35			3.87		
Coating				3.35			3.87		
Lowering pipe in and backfilling	3.99	3.75		3.35			3.87		3.51
Cathodic Protecting the pipe				3.35		3.38	3.87		3.51
Final fitting	3.99	3.75	3.8	3.35		3.38	3.87		3.51
As-built survey				3.35			3.87		3.51
Hydro, pressure test				3.35		3.38	3.87		
Backfilling				3.35			3.87		
Fencing and signage							3.87		
Final clean-up		3.75		3.35	3.49		3.87	3.54	3.51
Right-of-way reclamation	3.99			3.35			3.87		3.51
Safety barriers	3.99			3.35	3.49		3.87		3.51
Operation within design limits	3.99	3.75		3.35		3.38	3.87	3.54	3.51
Commissioning operation value	3.99	3.75	3.8	3.35	3.49	3.38	3.87	3.54	3.51
Measure the performance and efficiency	3.99	3.75	3.8	3.35	3.49	3.38	3.87	3.54	3.51

Enhanced performance and efficiency							3.87		
Monitoring and inspection of pipelines	3.99	3.75	3.8	3.35	3.49	3.38	3.87	3.54	3.51
Preventive and predictive maintenance of facilities			3.35			3.87			3.71
Risk Management (Risk evaluation and Reduced risk)	3.75	3.8	3.35		3.38	3.87	3.54		3.71
Concept and definitions	Geographical location	The pipeline is easy to access	Conflict over land ownership	Geological risks such as groundwater and landslides	Vehicles accidents	Animals accidents	Improper safety regulations		
Life-cycle plan									
Choosing the route(s)							3.7		
Route(s) approval		3.68	3.57	3.17	2.8	1.95	3.7		
Design and development		3.68	3.57	3.17	2.8	1.95	3.7		
Manufacturing and installation (procedure/plan)				3.17			3.7		
Risk assessment and management plans									
Time schedule		3.68	3.57	3.17			3.7		
Cost estimation									
Staking for construction and Communications									
Materials order									
Survey, staking and setting out									
Clearing and grading the Right-Of-Way (ROW)	3.76	3.68	3.57				3.7		
Topsoil stripping and Front-end grading	3.76		3.57		2.8	1.95	3.7		
Buildings, roads and rivers crossings	3.76		3.57				3.7		
Pipe transporting to sit	3.76		3.57	3.17	2.8	1.95	3.7		
Temporary fencing and signage	3.76		3.57		2.8	1.95	3.7		
Trenching		3.68	3.57				3.7		
Temporary erosion control and side support	3.76		3.57				3.7		
Pipe set-up	3.76			3.17			3.7		

Welding, fabrication and installing pipe			3.57				3.7		
NDT tests							3.7		
SAND BLAST							3.7		
Painting							3.7		
Coating									
Lowering pipe in and backfilling	3.76			3.17			3.7		
Cathodic Protecting the pipe			3.57				3.7		
Final fitting	3.76			3.17			3.7		
As-built survey							3.7		
Hydro, pressure test							3.7		
Backfilling							3.7		
Fencing and signage			3.57	3.17			3.7		
Final clean-up	3.76		3.57				3.7		
Right-of-way reclamation							3.7		
Safety barriers	3.76		3.57				3.7		
Operation within design limits					2.8	1.95	3.7		
Commissioning operation value	3.76	3.68	3.57	3.17	2.8	1.95	3.7		
Measure the performance and efficiency	3.76	3.68	3.57	3.17	2.8	1.95	3.7		
Enhanced performance and efficiency							3.7		
Monitoring and inspection of pipelines	3.76	3.68	3.57	3.17	2.8	1.95	3.7		
Preventive and predictive maintenance of facilities			3.17			3.7	3.69		
Risk Management (Risk evaluation and Reduced risk)			3.17			3.7	3.69		
Concept and definitions									
Life-cycle plan									
Choosing the route(s)	3.7		3.48	3.1	3.72	3.67	3.68	3.3	
Route(s) approval		3.56	3.48	3.1		3.67	3.68		
Design and development		3.56	3.48	3.1		3.67	3.68		
Manufacturing and installation (procedure/plan)			3.48			3.67	3.68		
Risk assessment and management plans					3.72		3.68		
Time schedule			3.48	3.1		3.67	3.68		
Cost estimation						3.67	3.68		

Staking for construction and Communications						3.67	3.68		
Materials order							3.68		
Survey, staking and setting out							3.68		
Clearing and grading the Right-Of-Way (ROW)	3.7		3.48	3.1		3.67	3.68		
Topsoil stripping and Front-end grading	3.7		3.48	3.1		3.67	3.68		
Buildings, roads and rivers crossings	3.7		3.48	3.1		3.67	3.68		
Pipe transporting to sit	3.7		3.48	3.1		3.67	3.68		
Temporary fencing and signage	3.7		3.48	3.1		3.67	3.68		
Trenching	3.7		3.48			3.67	3.68		
Temporary erosion control and side support			3.48	3.1		3.67	3.68		
Pipe set-up	3.7		3.48	3.1		3.67	3.68		
Welding, fabrication and installing pipe						3.67	3.68		
NDT tests						3.67	3.68		
SAND BLAST						3.67	3.68		
Painting					3.72		3.68		
Coating					3.72		3.68		
Lowering pipe in and backfilling					3.72		3.68		
Cathodic Protecting the pipe			3.48			3.67	3.68		
Final fitting				3.1	3.72	3.67	3.68		
As-built survey							3.68		
Hydro, pressure test							3.68		
Backfilling							3.68		
Fencing and signage						3.67	3.68		
Final clean-up	3.7	3.56	3.48			3.67	3.68		
Right-of-way reclamation			3.48			3.67	3.68		
Safety barriers			3.48	3.1		3.67	3.68		
Operation within design limits			3.48			3.67	3.68		
Commissioning operation value	3.7		3.48	3.1	3.72	3.67	3.68	3.3	
Measure the performance and efficiency	3.7		3.48	3.1	3.72	3.67	3.68	3.3	

Enhanced performance and efficiency			3.48			3.67	3.68		
Monitoring and inspection of pipelines	3.7		3.48	3.1	3.72	3.67	3.68	3.3	
Preventive and predictive maintenance of facilities		3.48	3.1		3.67	3.68			
Risk Management (Risk evaluation and Reduced risk)		3.48	3.1		3.67	3.68			

Table D.2: The total risk and risk levels of the project activities.

The activities of the project	The RFs			The total risk in the activity	The total risk from 100%	Risk level
Concept and definitions					0.859989363	LOW
Life-cycle plan				71.8	3.409565779	VERY HIGH
Choosing the route(s)	3.64	3.64	3.03	76.65	3.639877674	VERY HIGH
Route(s) approval		3.64		73.14	3.473198344	VERY HIGH
Design and development		3.64		43.44	2.062834783	MEDIUM
Manufacturing and installation (procedure/plan)		3.64		29.28	1.390419025	LOW
Risk assessment and management plans		3.64		49.67	2.358678722	HIGH
Time schedule				22.08	1.048512708	LOW
Cost estimation				22.08	1.048512708	LOW
Staking for construction and Communications				25.43	1.207594119	LOW
Materials order		3.64		18.41	0.874235459	LOW
Survey, staking and setting out				75.77	3.598089124	VERY HIGH
Clearing and grading the Right-Of-Way (ROW)	3.64			73.46	3.48839418	VERY HIGH
Topsoil stripping and Front-end grading	3.64			57.88	2.748546898	HIGH
Buildings, roads and rivers crossings	3.64			76.63	3.638927934	VERY HIGH
Pipe transporting to sit	3.64			59.02	2.802682065	HIGH
Temporary fencing and signage				51.09	2.426110246	HIGH
Trenching				54.05	2.566671732	HIGH
Temporary erosion control and side support	3.64			57.48	2.729552103	HIGH
Pipe set-up	3.64			43.84	2.081829579	MEDIUM
Welding, fabrication and installing pipe	3.64			36.28	1.722827945	MEDIUM
NDT tests	3.64			32.77	1.556148615	LOW
SAND BLAST	3.64			32.82	1.558522965	LOW
Painting	3.64			32.81	1.558048095	LOW
Coating	3.64			54.69	2.597063405	HIGH
Lowering pipe in and backfilling	3.64			46.71	2.218117236	MEDIUM
Cathodic Protecting the pipe	3.64			68.64	3.259506895	VERY HIGH
Final fitting	3.64			32.61	1.548550697	LOW
As-built survey	3.64			32.48	1.542377389	LOW

Hydro, pressure test	3.64			29.1	1.381871367	LOW
Backfilling	3.64			36.16	1.717129507	MEDIUM
Fencing and signage	3.64			61.49	2.919974927	HIGH
Final clean-up				40.11	1.904703111	MEDIUM
Right-of-way reclamation				54.03	2.565721992	HIGH
Safety barriers				55.53	2.636952475	HIGH
Operation within design limits				97.54	4.631880865	LOW
Commissioning operation value			3.03	97.54	4.631880865	VERY HIGH
Measure the performance and efficiency			3.03	29.26	1.389469285	VERY HIGH
Enhanced performance and efficiency				97.54	4.631880865	VERY HIGH
Monitoring and inspection of pipelines			3.03	42.57	2.021521103	MEDIUM
Preventive and predictive maintenance of facilities				59.54	2.827375299	LOW
Risk Management (Risk evaluation and Reduced risk)			2.5	36.31	1.724252555	HIGH

APPENDIX E: THE RESULTS OF THE TARGETED SURVEY EVALUATING THE IDENTIFIED AND RECOMMENDED RMMs (Stage I)

The appendix presents the results of the targeted survey, which was about collecting the perceptions of several experts in OGP projects in Iraq with regard to the recommended risk mitigation methods which could be used to manage the risk factors in OGP projects. The figures below show the details of the result of the targeted survey.

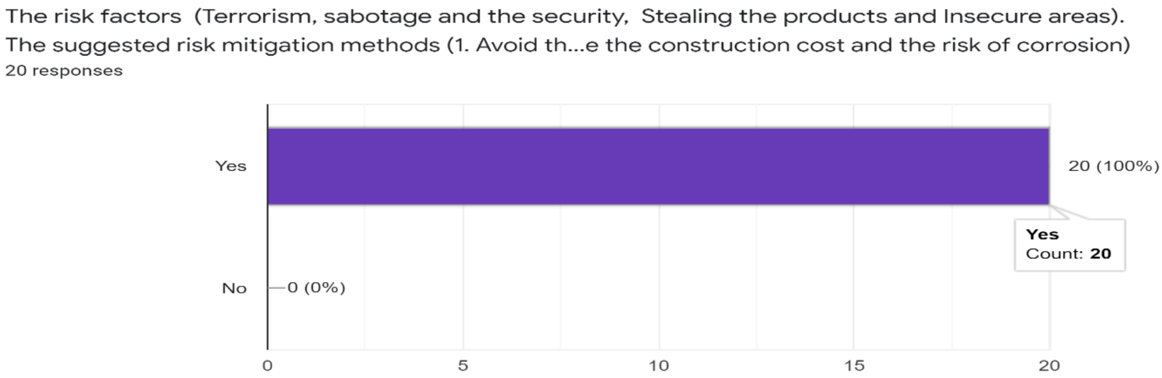


Figure E.1: The recommended RMM to manage the Terrorism, sabotage and the security, Stealing the products and Insecure areas IRFs.

As the size of the figure above was not big enough to explain the full details, the recommended RMM to manage the Terrorism, sabotage and the security, Stealing the products and Insecure areas IRFs, were 1. Avoid the insecure areas. 2. Anti-terrorism design. 3. Use protective barriers and perimeter fencing. 4. Use a high technology and advanced risk-monitoring system. 5. Government-public cooperation.6. Foot and vehicle patrols. 7. Use the rivers and lakes to extend the pipelines in the insecure areas despite the construction cost and the risk of corrosion.

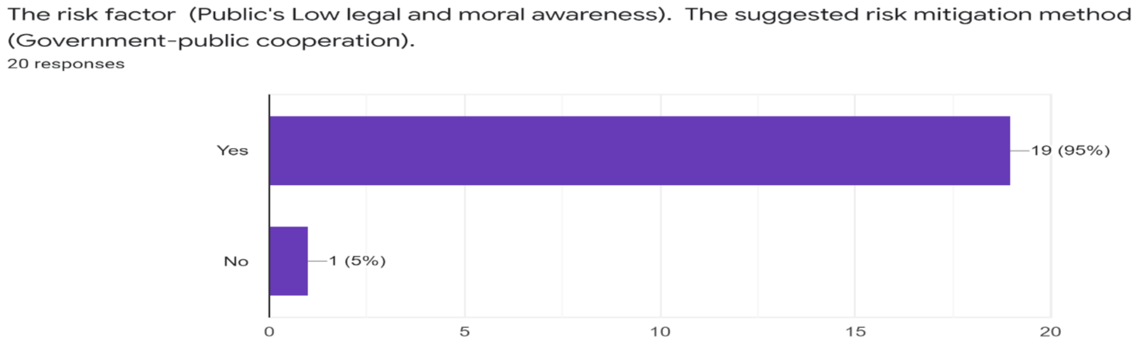


Figure E.2: The recommended RMM to manage the Public's low legal and moral awareness IRFs.

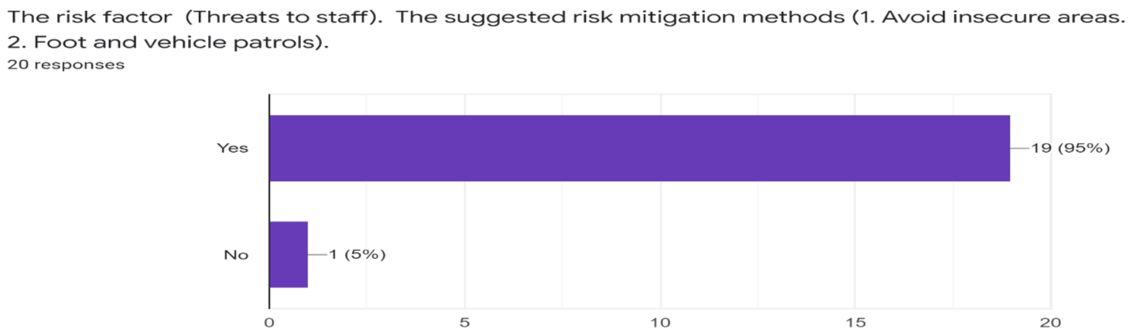


Figure E.3: The recommended RMMs to manage the Threats to staff IRF.

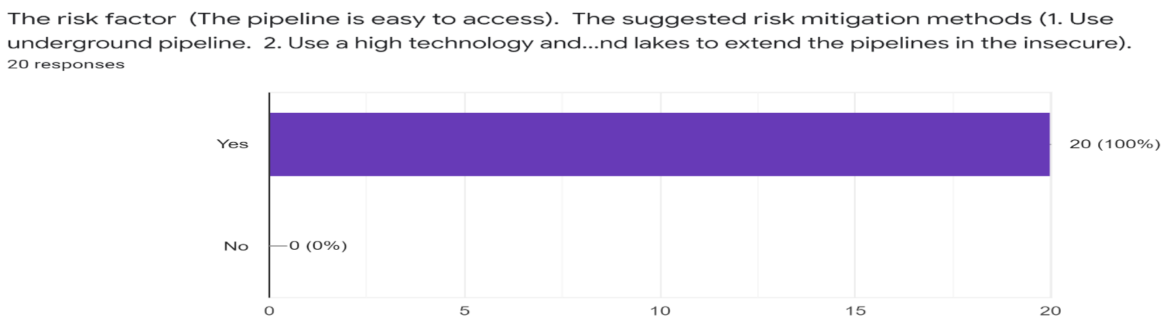


Figure E.4: The recommended RMMs to manage The pipeline is easy to access IRF.

As the size of the figure above was not big enough to explain the full details, the risk factor (The pipeline is easy to access). The suggested risk mitigation methods (1. Use underground pipeline. 2. Use a high technology and advanced risk-monitoring system. 3. Use protective barriers and perimeter fencing. 4. Foot and vehicle patrols. 5. Expand the protection zones along with the pipelines. 6. Use the rivers and lakes to extend the pipelines in the insecure).

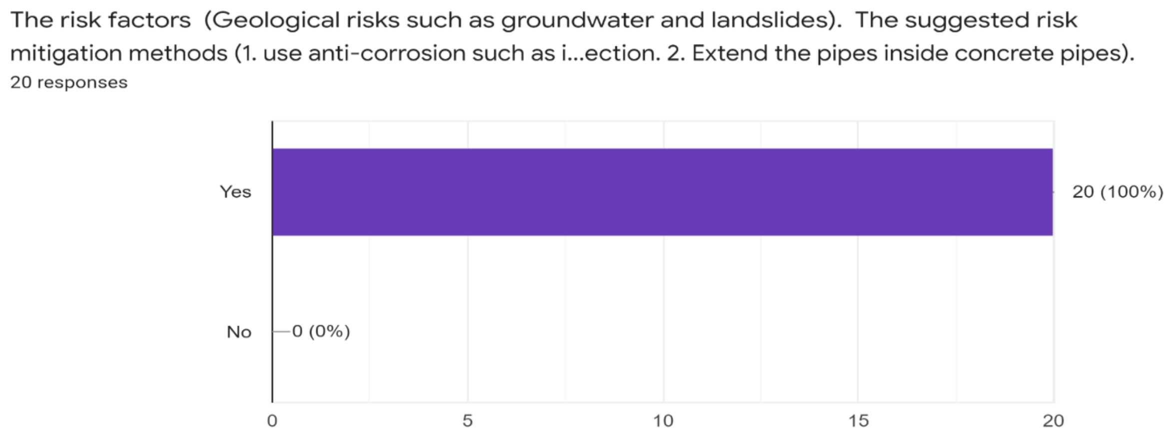


Figure E.5: The recommended RMMs to manage the Geological risks such as groundwater and landslides IRF.

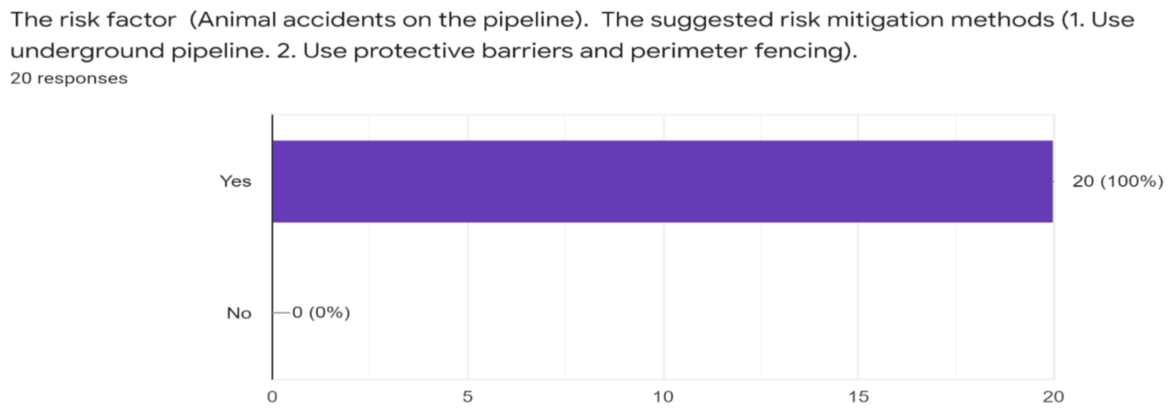


Figure E.6: The recommended RMMs to manage the Animal accidents on the pipeline IRF.

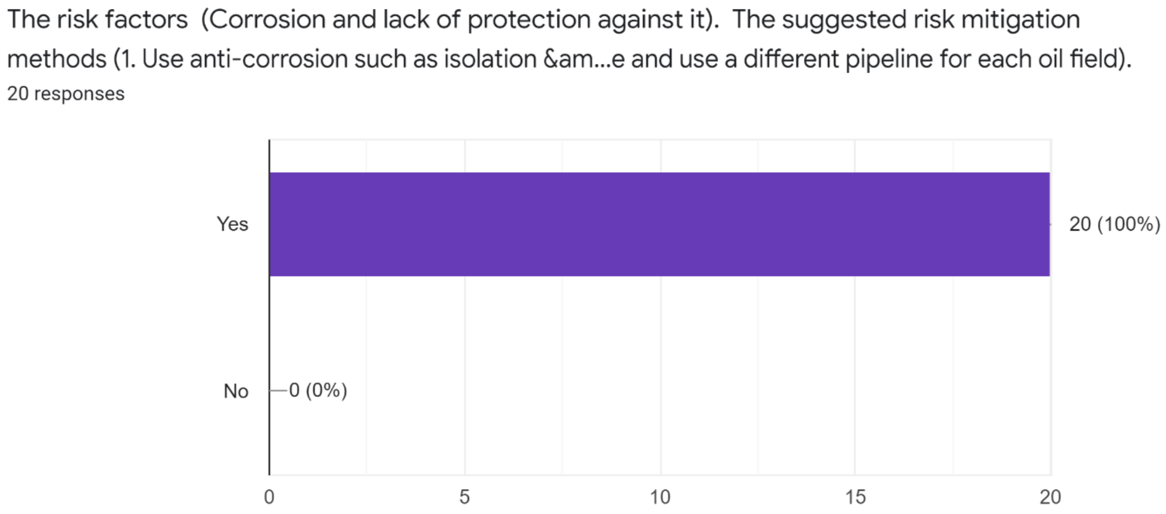


Figure E.7: The recommended RMMs to manage the Corrosion and lack of protection against it IRF.

As the size of the figure above was not big enough to explain the full details, the risk factors (Corrosion and lack of protection against it). The suggested risk mitigation methods (1. Use anti-corrosion such as isolation & cathodic protection 2. Extend the pipes inside concrete pipes. 3. Use optimisers and remove the salts and metals before pumping the petroleum products. 4. Pump only one type of product in the pipeline and use a different pipeline for each oil field).

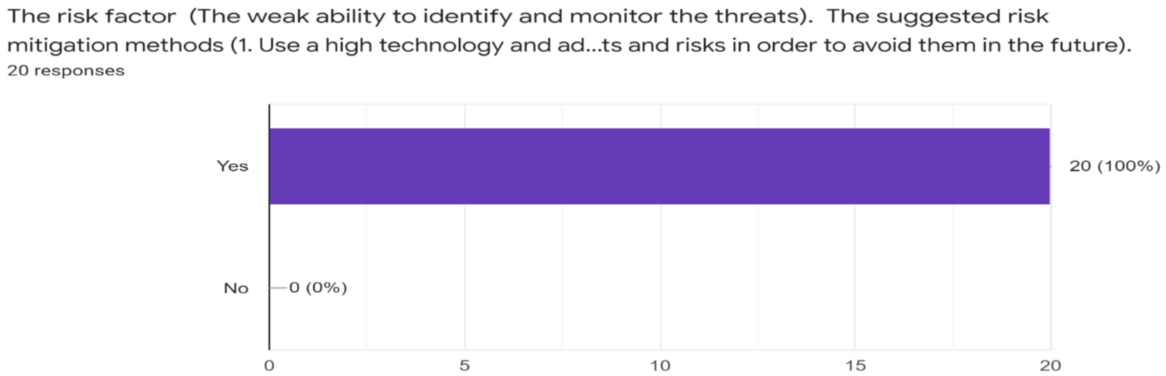


Figure E.8: The recommended RMMs to manage The weak ability to identify and monitor the threats IRF.

The risk factors (The weak ability to identify and monitor the threats). The suggested risk mitigation methods (1. Use a high technology and advanced risk-monitoring system. 2. Appropriateinspection, tests and maintenance. 3. Appropriatetraining. 4. Record pipelines accidents and risks in order to avoid them in the future).

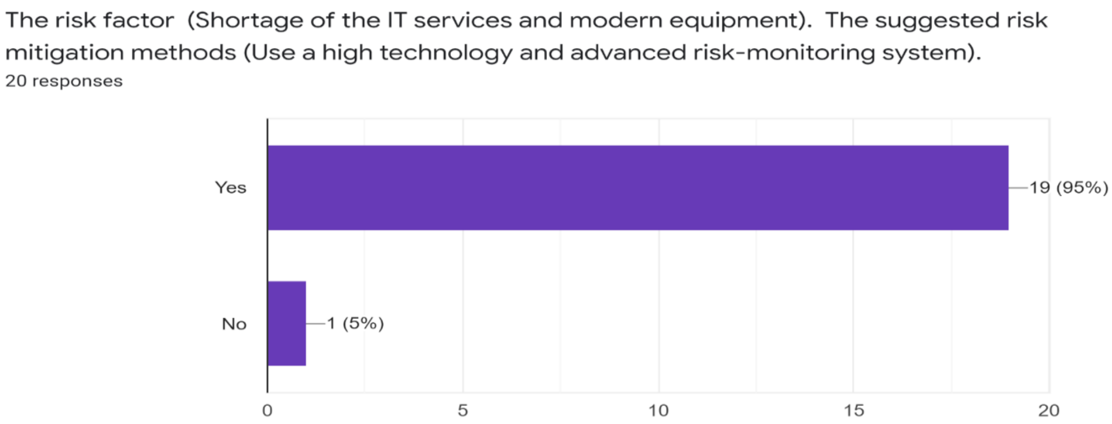


Figure E.9: The recommended RMM to manage the Shortage of the IT services and modern equipment) IRF.

As the size of the figure above was not big enough to explain the full details, the risk factors (Design, construction and material defects). The suggested risk mitigation methods (1. Appropriatetraining. 2. Make studies about the safety of the pipelines and follow the new research about risk management. 3. Use high-quality pipes and spare. 4. Choose ell-known design companies to minimise design errors. 5. Choose well-known construction companies to minimise construction defects).

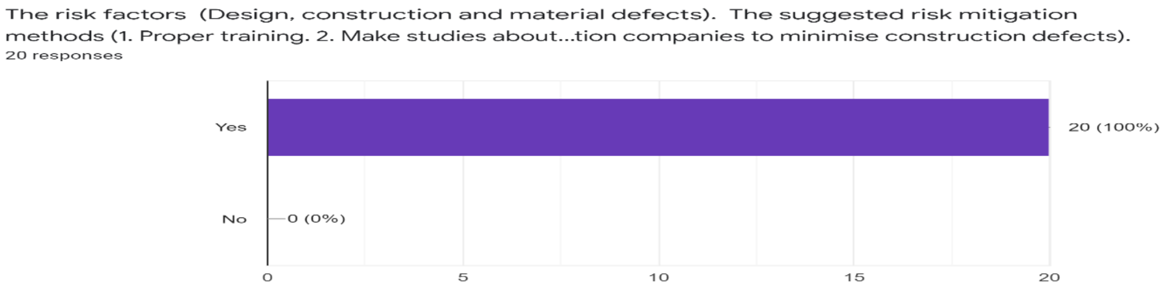


Figure E.10: The recommended RMMs to manage the Design, construction and material defects IRF.

As the size of the figure above was not big enough to explain the full details, the risk factors (Design, construction and material defects). The suggested risk mitigation methods (1. Appropriatetraining. 2. Make studies about the safety of the pipelines and follow the new research about risk management. 3. Use high-quality pipes and spare. 4. Choose well-known design companies to minimise design errors. 5. Choose well-known construction companies to minimise construction defects).

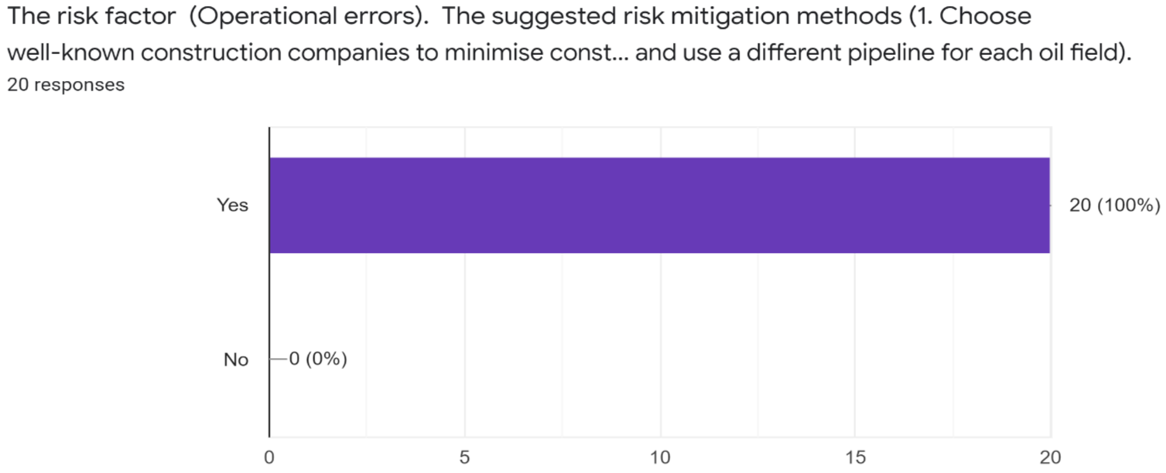


Figure E.11: The recommended RMMs to manage the Operational errors IRF.

As the size of the figure above was not big enough to explain the full details, the risk factor (Operational errors). The suggested risk mitigation methods (1. Choose well-known construction companies to minimise construction defects. 2. Commit to the operating standards. (e.g. do not pass the design capacity .3. Use optimisers and remove the salts and metals before pumping the petroleum products. 4. Pump only one type of product in the pipeline and use a different pipeline for each oil field).

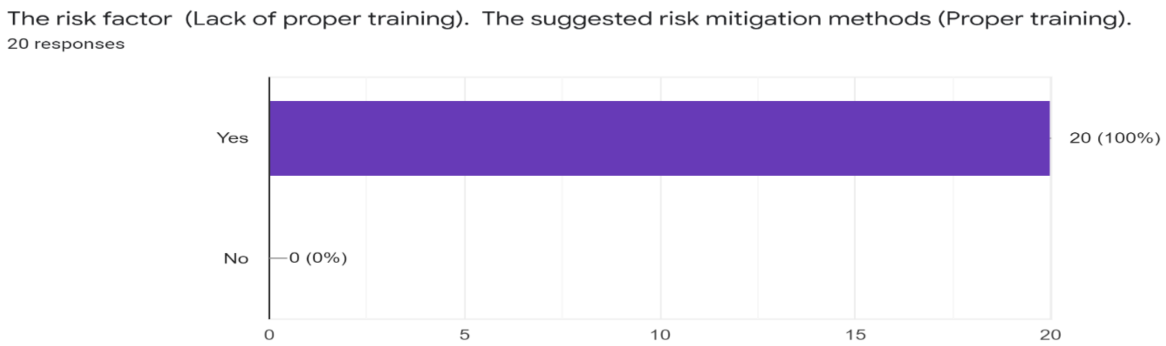


Figure E.12: The recommended RMM to manage the Lack of appropriatetraining IRF.

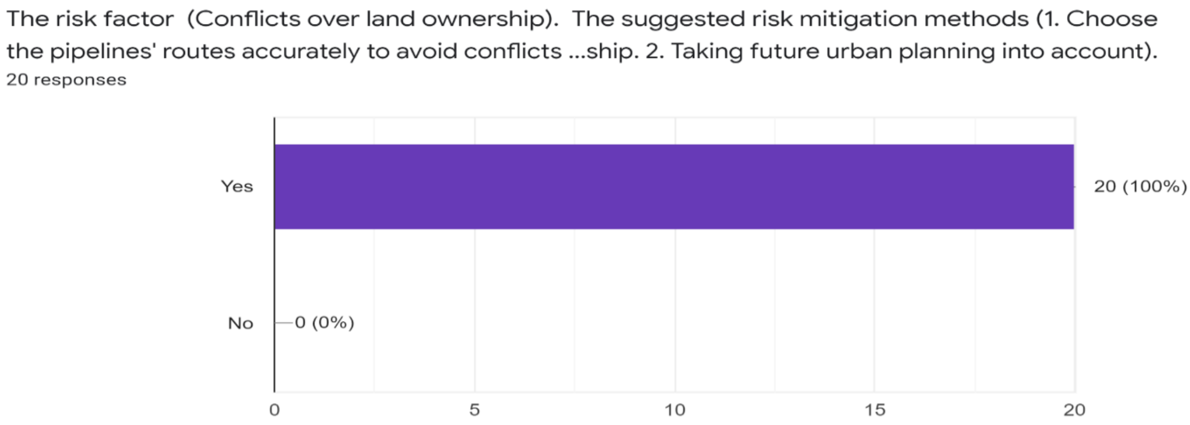


Figure E.13: The recommended RMMs to manage the Conflicts over land ownership IRF.

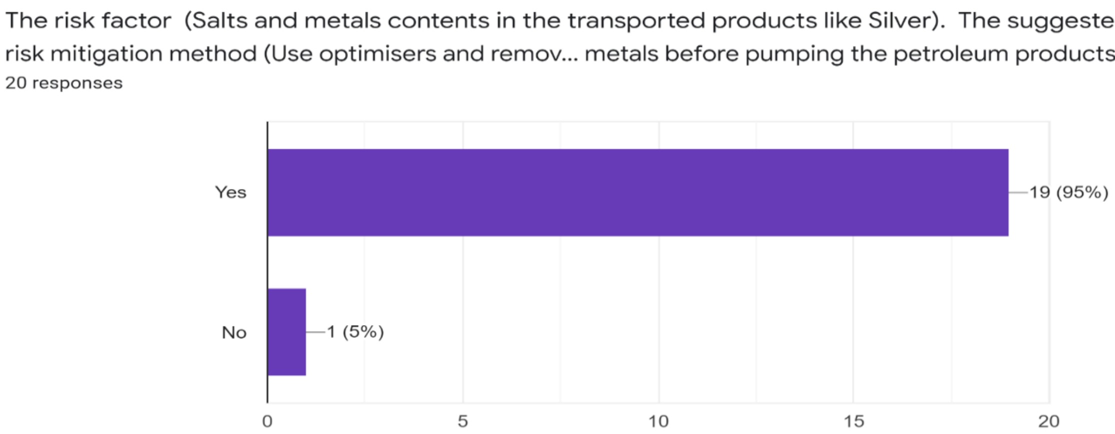


Figure E.14: The recommended RMM to manage the Salt and metal contents in transported products such as silver IRF.

As the size of the figure above was not big enough to explain the full details, the risk factor (Salts and metals contents in the transported products such as Silver). The suggested risk mitigation method (Use optimisers and remove the salts and metals before pumping the petroleum products).

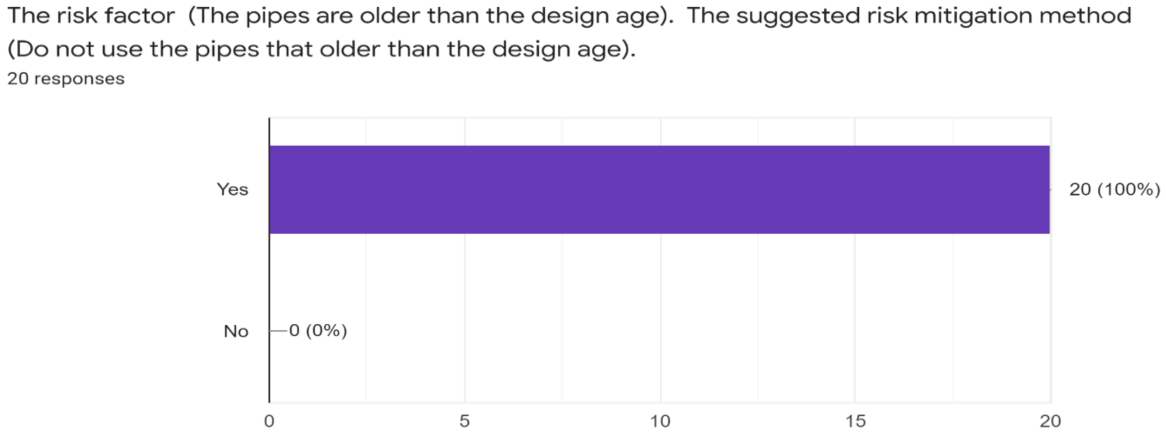


Figure E.15: The recommended RMM to manage The pipes are older than the design age IRF.

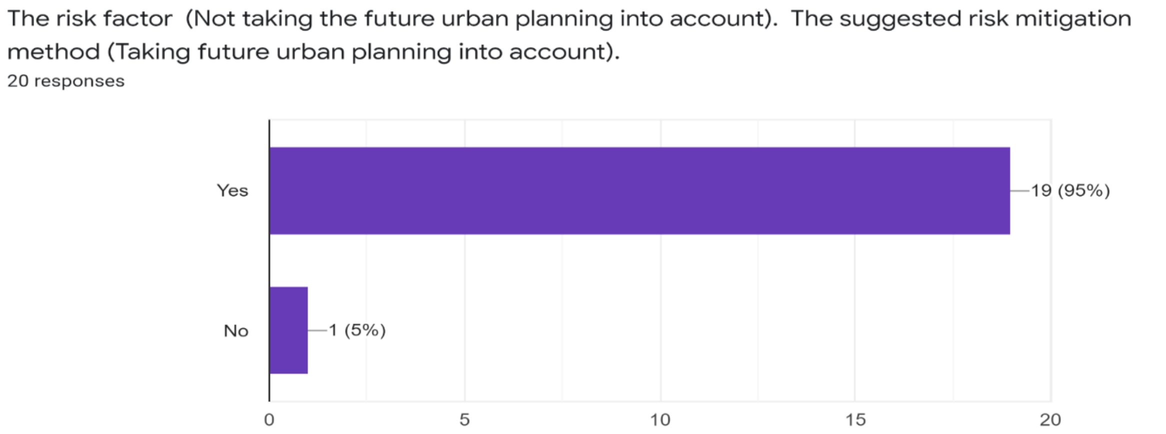


Figure E.16: The recommended RMM to manage Not taking the future urban planning into account IRF.

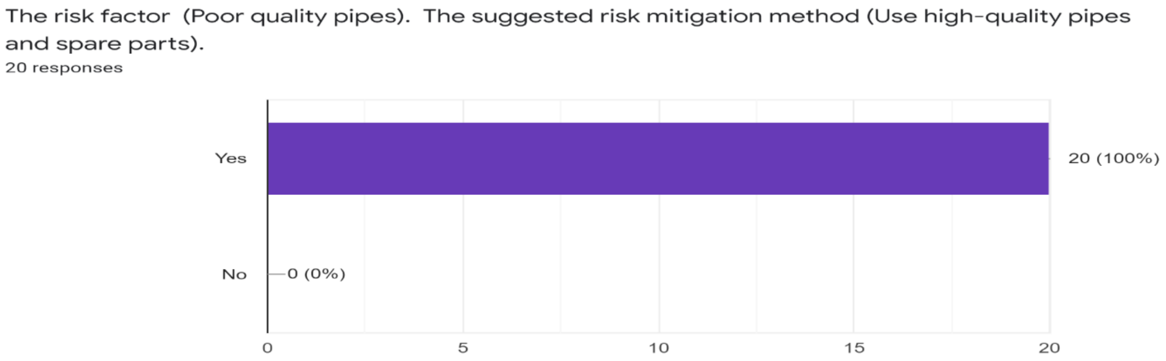


Figure E.17: The recommended RMM to manage the Poor quality pipes IRF.

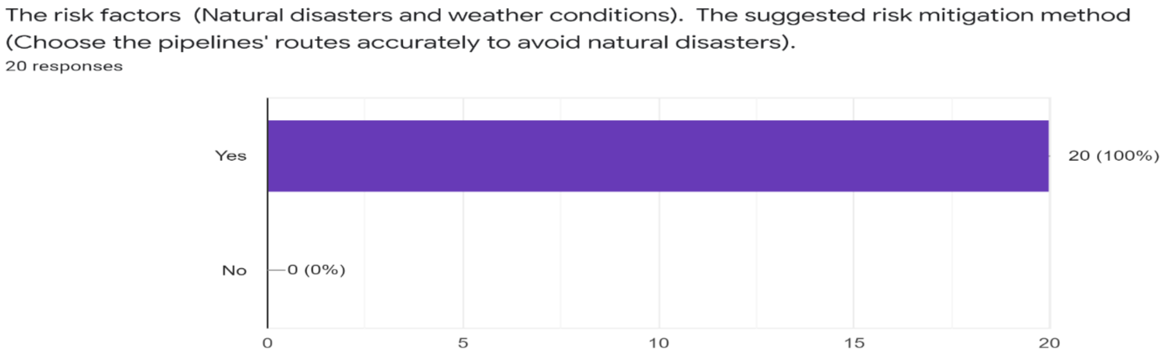


Figure E.18: The recommended RMMs to manage the Natural disasters and weather conditions IRF.

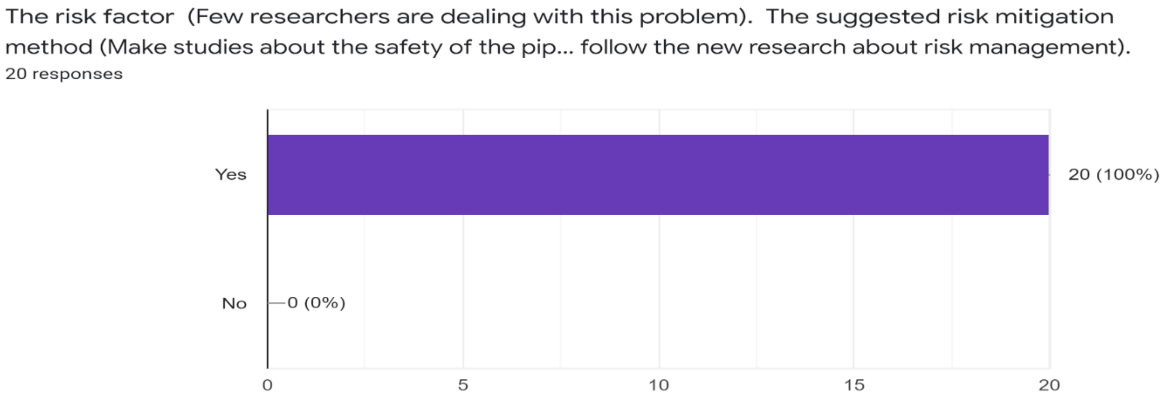


Figure E.19: The recommended RMMs to manage the Few researchers are dealing with this problem IRF.

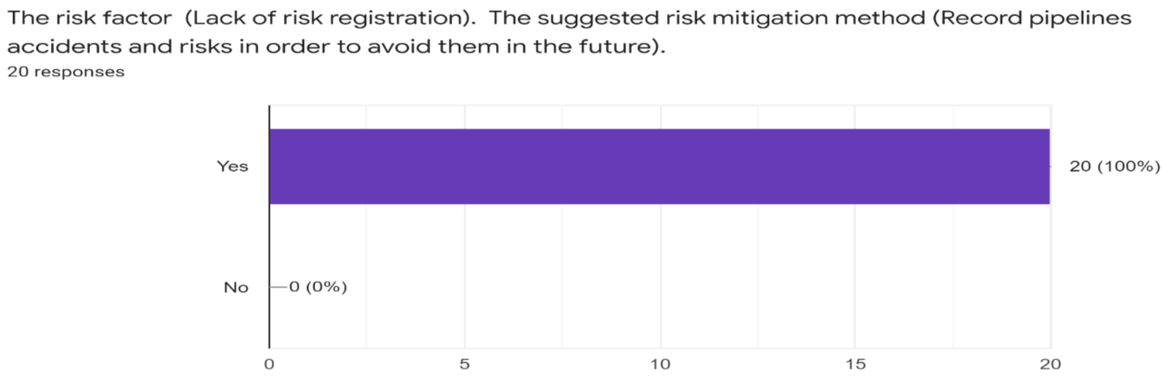


Figure E.20: The recommended RMM to manage the Lack of risk registration) IRF.

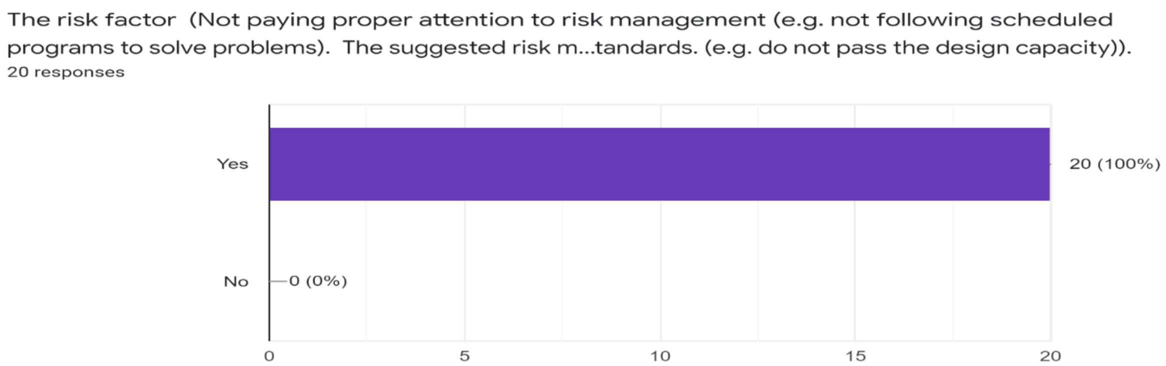


Figure E.21: The recommended RMM to manage the Not paying appropriateattention to risk management (e.g. not following scheduled programmes to solve problems) IRF.

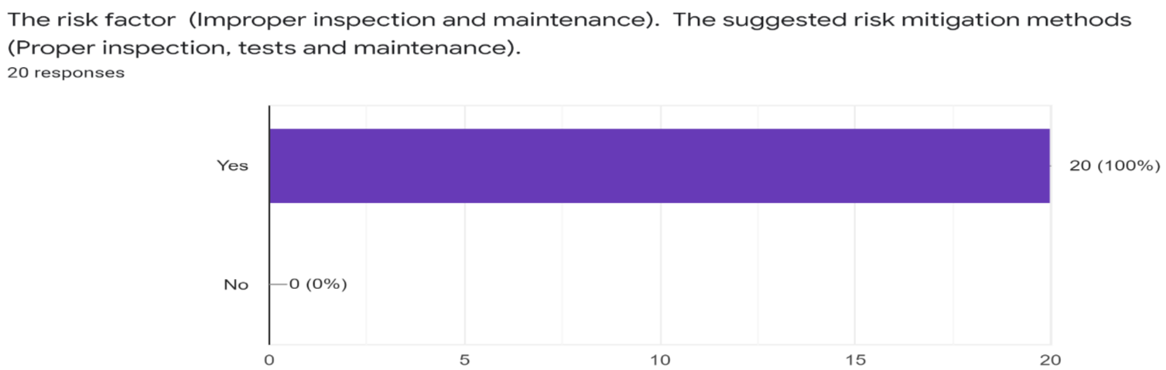


Figure E.22: The recommended RMM to manage the Improper inspection and maintenance) IRF.

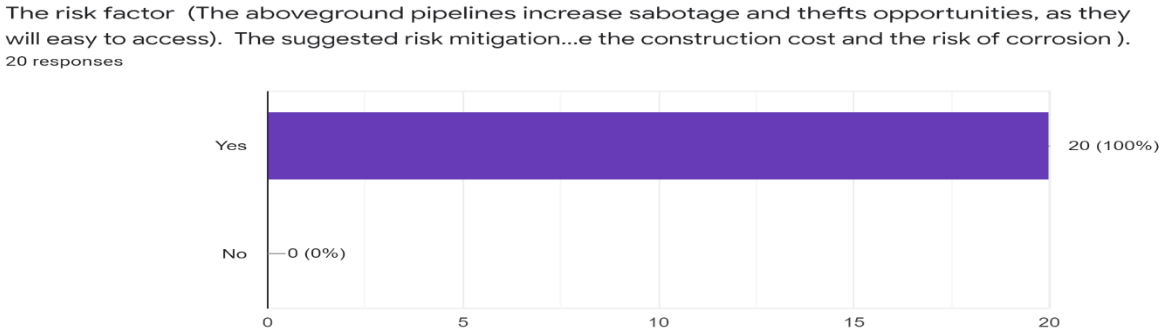


Figure E.23: The recommended RMMs to manage The aboveground pipelines increase sabotage and theft opportunities, as they will be easy to access IRF.

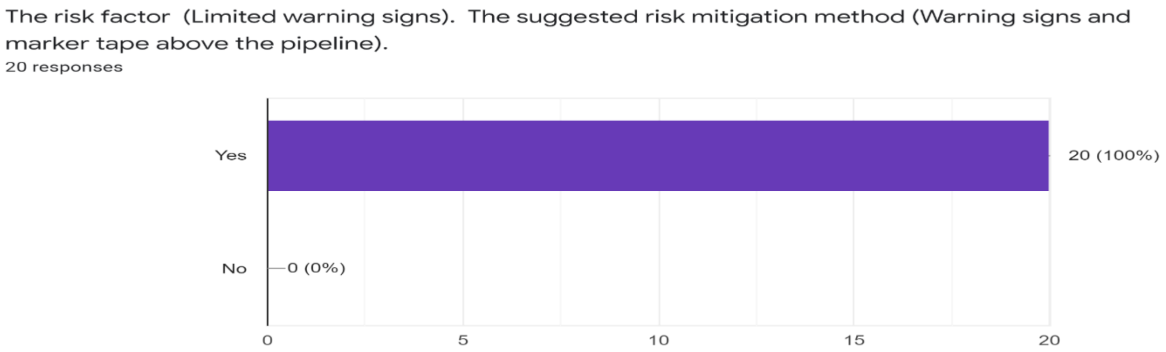


Figure E.24: The recommended RMM to manage the Limited warning signs IRF.

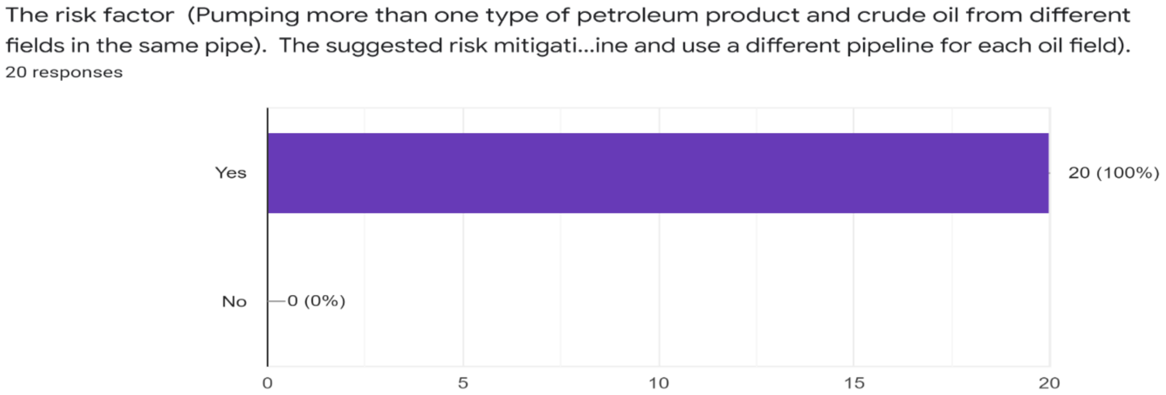


Figure E.25: The recommended RMMs to manage the Pumping more than one type of petroleum product and crude oil from different fields in the same pipe IRF.

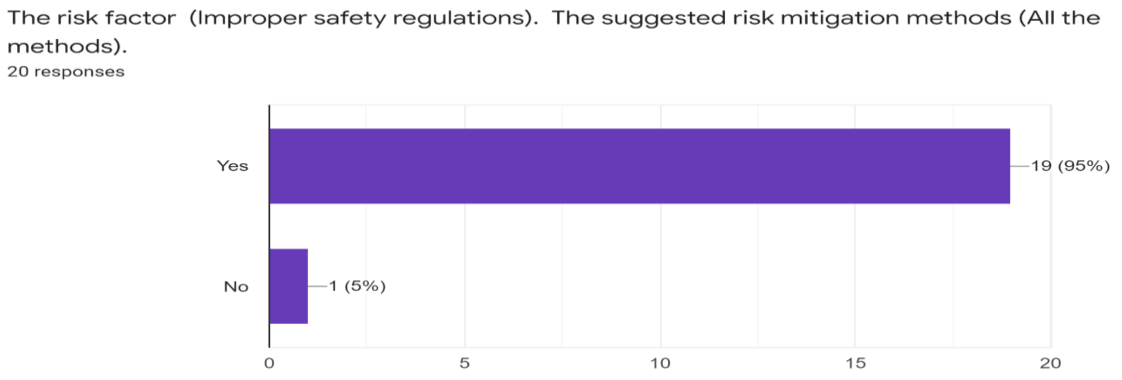


Figure E.26: The recommended RMMs to manage the Improper safety regulations IRF.

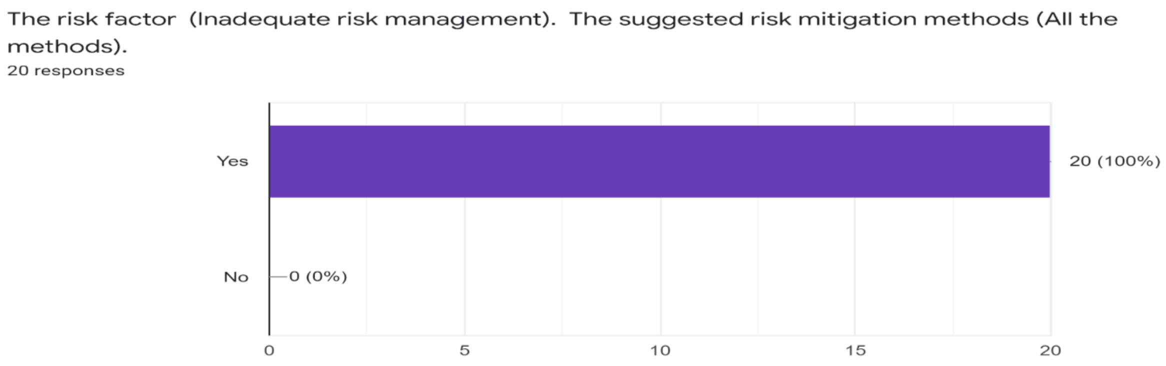


Figure E.27: The recommended RMMs to manage the Inadequate risk management IRF.

Below are the risk mitigations methods that were added by the participants in the targeted survey.

- In the case of a leak, the central control room (CCR) to monitor and identify the damage
- One of the advanced technology maintenance systems is SAP software, to provide appropriatepreventative maintenance.
- Permanent pipeline warning signs: one of the monitoring inspection application is remote pipeline acoustic inspection.
- During in-service operations, chemical additives should be applied to reduce the corrosion of metals.
- Use periodic sampling for labs to make sure that a suitable system is in operation.
- Use appropriatecoating to mitigate external corrosion.

- Additional trench and slope protection to be executed as required to mitigate the deposit contamination.
- Right of Way (ROW) to provide more access for maintenance and frequent surveillance.
- To measure the corrosive effect of the stream on pipelines, we suggest installing a corrosion coupons for excellent sources of corrosion information.

APPENDIX F: THE RESULTS OF THE TARGETED SURVEY EVALUATING THE IDENTIFIED AND RECOMMENDED RMMs (Stage II)

The appendix presents the results of the targeted survey, which was about collecting the perceptions of several experts in OGP projects in Iraq with regard to the recommended risk mitigation methods which could be used to manage the risk factors in OGP projects. At this survey, the participants were asked to explain their agreement with the suggested RMMs. The participants were asked to answer the questions on a five-point Likert scale when 5 mean strongly agree and 1 meant strongly disagree. The figures below show the details of the result of the targeted survey. As the size of the figure above was not big enough to explain the full details, the recommended RMM to manage the Terrorism, sabotage and the security, Stealing the products and Insecure areas IRFs, were 1. Avoid the insecure areas. 2. Anti-terrorism design. 3. Use protective barriers and perimeter fencing. 4. Use a high technology and advanced risk-monitoring system. 5. Government-public cooperation.6. Foot and vehicle patrols. 7. Use the rivers and lakes to extend the pipelines in the insecure areas despite the construction cost and the risk of corrosion.

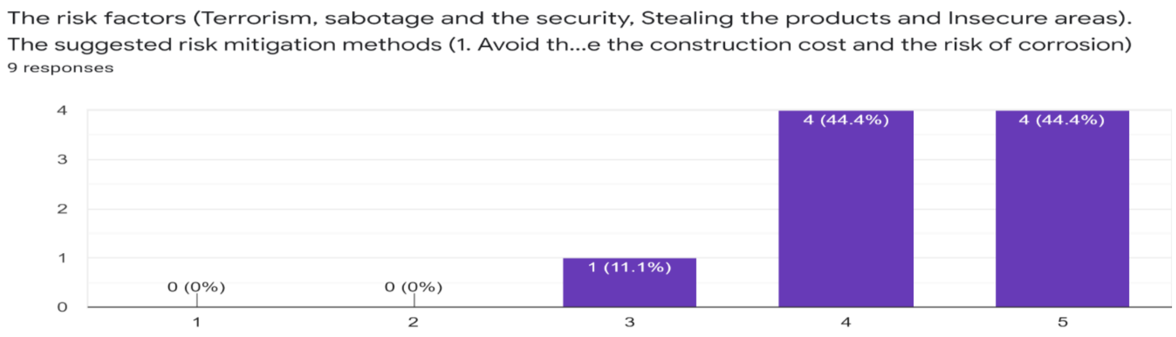


Figure F.1: The recommended RMM to manage the Terrorism, sabotage and the security, Stealing the products and Insecure areas IRFs.

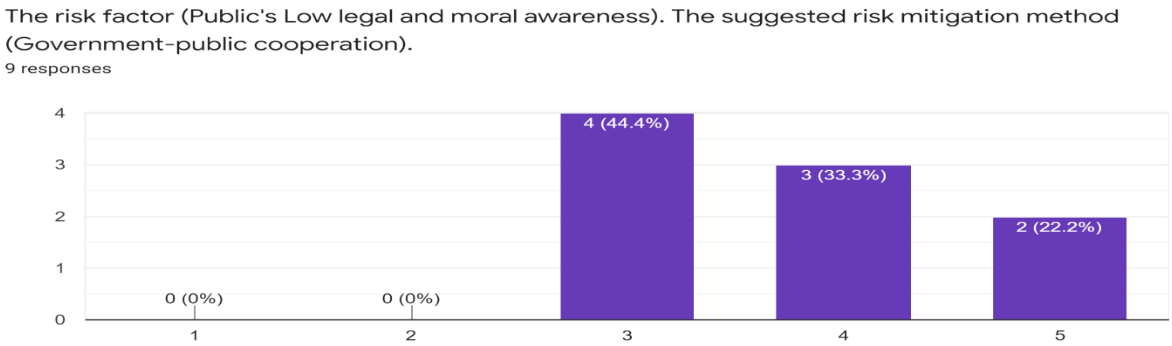


Figure F.2: The recommended RMM to manage the Public's low legal and moral awareness IRFs.

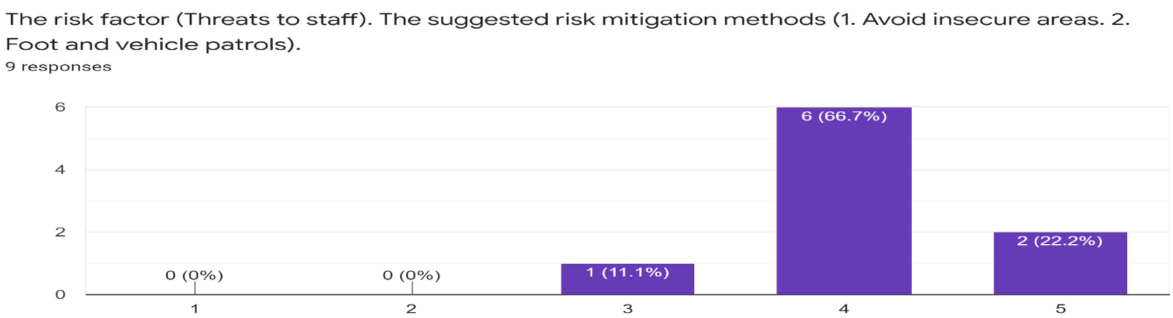


Figure F.3: The recommended RMMs to manage the Threats to staff IRF.

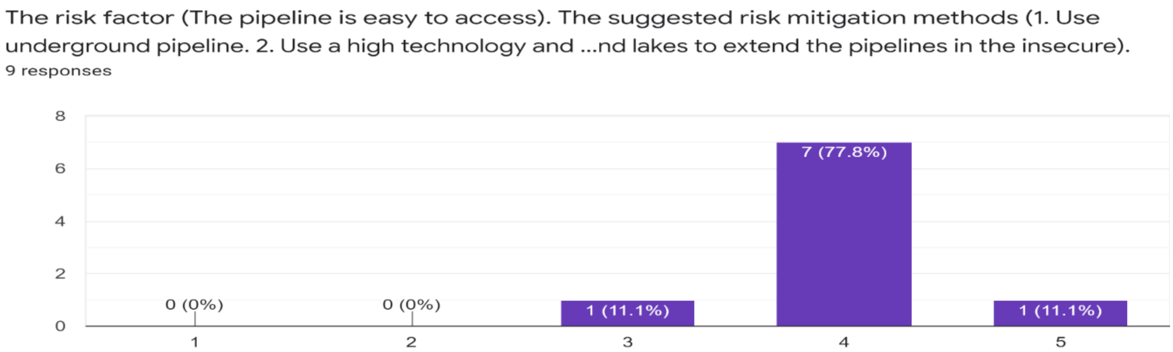


Figure F.4: The recommended RMMs to manage The pipeline is easy to access IRF.

As the size of the figure above was not big enough to explain the full details, the risk factor (The pipeline is easy to access). The suggested risk mitigation methods (1. Use underground pipeline. 2. Use a high technology and advanced risk-monitoring system. 3. Use protective barriers and perimeter fencing. 4. Foot and vehicles patrols. 5. Expand the protection zones along with the pipelines. 6. Use the rivers and lakes to extend the pipelines in the insecure).

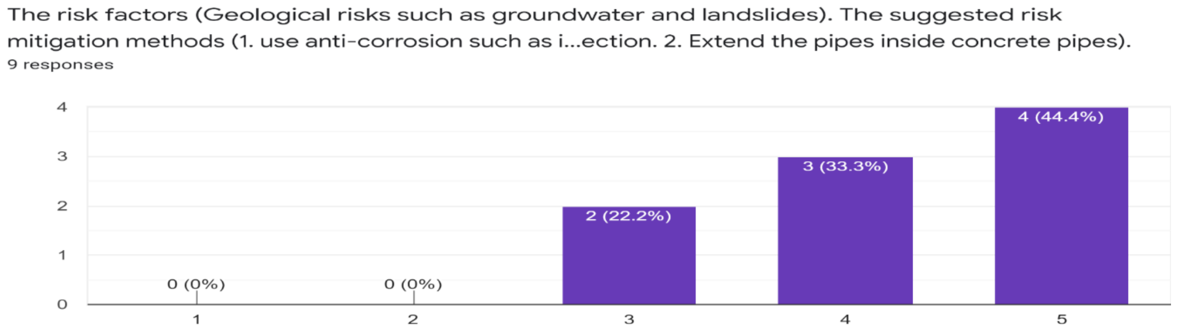


Figure F.5: The recommended RMMs to manage the Geological risks such as groundwater and landslides IRF.

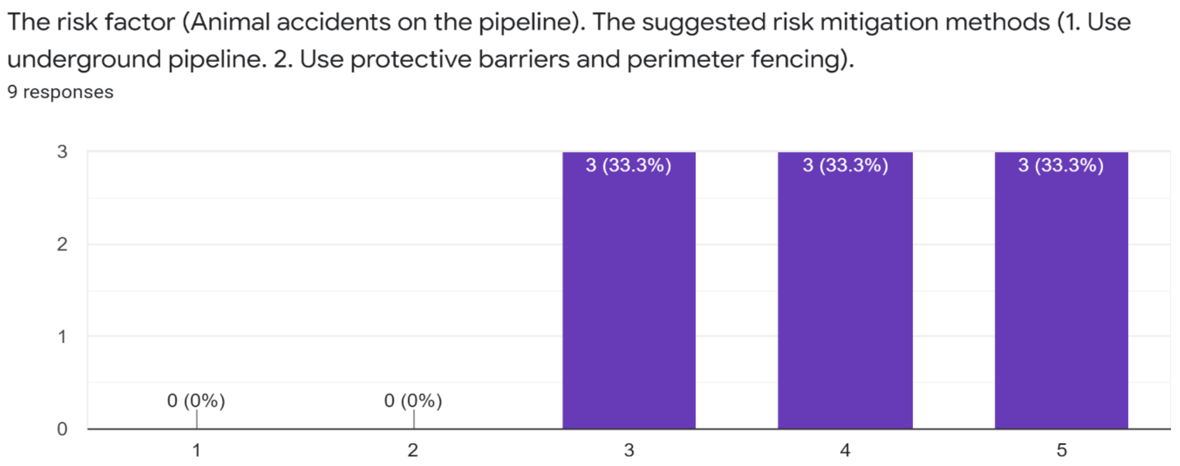


Figure F.6: The recommended RMMs to manage the Animal accidents on the pipeline IRF.

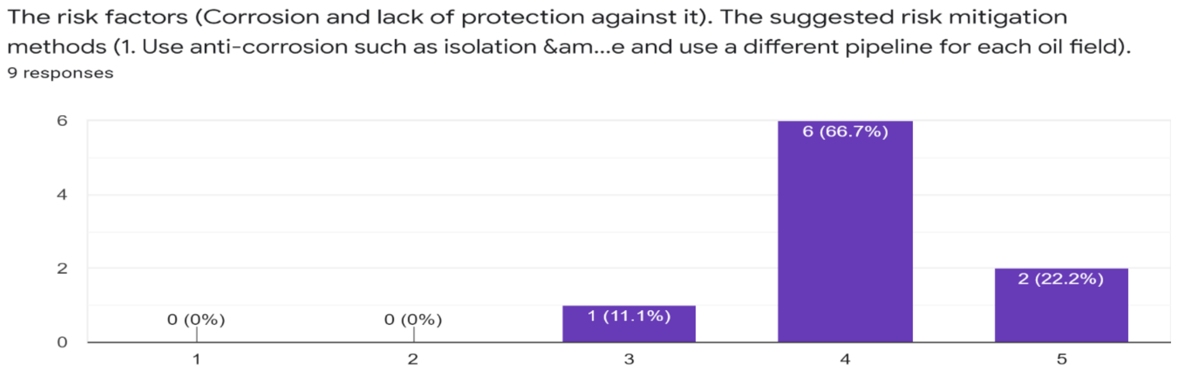


Figure F.7: The recommended RMMs to manage the Corrosion and lack of protection against it IRF.

As the size of the figure above was not big enough to explain the full details, the risk factors (Corrosion and lack of protection against it). The suggested risk mitigation methods (1. Use anti-corrosion such as isolation & cathodic protection 2. Extend the pipes inside concrete pipes. 3. Use optimisers and remove the salts and metals before pumping the petroleum products. 4. Pump only one type of product in the pipeline and use a different pipeline for each oil field).

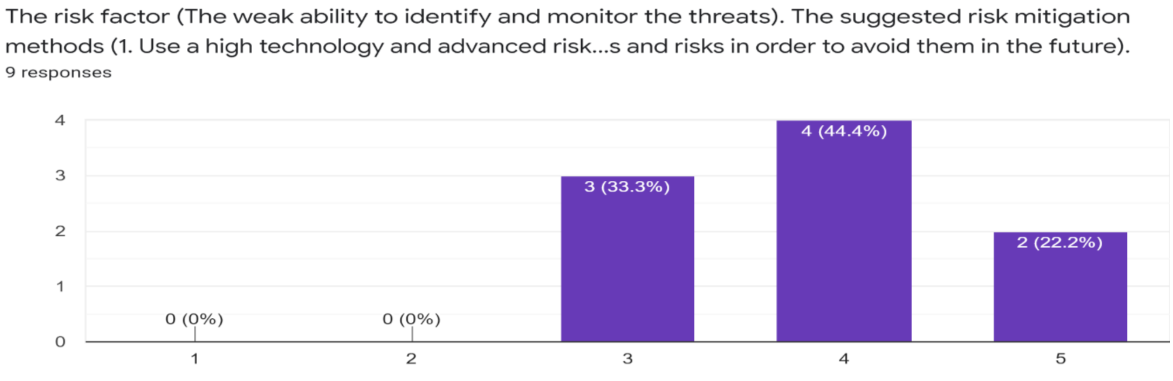


Figure F.8: The recommended RMMs to manage The weak ability to identify and monitor the threats IRF.

The risk factors (The weak ability to identify and monitor the threats). The suggested risk mitigation methods (1. Use a high technology and advanced risk-monitoring system. 2. Appropriateinspection, tests and maintenance. 3. Appropriatetraining. 4. Record pipelines accidents and risks in order to avoid them in the future).

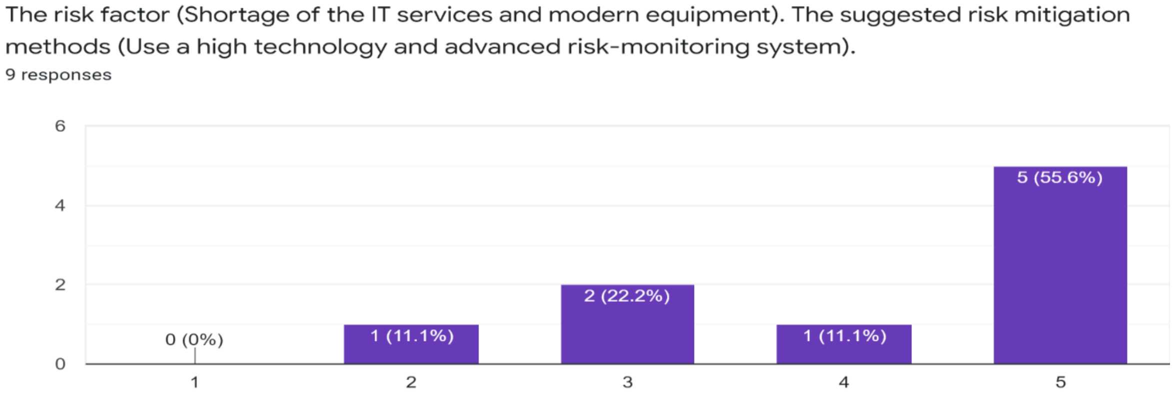


Figure F.9: The recommended RMM to manage the Shortage of the IT services and modern equipment) IRF.

As the size of the figure above was not big enough to explain the full details, the risk factors (Design, construction and material defects). The suggested risk mitigation methods (1. Appropriatetraining. 2. Make studies about the safety of the pipelines and follow the new research about risk management. 3. Use high-quality pipes and spare. 4. Choose ell-known design companies to minimise design errors. 5. Choose well-known construction companies to minimise construction defects).

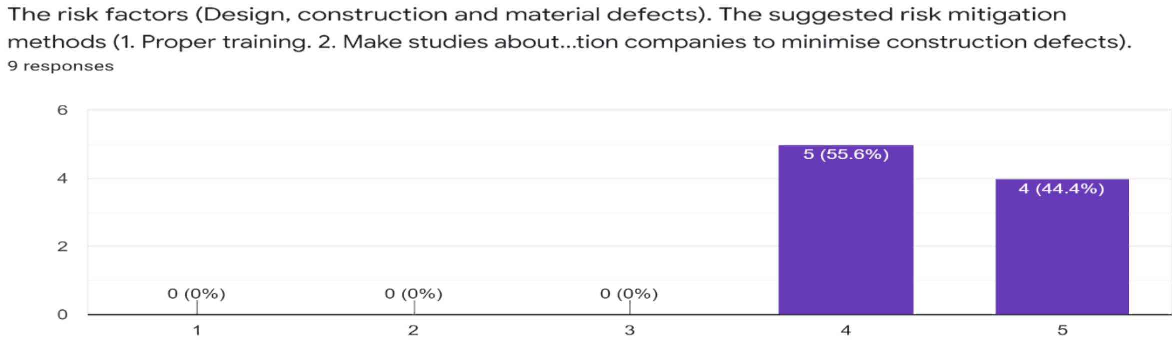


Figure F.10: The recommended RMMs to manage the Design, construction and material defects IRF.

As the size of the figure above was not big enough to explain the full details, the risk factors (Design, construction and material defects). The suggested risk mitigation methods (1. Appropriatetraining. 2. Make studies about the safety of the pipelines and follow the new research about risk management. 3. Use high-quality pipes and spare. 4. Choose well-known design companies to minimise design errors. 5. Choose well-known construction companies to minimise construction defects).

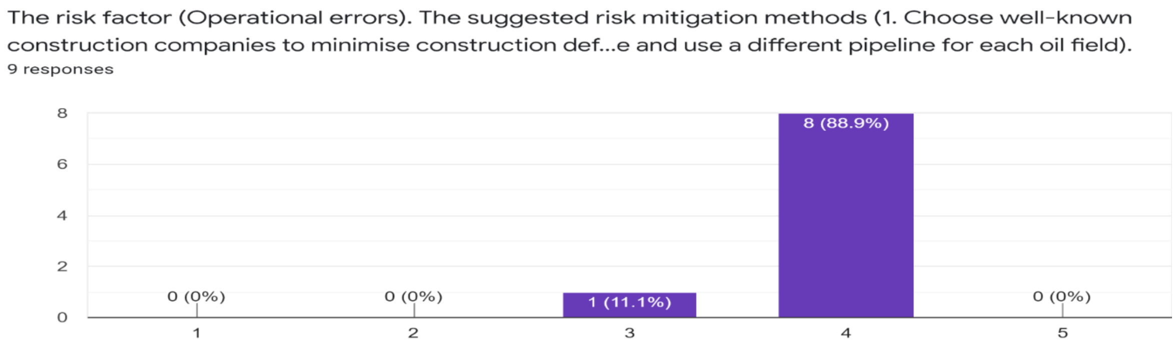


Figure F.11: The recommended RMMs to manage the Operational errors IRF.

As the size of the figure above was not big enough to explain the full details, the risk factor (Operational errors). The suggested risk mitigation methods (1. Choose well-known construction companies to minimise construction defects. 2. Commit to the operating standards. (e.g. do not pass the design capacity .3. Use optimisers and remove the salts and metals before pumping the petroleum products. 4. Pump only one type of product in the pipeline and use a different pipeline for each oil field).

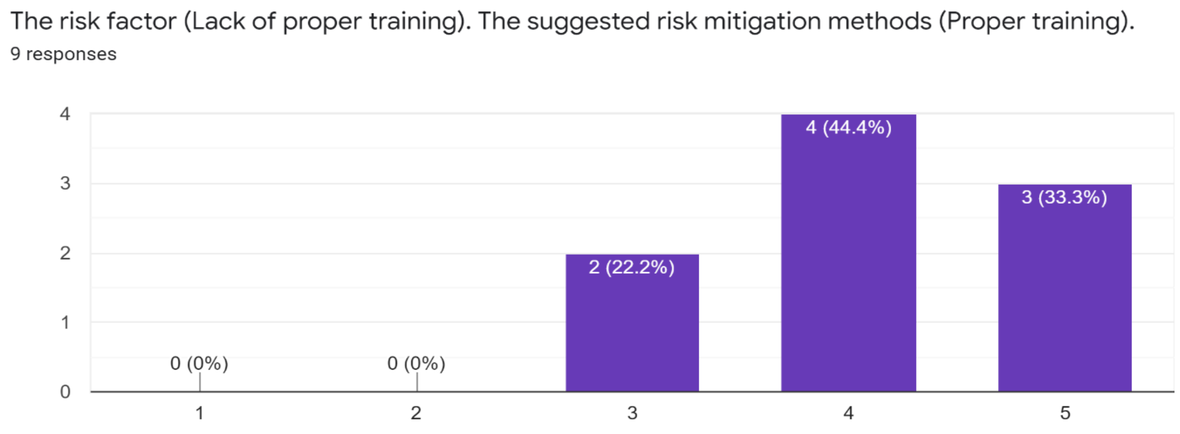


Figure F.12: The recommended RMM to manage the Lack of appropriatetraining IRF.

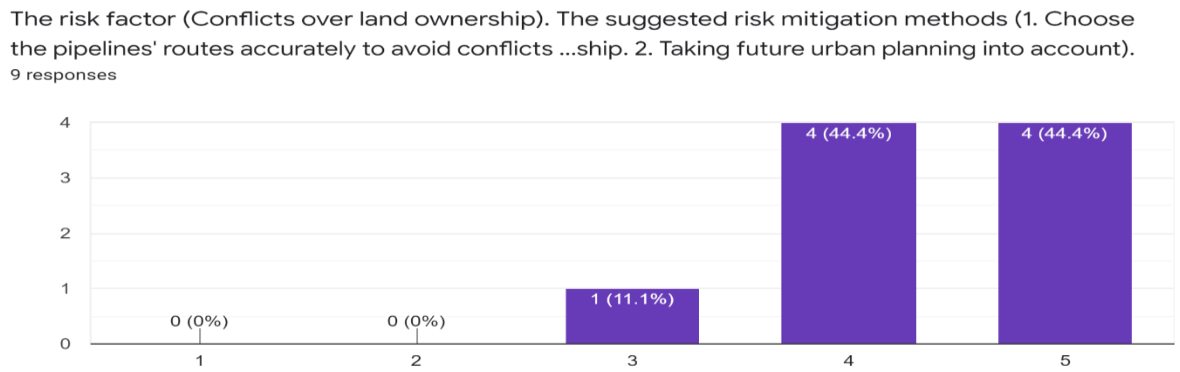


Figure F.13: The recommended RMMs to manage the Conflicts over land ownership IRF.

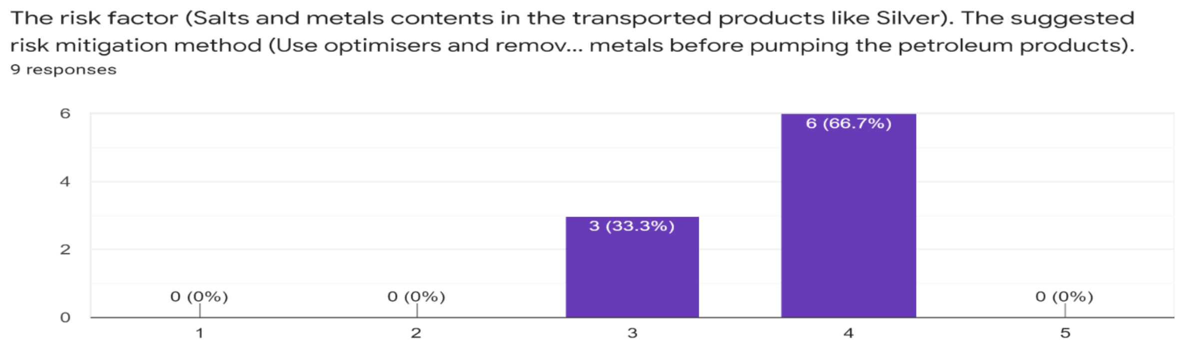


Figure F.14: The recommended RMM to manage the Salt and metal contents in transported products such as silver IRF.

As the size of the figure above was not big enough to explain the full details, the risk factor (Salts and metals contents in the transported products such as Silver). The suggested risk mitigation method (Use optimisers and remove the salts and metals before pumping the petroleum products).

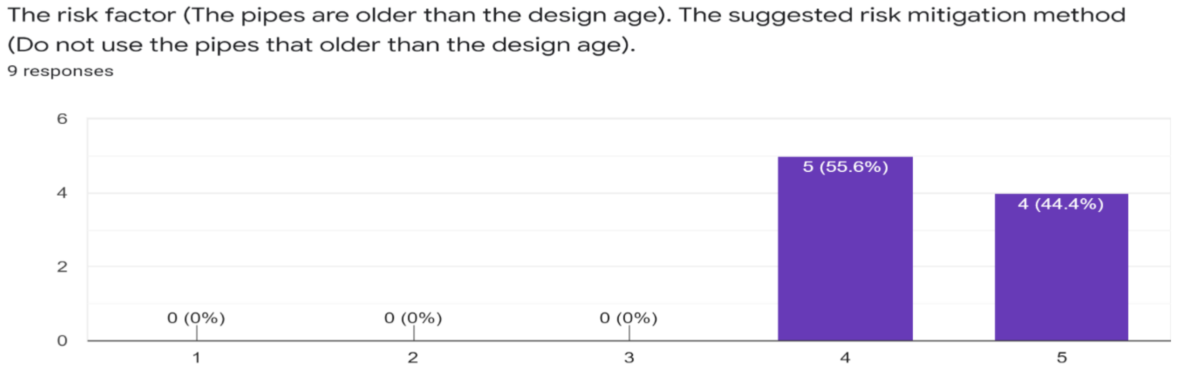


Figure F.15: The recommended RMM to manage The pipes are older than the design age IRF.

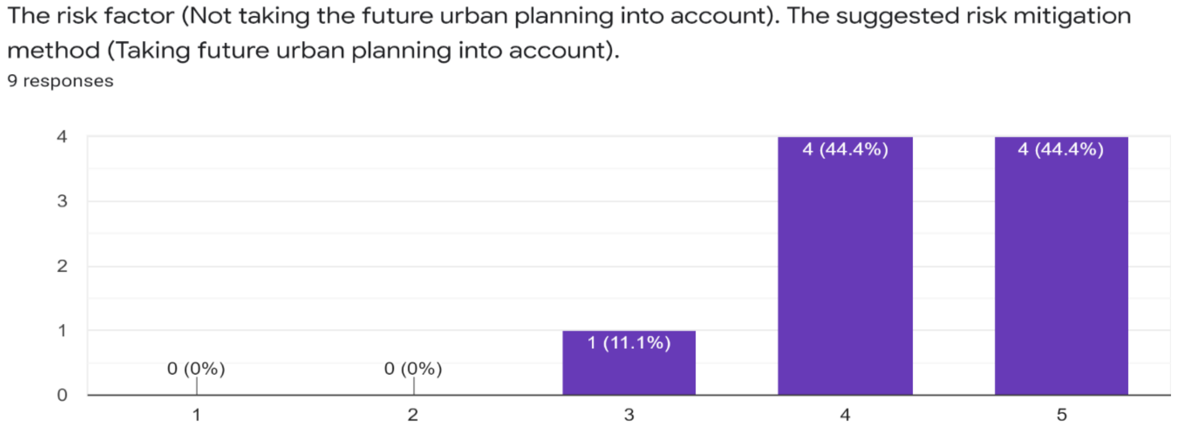


Figure F.16: The recommended RMM to manage Not taking the future urban planning into account IRF.

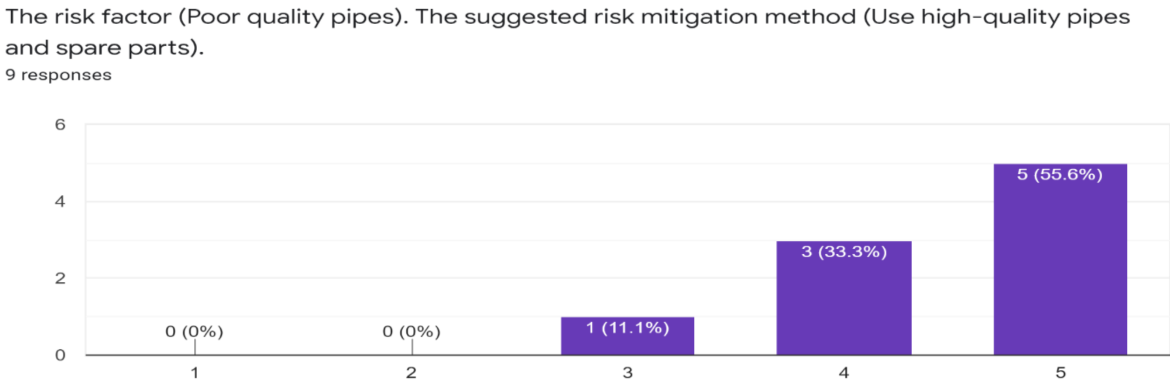


Figure F.17: The recommended RMM to manage the Poor quality pipes IRF.

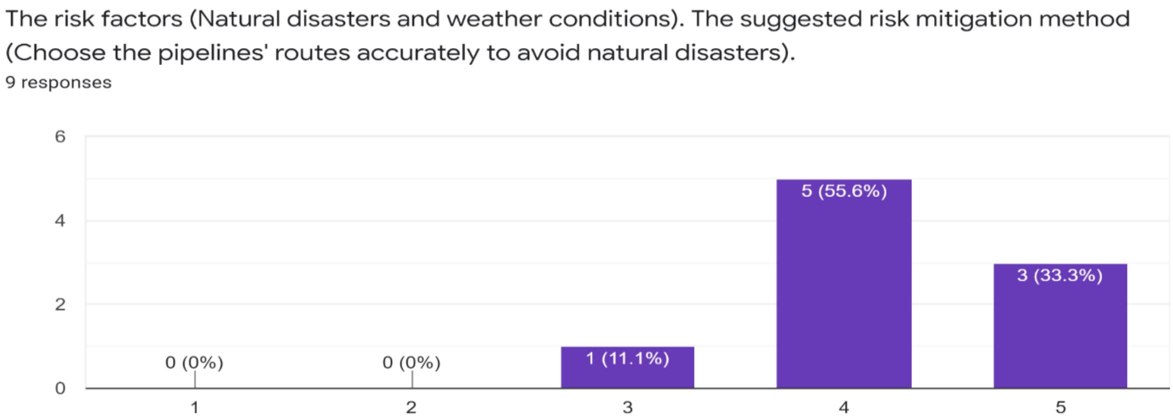


Figure F.18: The recommended RMMs to manage the Natural disasters and weather conditions IRF.

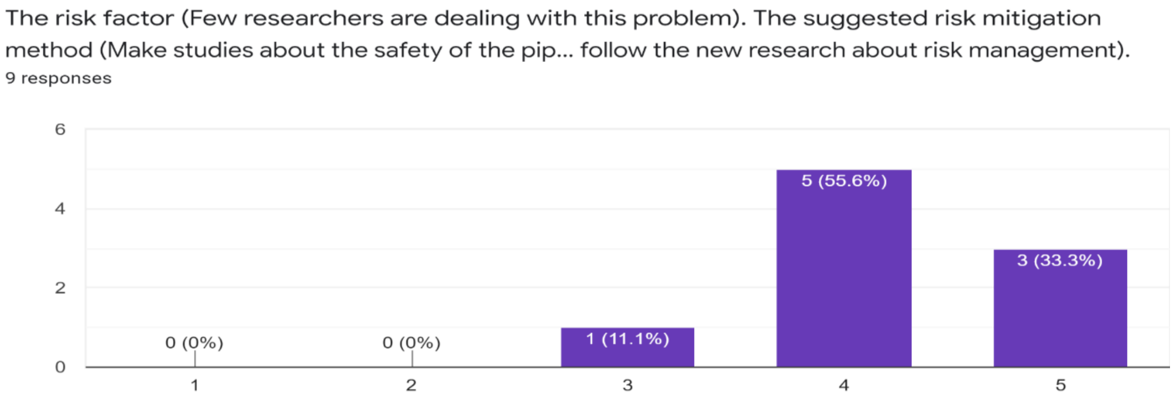


Figure F.19: The recommended RMMs to manage the Few researchers are dealing with this problem IRF.

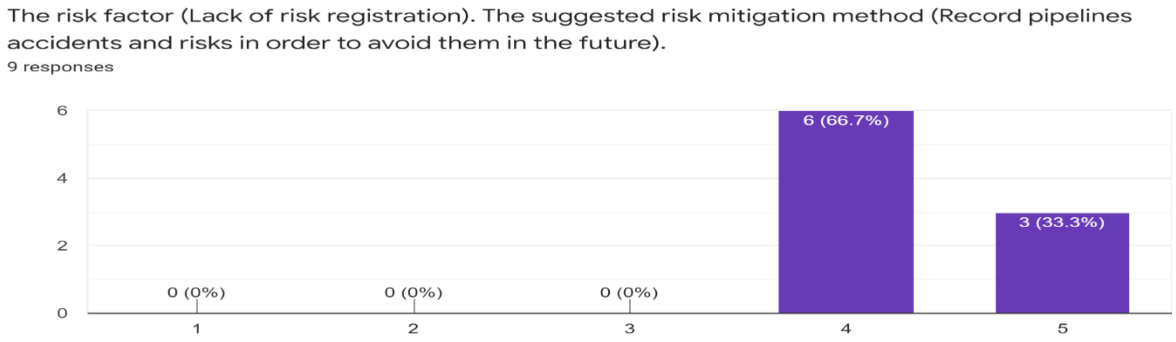


Figure F.20: The recommended RMM to manage the Lack of risk registration) IRF.

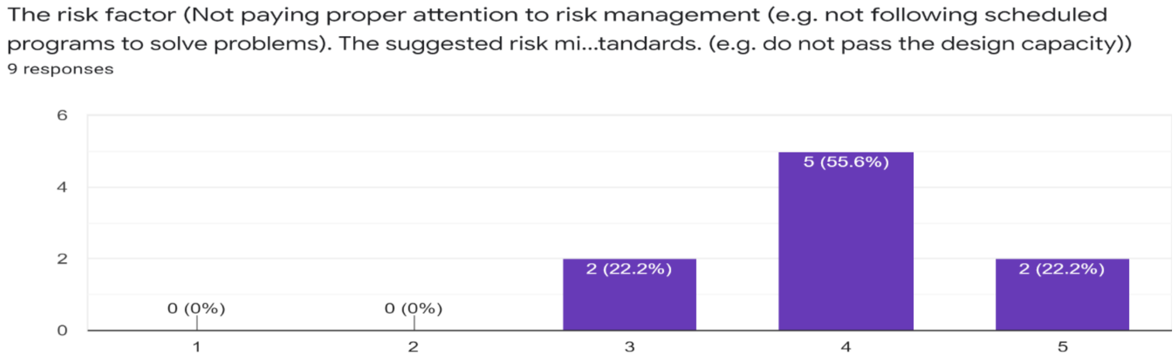


Figure F.21: The recommended RMM to manage the Not paying appropriateattention to risk management (e.g. not following scheduled programmes to solve problems) IRF.

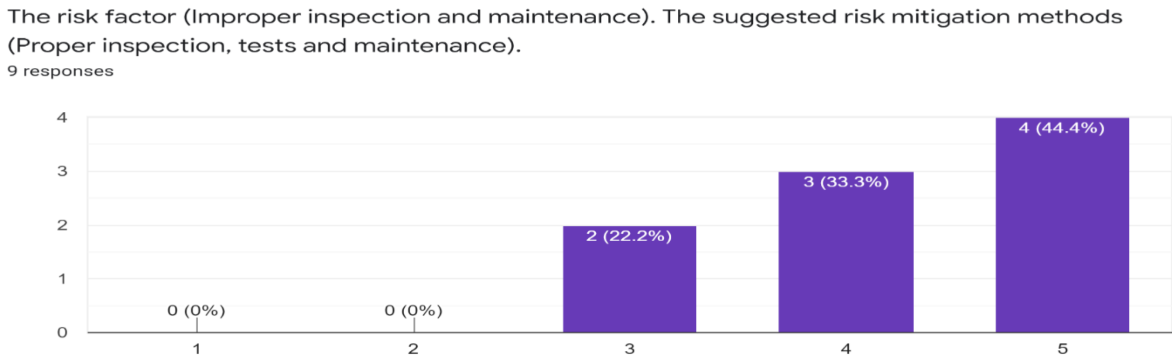


Figure F.22: The recommended RMM to manage the Improper inspection and maintenance) IRF.

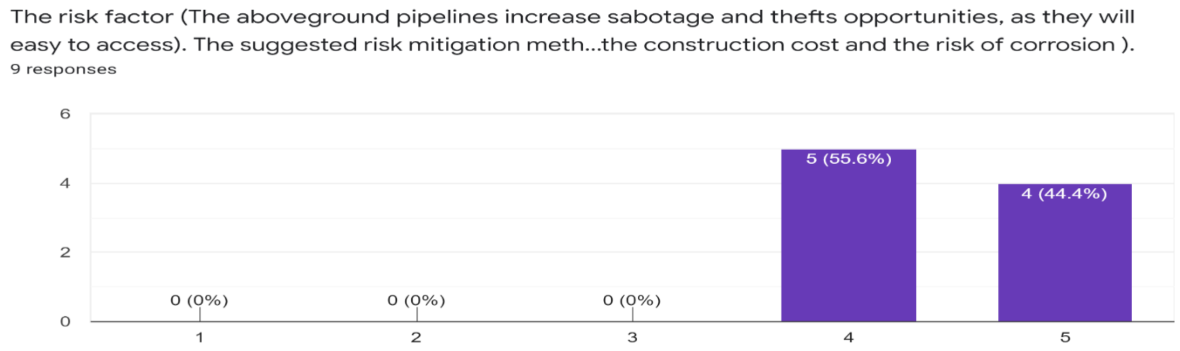


Figure F.23: The recommended RMMs to manage The aboveground pipelines increase sabotage and theft opportunities, as they will be easy to access IRF.

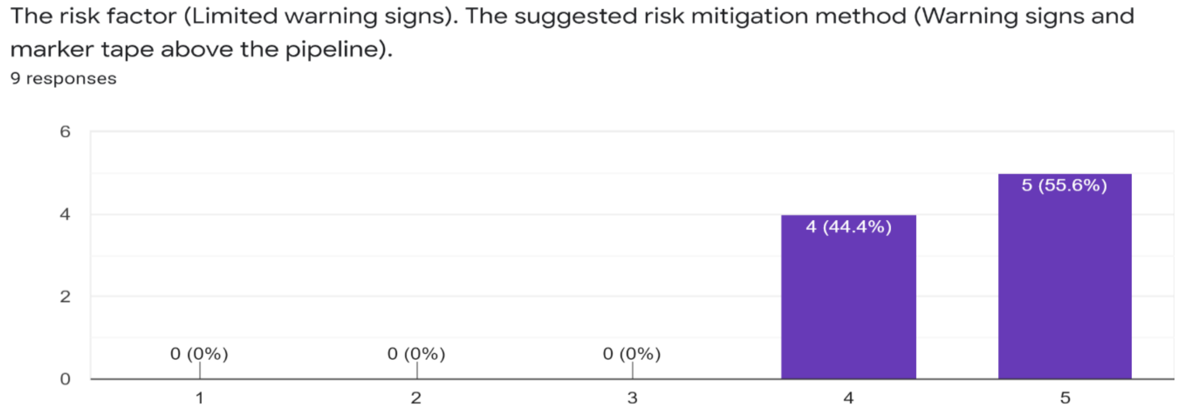


Figure F.24: The recommended RMM to manage the Limited warning signs IRF.

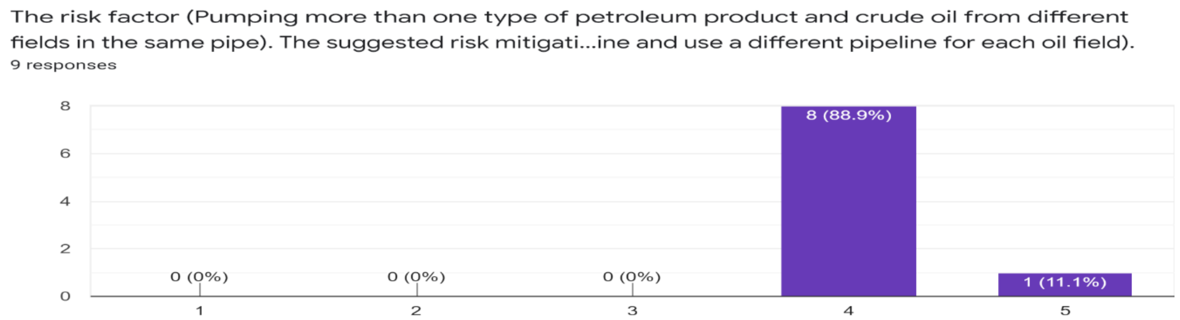


Figure F.25: The recommended RMMs to manage the Pumping more than one type of petroleum product and crude oil from different fields in the same pipe IRF.

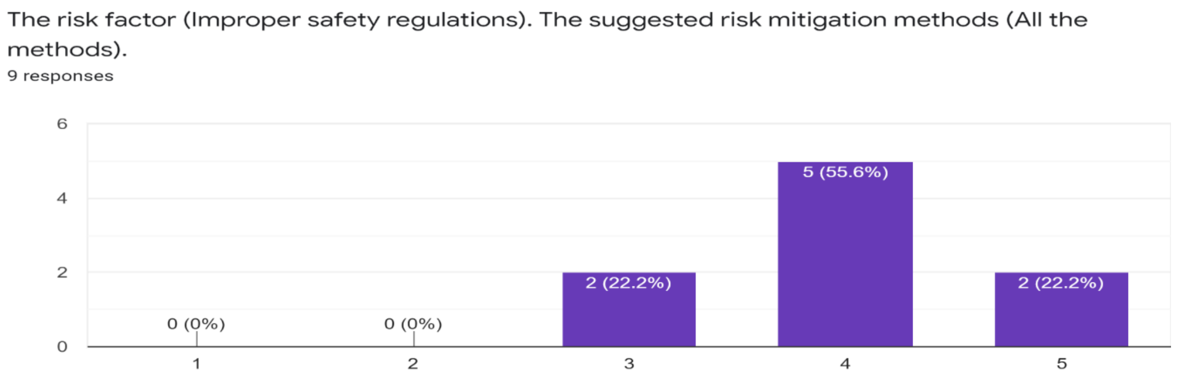


Figure F.26: The recommended RMMs to manage the Improper safety regulations IRF.

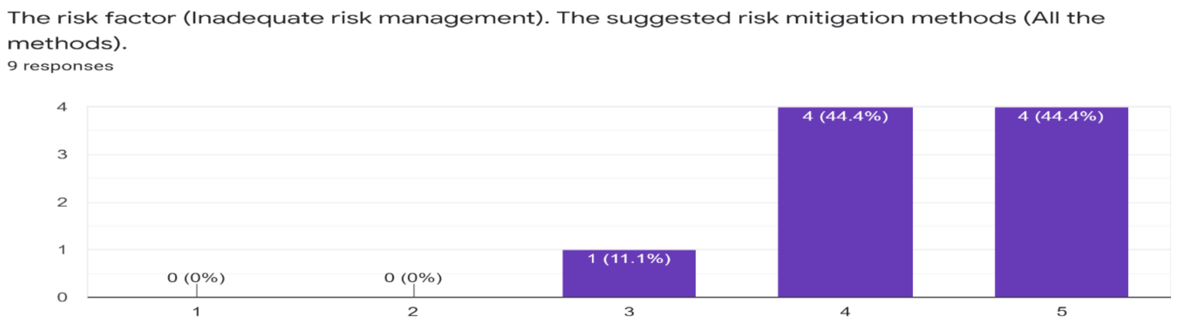


Figure F.27: The recommended RMMs to manage the Inadequate risk management IRF.

APPENDIX G: THE RESULTS OF RISK SIMULATION USING ASTA RISK SIMULATOR

This appendix presents the results of using ASTA risk simulator to analyse the delay in the project using two risk simulation methods (which are Monte Carlo Simulation (MCS) and Latin Hypercube Simulation (LHS)) and four risk distribution methods (which are Uniform, Normal, Skewed Normal and Skewed Triangular), which are integrated with the ASTA risk simulator. The results of using these distribution methods are as follows.

G.1. The Results of Using MCS to Analyse Risk Delay Impact in the Project

This section presents the results of using **MCS** to analyse the delay in the project using four risk distribution methods, which are Uniform, Normal, Skewed Normal and Skewed Triangular, which are integrated with the ASTA risk simulator. The results of using these distribution methods are as follows.

1- **Considering Uniform risk distribution**, it was found that the project needs 1352 days to be completed rather than 1334 days, which is the initial duration of the project. This means that the project will take a longer time due to the impact of the IRFs associated with it. It was found that the project is expected to be completed on January 31, 2023, rather than January 14, 2023, which means that the average delay in the project is 18 days with 50% probability, see Figure G.1.

   Additionally, the ASTA risk simulator shows the maximum hits of each sample, which is the date that got the highest frequency as a project finishing date during the simulation process. The maximum hits rate using the Uniform risk distribution method is 353, which reflects the mean value of the project duration. Moreover, the ASTA risk simulator shows the Standard Deviation (Std) of each sample. The Std measures the dispersion of the data from the mean, which shows the variability within the sample. In other words, the Std characterises the average distance of the data from the mean of the distribution value of the sample; which means the sample with a low Std is the more significant sample. The Std of this distribution method is 18 days. This means there is a 68% probability that the project will be finished between 1334 and 1370 days, whereas there is a 95% probability that it will be finished between 1316 and 1388 days, see Figure G.1.

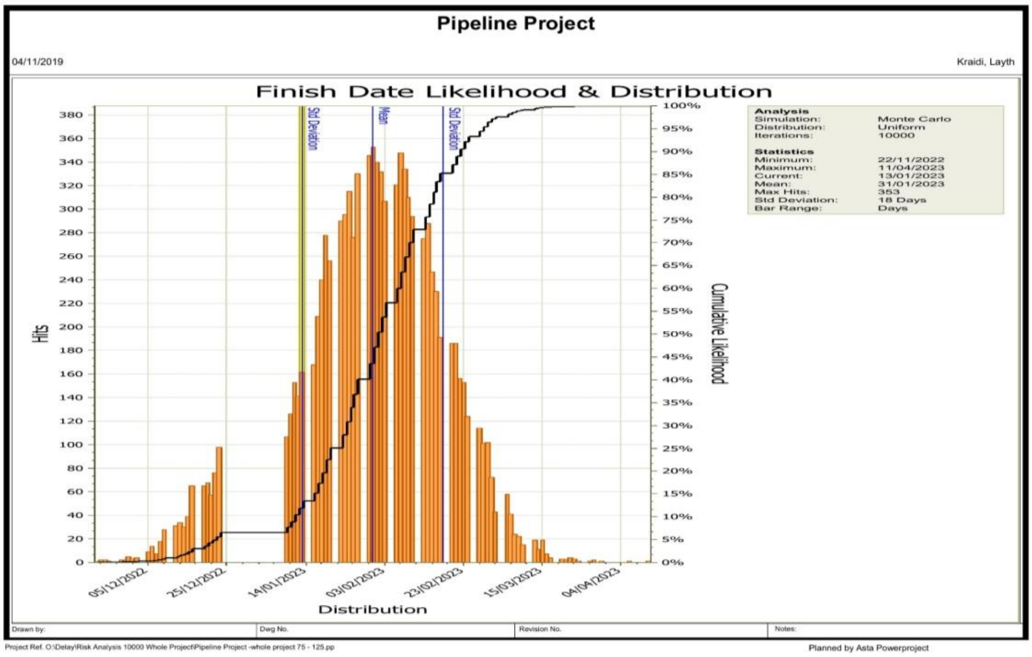


Figure G.1: Finish date likelihood and distribution using the **Uniform data distribution method, using MCS**.

2- **Considering Normal risk distribution**, it was found that the average delay in the project is 16 days, which means it is expected that the project will be completed on January 29, 2023, with 50% probability, see Figure G.2. The maximum hits rate of this distribution method is 367, which reflects the mean value of the project duration. Meanwhile, the Std of this distribution method is 18 days. This means there is a 68% probability that the project will be finished between 1332 and 1368 days, whereas there is a 95% probability that it will be finished between 1314 and 1386 days, see Figure G.2.

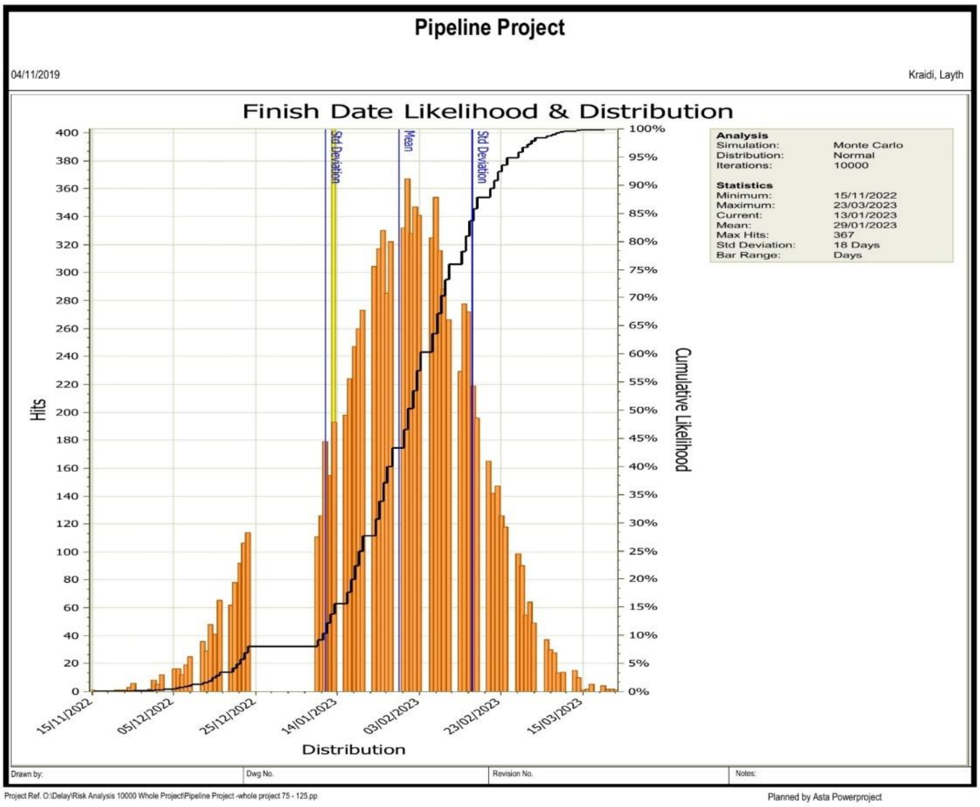


Figure G.2: Finish date likelihood and distribution using the **Normal distribution method, using MCS**.

3- **Considering Skewed Normal risk distribution**, it was found that the average delay in the project is 16 days, which means it is expected that the project will be completed on January 29, 2023, with 50% probability, see Figure G.3. The maximum hits rate of this distribution method is 382, which reflects the mean value of the project duration. The Std of this distribution method is 18 days. This means there is a 68% probability that the project will be finished between 1332 and 1368 days, whereas there is a 95% probability that it will be finished between 1314 and 1386 days, see Figure G.3.

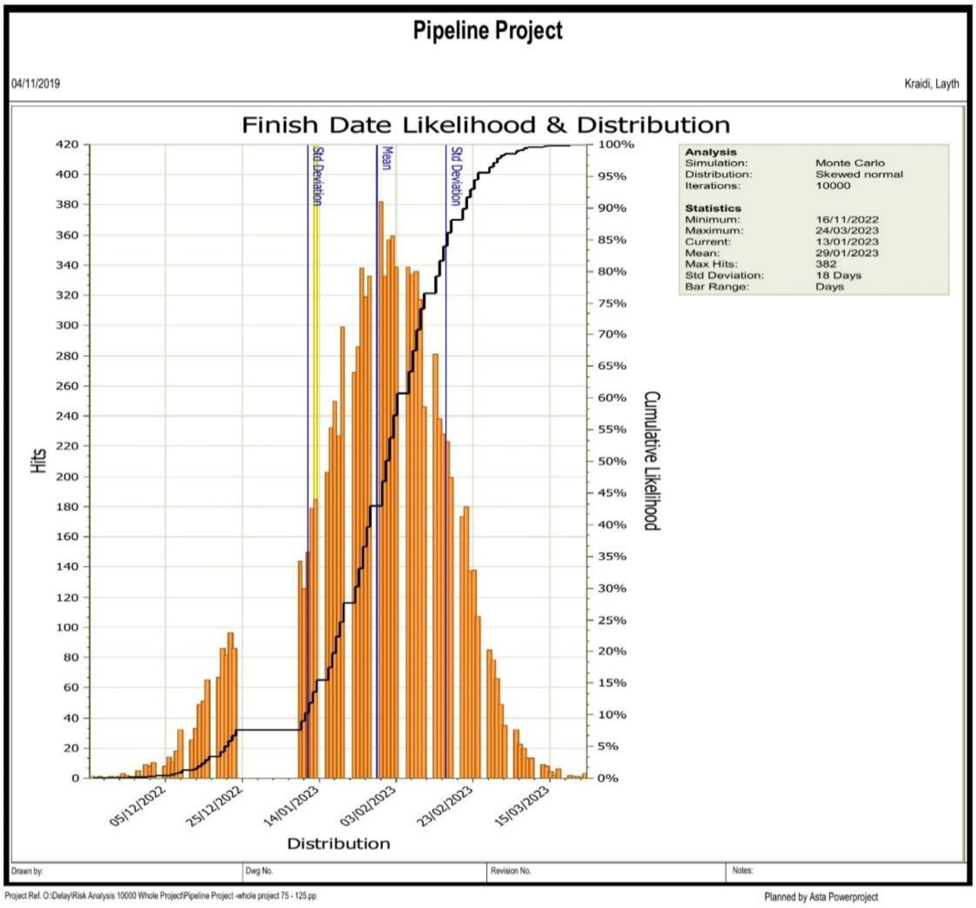


Figure G.3: Finish date likelihood and distribution using the **Skewed Normal data distribution method, using MCS**.

4- **Considering Skewed Triangular risk distribution**, it was found that the average delay in the project is 15 days, which means it is expected that the project will be completed on January 28, 2023, with 50% probability, see Figure G.4. The maximum hits rate of this distribution method is 310, which reflects the mean value of the project duration. The Std of this distribution method is 22 days. This means there is a 68% probability that the project will be finished between 1327 and 1371 days, whereas there is a 95% probability that it will be finished between 1305 and 1393 days, see Figure G.4.

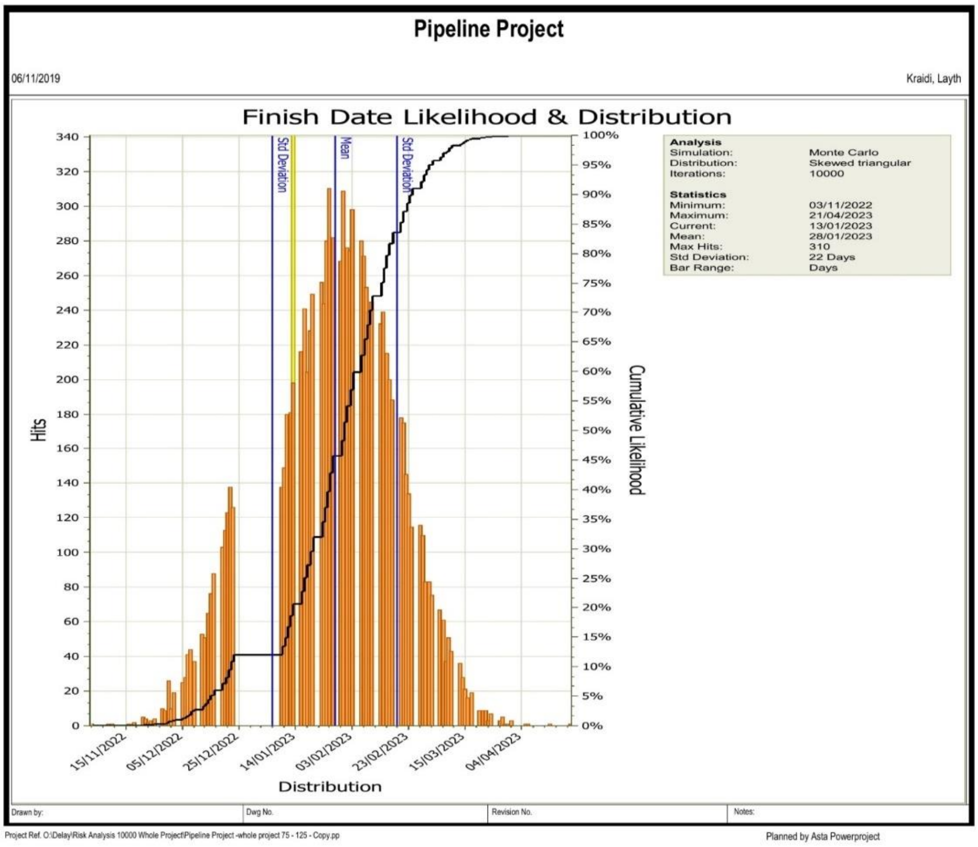


Figure G.4: Finish date likelihood and distribution using the **Skewed Triangular data distribution method, using MCS**.

The next section presents the results of using the ASTA risk simulator and HLS to analyse the impact of the IRFs on the case study project.

G.2. The Results of Using LHS to Analyse Delay in the Project

This section presents the results of using **LHS** to analyse the delay in the project using four risk simulation methods, which are Uniform, Normal, Skewed Normal and Skewed Triangular, which are integrated with the ASTA risk simulator. The results of using these distribution methods are as follows.

1- **Considering Uniform risk distribution**, it was found that the average delay in the project is 17 days, which means it is expected that the project will be completed on January 30, 2023, with 50% probability, see Figure G.5. The maximum hits rate of this distribution method is 299, which reflects the mean value of the project duration. The Std of this distribution method is 18 days. This means there is a 68% probability that the project will be finished between 1330 and 1372 days, whereas there is a 95% probability that it will be finished between 1309 and 1393 days, see Figure G.5.

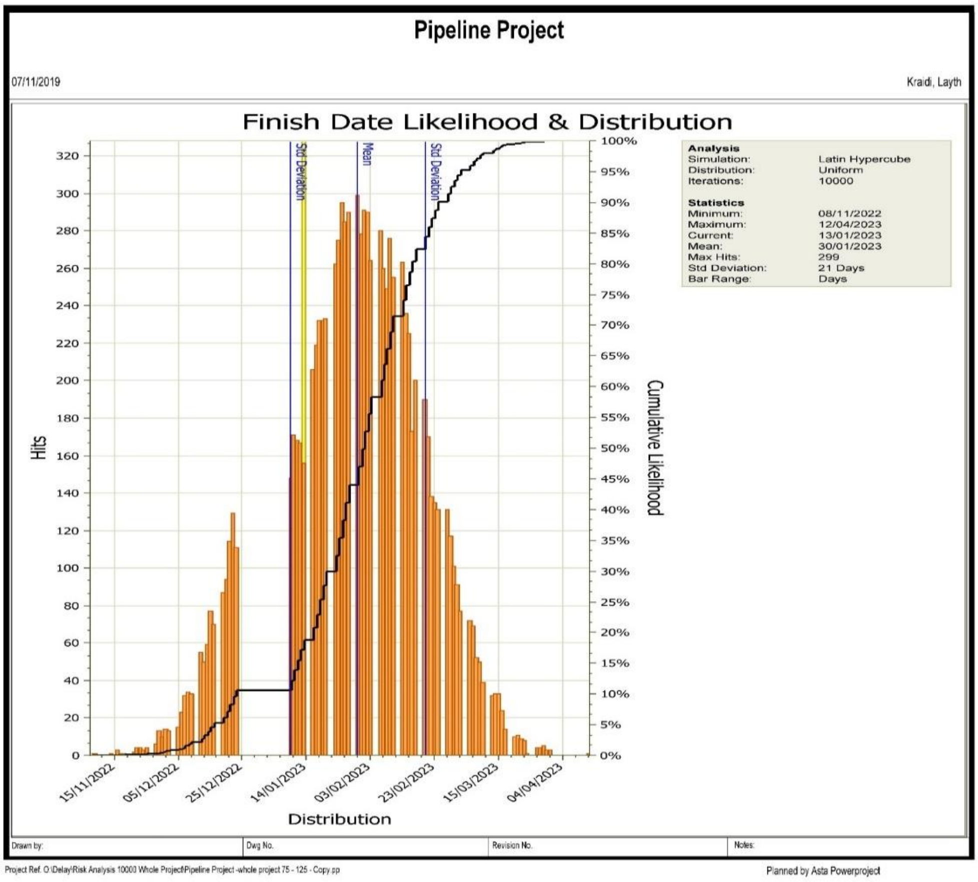


Figure G.5: Finish date likelihood and distribution using the **Uniform data distribution method, using LHS**.

2- **Considering Normal risk distribution**, it was found that the average delay in the project is 16 days. The delay means that the project will take 1350 days to complete rather than the planned 1334 days, which means it is expected that the project will be completed on January 29, 2023, with 50% probability, see Figure G.6. The maximum hits rate of this distribution method is 300, which reflects the mean value of the project duration. The Std of this distribution method is 22 days. This means there is a 68% probability that the project will be finished between 1328 and 1372 days, whereas there is a 95% probability that it will be finished between 1306 and 1394 days, see Figure G.6.

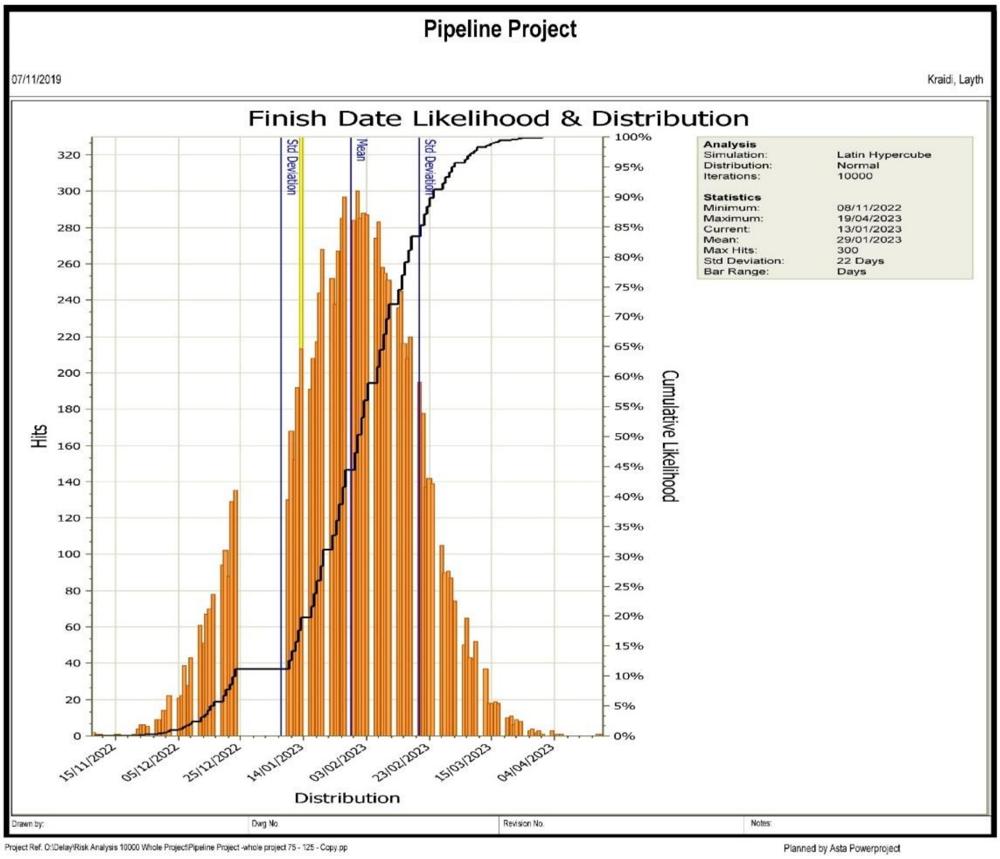


Figure G.6: Finish date likelihood and distribution using the **Normal data distribution method, using LHS**.

3- **Considering Skewed Normal risk distribution**, it was found that the average delay in the project is 15 days. The delay means that the project will take 1349 days to complete rather than the planned 1334 days, which means it is expected that the project will be completed on January 28, 2023, with 50% probability, see Figure G.7. The maximum hits rate of this distribution method is 322, which reflects the mean value of the project duration. The Std of this distribution method is 22 days. This means there is a 68% probability that the project will be finished between 1328 and 1371 days, whereas there is a 95% probability that it will be finished between 1307 and 1391 days, see Figure G.7.

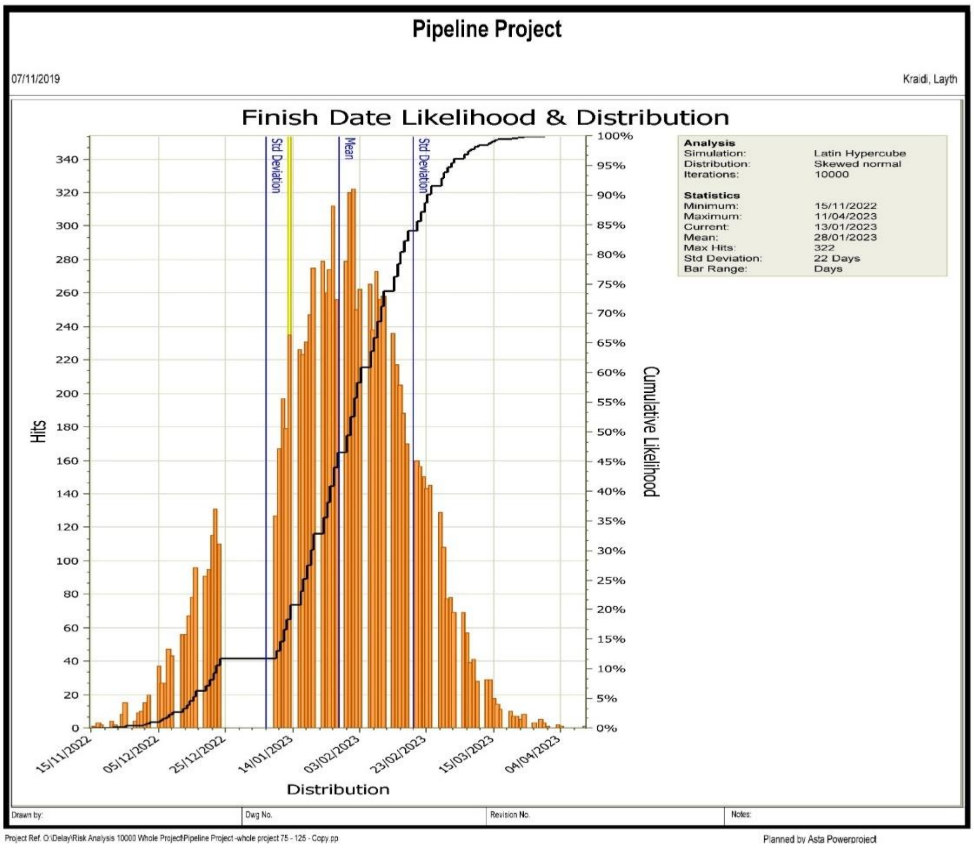


Figure G.7: Finish date likelihood and distribution using **the Skewed Normal data distribution method, using LHS**.

4- **Considering Skewed Triangular risk distribution**, it was found that the average delay in the project is 15 days, which means it is expected that the project will be completed on January 28, 2023, with 50% probability, see Figure G.8. The maximum hits rate of this distribution method is 311, which reflects the mean value of the project duration. The Std of this distribution method is 22 days. This means there is a 68% probability that the project will be finished between 1327 and 1371 days, whereas there is a 95% probability that it will be finished between 1305 and 1393 days, see Figure G.8.

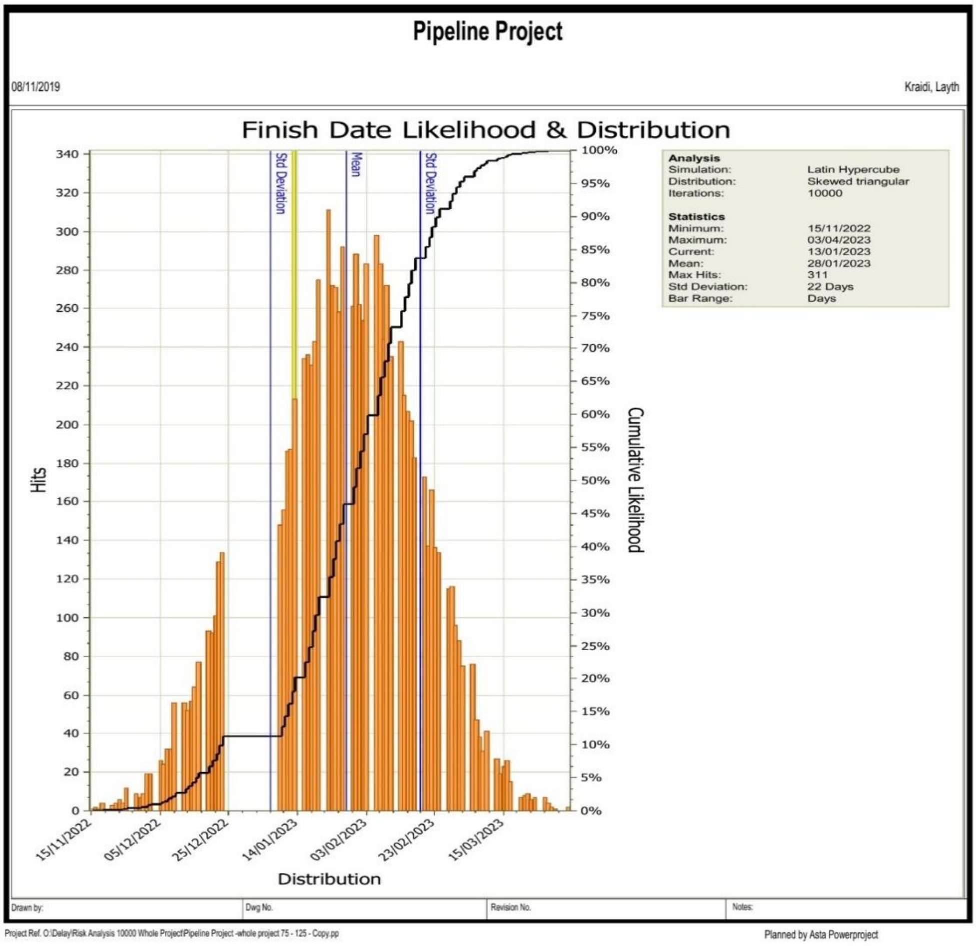


Figure G.8: Finish date likelihood and distribution using the **Skewed Triangular data distribution method, using LHS**.

G.3. The Results Duration Sensitivity

This section provides the results of using the ASTA risk simulator to analyse the sensitivity index of the project activities and analyse their degree of impact affecting the duration of the project. ASTA risk simulator shows the sensitivity analysis of the activities of the project that are most likely to affect the duration of the project if their duration changes. In other words, the ASTA risk simulator ranks these tasks in terms of their likelihood of delaying the project finishing date. As shown in the table above, using different simulation and distribution methods to analyse the sensitivity index of the project activities has confirmed the two top activities that have a positive impact on the duration of the project, which are as follows. (i) The right of the way, which comes top twice; and (ii) the design and development, which come top six times. Similarly, the two top activities that have a negative impact on the duration of the project are (i) the trenching activities, which come top twice; and (ii) manufacturing and installation, which come top six times. Figure G.9 to Figure G.16

show the detailed ranking of the project's activities using different simulation and distribution methods.

1- With regard to analysing the duration sensitivity index of the project activities using **MCS and Uniform** methods, it was found that the right-of-way, design and development, final fitting, safety barriers, choosing routes, route approval and survey are the activities most likely to affect the duration of the project, see Figure G.9.

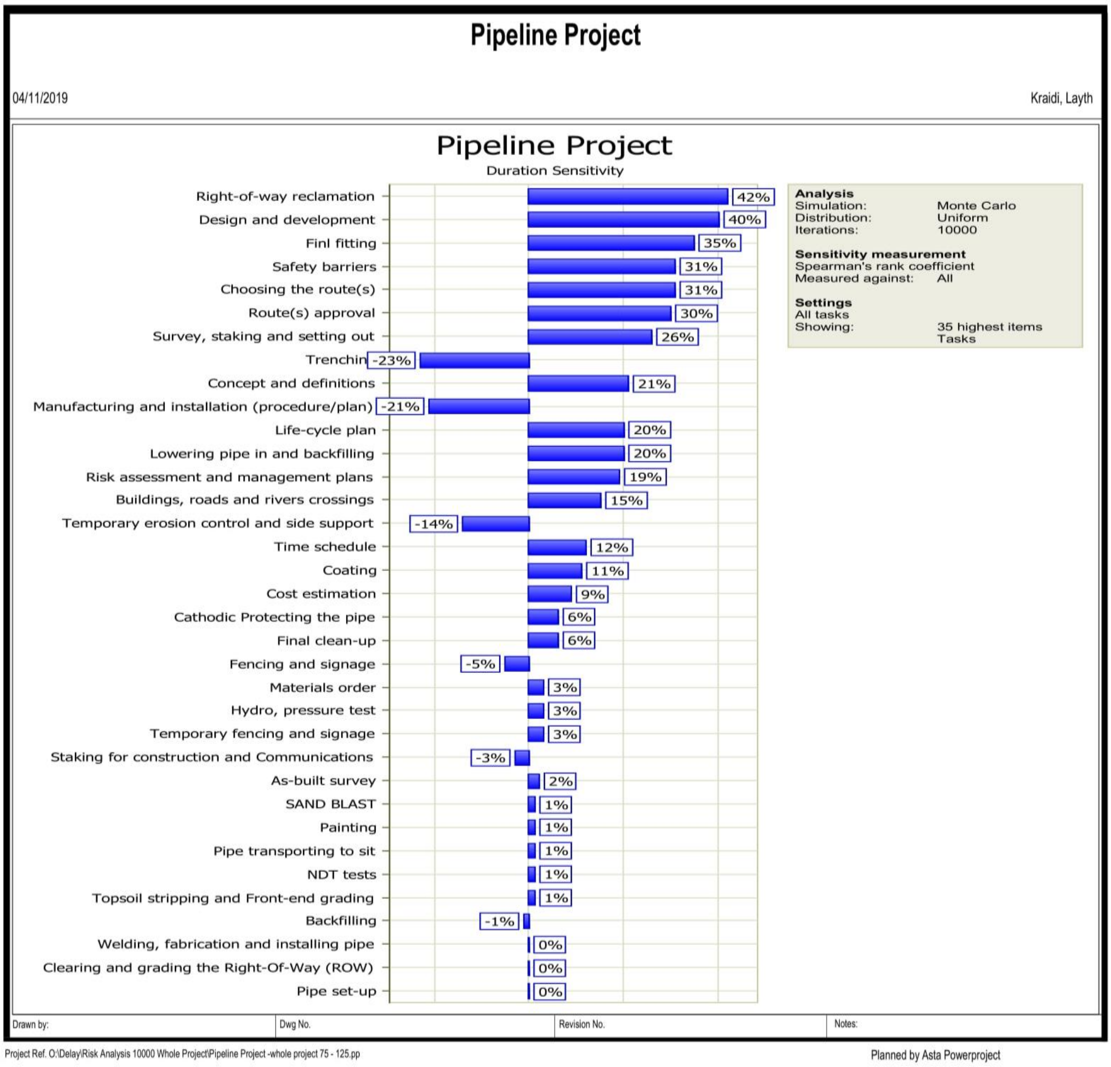


Figure G.9: The duration sensitivity using the **MCS method and Uniform** data distribution method.

2- With regard to analysing the duration sensitivity index of the project activities using **MCS and Normal** methods, it was found that the right-of-way, design and development, final fitting, safety barriers, choosing routes, route approval and survey are the activities most likely to affect the duration of the project, see Figure G.10.

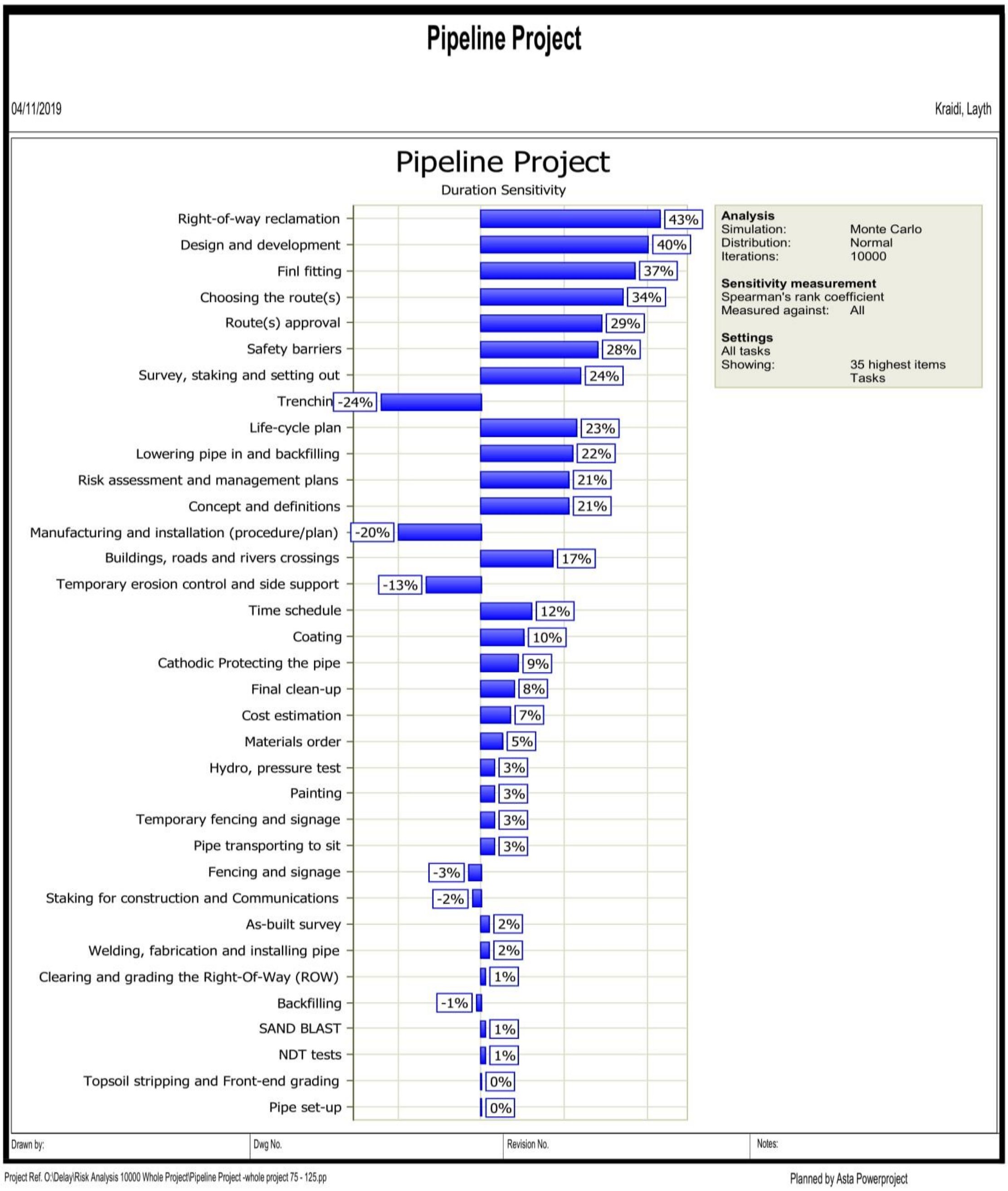


Figure G.10: The duration sensitivity using the **MCS and Normal** data distribution method.

3- With regard to analysing the duration sensitivity index of the project activities using **MCS and Skewed Normal** methods, it was found that the design and development and right of way are the activities most likely to affect the duration of the project, see Figure G.11.

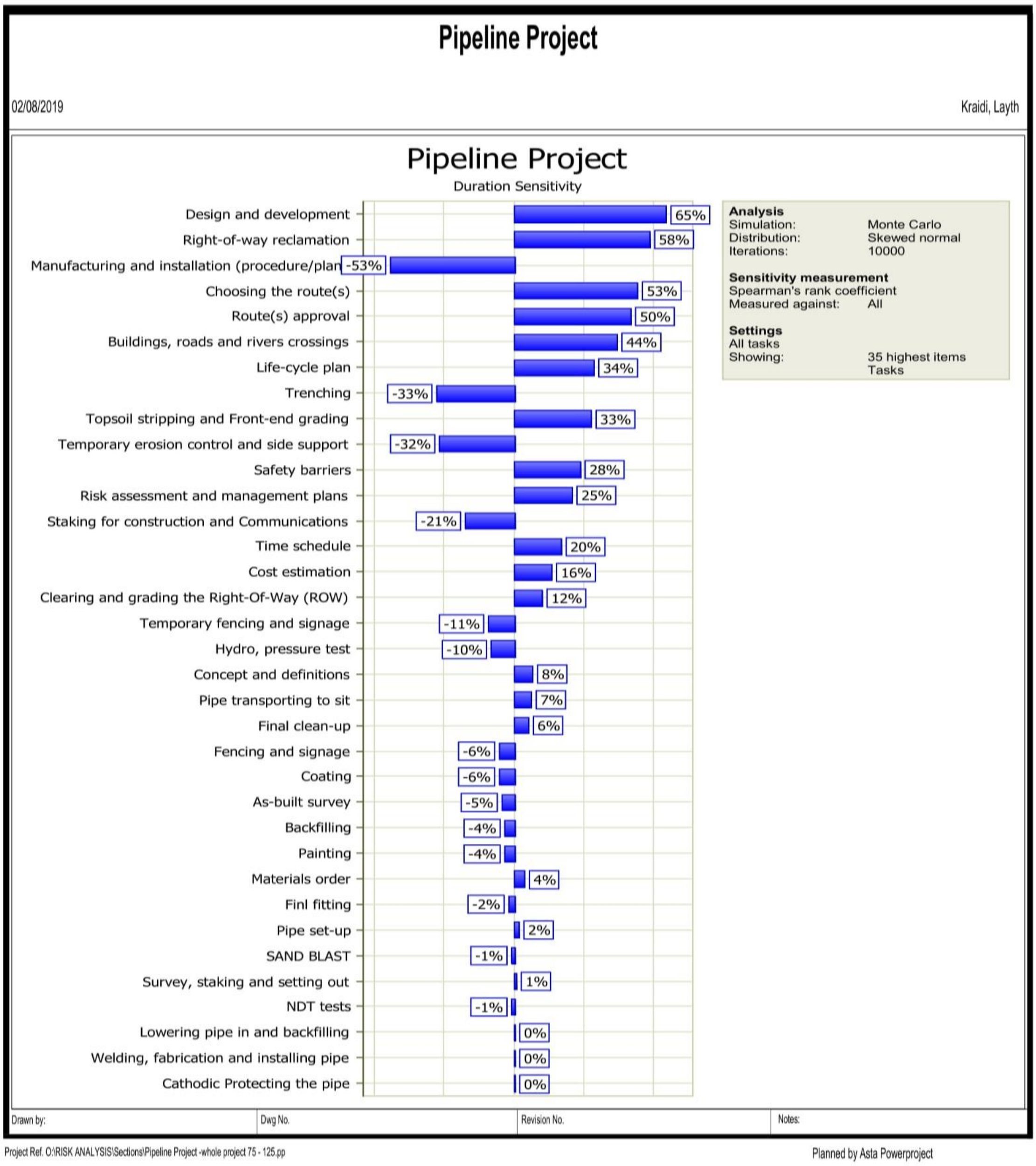


Figure G.11: The duration sensitivity using the **MCS and Skewed Normal** data distribution method.

4- With regard to analysing the duration sensitivity index of the project activities using **MCS and Skewed Triangular** methods, it was found that the design and development, right of way and choosing routes are the activities most likely to affect the duration of the project, see Figure G.12.

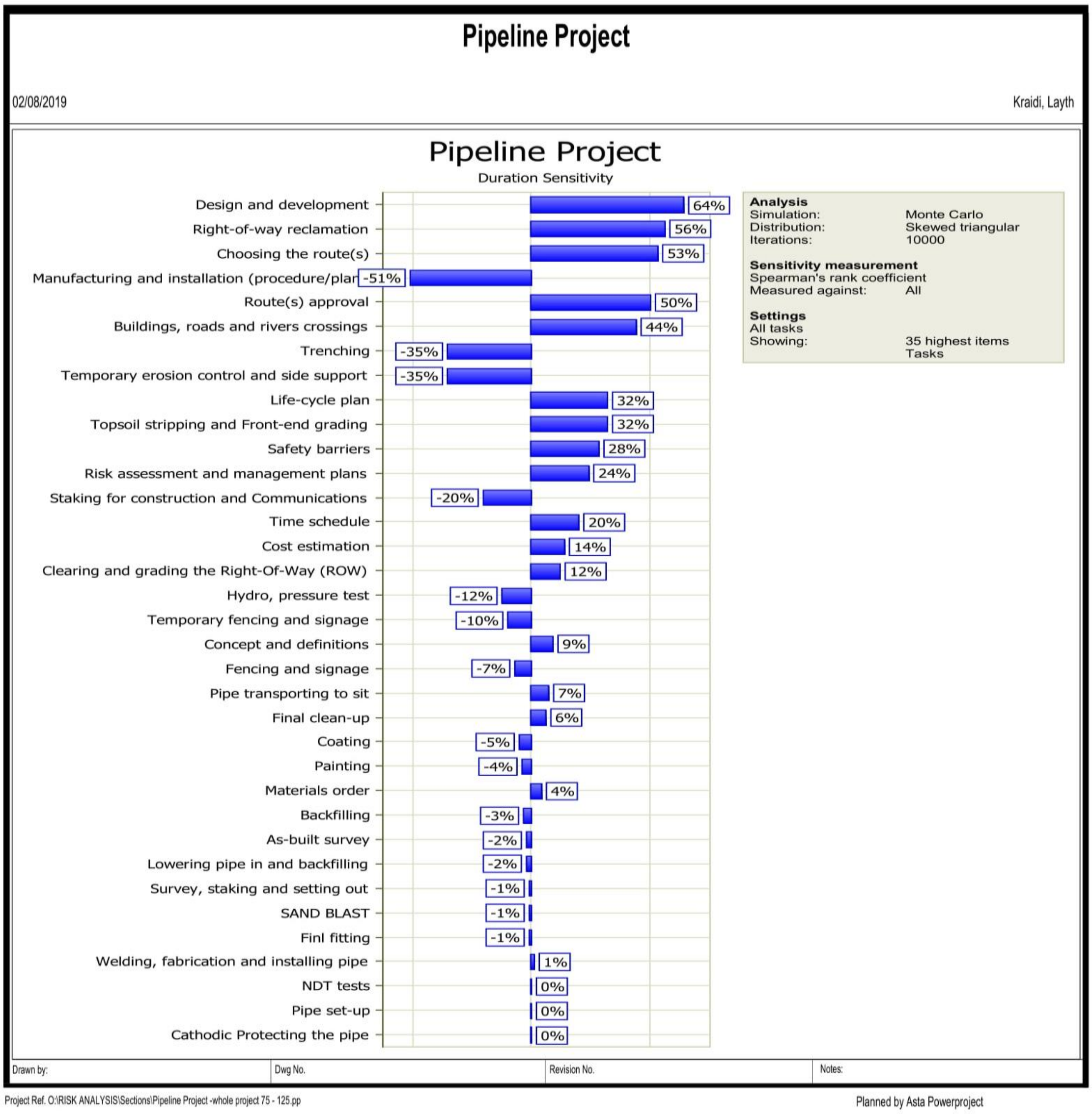


Figure G.12: The duration sensitivity using the **MCS and Skewed Triangular** data distribution method.

5- With regard to analysing the duration sensitivity index of the project activities using **LHS and Uniform** methods, it was found that the design and development and right of way are the activities most likely to affect the duration of the project, see Figure G.13.

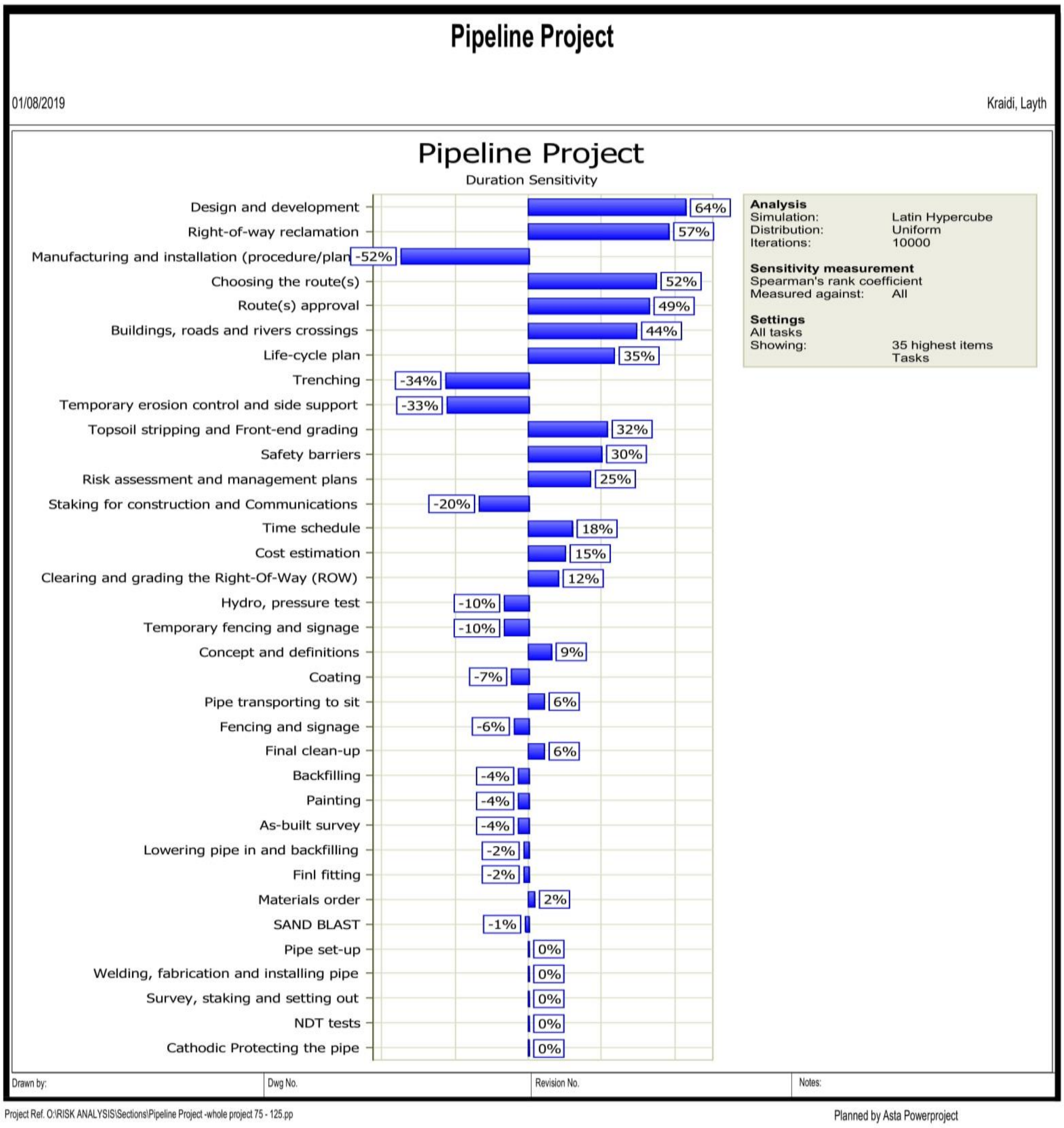


Figure G.13: The duration sensitivity using the **LHS and Uniform** data distribution method.

6- With regard to analysing the duration sensitivity index of the project activities using **LHS and Normal** methods, it was found that the design and development, right of way and choosing routes are the activities most likely to affect the duration of the project, see Figure G.14.

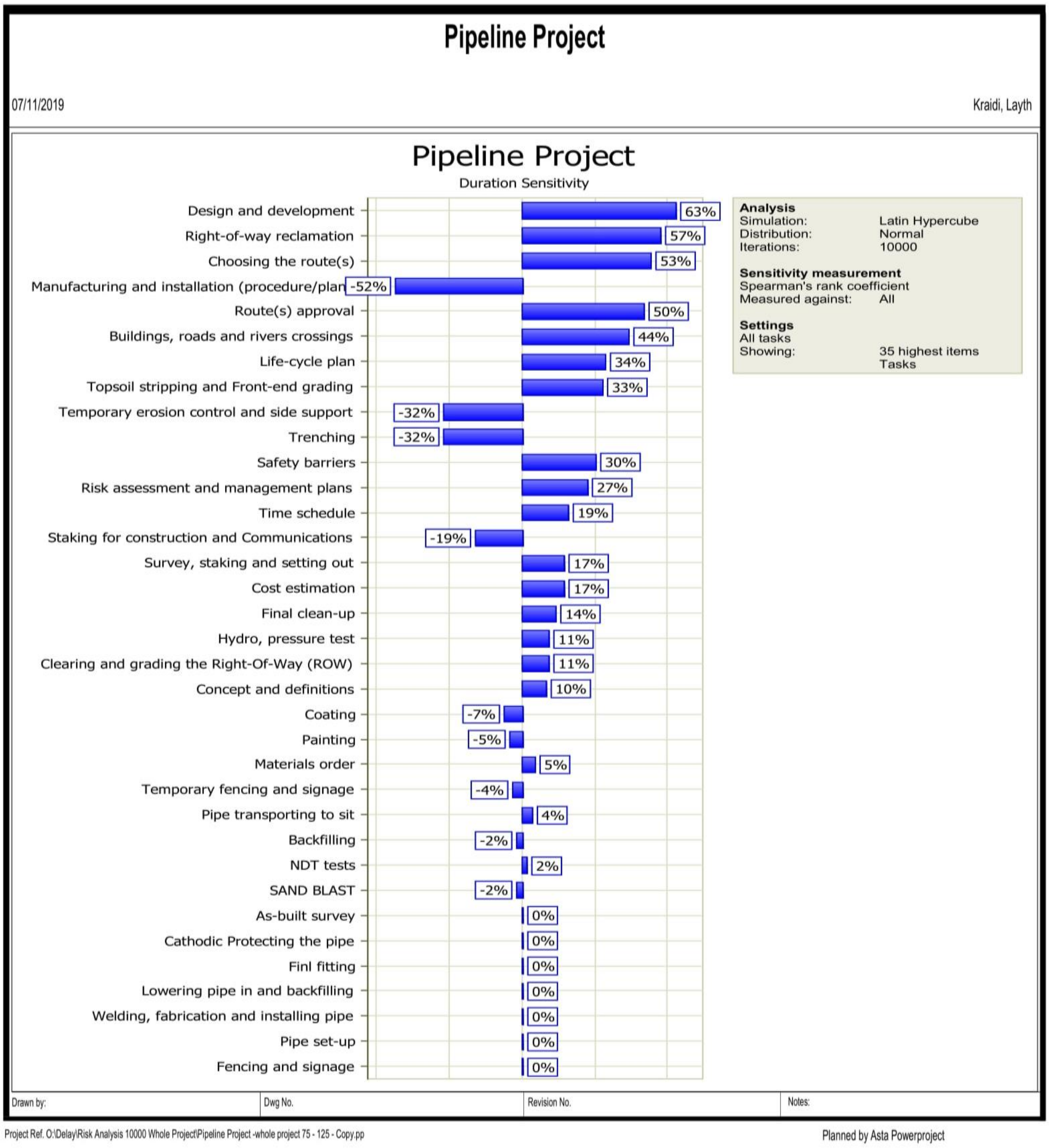


Figure G.14: The duration sensitivity using **the LHS and Normal** data distribution method.

7- With regard to analysing the duration sensitivity index of the project activities using **LHS and Skewed Normal** methods, it was found that the design and development, right of way and choosing routes are the activities most likely to affect the duration of the project, see Figure G.15.

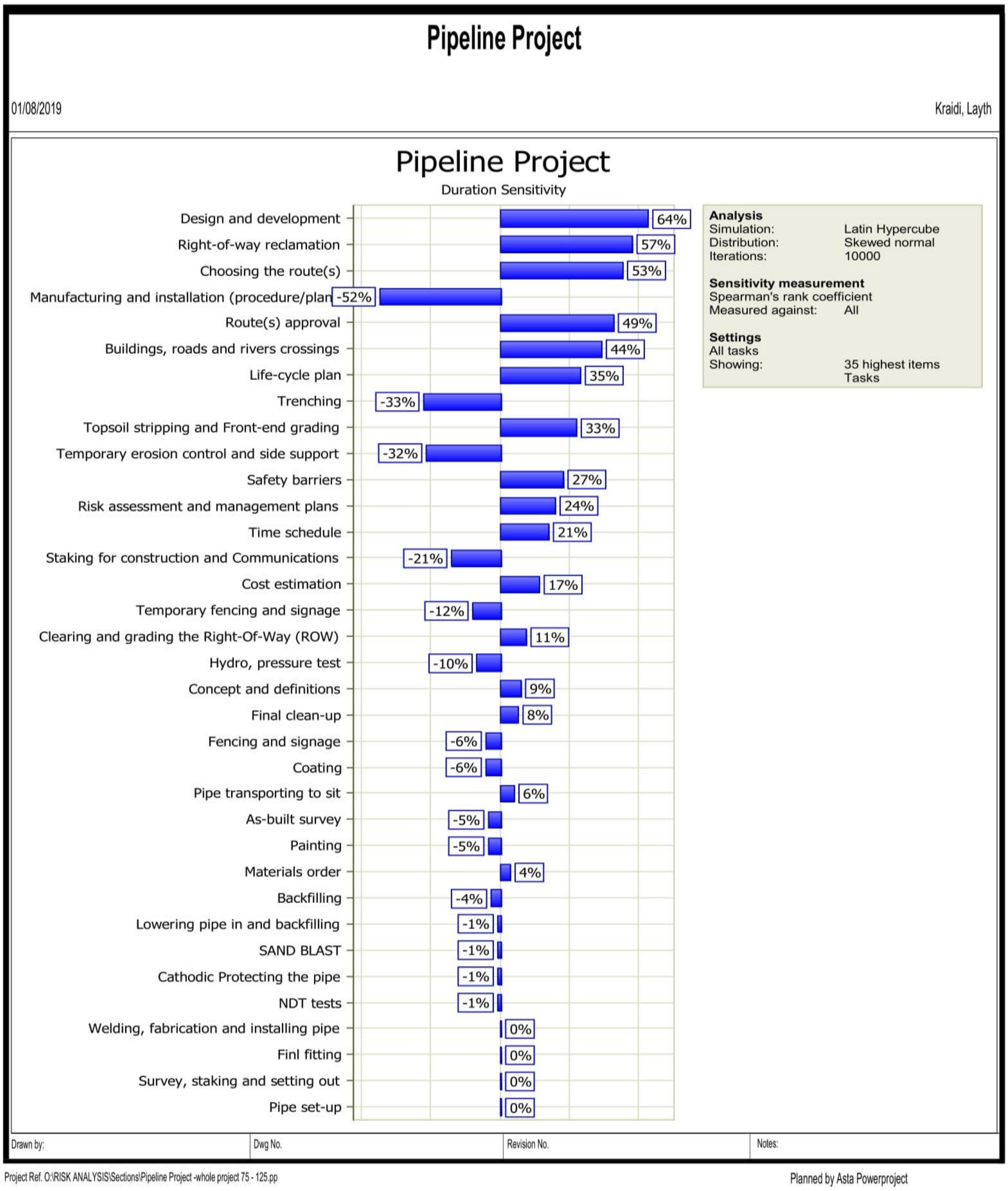


Figure G.15: The duration sensitivity using the **LHS method and Skewed Normal** data distribution method.

8- With regard to analysing the duration sensitivity index of the project activities using **LHS and Skewed Triangular** methods, it was found that the design and development, right of way and choosing routes are the activities most likely to affect the duration of the project, see Figure G.16.

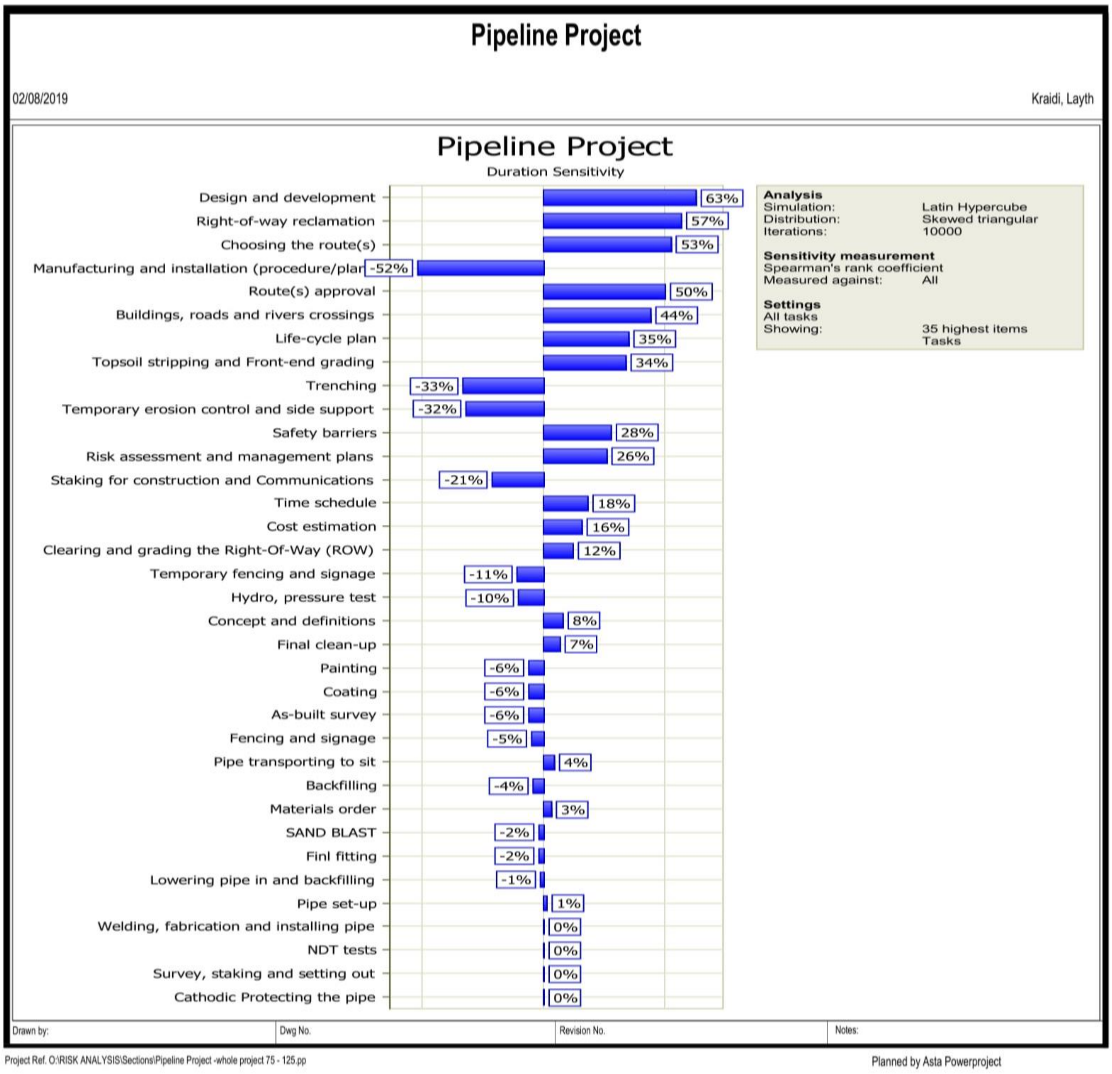


Figure G.16: The duration sensitivity using the **LHS and Skewed Triangular** data distribution method.

G.4 The Results of Criticality Index Sensitivity

This section provides the results of using the ASTA risk simulator to analyse the criticality index of the activities that appear on the critical path of the project and their degree of impact on changing the duration of the project in case their durations are changed. The ASTA risk simulator identifies the tasks that have the highest iterations as the activities that might change the project duration. After running thousands of simulations (depending on the number of iterations), the ASTA risk simulator generates a report to rank the activities of the project from highest to lowest impact in terms of their degrees of criticality impact on the project duration. The activities with the higher criticality index are those that are more likely to affect the finishing date of the project. Some activities may appear as critical activities using a certain simulation or distribution method, but they might not appear as critical activities using different methods.

With regard to using **MCS** to analyse the criticality sensitivity index of the project activities, the activities stayed in the same position of ranking using Uniform and Normal distribution or Skewed Normal and Skewed Triangular distribution. However, the ranking positions of these activities are slightly different using Uniform and Normal distribution comparing to Skewed Normal and Skewed Triangular distribution. In the meanwhile, the ranking positions of the project activities were not changed using the four different risk distribution methods along with **LHS**. Nevertheless, the ranking positions were slightly changed comparing the results of MCS to LHS.

1- The results of analysing the criticality sensitivity index of the project activities using **MCS and Uniform** distribution are shown in the figure below.

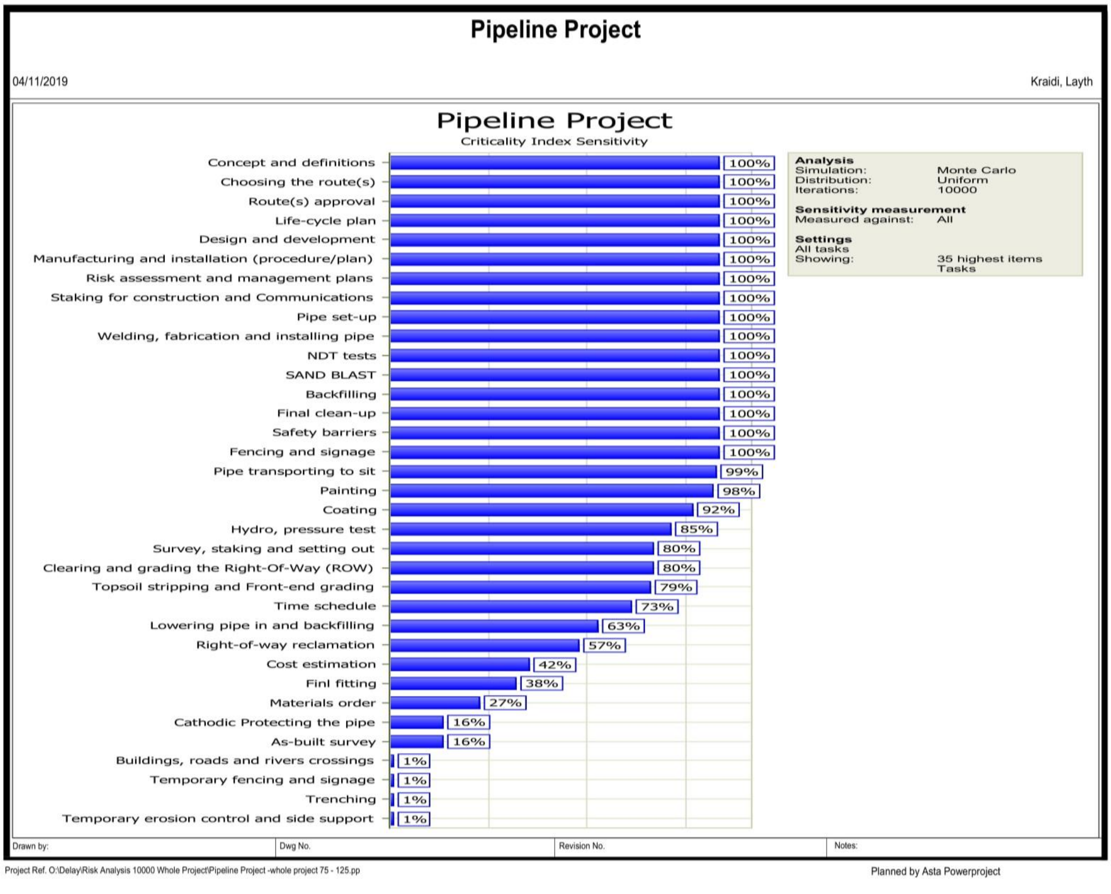


Figure G.17: Results of criticality index sensitivity using **MCS and Uniform** distribution.

2- Results of analysing the criticality sensitivity index of the project activities using **MCS and Normal** distribution are shown in the figure below.

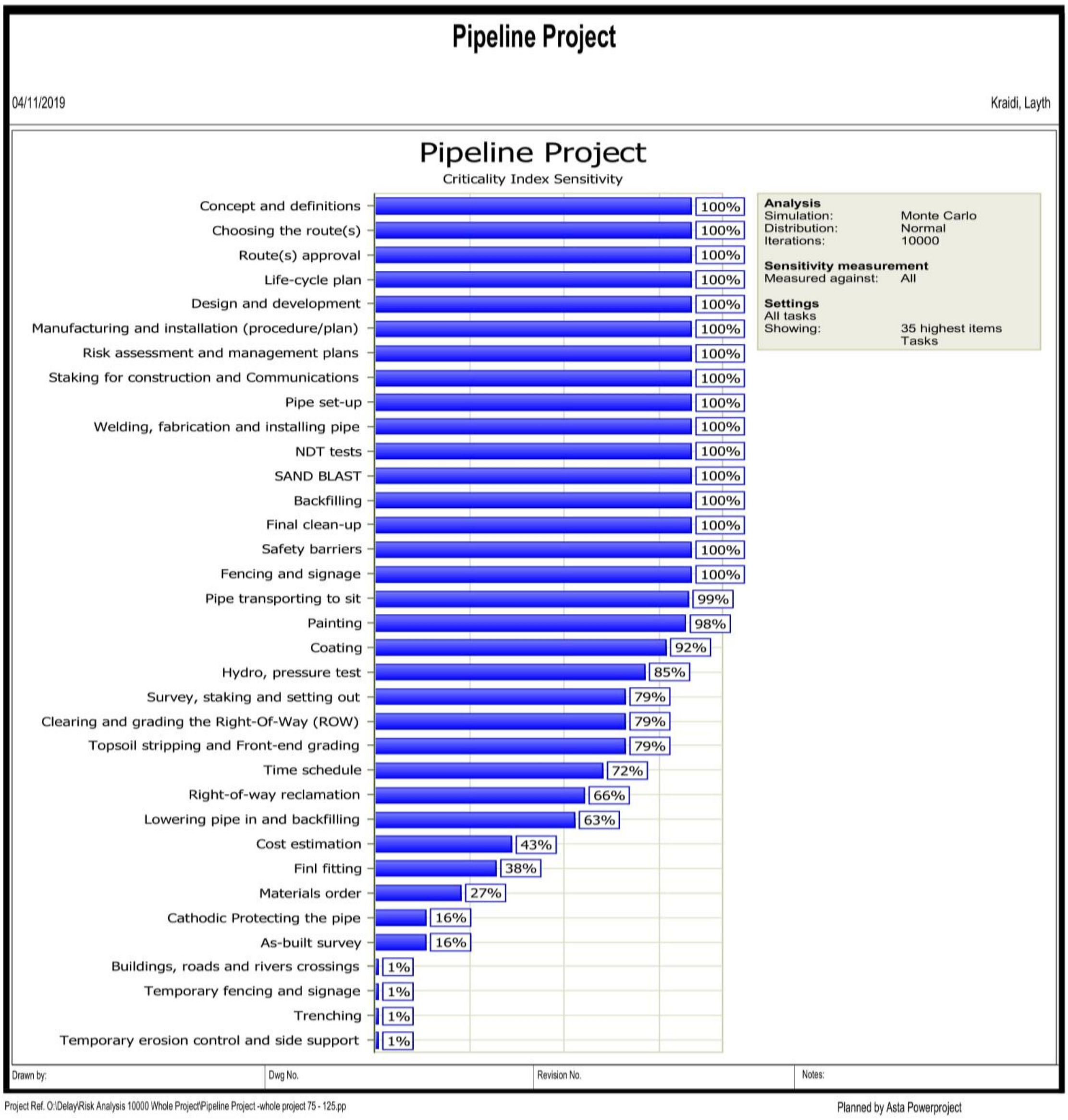


Figure G.18: Results of criticality index sensitivity using **MCS and Normal** distribution.

3- Results of analysing the criticality sensitivity index of the project activities using **MCS and Skewed Normal** distribution are shown in the figure below.

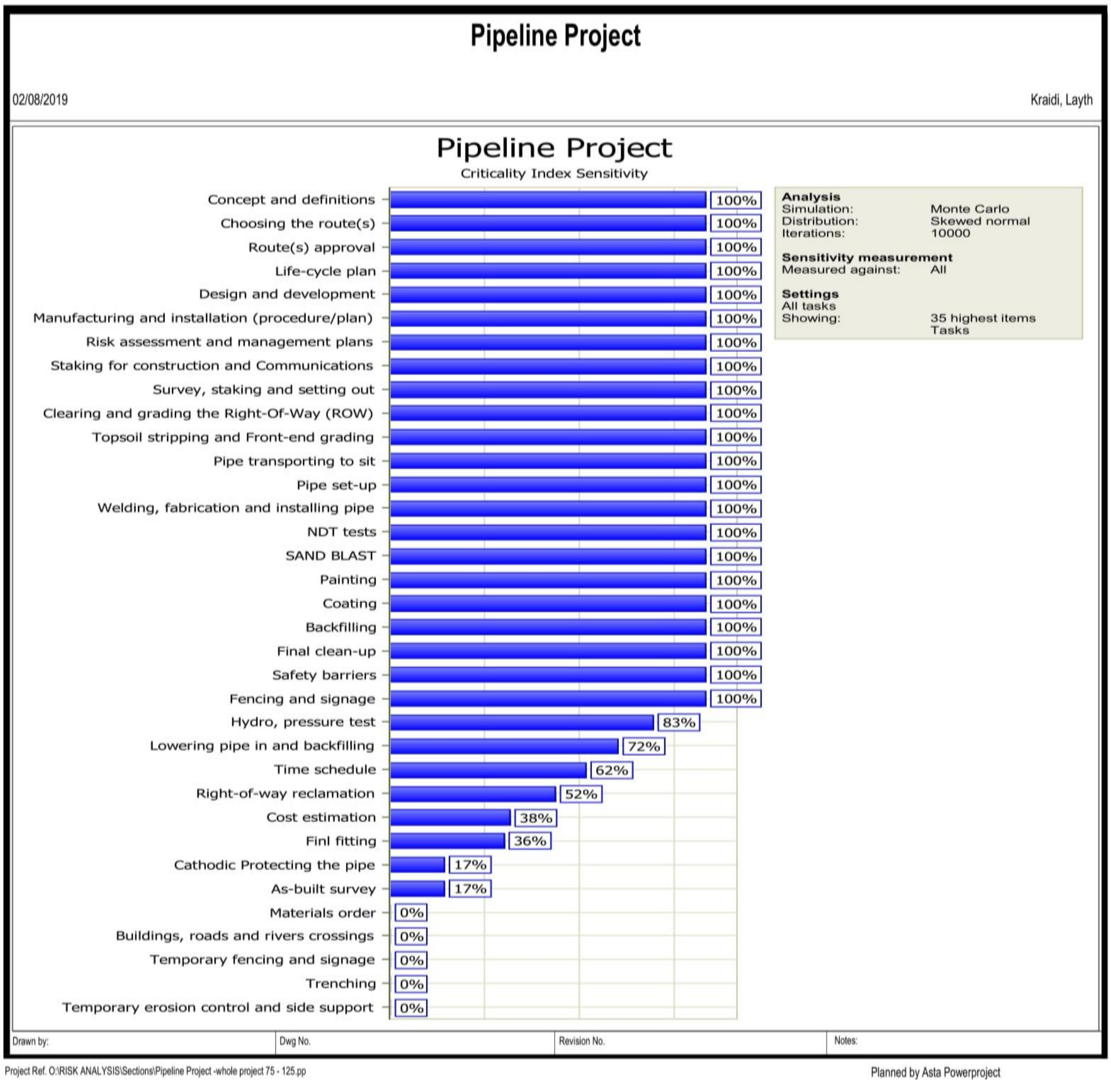


Figure G.19: Results of criticality index sensitivity using **MCS and Skewed Normal** distribution.

4- Results of analysing the criticality sensitivity index of the project activities using **MCS and Skewed Triangular** distribution are shown in the figure below.

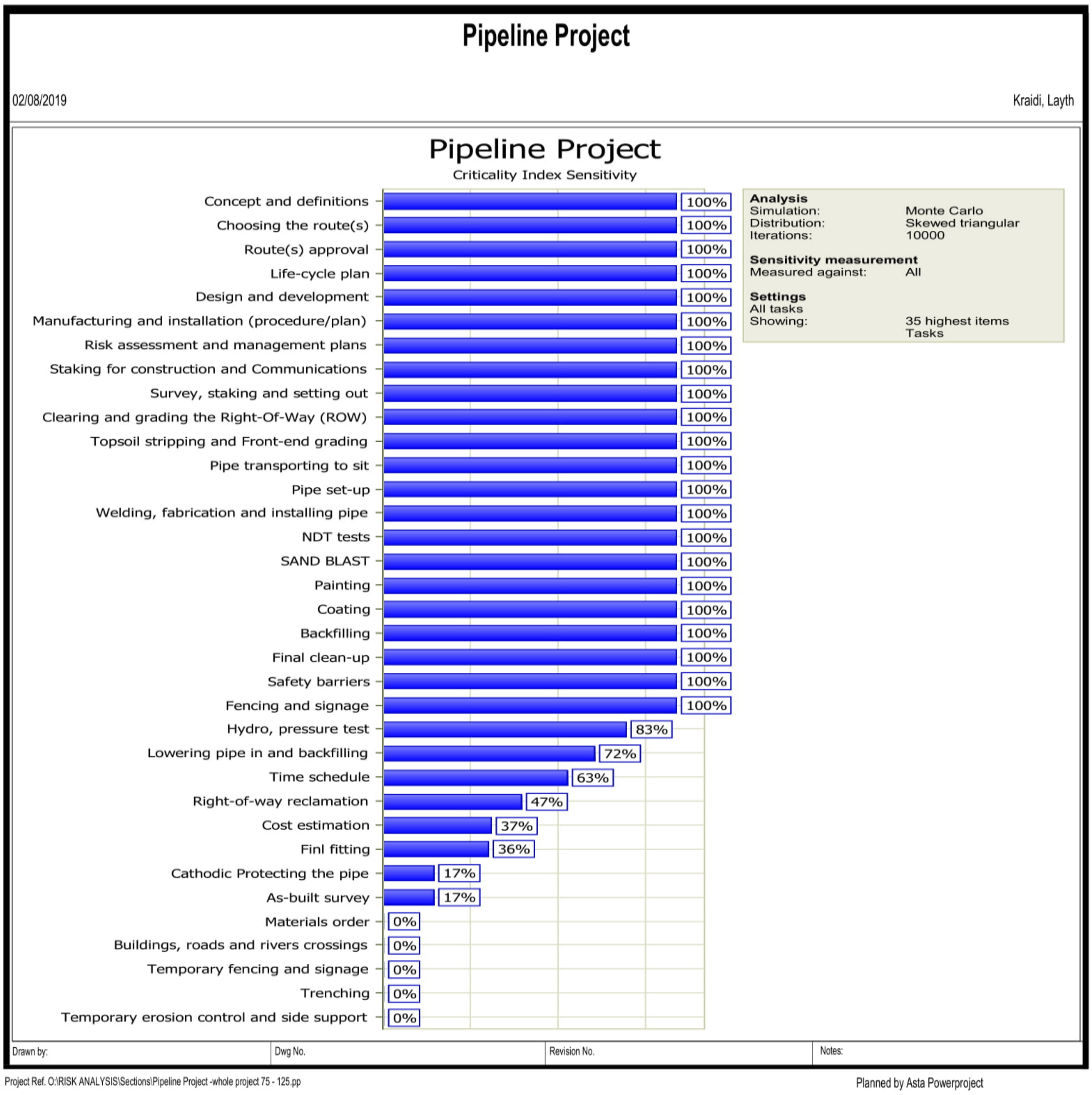


Figure G.20: Results of criticality index sensitivity using **MCS and Skewed Triangular** distribution.

5- Results of analysing the criticality sensitivity index of the project activities using **LHS and Uniform** distribution are shown in the figure below.

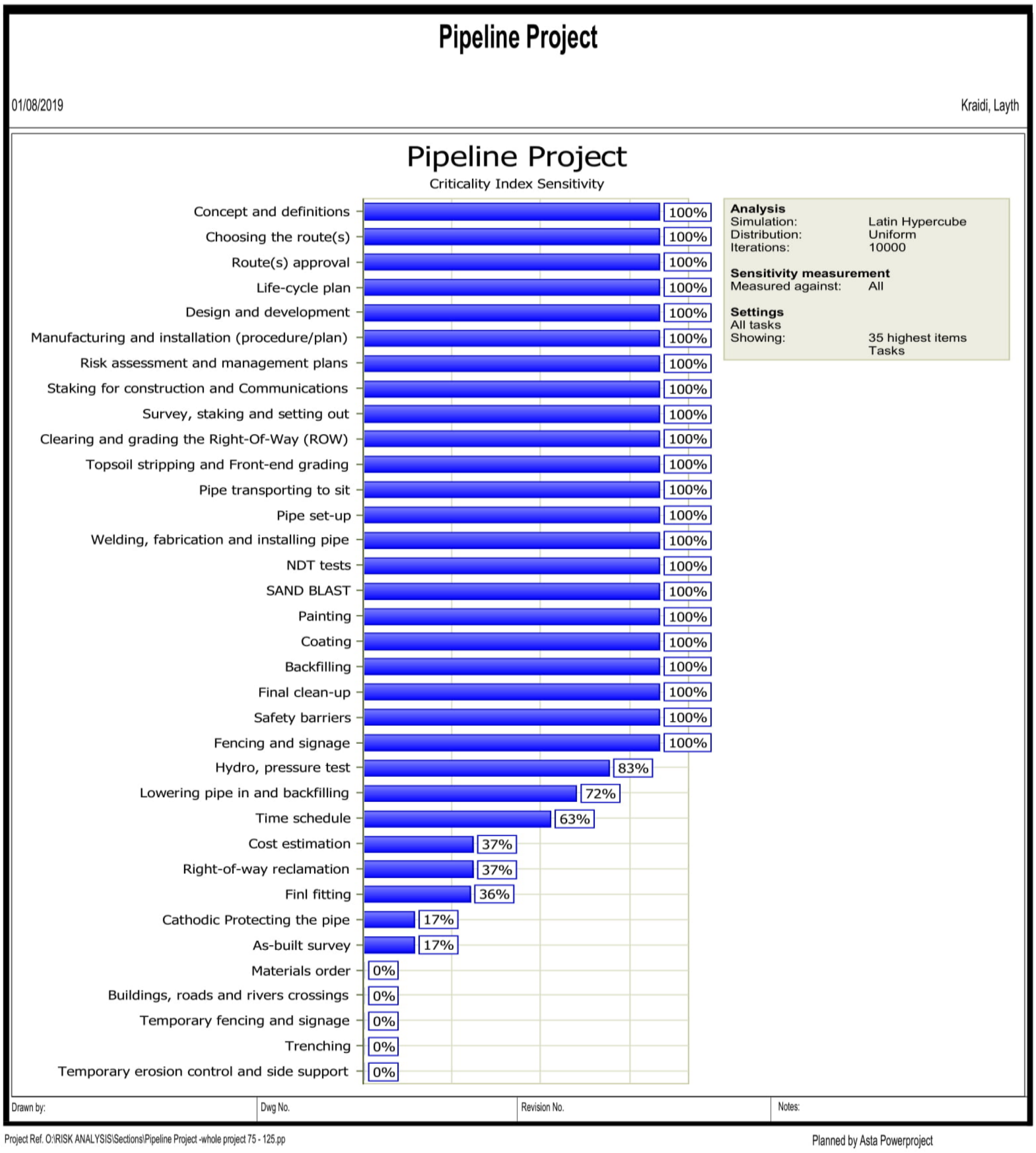


Figure G.21: Results of criticality index sensitivity using **LHS and Uniform** distribution.

6- Results of analysing the criticality sensitivity index of the project activities using **LHS and Normal** distribution are shown in the figure below.

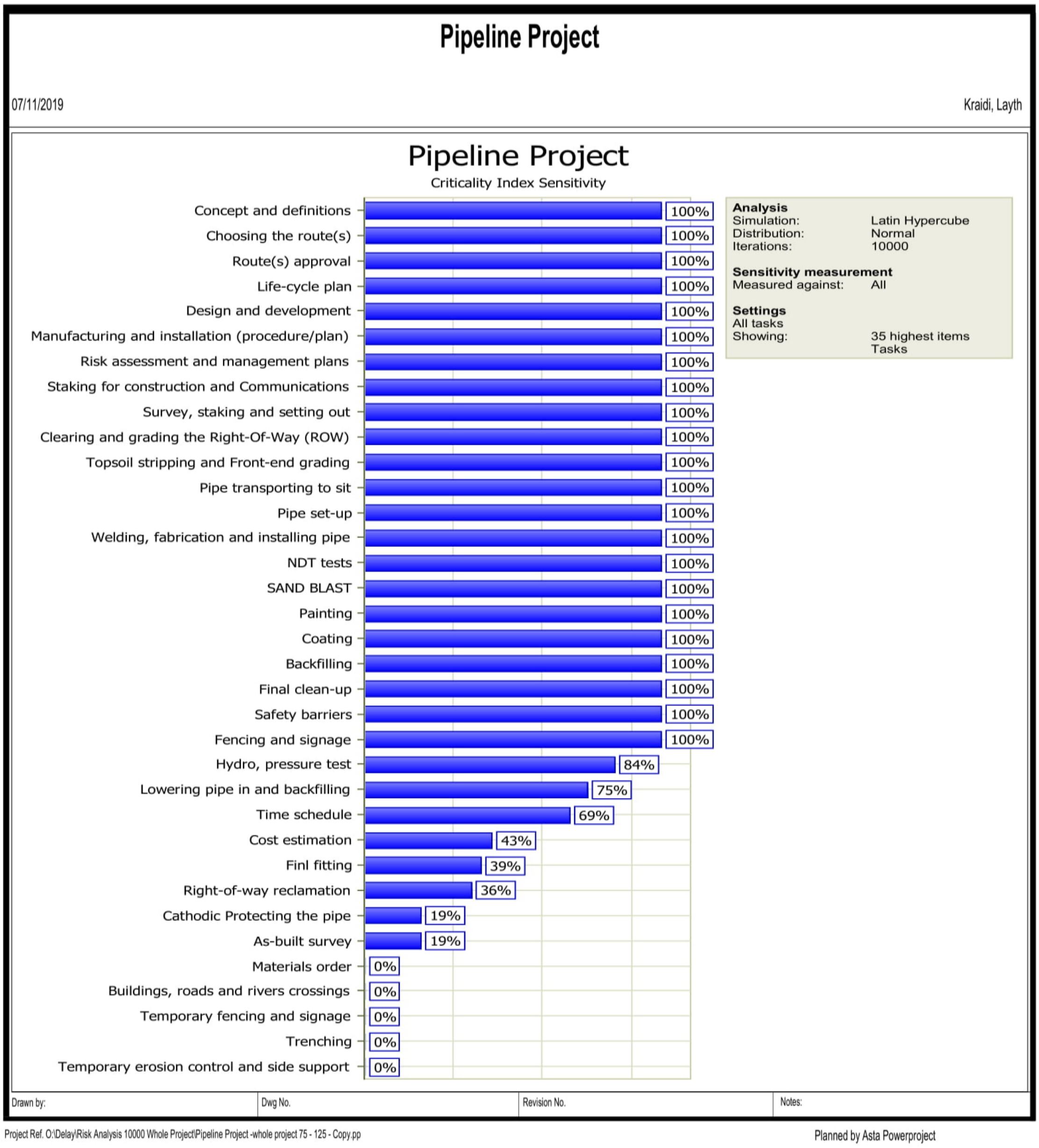


Figure G.22: Results of criticality index sensitivity using **LHS and Normal** distribution.

7- Results of analysing the criticality sensitivity index of the project activities using **LHS and Skewed Normal** distribution are shown in the figure below.

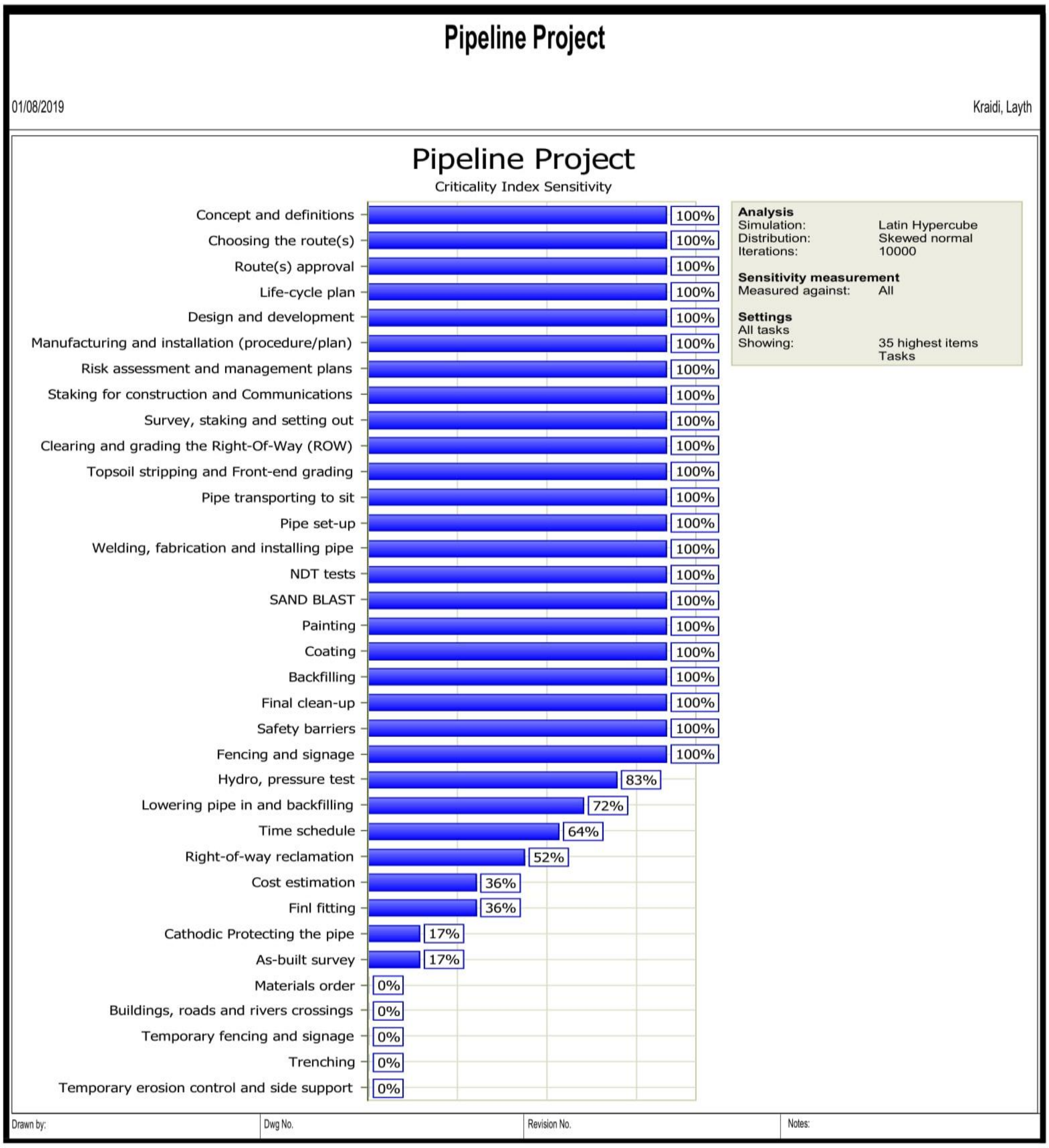


Figure G.23: Results of criticality index sensitivity using **LHS and Skewed Normal** distribution.

8- Results of analysing the criticality sensitivity index of the project activities using **LHS and Skewed Triangular** distribution are shown in the figure below.

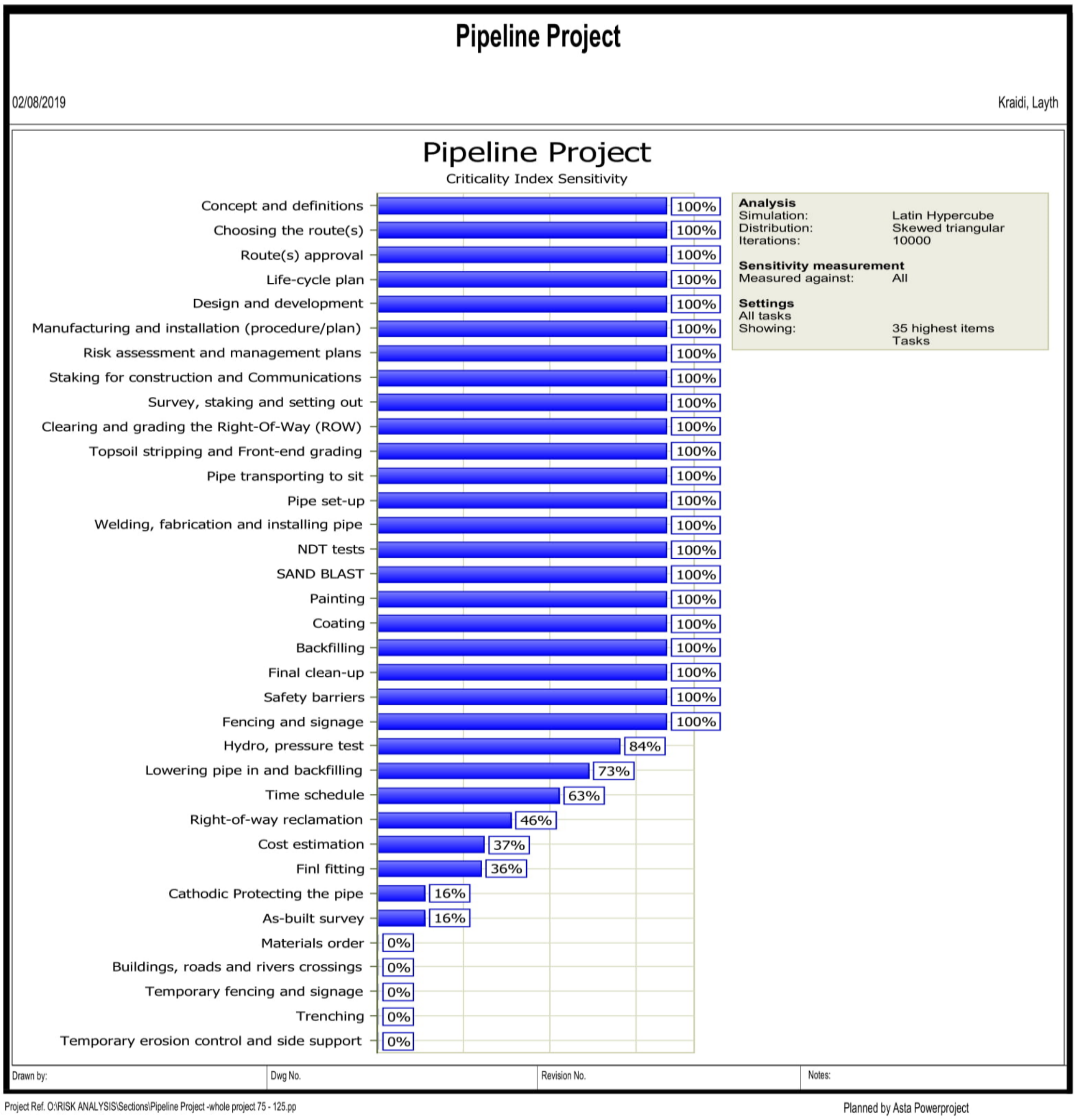


Figure G.24: Results of criticality index sensitivity using **LHS and Skewed Triangular** distribution.

G.5. Construction Programme of the Project

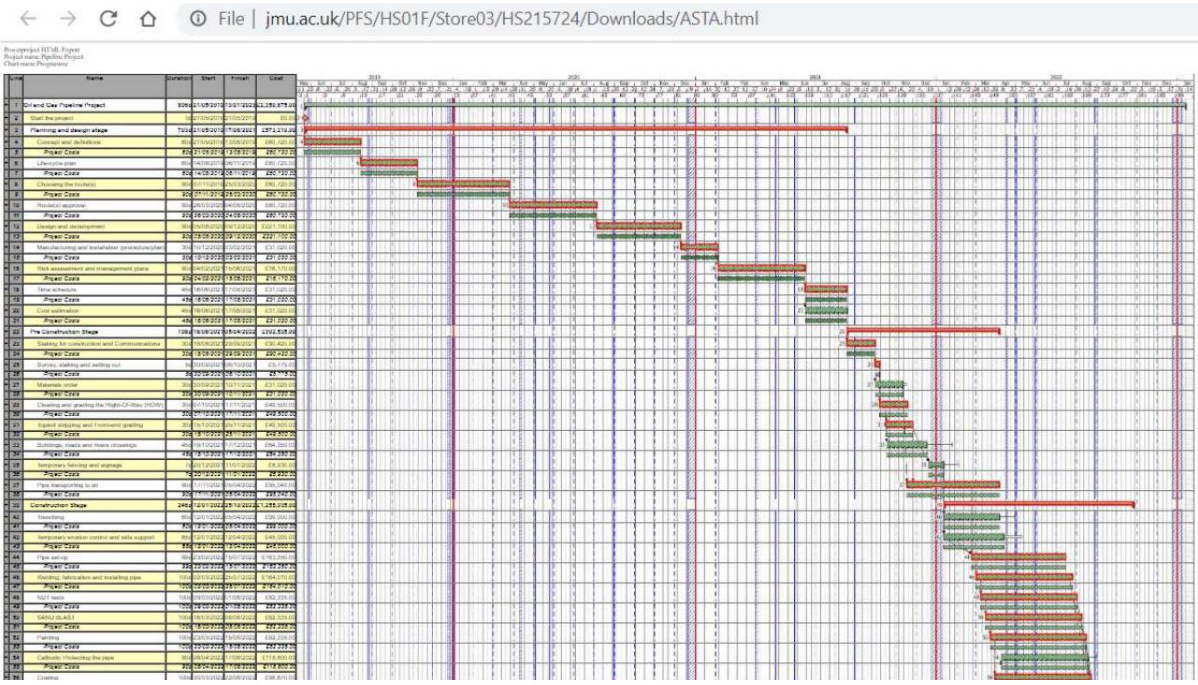
Below is the construction programme for the new oil and gas export pipeline.

Powerproject HTML Export
Project name:Pipeline Project
Chart name:Programme

	Line	Name	Duration	Start	Finish
+	**1**	**Oil and Gas Pipeline Project**	**896d**	**21/05/2019**	**13/01/2023**
+	**2**	Start the project	0d	21/05/2019	21/05/2019
+	**3**	**Planning and design stage**	**703d**	**21/05/2019**	**17/08/2021**
+	**4**	Concept and definitions	60d	21/05/2019	13/08/2019
	5	*Project Costs*	*60d*	*21/05/2019*	*13/08/2019*
+	**6**	Life-cycle plan	60d	14/08/2019	06/11/2019
	7	*Project Costs*	*60d*	*14/08/2019*	*06/11/2019*
+	**8**	Choosing the route(s)	90d	07/11/2019	25/03/2020
	9	*Project Costs*	*90d*	*07/11/2019*	*25/03/2020*
+	**10**	Route(s) approval	90d	26/03/2020	04/08/2020
	11	*Project Costs*	*90d*	*26/03/2020*	*04/08/2020*
+	**12**	Design and development	90d	05/08/2020	09/12/2020
	13	*Project Costs*	*90d*	*05/08/2020*	*09/12/2020*
+	**14**	Manufacturing and installation (procedure/plan)	30d	10/12/2020	03/02/2021
	15	*Project Costs*	*30d*	*10/12/2020*	*03/02/2021*
+	**16**	Risk assessment and management plans	90d	04/02/2021	15/06/2021
	17	*Project Costs*	*90d*	*04/02/2021*	*15/06/2021*
+	**18**	Time schedule	45d	16/06/2021	17/08/2021
	19	*Project Costs*	*45d*	*16/06/2021*	*17/08/2021*
+	**20**	Cost estimation	45d	16/06/2021	17/08/2021
	21	*Project Costs*	*45d*	*16/06/2021*	*17/08/2021*
+	**22**	**Pre Construction Stage**	**198d**	**18/08/2021**	**05/04/2022**
+	**23**	Staking for construction and Communications	30d	18/08/2021	29/09/2021
	24	*Project Costs*	*30d*	*18/08/2021*	*29/09/2021*
+	**25**	Survey, staking and setting out	5d	30/09/2021	06/10/2021
	26	*Project Costs*	*5d*	*30/09/2021*	*06/10/2021*
+	**27**	Materials order	30d	30/09/2021	10/11/2021
	28	*Project Costs*	*30d*	*30/09/2021*	*10/11/2021*
+	**29**	Clearing and grading the Right-Of-Way (ROW)	30d	07/10/2021	17/11/2021
	30	*Project Costs*	*30d*	*07/10/2021*	*17/11/2021*
+	**31**	Topsoil stripping and Front-end grading	30d	15/10/2021	25/11/2021
	32	*Project Costs*	*30d*	*15/10/2021*	*25/11/2021*
+	**33**	Buildings, roads and rivers crossings	45d	18/10/2021	17/12/2021
	34	*Project Costs*	*45d*	*18/10/2021*	*17/12/2021*
+	**35**	Temporary fencing and signage	7d	20/12/2021	11/01/2022
	36	*Project Costs*	*7d*	*20/12/2021*	*11/01/2022*
+	**37**	Pipe transporting to sit	90d	17/11/2021	05/04/2022
	38	*Project Costs*	*90d*	*17/11/2021*	*05/04/2022*

	36	*Project Costs*	*7d*	*20/12/2021*	*11/01/2022*
+	37	Pipe transporting to sit	90d	17/11/2021	05/04/2022
	38	*Project Costs*	*90d*	*17/11/2021*	*05/04/2022*
+	39	**Construction Stage**	**246d**	**12/01/2022**	**25/10/2022**
+	40	Trenching	60d	12/01/2022	05/04/2022
	41	*Project Costs*	*60d*	*12/01/2022*	*05/04/2022*
+	42	Temporary erosion control and side support	65d	12/01/2022	12/04/2022
	43	*Project Costs*	*65d*	*12/01/2022*	*12/04/2022*
+	44	Pipe set-up	99d	23/02/2022	15/07/2022
	45	*Project Costs*	*99d*	*23/02/2022*	*15/07/2022*
+	46	Welding, fabrication and installing pipe	100d	02/03/2022	25/07/2022
	47	*Project Costs*	*100d*	*02/03/2022*	*25/07/2022*
+	48	NDT tests	100d	09/03/2022	01/08/2022
	49	*Project Costs*	*100d*	*09/03/2022*	*01/08/2022*
+	50	SAND BLAST	100d	16/03/2022	08/08/2022
	51	*Project Costs*	*100d*	*16/03/2022*	*08/08/2022*
+	52	Painting	100d	23/03/2022	15/08/2022
	53	*Project Costs*	*100d*	*23/03/2022*	*15/08/2022*
+	54	Cathodic Protecting the pipe	90d	08/04/2022	17/08/2022
	55	*Project Costs*	*90d*	*08/04/2022*	*17/08/2022*
+	56	Coating	100d	30/03/2022	22/08/2022
	57	*Project Costs*	*100d*	*30/03/2022*	*22/08/2022*
+	58	Lowering pipe in and backfilling	100d	06/04/2022	30/08/2022
	59	*Project Costs*	*100d*	*06/04/2022*	*30/08/2022*
+	60	As-built survey	10d	18/08/2022	01/09/2022
+	61	Finl fitting	100d	13/04/2022	06/09/2022
	62	*Project Costs*	*100d*	*13/04/2022*	*06/09/2022*
+	63	Hydro, pressure test	5d	07/09/2022	13/09/2022
	64	*Project Costs*	*5d*	*07/09/2022*	*13/09/2022*
+	65	Backfilling	30d	14/09/2022	25/10/2022
	66	*Project Costs*	*30d*	*14/09/2022*	*25/10/2022*
+	67	**Post Construction Stage**	**94d**	**26/09/2022**	**12/01/2023**
+	68	Fencing and signage	14d	26/09/2022	13/10/2022
	69	*Project Costs*	*14d*	*26/09/2022*	*13/10/2022*
+	70	Final clean-up	21d	04/10/2022	01/11/2022
	71	*Project Costs*	*21d*	*04/10/2022*	*01/11/2022*
+	72	Right-of-way reclamation	29d	18/10/2022	25/11/2022
	73	*Project Costs*	*29d*	*18/10/2022*	*25/11/2022*
+	74	Safety barriers	41d	03/11/2022	12/01/2023
	75	*Project Costs*	*41d*	*03/11/2022*	*12/01/2023*
+	76	Delver the project	0d	13/01/2023	13/01/2023

Export date:15/04/2020 10:00:54


File | jmu.ac.uk/PFS/HS01F/Store03/HS215724/Downloads/ASTA.html

APPENDIX H: THE RESULTS OF RISK SIMULATION USING @RISK

The Excel sheet presented below shows the detailed results of the @Risk simulator, including the IRFs allocated to the project work activities and the assigned risk distribution methods.

@RISK6.xlsx

H.1. The Impact of the IRFs on the Duration of New OGP Projects

The planned (original) duration of the project was 1334 days. This section shows the delay in the projects using the @Risk simulator. The delay was analysed in (1) the overall duration of the project, (2) the planning and design stage of the project, (3) the pre-construction stage of the project, (4) the construction stage of the project and (5) the post-construction stage of the project.

H.1.1. The results of the delay in the overall duration of the project

The results of risk simulation show the minimum and maximum duration of the projects are 1329.30 days and 1441.84 days, respectively. The project has a 5% chance of being completed in a duration between 1329.30 and 1349.1 days or between 1404.5 days and 1441.84 days. The project has a 90% probability of being finished in a duration between 1349.1 days and 1404.5 days. The results are explained in Figure H.1.

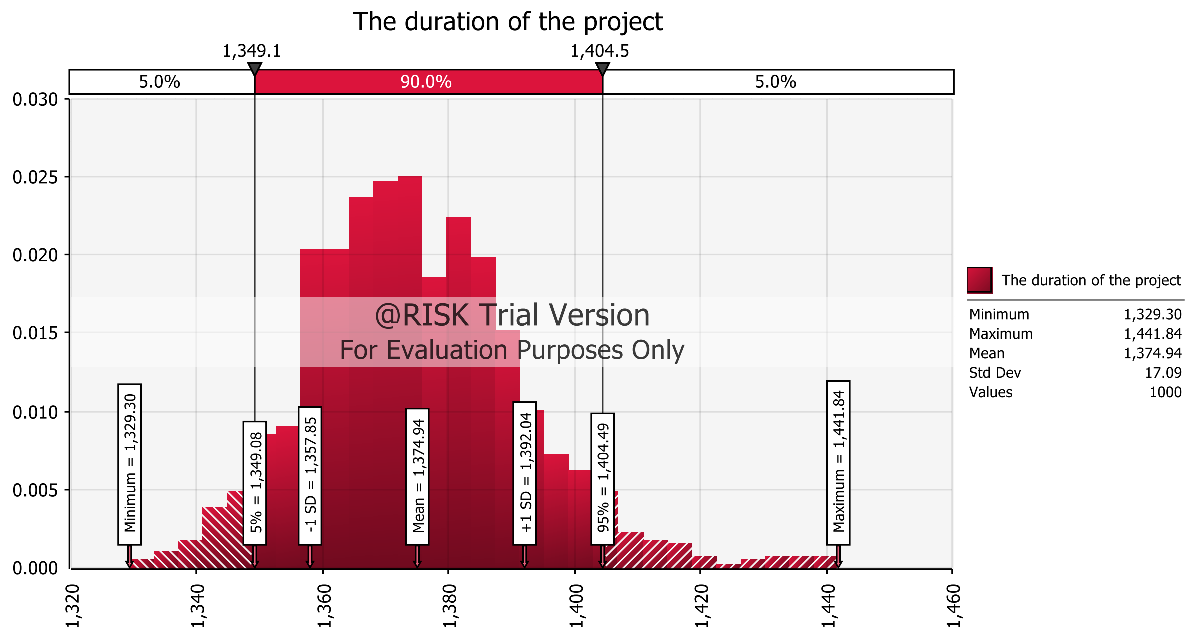


Figure H.1: The results of simulating the duration of the project using @Risk.

The mean duration of the project is 1374.94 days, which means the project has a 50% probability of being completed in this duration, see Figure H.2.

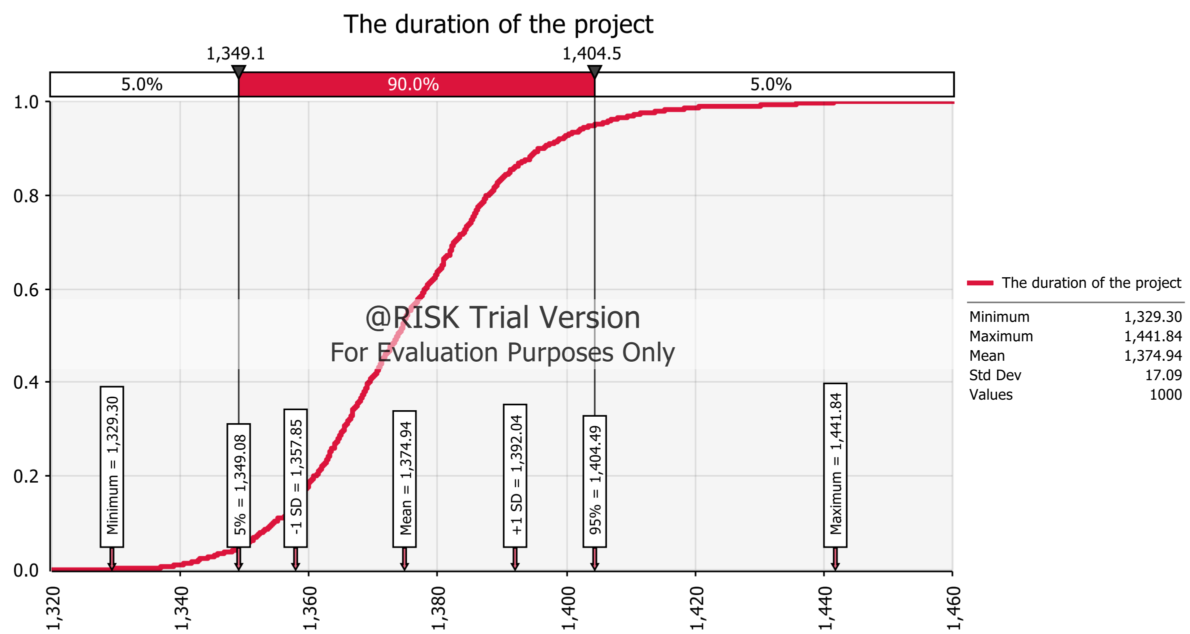


Figure H.2: The results of the accumulative duration of the projects using @Risk.

The minimum delay and maximum delay in the project are -0.703 days and 111.84 days. The project has a 5% probability to be delayed between -0.703 and 19.1 days or 74.5 and 111.84 days. The project has a 90% probability of being delayed between 19.1 days and 74.5 days, see Figure H.3.

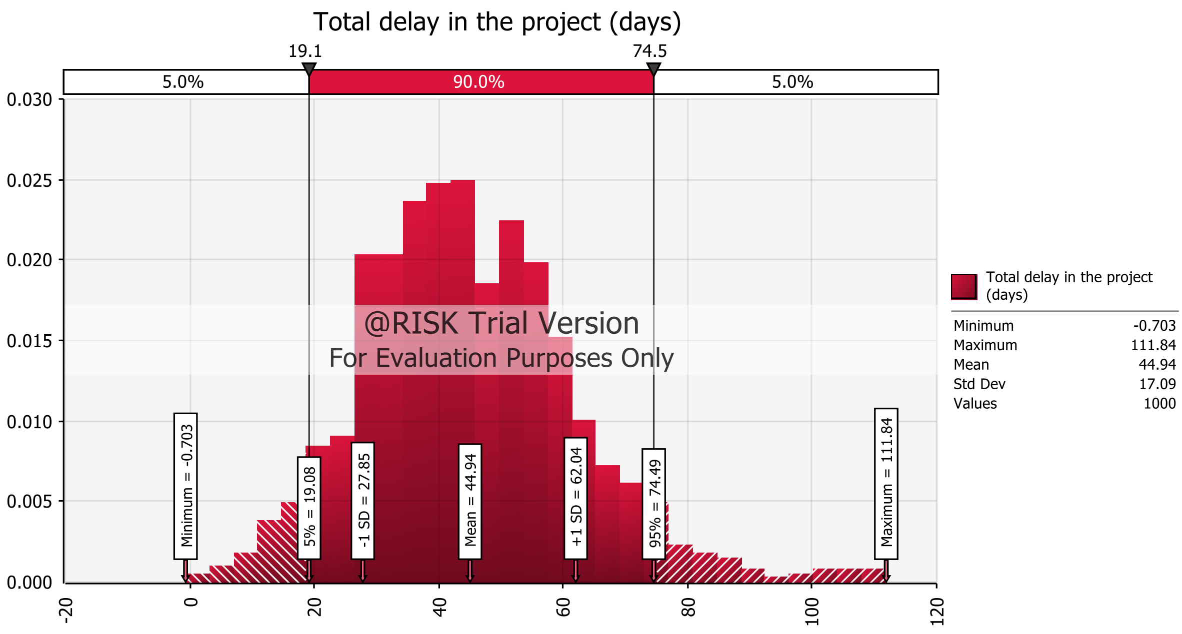


Figure H.3: The delay in the project using @Risk.

The mean delay in the duration of the project is 44.94 days, with a probability of 50%, see Figure H.4.

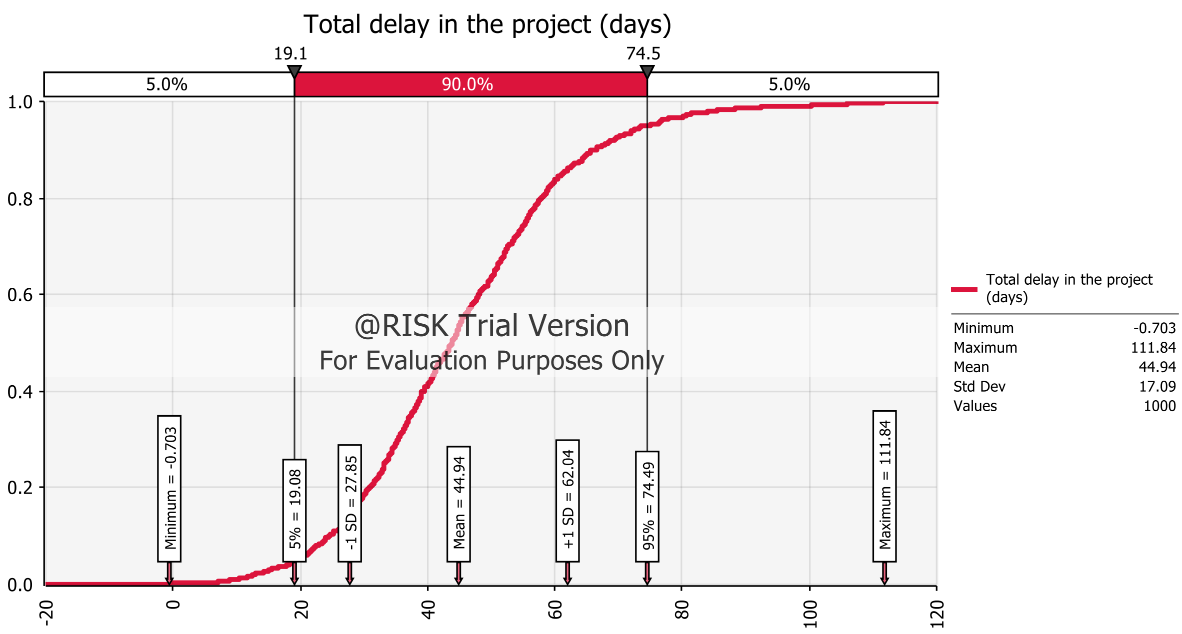


Figure H.4: The accumulative delay in the project using @Risk.

H.1.2. The results of the delay in the planning and design stage of the project

The results of risk simulation show the minimum and maximum duration of the planning and design stage of the project are 771.260 days and 834.608 days, respectively. The project has a 5% chance of being completed in a duration between 771.260 days and 782.0 days or between 813.5 days and 834.608 days. The planning and design stage has a 90% probability of being completed between 782.0 days and 813.5 days, see Figure H.5.

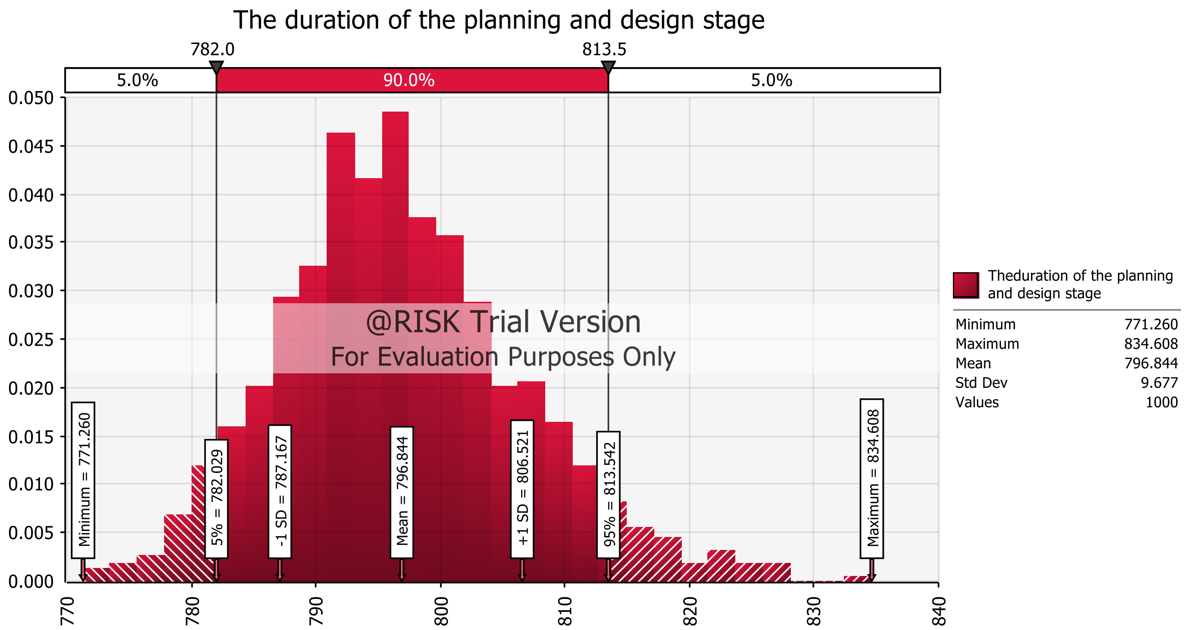


Figure H.5: The results of simulating the duration of the project (planning stage) using @Risk.

The mean duration of the planning and design stage is 796.844 days, which means this stage has a 50% probability of being completed in this duration, see Figure H.6.

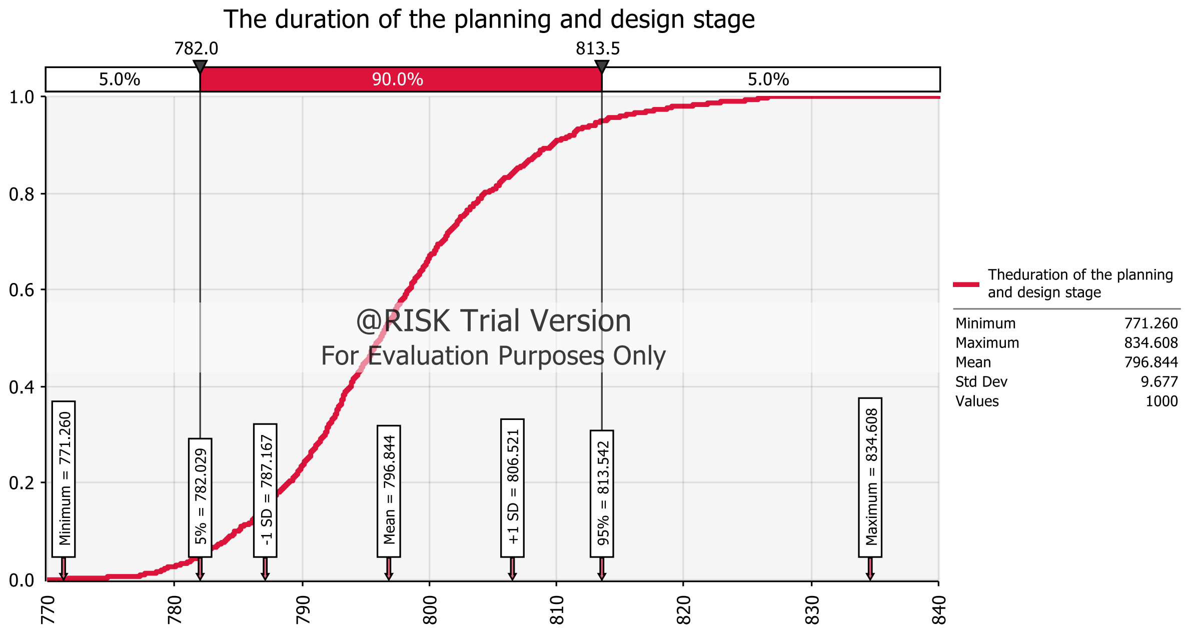


Figure H.6: The results of simulating the calculative duration of the project (planning stage) using @Risk.

The minimum delay and maximum delay in the planning and design stage of the project are -40.740 days and 22.608 days. The project has a 5% probability of being delayed between -40.740 and -30 days or 1.5 and 22.608 days. This stage has a 90% probability of being delayed between -30 and 1.5 days, see Figure H.7.

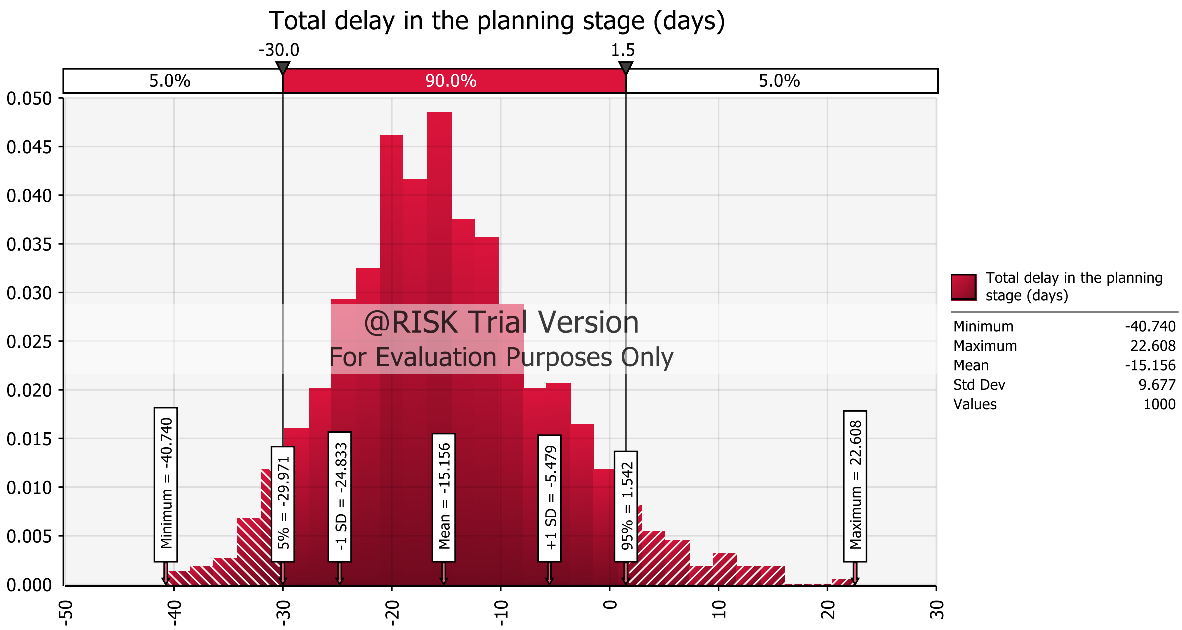


Figure H.7: The delay in the planning stage using @Risk.

The mean delay at this stage of the project is -15.156, which means this stage of the project could be completed within 15 days of the original duration, see Figure H.8.

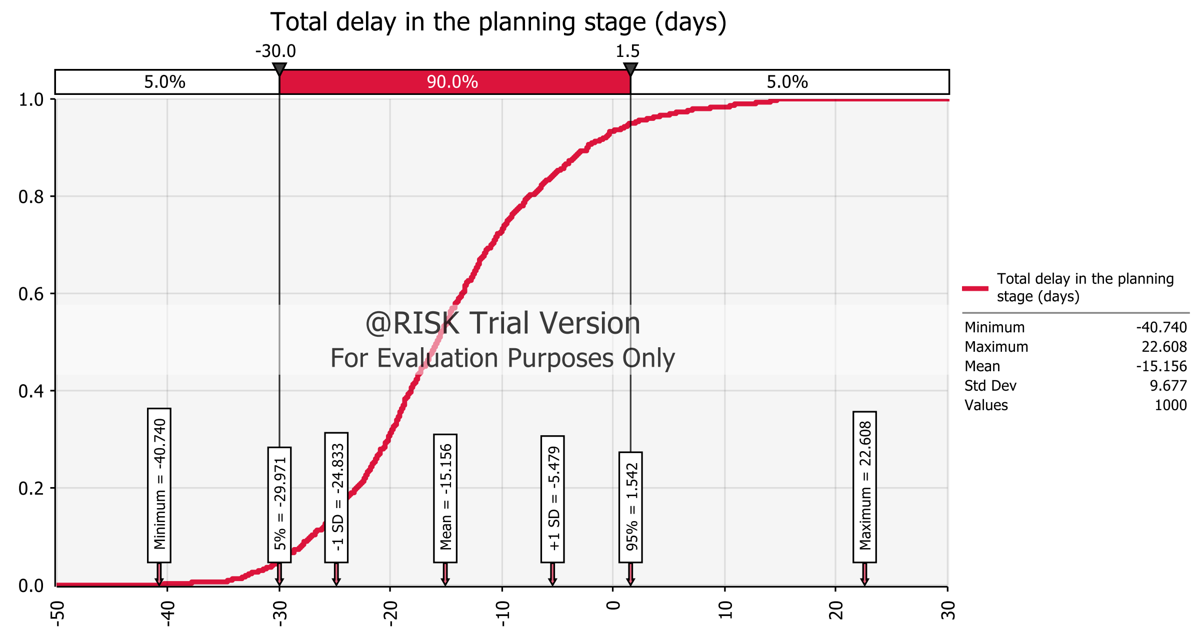


Figure H.8: The accumulative delay in the planning stage using @Risk.

H.1.3. The results of the delay in the pre-construction stage of the project

The results of the risk simulation show that the minimum and maximum duration of the project are 214.902 days and 267.182 days. The pre-construction stage has a 5% probability of being completed in a duration between 214.902 days and 229.8 days or between 255.9 days and 267.182 days. This stage of the project has a 90% probability of being completed between 229.8 days and 255.9 days, see Figure H.9.

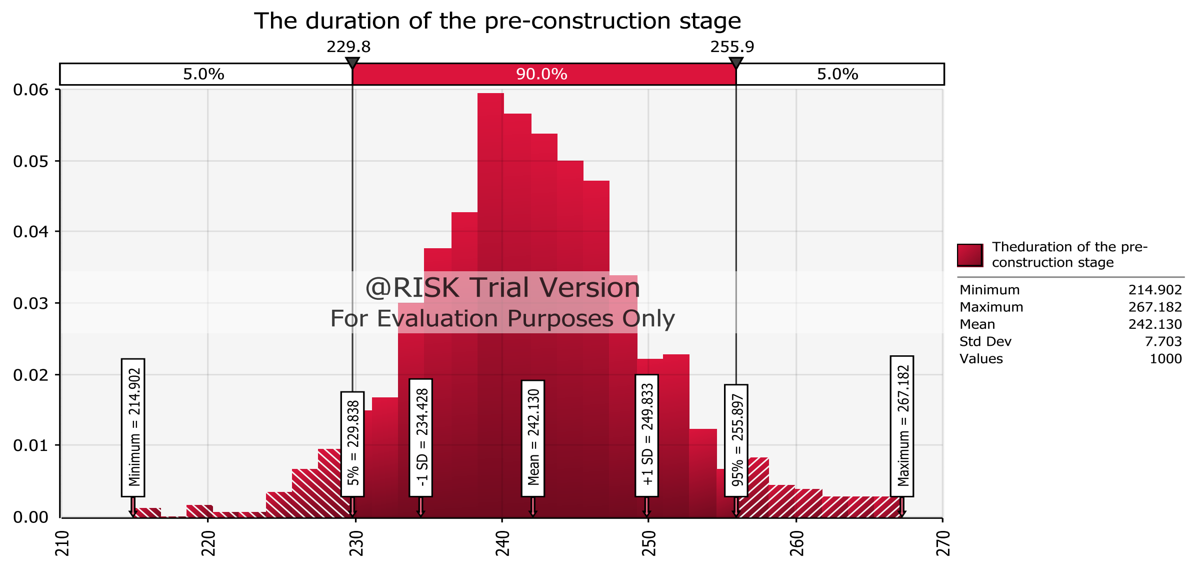


Figure H.9: The results of simulating the duration of the project (pre-construction stage) using @Risk.

The mean duration of the pre-construction stage of the project is 242.130 days, which means there is a 50% probability that this stage of the project will be completed in the mean duration, see Figure H.10.

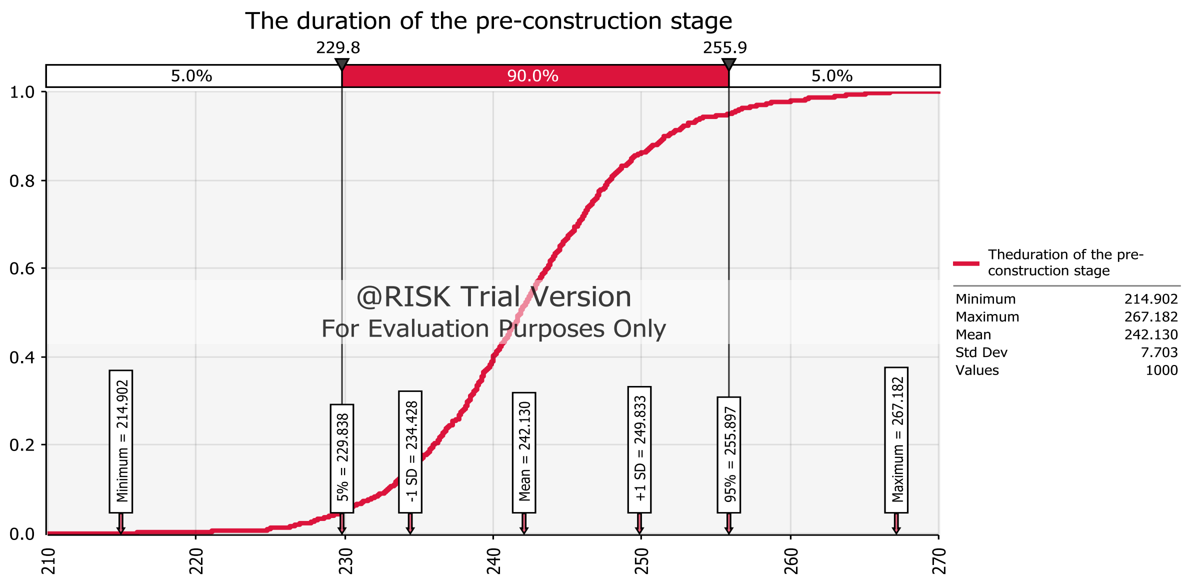


Figure H.10: The results of simulating the accumulative duration of the project (pre-construction stage) using @Risk.

The minimum delay and maximum delay in the this stage of the project are 14.902 days and 67.182 days. The project has a 5% probability of being delayed between 14.902 and 29.8 days or 55.9 and 67.182 days. The delay in the duration of the pre-construction stage of the project has a 90% probability of being delayed between 29.8 days and 55.9 days, see Figure H.11.

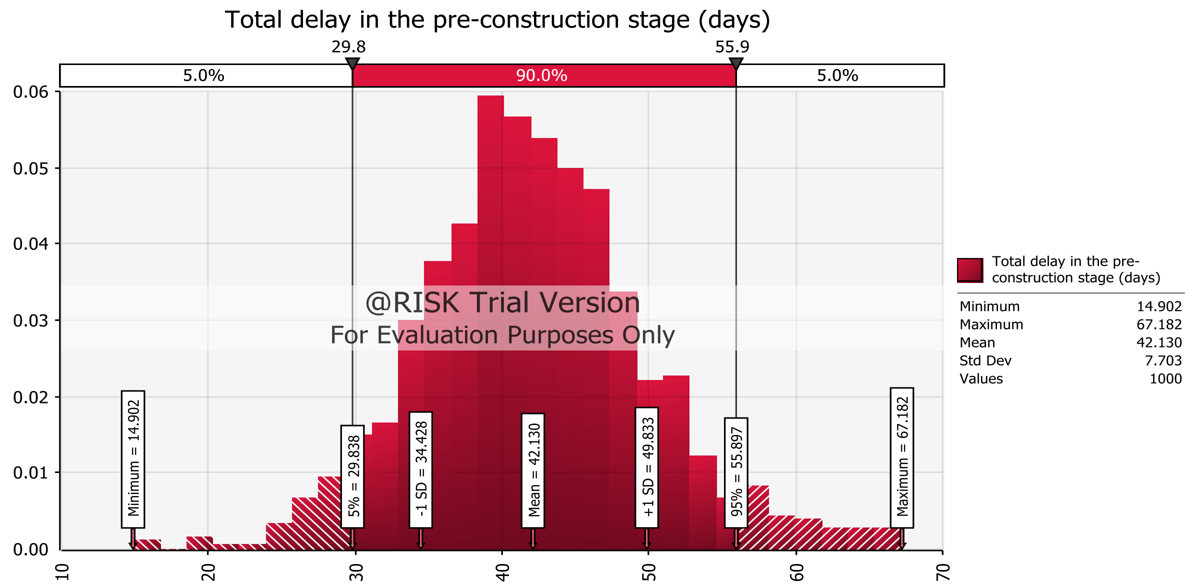


Figure H.11: The delay in the pre-construction stage using @Risk.

The mean delay at this stage of the project is 42.10 days, with the probability of 50%, see Figure H.12.

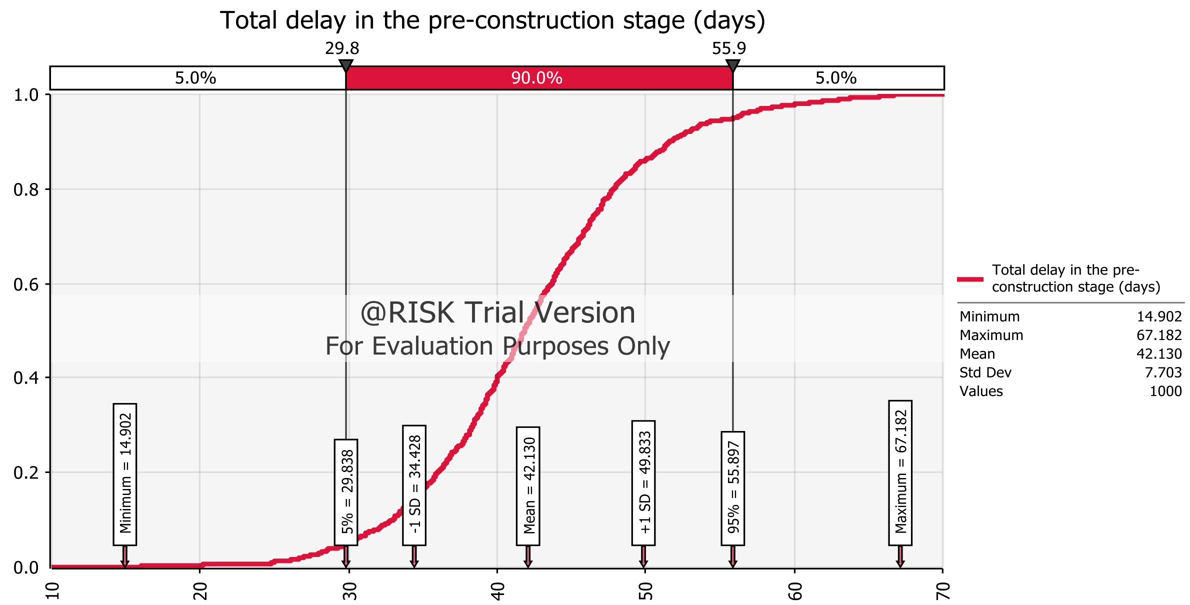


Figure H.12: The accumulative delay in the pre-construction stage using @Risk.

H.1.4. The results of the delay in the construction stage of the project

The results of the risk simulation show that the minimum and maximum duration of the project are 201.911 days and 283.328 days, respectively. This stage of the project has a 5% chance of being completed in a duration between 201.911 days and 211.7 days or between

243.9 days and 283.328 days. The construction stage has a 90% probability of being completed between 211.7 days and 243.9 days, see Figure H.13.

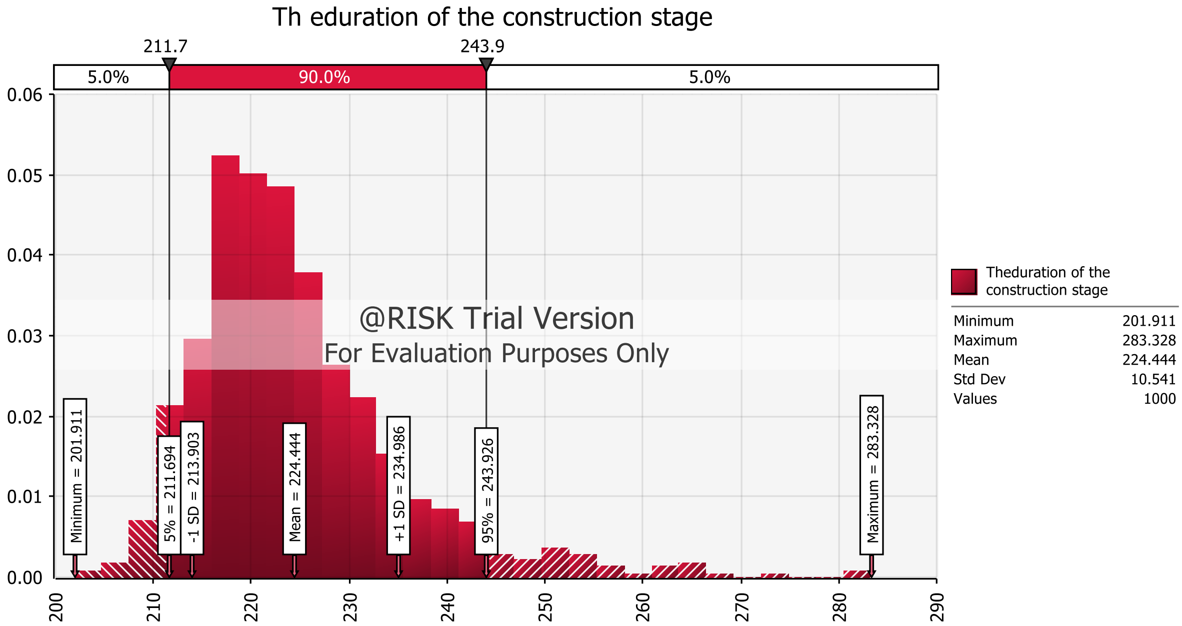


Figure H.13: The results of simulating the duration of the project (construction stage) using @Risk.

The mean duration of the project is 224.444 days, with a probability of 50%, see Figure H.14.

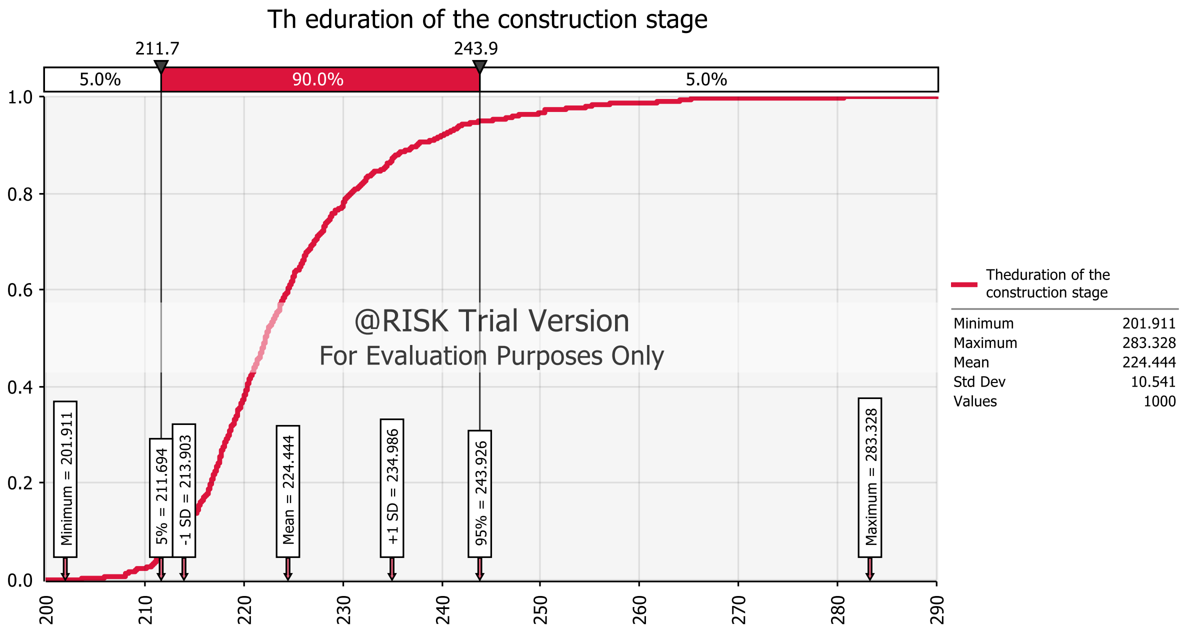


Figure H.14: The results of simulating the accumulative duration of the project (construction stage) using @Risk.

The minimum delay and maximum delay in the project are -11.089 days and 70.328 days. The project has a 5% probability of being delayed between -11.089 and -1.3 days or 30.9 and 70.328 days. The delay in the duration of the construction stage of the project is between -1.3 days and 30.9 days, with a probability of 90%, see Figure H.15.

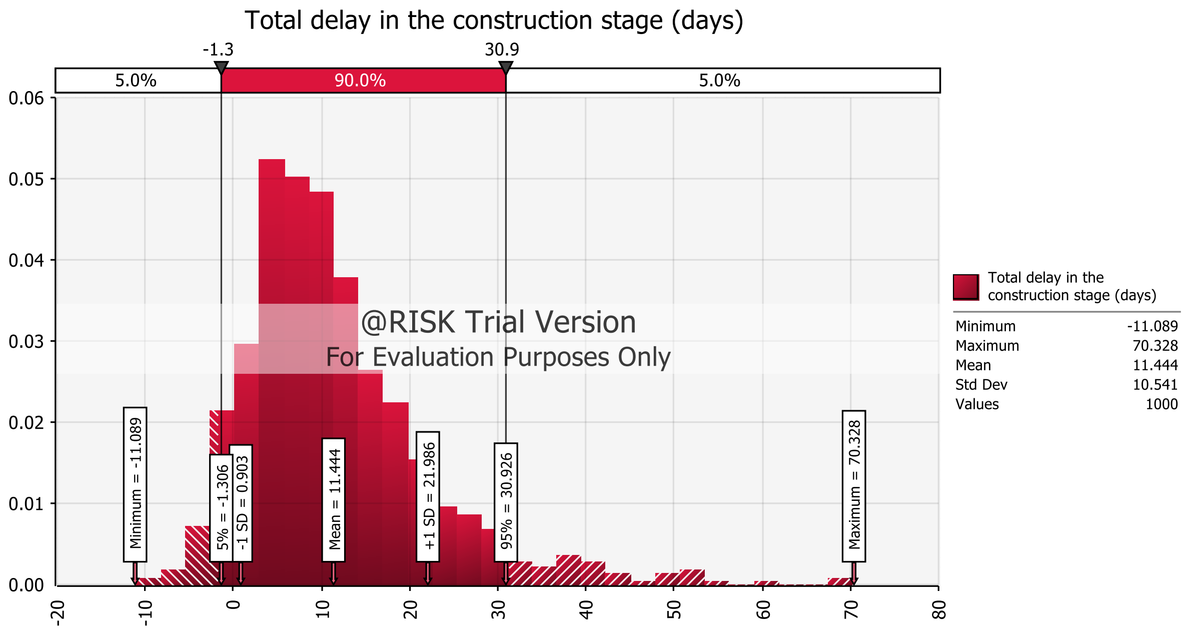


Figure H.15: The delay in the construction stage using @Risk.

The mean delay at this stage of the project is 11.444 days, with a probability of 50%, see Figure H.16.

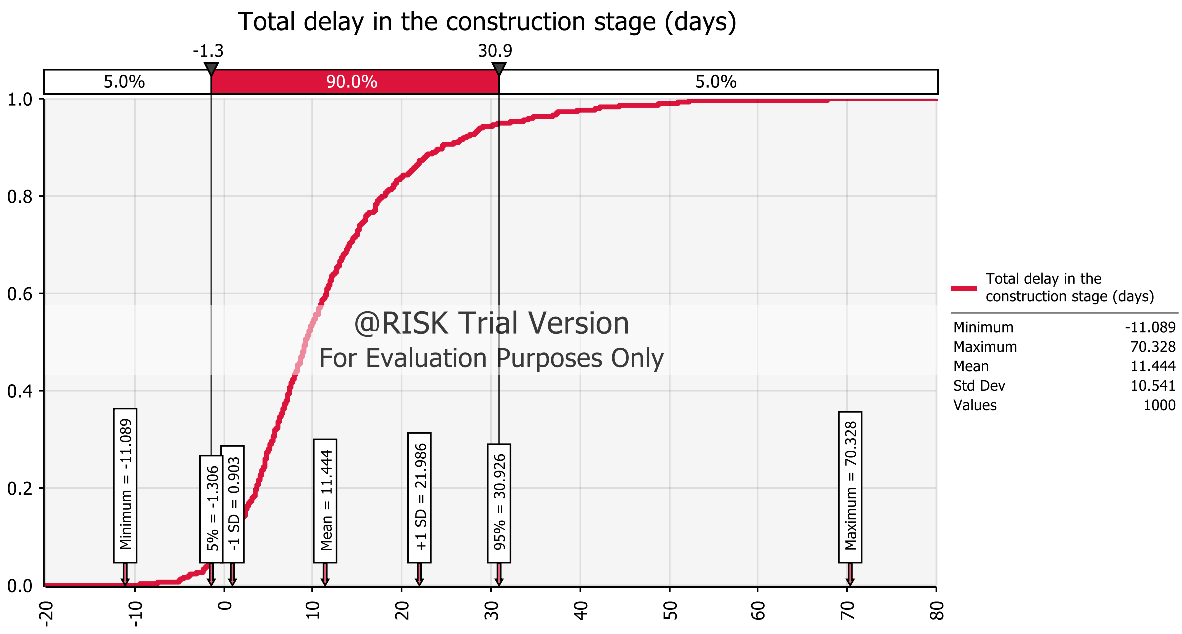


Figure H.16: The accumulative delay in the construction stage using @Risk.

H.1.5. The results of the delay in the post-construction stage of the project

The results of the risk simulation show that the minimum and maximum duration of the post-construction stage of the projects are 93.209 days and 136.005 days, respectively. This stage of the project has a 5% chance of being completed in a duration between 93.209 days and 103.26 days or between 120.77 days and 136.005 days. The post-construction stage of the project has a 90% probability of being completed in a duration between 103.26 days and 120.77 days, see Figure H.17.

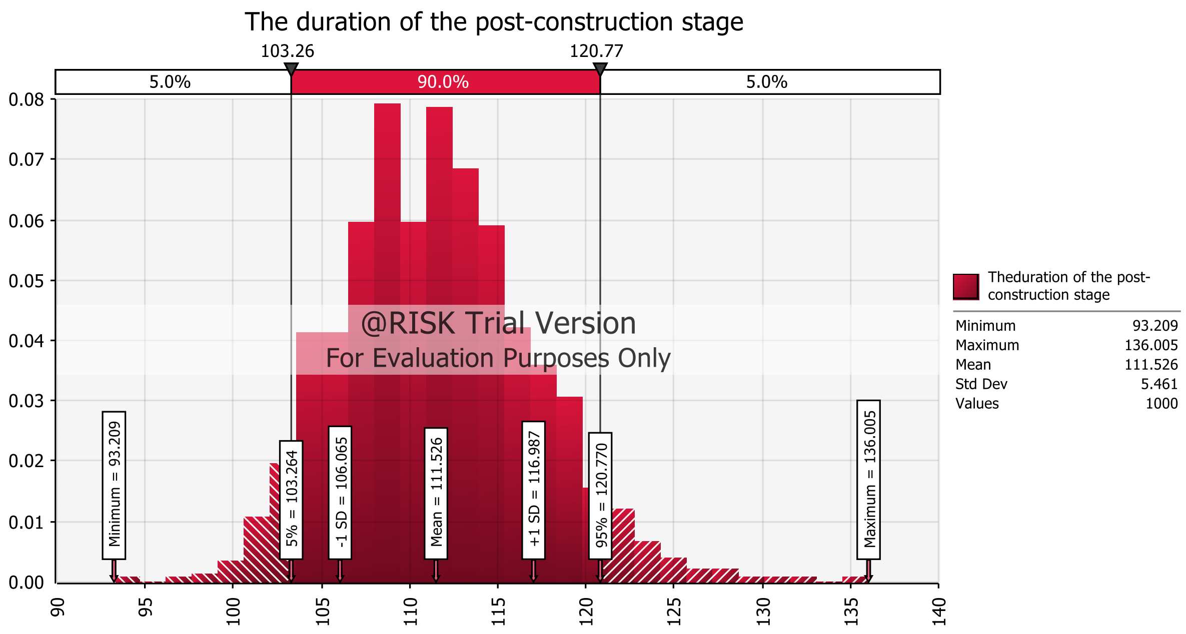


Figure H.17: The results of simulating the duration of the project (post-construction stage) using @Risk.

The mean duration of the project is 111.526 days, with a probability of 50%, see Figure H.18.

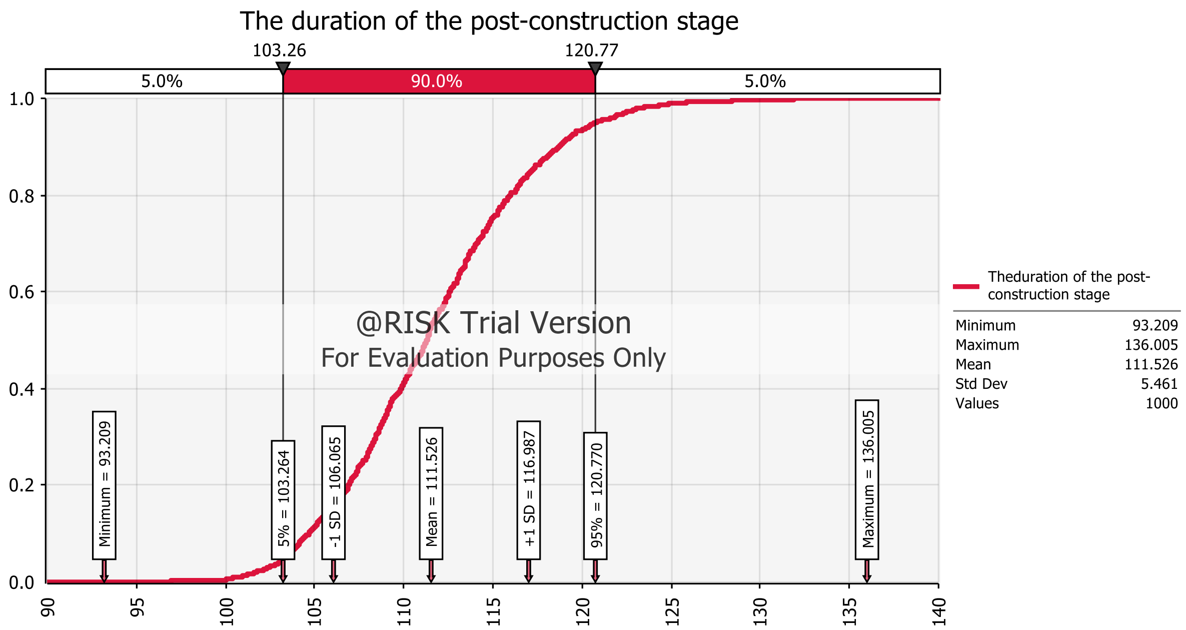


Figure H.18: The results of simulating the accumulative duration of the project (post-construction stage) using @Risk.

The minimum delay and maximum delay in the project are -11.791 days and 31.005 days. The project has a 5% probability of being delayed between -11.791 and -1.74 days or 15.77 and 31.005 days. The delay in the duration of the post-construction stage of the project is between -1.74 days and 15.77 days, with a probability of 90%, see Figure H.19.

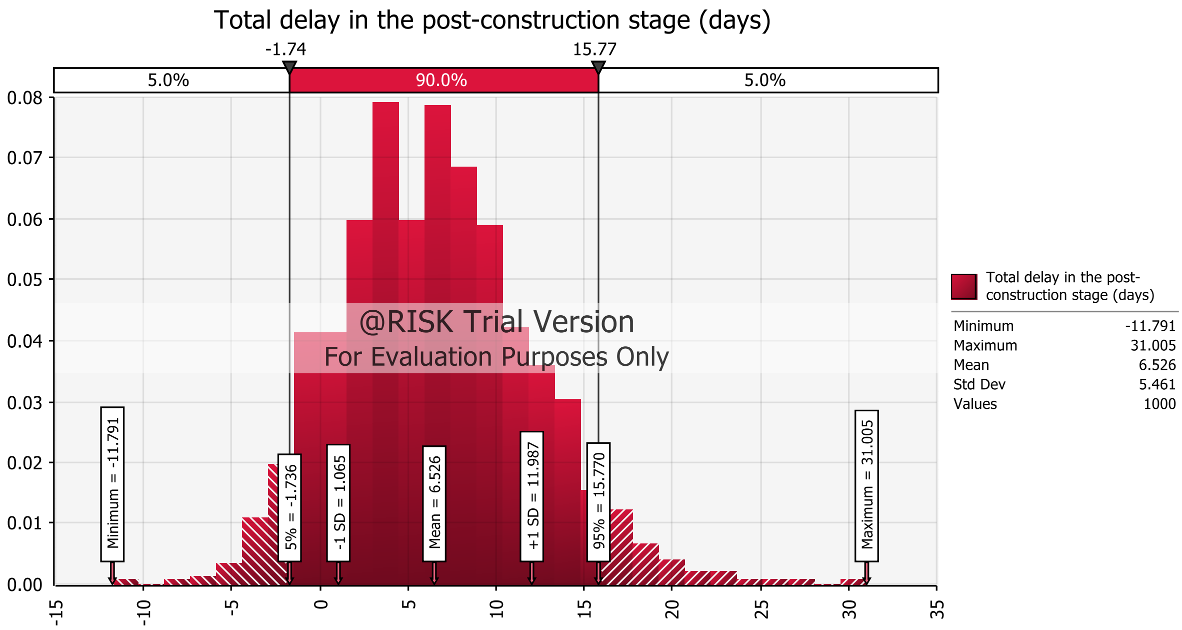


Figure H.19: The delay in the post-construction stage.

The mean delay at this stage of the project is 6.526 days, with a probability of 50%, see Figure H.20.

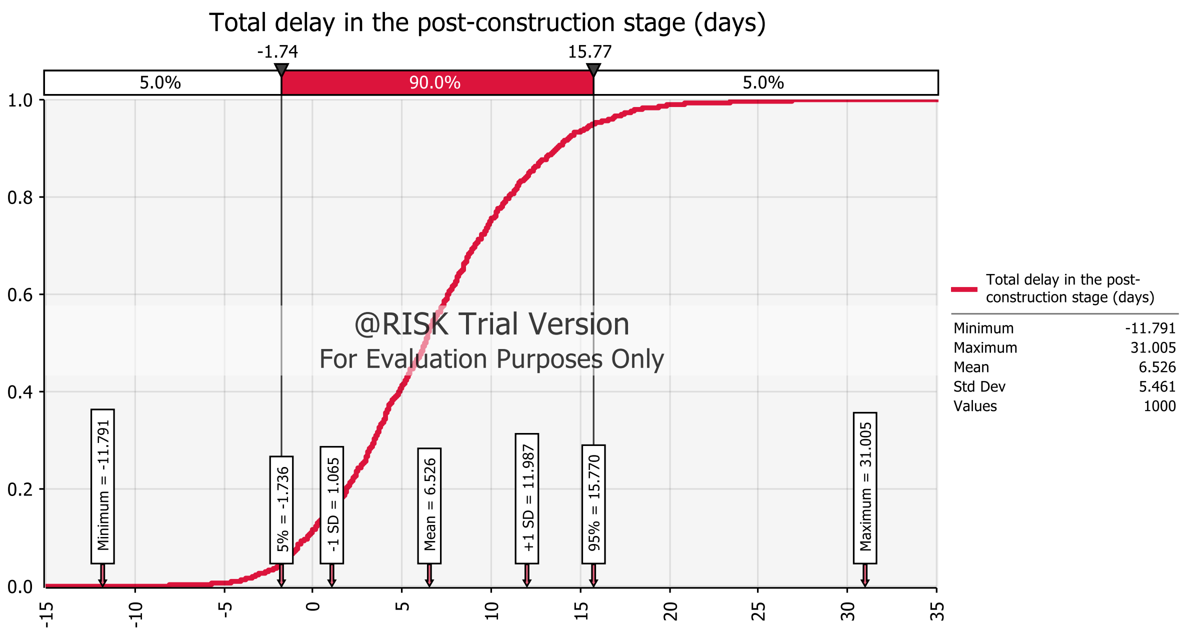
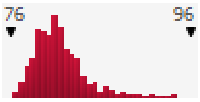
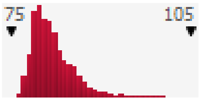
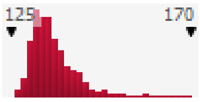
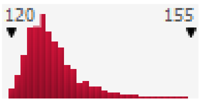
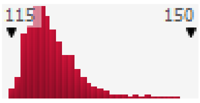
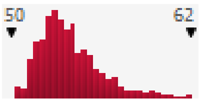
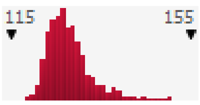
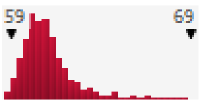
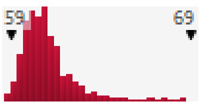
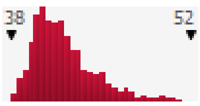
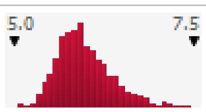
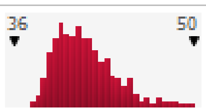
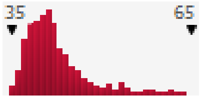
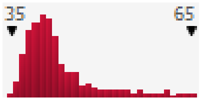
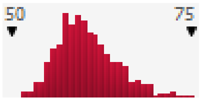
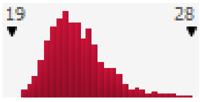
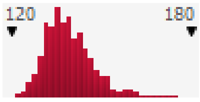
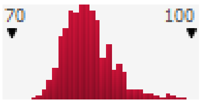
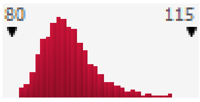
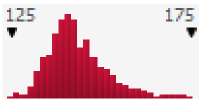
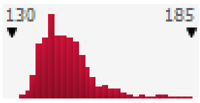
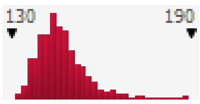
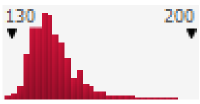
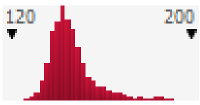
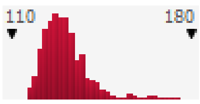
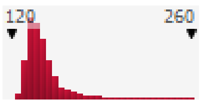


Figure H.20: The accumulative delay in the post-construction stage.

The figures and tables below present the results of calculating the delay in duration of the activities and the stages of the case study project of this research considering the associated risk factors. Additionally, the results show the delay in the overall duration of the project.

Activity	Graph	Planned duration (day)	Min (day)	Mean (day)	Max (day)	5% (day)	95% (day)	Delay = mean – planned duration
The duration of the project activities of the planning and design stage								
The duration of concept and definitions activity		84	77.09	81.82	94.02	78.51	86.62	-2.184
The duration of life-cycle plan activity		84	77.12	82.56	100.09	79.03	87.85	-1.445
The duration choosing the route(s) activity		139	127.90	136.40	169.17	130.86	144.60	-2.609
The duration of route(s) approval activity		131	120.97	128.53	153.33	123.17	136.70	-2.459
The duration of the design and development activity		126	116.29	123.65	147.10	118.57	131.09	-2.365
The duration of manufacturing and installation (procedure/plan)		55	50.76	54.10	61.70	51.79	57.48	-0.899
The duration of risk assessment and management plans activity		131	119.59	128.56	150.02	123.37	136.68	-2.441
The duration of time schedule activity		62	59.11	61.24	68.57	59.78	63.41	-0.754
The duration of the project activities of the pre-construction stage								
The duration of staking for construction and communications activity		42	59.12	61.24	68.42	59.82	63.36	0.349
The duration of survey, staking and setting out		6	38.59	42.35	51.01	39.74	46.44	0.015
The duration of materials order activity		41	5.16	6.01	7.39	5.53	6.63	0.715
The duration of clearing and grading the		41	37.75	41.71	49.77	39.01	45.47	2.115

Right-Of-Way (ROW) activity								
The duration of topsoil stripping and front-end grading activity		41	35.89	43.12	63.31	37.83	53.58	1.951
The duration of buildings, roads and rivers crossings		60	35.53	42.95	64.95	38.00	53.85	0.717
The duration of temporary fencing and signage activity		22	52.33	60.71	74.68	55.58	67.24	0.427
The duration of pipe transporting to sit activity		139	19.83	22.43	27.84	20.69	24.58	1.174
The duration of the project activities in the construction stage								
The duration of the trenching activity		83	123.86	140.17	174.32	130.59	152.35	0.074
The duration of the temporary erosion control and side support		90	74.35	83.07	98.40	78.15	89.05	1.739
The duration of the pipe set-up activity		142	82.93	91.73	110.59	85.73	99.81	1.913
The duration of the welding, fabrication and installing pipe activity		145	126.19	143.91	173.88	133.85	157.37	2.667
The duration of the NDT tests activity		145	134.46	147.66	183.78	139.65	159.48	2.883
The duration of the sand blast activity		145	133.73	147.88	187.16	138.43	160.90	2.713
The duration of the painting activity		145	131.09	147.72	192.93	138.50	161.43	2.635
The duration of the cathodic protecting the pipe activity		131	128.92	147.62	190.54	137.88	162.21	0.834
The duration of the coating activity		145	118.62	131.84	173.73	122.66	144.31	2.736
The duration of the lowering pipe in and backfilling activity		146	129.64	147.79	257.83	136.51	166.62	1.036

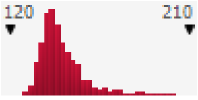
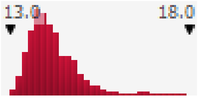
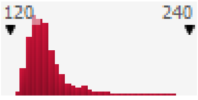
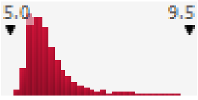
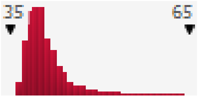
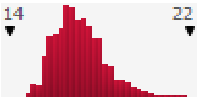
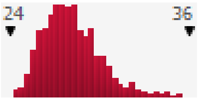
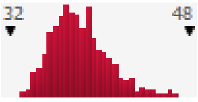
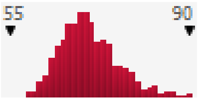
The duration of the as-built survey activity		14	130.02	147.04	201.60	136.68	162.73	0.276
The duration of the final fitting activity		146	13.22	14.28	17.78	13.59	15.26	1.070
The duration of the hydro pressure test activity		6	128.46	147.07	228.57	134.79	168.12	0.038
The duration of the backfilling activity		41	5.31	6.04	9.17	5.57	6.82	0.074
The duration of the project activities of the pre-construction stage								
The duration of the fencing and signage activity		17	37.23	41.65	63.38	38.41	47.17	0.190
The duration of the final clean-up activity		28	14.98	17.19	21.65	15.79	18.94	0.312
The duration of the right-of-way reclamation activity		38	24.70	28.31	35.22	25.96	31.27	0.424
The duration of the safety barriers activity		70	33.51	38.42	46.66	35.18	42.51	0.778
The duration of the fencing and signage activity		17	59.35	70.79	89.65	63.64	79.99	0.190

Table H.1: The results of simulating the duration of the project using @Risk.

Simulation Summary Information	
Workbook Name	@RISK6.xlsx
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.2: The results of the accumulative duration of the project using @Risk.

Summary Statistics for The duration of the project			
Statistics		**Percentile**	
Minimum	1314.63	**1.0%**	1338.82
Maximum	1494.82	**2.5%**	1344.54

Mean	1374.94	**5.0%**	1348.84
Std Dev	17.27	**10.0%**	1353.86
Variance	298.4160467	**20.0%**	1360.65
Skewness	0.515618309	**25.0%**	1363.22
Kurtosis	4.108770087	**50.0%**	1373.72
Median	1373.72	**75.0%**	1385.60
Mode	1372.04	**80.0%**	1388.44
Left X	1348.84	**90.0%**	1396.60
Left P	5%	**95.0%**	1404.42
Right X	1404.42	**97.5%**	1412.15
Right P	95%	**99.0%**	1422.24
#Errors	0		

Table H.3: The delay in the project using @Risk.

Simulation Summary Information	
Workbook Name	@RISK6.xlsx
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.4: The accumulative delay in the project using @Risk.

Summary Statistics for Total delay in the project (days)			
Statistics		**Percentile**	
Minimum	-15.37	**1.0%**	8.82
Maximum	164.82	**2.5%**	14.54
Mean	44.94	**5.0%**	18.84
Std Dev	17.27	**10.0%**	23.86
Variance	298.4160467	**20.0%**	30.65
Skewness	0.515618309	**25.0%**	33.22
Kurtosis	4.108770087	**50.0%**	43.72
Median	43.72	**75.0%**	55.60
Mode	42.04	**80.0%**	58.44
Left X	18.84	**90.0%**	66.60
Left P	5%	**95.0%**	74.42
Right X	74.42	**97.5%**	82.15
Right P	95%	**99.0%**	92.24
#Errors	0		

Table H.5: The duration of the planning and design using @Risk

Simulation Summary Information	
Workbook Name	@RISK6.xlsx
Number of Simulations	1
Number of Iterations	10000

Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.6: The results of the accumulative duration of the planning and design using @Risk.

Summary Statistics for The duration of the planning and design stage			
Statistics		**Percentile**	
Minimum	770.05	**1.0%**	777.91
Maximum	838.58	**2.5%**	780.54
Mean	796.84	**5.0%**	782.72
Std Dev	9.35	**10.0%**	785.42
Variance	87.39155523	**20.0%**	788.86
Skewness	0.418719934	**25.0%**	790.25
Kurtosis	3.286047284	**50.0%**	796.22
Median	796.22	**75.0%**	802.65
Mode	793.76	**80.0%**	804.41
Left X	782.72	**90.0%**	809.12
Left P	5%	**95.0%**	813.21
Right X	813.21	**97.5%**	817.03
Right P	95%	**99.0%**	821.40
#Errors	0		

Table H.7: The results of simulating the duration of the project (planning stage) using @Risk.

Simulation Summary Information	
Workbook Name	@RISK6.xlsx
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.8: The results of simulating the calculative duration of the project (planning stage) using @Risk.

Summary Statistics for Total delay in the planning stage (days)

Statistics		Percentile	
Minimum	-41.95	**1.0%**	-34.09
Maximum	26.58	**2.5%**	-31.46
Mean	-15.16	**5.0%**	-29.28
Std Dev	9.35	**10.0%**	-26.58
Variance	87.39155523	**20.0%**	-23.14
Skewness	0.418719934	**25.0%**	-21.75
Kurtosis	3.286047284	**50.0%**	-15.78
Median	-15.78	**75.0%**	-9.35
Mode	-18.24	**80.0%**	-7.59
Left X	-29.28	**90.0%**	-2.88
Left P	5%	**95.0%**	1.21
Right X	1.21	**97.5%**	5.03
Right P	95%	**99.0%**	9.40
#Errors	0		

Table H.9: The results of the duration of the pre-construction using @Risk.

Simulation Summary Information	
Workbook Name	@RISK6.xlsx
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.10: The results of the accumulative duration of the pre-construction using @Risk.

Summary Statistics for The duration of the pre-construction stage			
Statistics		**Percentile**	
Minimum	212.53	**1.0%**	223.43
Maximum	278.97	**2.5%**	226.95
Mean	242.12	**5.0%**	229.66
Std Dev	7.75	**10.0%**	232.64
Variance	60.05647259	**20.0%**	235.96
Skewness	0.145673833	**25.0%**	237.26
Kurtosis	3.694922415	**50.0%**	242.03
Median	242.03	**75.0%**	246.82
Mode	238.20	**80.0%**	248.02
Left X	229.66	**90.0%**	251.62
Left P	5%	**95.0%**	255.27
Right X	255.27	**97.5%**	258.60
Right P	95%	**99.0%**	262.39

Table H.11: The delay in the pre-construction stage using @Risk.

Simulation Summary Information	
Workbook Name	@RISK6.xlsx

Number of Simulations	1
Number of Iterations	10000
Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.12: The accumulative delay in the pre-construction stage using @Risk.

Summary Statistics for Total delay in the pre-construction stage (days)			
Statistics		**Percentile**	
Minimum	12.53	**1.0%**	23.43
Maximum	78.97	**2.5%**	26.95
Mean	42.12	**5.0%**	29.66
Std Dev	7.75	**10.0%**	32.64
Variance	60.05647259	**20.0%**	35.96
Skewness	0.145673833	**25.0%**	37.26
Kurtosis	3.694922415	**50.0%**	42.03
Median	42.03	**75.0%**	46.82
Mode	38.20	**80.0%**	48.02
Left X	29.66	**90.0%**	51.62
Left P	5%	**95.0%**	55.27
Right X	55.27	**97.5%**	58.60
Right P	95%	**99.0%**	62.39
#Errors	0		

Table H.13: The delay in construction stage using @Risk.

Simulation Summary Information	
Workbook Name	@RISK6.xlsx
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.14: The accumulative delay in construction stage using @Risk.

Summary Statistics for The duration of the construction stage			
Statistics		**Percentile**	

Minimum	201.56	**1.0%**	207.83
Maximum	334.58	**2.5%**	209.70
Mean	224.45	**5.0%**	211.48
Std Dev	10.76	**10.0%**	213.66
Variance	115.7014887	**20.0%**	216.39
Skewness	1.730903149	**25.0%**	217.40
Kurtosis	9.007190789	**50.0%**	222.27
Median	222.27	**75.0%**	229.06
Mode	219.49	**80.0%**	231.10
Left X	211.48	**90.0%**	237.61
Left P	5%	**95.0%**	244.42
Right X	244.42	**97.5%**	251.60
Right P	95%	**99.0%**	262.29
#Errors	0		

Table H.15: The delay in the construction stage using @Risk.

Simulation Summary Information	
Workbook Name	@RISK6.xlsx
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.16: The accumulative delay in the construction stage using @Risk.

Summary Statistics for Total delay in the construction stage (days)			
Statistics		**Percentile**	
Minimum	-11.44	**1.0%**	-5.17
Maximum	121.58	**2.5%**	-3.30
Mean	11.45	**5.0%**	-1.52
Std Dev	10.76	**10.0%**	0.66
Variance	115.7014887	**20.0%**	3.39
Skewness	1.730903149	**25.0%**	4.40
Kurtosis	9.007190789	**50.0%**	9.27
Median	9.27	**75.0%**	16.06
Mode	6.49	**80.0%**	18.10
Left X	-1.52	**90.0%**	24.61
Left P	5%	**95.0%**	31.42
Right X	31.42	**97.5%**	38.60
Right P	95%	**99.0%**	49.29
#Errors	0		

Table H.17: The results of simulating the duration of the project (post-construction stage) using @Risk.

Simulation Summary Information

Workbook Name	@RISK6.xlsx
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.18: The results of simulating the accumulative duration of the project (post-construction stage) using @Risk.

Summary Statistics for The duration of the post-construction stage			
Statistics		**Percentile**	
Minimum	90.81	**1.0%**	100.04
Maximum	136.25	**2.5%**	101.71
Mean	111.52	**5.0%**	103.06
Std Dev	5.61	**10.0%**	104.73
Variance	31.45622659	**20.0%**	106.84
Skewness	0.444457666	**25.0%**	107.66
Kurtosis	3.455551585	**50.0%**	111.09
Median	111.09	**75.0%**	114.99
Mode	110.61	**80.0%**	116.00
Left X	103.06	**90.0%**	118.85
Left P	5%	**95.0%**	121.37
Right X	121.37	**97.5%**	123.73
Right P	95%	**99.0%**	126.55
#Errors	0		

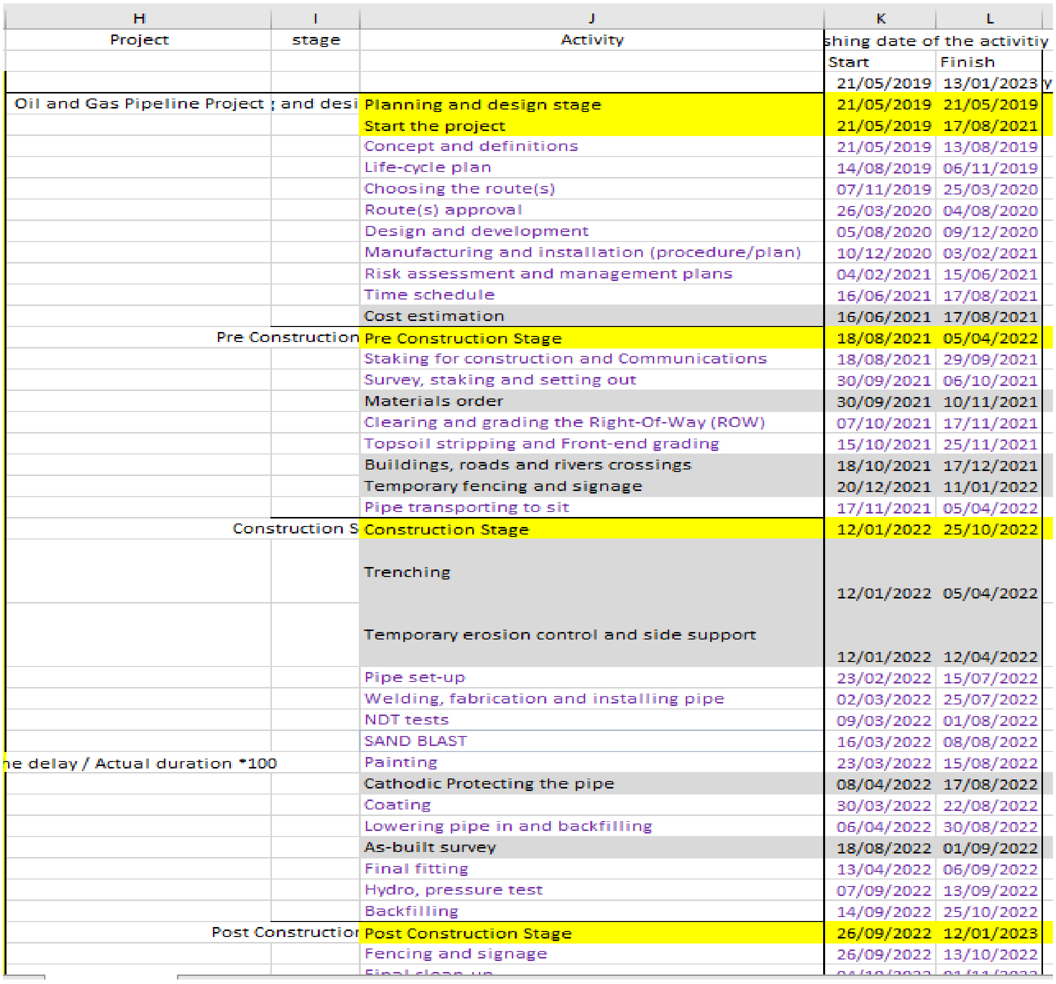
Table H.19: The delay in the post-construction stage.

Simulation Summary Information	
Workbook Name	@RISK6.xlsx
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	586
Number of Outputs	45
Sampling Type	Latin Hypercube
Simulation Start Time	10/12/2019 12:56
Simulation Stop Time	10/12/2019 12:58
Simulation Duration	00:01:59
Random # Generator	Mersenne Twister
Random Seed	1285830980
Total Errors	0
Collect Distribution Samples	All
Convergence Testing	Disabled
Smart Sensitivity Analysis	Enabled

Table H.20: The accumulative delay in the post-construction stage.

Summary Statistics for Total delay in the post-construction stage (days)			
Statistics		**Percentile**	
Minimum	-14.19	**1.0%**	-4.96
Maximum	31.25	**2.5%**	-3.29
Mean	6.52	**5.0%**	-1.94
Std Dev	5.61	**10.0%**	-0.27
Variance	31.45622659	**20.0%**	1.84
Skewness	0.444457666	**25.0%**	2.66
Kurtosis	3.455551585	**50.0%**	6.09
Median	6.09	**75.0%**	9.99
Mode	5.61	**80.0%**	11.00
Left X	-1.94	**90.0%**	13.85
Left P	5%	**95.0%**	16.37
Right X	16.37	**97.5%**	18.73
Right P	95%	**99.0%**	21.55
#Errors	0		

Below are some of screenshots from the calculations of the @Risk simulator.



H	I	J	K	L
Project	stage	Activity	shing date of the activitiy	
			Start	Finish
			21/05/2019	13/01/2023
Oil and Gas Pipeline Project	and desi	Planning and design stage	21/05/2019	21/05/2019
		Start the project	21/05/2019	17/08/2021
		Concept and definitions	21/05/2019	13/08/2019
		Life-cycle plan	14/08/2019	06/11/2019
		Choosing the route(s)	07/11/2019	25/03/2020
		Route(s) approval	26/03/2020	04/08/2020
		Design and development	05/08/2020	09/12/2020
		Manufacturing and installation (procedure/plan)	10/12/2020	03/02/2021
		Risk assessment and management plans	04/02/2021	15/06/2021
		Time schedule	16/06/2021	17/08/2021
		Cost estimation	16/06/2021	17/08/2021
	Pre Construction	Pre Construction Stage	18/08/2021	05/04/2022
		Staking for construction and Communications	18/08/2021	29/09/2021
		Survey, staking and setting out	30/09/2021	06/10/2021
		Materials order	30/09/2021	10/11/2021
		Clearing and grading the Right-Of-Way (ROW)	07/10/2021	17/11/2021
		Topsoil stripping and Front-end grading	15/10/2021	25/11/2021
		Buildings, roads and rivers crossings	18/10/2021	17/12/2021
		Temporary fencing and signage	20/12/2021	11/01/2022
		Pipe transporting to sit	17/11/2021	05/04/2022
	Construction S	Construction Stage	12/01/2022	25/10/2022
		Trenching	12/01/2022	05/04/2022
		Temporary erosion control and side support	12/01/2022	12/04/2022
		Pipe set-up	23/02/2022	15/07/2022
		Welding, fabrication and installing pipe	02/03/2022	25/07/2022
		NDT tests	09/03/2022	01/08/2022
		SAND BLAST	16/03/2022	08/08/2022
e delay / Actual duration *100		Painting	23/03/2022	15/08/2022
		Cathodic Protecting the pipe	08/04/2022	17/08/2022
		Coating	30/03/2022	22/08/2022
		Lowering pipe in and backfilling	06/04/2022	30/08/2022
		As-built survey	18/08/2022	01/09/2022
		Final fitting	13/04/2022	06/09/2022
		Hydro, pressure test	07/09/2022	13/09/2022
		Backfilling	14/09/2022	25/10/2022
	Post Constructior	Post Construction Stage	26/09/2022	12/01/2023
		Fencing and signage	26/09/2022	13/10/2022

Figure H.21: A screenshot from the calculations of the @Risk simulator.

J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Activity	shing date of the activitiy						The duration of the activity						
	Start	Finish			Min Duration = [the mean duration -(theThe variance factor*the					Mean Duration			Max Durat
	21/05/2019	13/01/2023	y / Sum of	Sum of the	Risk Level in the activity	The varia	1166.70			1330			1562.20
Planning and design stage	21/05/2019	21/05/2019					733.90			812			890
Start the project	21/05/2019	17/08/2021											
Concept and definitions	21/05/2019	13/08/2019	1.29	1.16	LOW 90% - 110%	0.10	75.60			84.00			92.40
Life-cycle plan	14/08/2019	06/11/2019	1.95	1.75	LOW 90% - 110%	0.10	75.60			84.00			92.40
Choosing the route(s)	07/11/2019	25/03/2020	2.16	1.93	LOW 90% - 110%	0.10	125.10			139.00			152.90
Route(s) approval	26/03/2020	04/08/2020	2.16	1.93	LOW 90% - 110%	0.10	117.90			131.00			144.10
Design and development	05/08/2020	09/12/2020	2.16	1.93	LOW 90% - 110%	0.10	113.40			126.00			138.60
Manufacturing and installation (procedure/plan)	10/12/2020	03/02/2021	1.74	1.56	LOW 90% - 110%	0.10	49.50			55.00			60.50
Risk assessment and management plans	04/02/2021	15/06/2021	1.94	1.74	LOW 90% - 110%	0.10	117.90			131.00			144.10
Time schedule	16/06/2021	17/08/2021	0.88	0.79	VERY LOW 95% - 105%	0.05	58.90			62.00			65.10
Cost estimation	16/06/2021	17/08/2021	0.88	0.79	VERY LOW 95% - 105%	0.05	58.90			62.00			65.10
Pre Construction Stage	18/08/2021	05/04/2022					184.05			200			240
Staking for construction and Communications	18/08/2021	29/09/2021	1.51	1.36	LOW 90% - 110%	0.10	37.80			42.00			46.20
Survey, staking and setting out	30/09/2021	06/10/2021	5.24	4.69	VERY HIGH - 75% -125%	0.25	4.50			6.00			7.50
Materials order	30/09/2021	10/11/2021	1.53	1.37	LOW 90% - 110%	0.10	36.90			41.00			45.10
Clearing and grading the Right-Of-Way (ROW)	07/10/2021	17/11/2021	4.84	4.33	VERY HIGH - 75% -125%	0.25	30.75	6.75	9	41.00		10	51.25
Topsoil stripping and Front-end grading	15/10/2021	25/11/2021	5.03	4.50	VERY HIGH - 75% -125%	0.25	30.75	21.75	29	41.00		36	51.25
Buildings, roads and rivers crossings	18/10/2021	17/12/2021	4.75	4.25	VERY HIGH - 75% -125%	0.25	45.00			60.00			75.00
Temporary fencing and signage	20/12/2021	11/01/2022	4.09	3.66	HIGH 80% - 120%	0.20	17.60			22.00			26.40
Pipe transporting to sit	17/11/2021	05/04/2022	4.40	3.94	HIGH 80% - 120%	0.20	111.20	65.60	82	139.00		98	166.80
Construction Stage	12/01/2022	25/10/2022					168			213			290
Trenching	12/01/2022	05/04/2022	5.45	4.88	VERY HIGH - 75% -125%	0.25	62.25			83.00			103.75
Temporary erosion control and side support	12/01/2022	12/04/2022	4.59	4.10	VERY HIGH - 75% -125%	0.25	67.50			90.00			112.50
Pipe set-up	23/02/2022	15/07/2022	4.50	4.02	VERY HIGH - 75% -125%	0.25	106.50	3.75	5	142.00		10	177.50
Welding, fabrication and installing pipe	02/03/2022	25/07/2022	4.27	3.82	HIGH 80% - 120%	0.20	116.00	4.00	5	145.00		10	174.00
NDT tests	09/03/2022	01/08/2022	3.97	3.55	HIGH 80% - 120%	0.20	116.00	4.00	5	145.00		10	174.00
SAND BLAST	16/03/2022	08/08/2022	4.09	3.66	HIGH 80% - 120%	0.20	116.00	4.00	5	145.00		10	174.00
Painting	23/03/2022	15/08/2022	5.10	4.56	VERY HIGH - 75% -125%	0.25	108.75	3.75	5	145.00		10	181.25
Cathodic Protecting the pipe	08/04/2022	17/08/2022	5.59	5.00	VERY HIGH - 75% -125%	0.25	98.25			131.00			163.75
Coating	30/03/2022	22/08/2022	4.59	4.11	VERY HIGH - 75% -125%	0.25	108.75	3.75	5	145.00		10	181.25
Lowering pipe in and backfilling	06/04/2022	30/08/2022	5.29	4.74	VERY HIGH - 75% -125%	0.25	109.50	3.75	5	146.00		10	182.50
As-built survey	18/08/2022	01/09/2022	1.91	1.71	LOW 90% - 110%	0.10	12.60			14.00			15.40
Final fitting	13/04/2022	06/09/2022	4.77	4.27	VERY HIGH - 75% -125%	0.25	109.50			146.00			182.50
Hydro, pressure test	07/09/2022	13/09/2022	5.11	4.57	VERY HIGH - 75% -125%	0.25	4.50			6.00			7.50
Backfilling	14/09/2022	25/10/2022	5.33	4.77	VERY HIGH - 75% -125%	0.25	30.75	19.50	26	41.00		30	51.25
Post Construction Stage	26/09/2022	12/01/2023					81			105			143
Fencing and signage	26/09/2022	13/10/2022	4.37	3.91	HIGH 80% - 120%	0.20	13.60	4.80	6	17.00		10	20.40
Final clean up	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

Figure H.22: A screenshot from the calculations of the @Risk simulator.

Activity					
	sensitive information				
Planning and design stage					
Start the project					
Concept and definitions	3.380000	0.156554	=RiskGam	0.200000	0.031311
Life-cycle plan	3.380000	0.103745	=RiskGam	0.200000	0.020749
Choosing the route(s)	3.380000	0.093655	=RiskGam	0.200000	0.018731
Route(s) approval	3.380000	0.093655	=RiskGam	0.200000	0.018731
Design and development	3.380000	0.093655	=RiskGam	0.200000	0.018731
Manufacturing and installation (procedure/plan)					
Risk assessment and management plans	3.380000	0.104160	=RiskGam	0.200000	0.020832
Time schedule					
Cost estimation					
Pre Construction Stage					
Staking for construction and Communications	3.380000	0.133597	=RiskTria	0.466667	0.062345
Survey, staking and setting out	3.380000	0.038655	=RiskTria	0.466667	0.018039
Materials order					
Clearing and grading the Right-Of-Way (ROW)					
Topsoil stripping and Front-end grading					
Buildings, roads and rivers crossings					
Temporary fencing and signage					
Pipe transporting to sit					
Construction Stage					
Trenching	3.380000	0.037143	=RiskTria	0.466667	0.017333
Temporary erosion control and side support					
Pipe set-up	3.380000	0.045007	=RiskTria	0.466667	0.021003
Welding, fabrication and installing pipe	3.380000	0.047372	=RiskTria	0.466667	0.022107
NDT tests					
SAND BLAST					
Painting					
Cathodic Protecting the pipe	3.380000	0.036227	=RiskTria	0.466667	0.016906
Coating					
Lowering pipe in and backfilling	3.380000	0.038244	=RiskTria	0.466667	0.017847
As-built survey	3.380000	0.105757	=RiskTria	0.466667	0.049353
Final fitting					
Hydro, pressure test					
Backfilling					

Figure H.23: A screenshot from the calculations of the @Risk simulator.

Activity							
	Duration			1374.94			
Planning and design stage				796.84			
Start the project							
Concept and definitions	81.82					81.82	Between the Min and Mean Duration
Life-cycle plan	82.55					82.55	Between the Min and Mean Duration
Choosing the route(s)	136.39					136.39	Between the Min and Mean Duration
Route(s) approval	128.54					128.54	Between the Min and Mean Duration
Design and development	123.63					123.63	Between the Min and Mean Duration
Manufacturing and installation (procedure/plan)	54.10					54.10	Between the Min and Mean Duration
Risk assessment and management plans	128.56					128.56	Between the Min and Mean Duration
Time schedule	61.25					61.25	Between the Min and Mean Duration
Cost estimation	61.25					61.25	Between the Min and Mean Duration
Pre Construction Stage				242.12			
Staking for construction and Communications	42.35					42.35	Between the Mean and Max Duration
Survey, staking and setting out	6.01					6.01	Between the Mean and Max Duration
Materials order	41.72					41.72	Between the Mean and Max Duration
Clearing and grading the Right-Of-Way (ROW)	43.12					43.12	Between the Mean and Max Duration
Topsoil stripping and Front-end grading	42.95		27.62			42.95	Between the Mean and Max Duration
Buildings, roads and rivers crossings	60.72					60.72	Between the Mean and Max Duration
Temporary fencing and signage	22.43					22.43	Between the Mean and Max Duration
Pipe transporting to sit	140.17		81.31			140.17	Between the Mean and Max Duration
Construction Stage				224.45			
Trenching	83.07					83.07	Between the Mean and Max Duration
Temporary erosion control and side support	91.74					91.74	Between the Mean and Max Duration
Pipe set-up	143.91		6.71			143.91	Between the Mean and Max Duration
Welding, fabrication and installing pipe	147.67		6.72			147.67	Between the Mean and Max Duration
NDT tests	147.88		6.70			147.88	Between the Mean and Max Duration
SAND BLAST	147.71		6.72			147.71	Between the Mean and Max Duration
Painting	147.63		6.65			147.63	Between the Mean and Max Duration
Cathodic Protecting the pipe	131.83					131.83	Between the Mean and Max Duration
Coating	147.74		6.64			147.74	Between the Mean and Max Duration
Lowering pipe in and backfilling	147.04		6.79			147.04	Between the Mean and Max Duration
As-built survey	14.28					14.28	Between the Mean and Max Duration
Final fitting	147.07		5.00			147.07	Between the Mean and Max Duration
Hydro, pressure test	6.04					6.04	Between the Mean and Max Duration
Backfilling	41.66		24.41			41.66	Between the Mean and Max Duration
Post Construction Stage				111.52			
Fencing and signage	17.19		7.26			17.19	Between the Mean and Max Duration
Final clean up	28.31		15.25			28.31	Between the Mean and Max Duration

Figure H.24: A screenshot from the calculations of the @Risk simulator.

H.2. The Results for Duration Sensitivity

In this section, the research has used different methods and tests in order to test the sensitivity analysis of the IRFs and their impact on the duration of the project. The tests were Tornado-Change in output mean, Tornado-Regression coefficients, Tornado-Correlation coefficients, Tornado-Regression mapped values, and Tornado-Contribution to variance tests. The results of the sensitivity tests were shown by the stages of the project as follows.

H.2.1. The IRFs that affect the overall duration of the project

The different types of sensitivity tests have confirmed the IRFs that have the highest impact on the duration of the project. These IRFs are limited warning sings; animal accidents;

terrorism, sabotage and security; corruption; inadequate risk management; little research about risk management; and the weak ability to identify and monitor the threats and the IRFs, see Figure H.25 to Figure H.30.

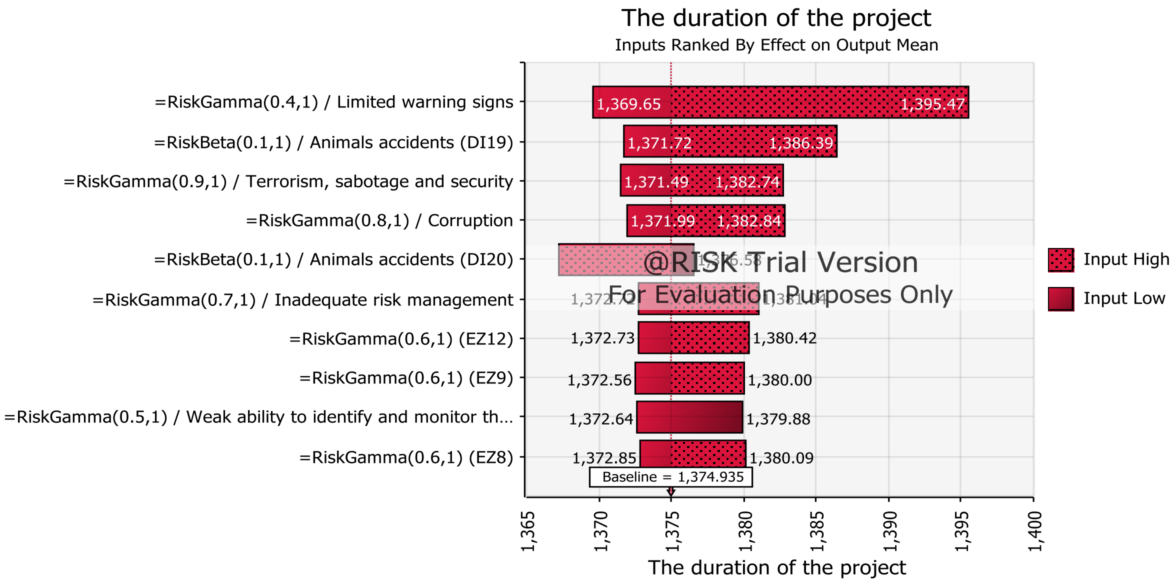


Figure H.25: Tornado-Change in output mean (the overall project).

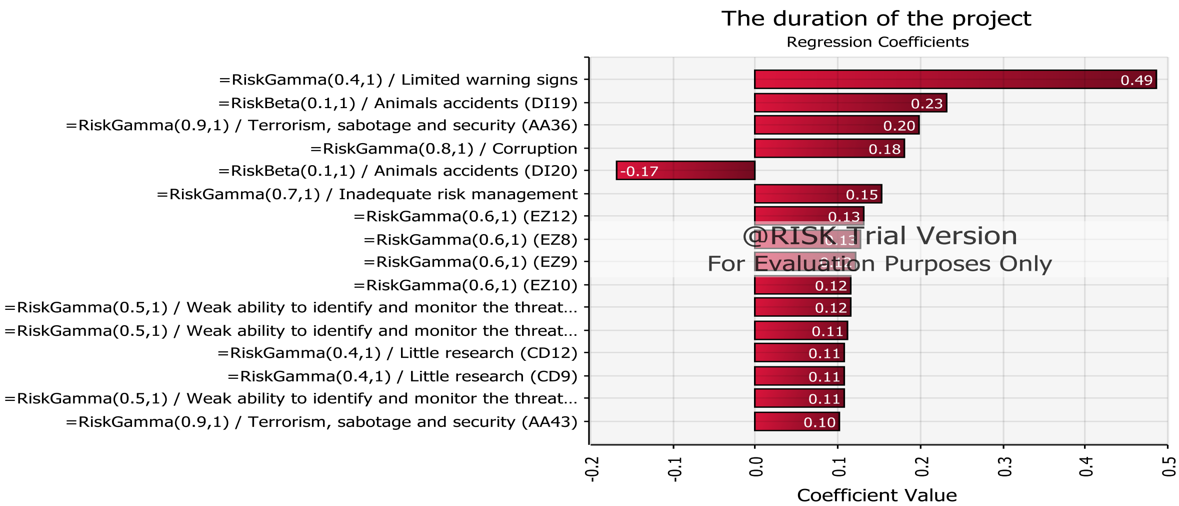


Figure H.26: Tornado-Regression coefficients (the overall project).

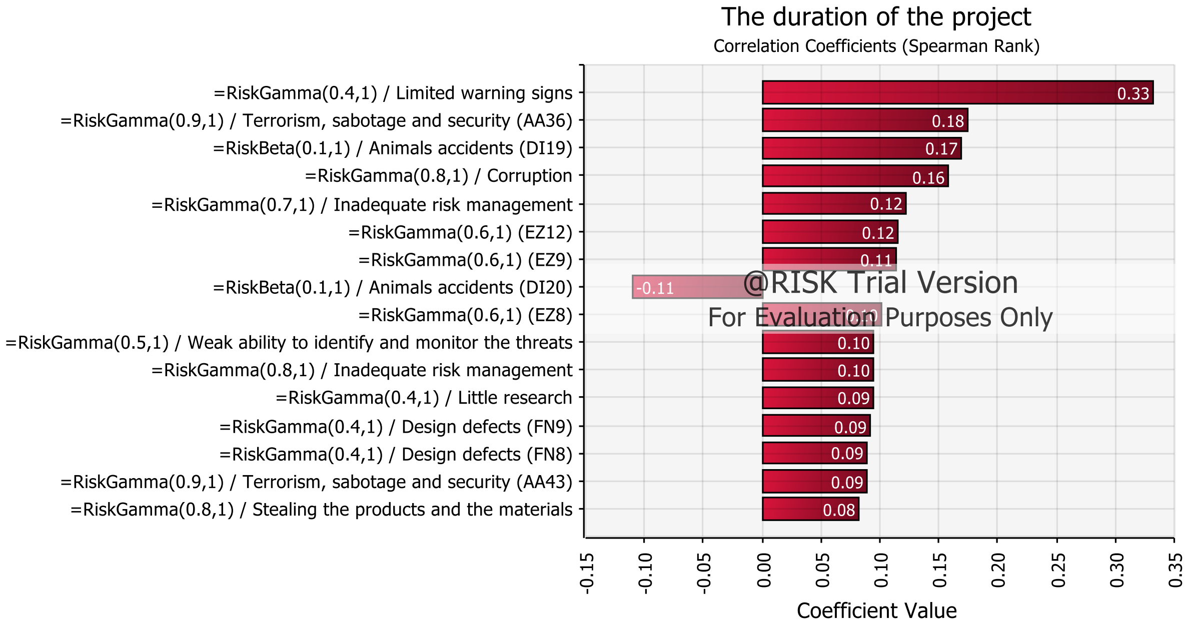


Figure H.27: Tornado-Correlation coefficients (the overall project).

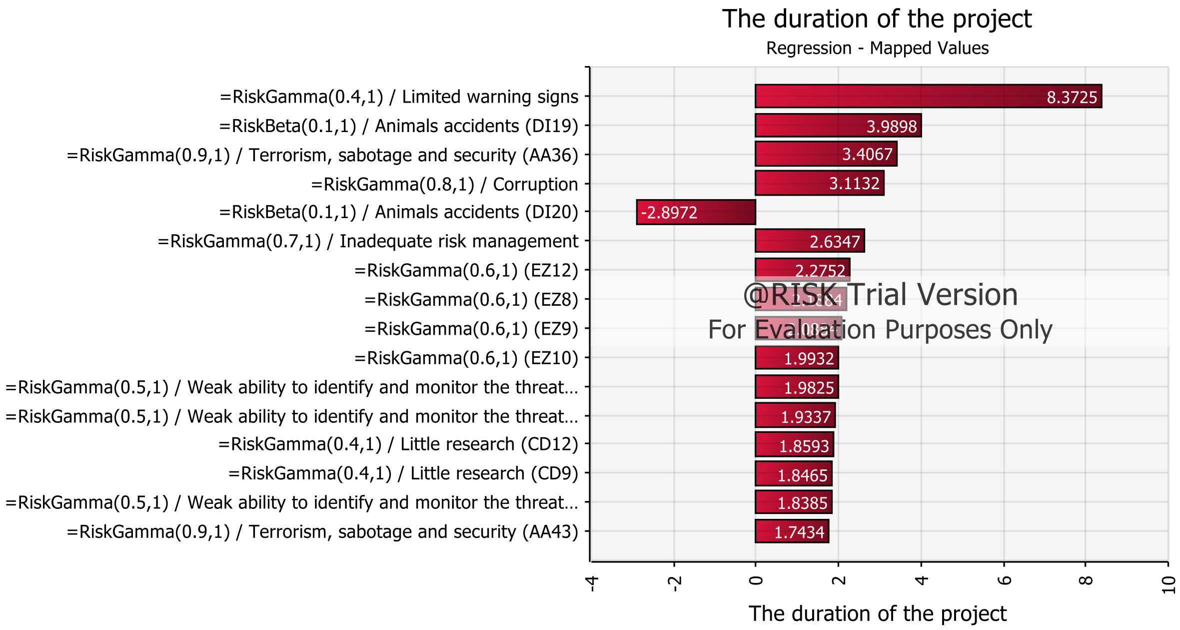


Figure H.28: Tornado-Regression mapped values (the overall project).

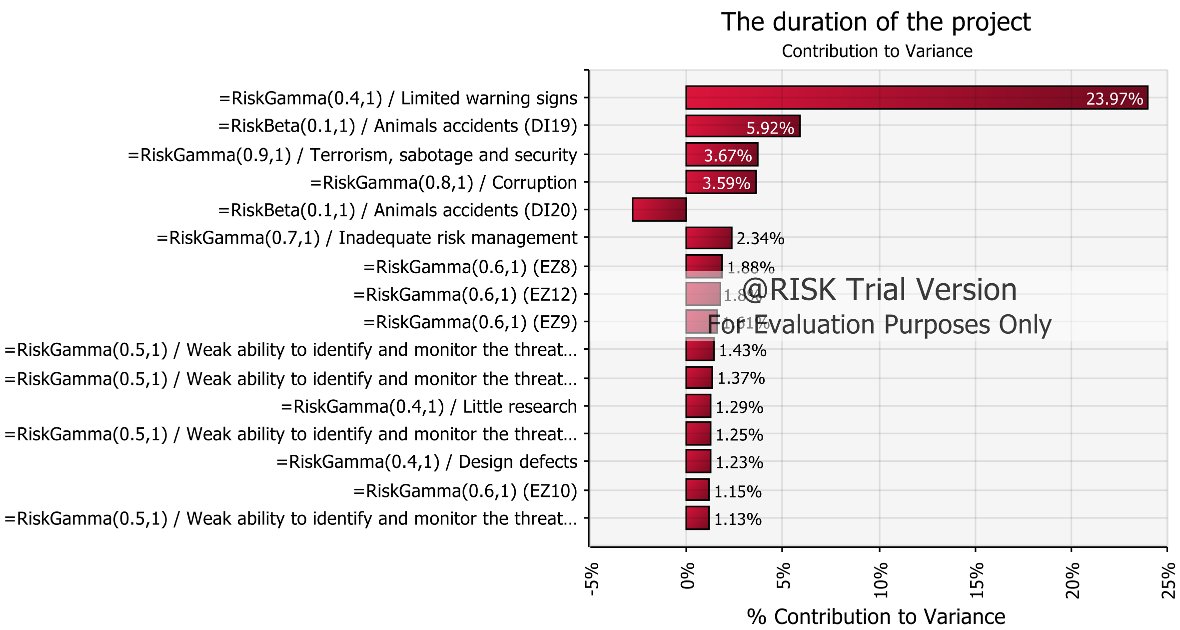


Figure H.29: Tornado-Contribution to variance (the overall project).

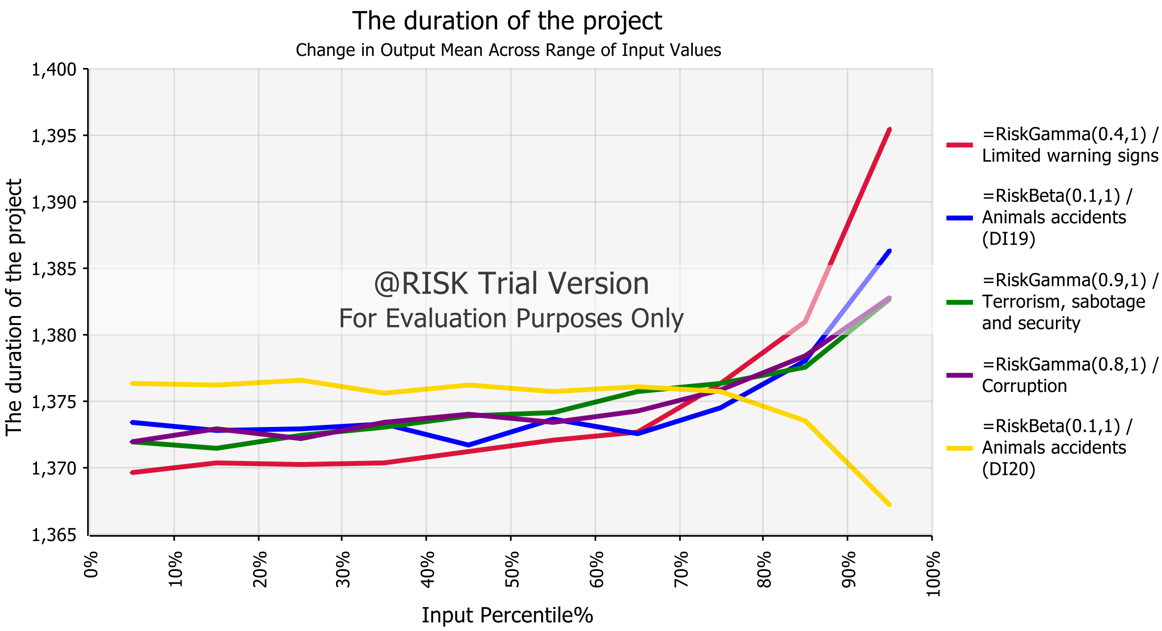


Figure H.30: Spider graph – Change in output mean (the overall project).

H.2.2. The IRFs that affect the duration of the planning and design stage of the project

The different types of sensitivity tests have confirmed the IRFs that have the highest impact on the duration of the planning and design stage of the project. These IRFs are animal accidents; terrorism, sabotage and security; corruption; lack of records; inadequate risk management; the pipelines are exposed and easy to access; and lack of appropriatetraining and practice about risk management, see Figure H.31 to Figure H.36.

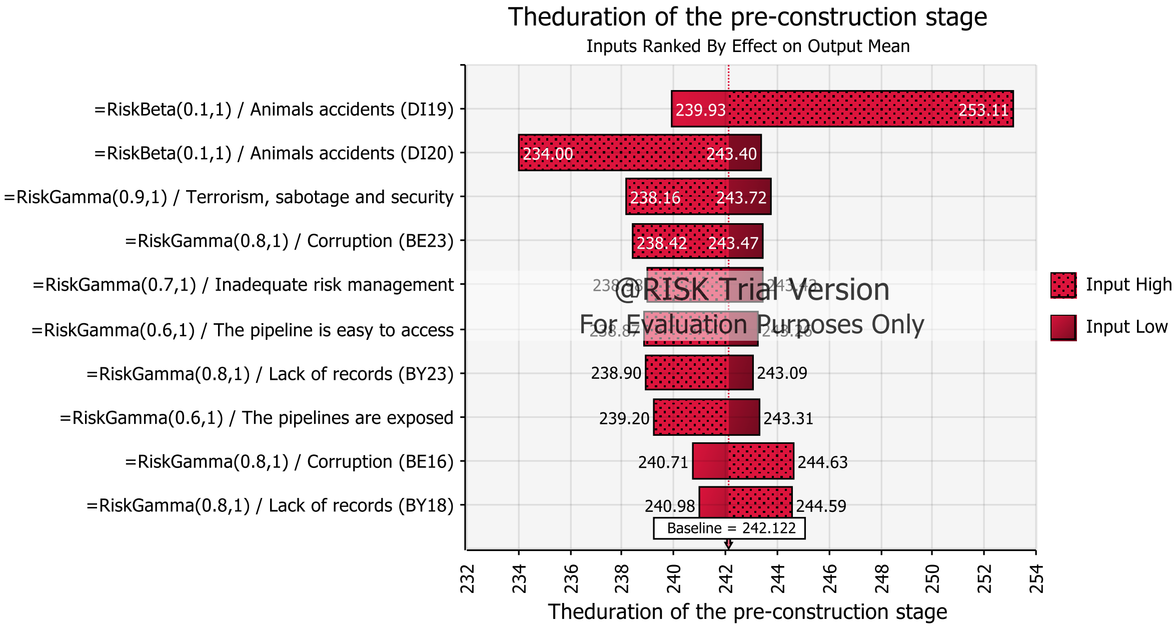


Figure H.31: Tornado-Change in output mean (Planning and design stage).

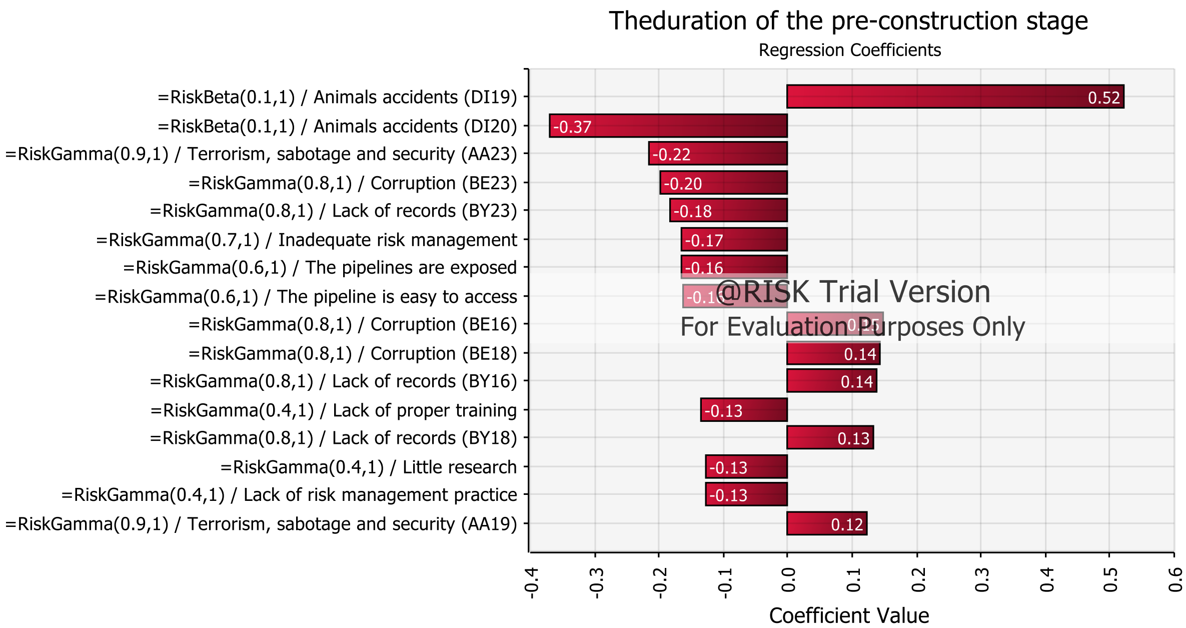


Figure H.32: Tornado- Regression coefficients (Planning and design stage).

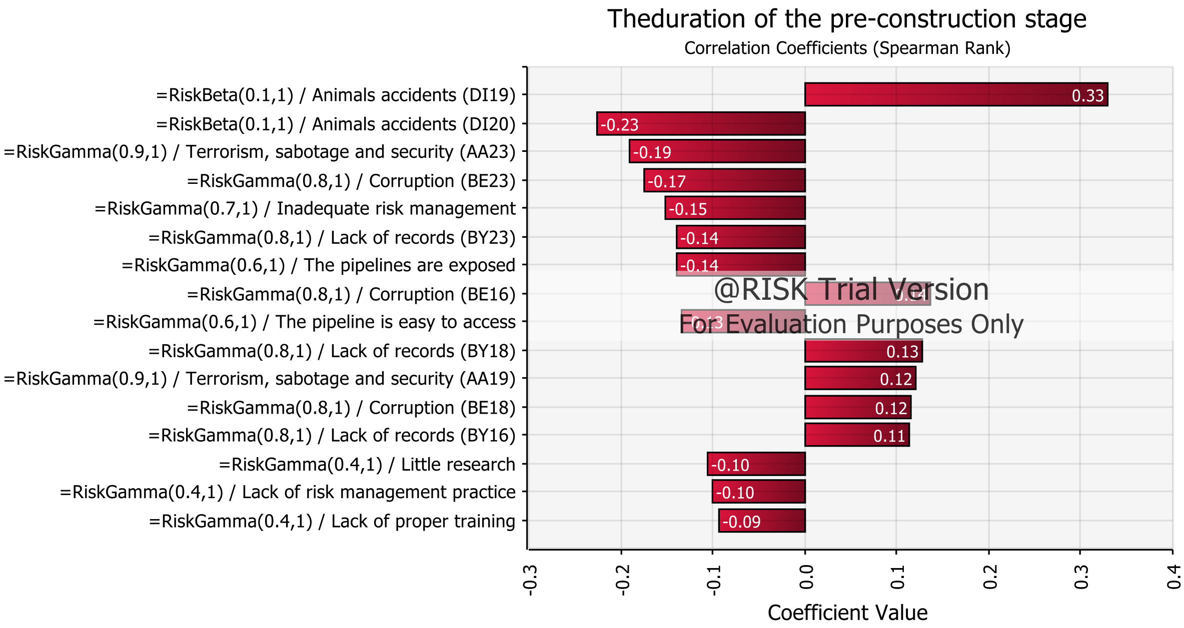


Figure H.33: Tornado-Correlation coefficients (Planning and design stage).

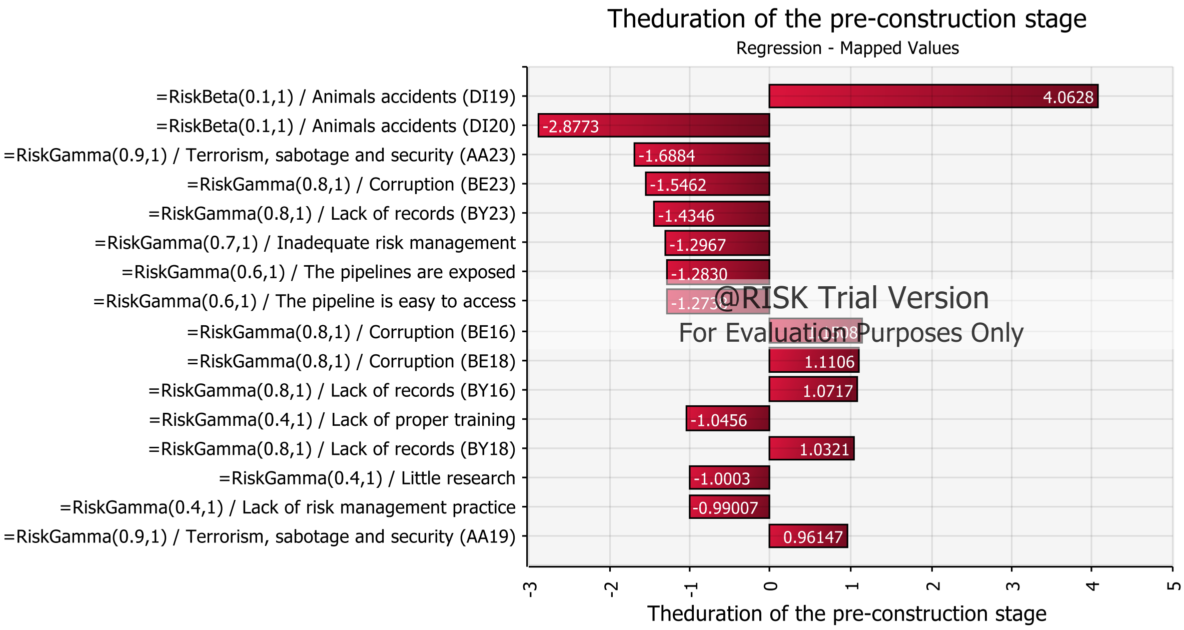


Figure H.34: Tornado-Regression mapped values (Planning and design stage).

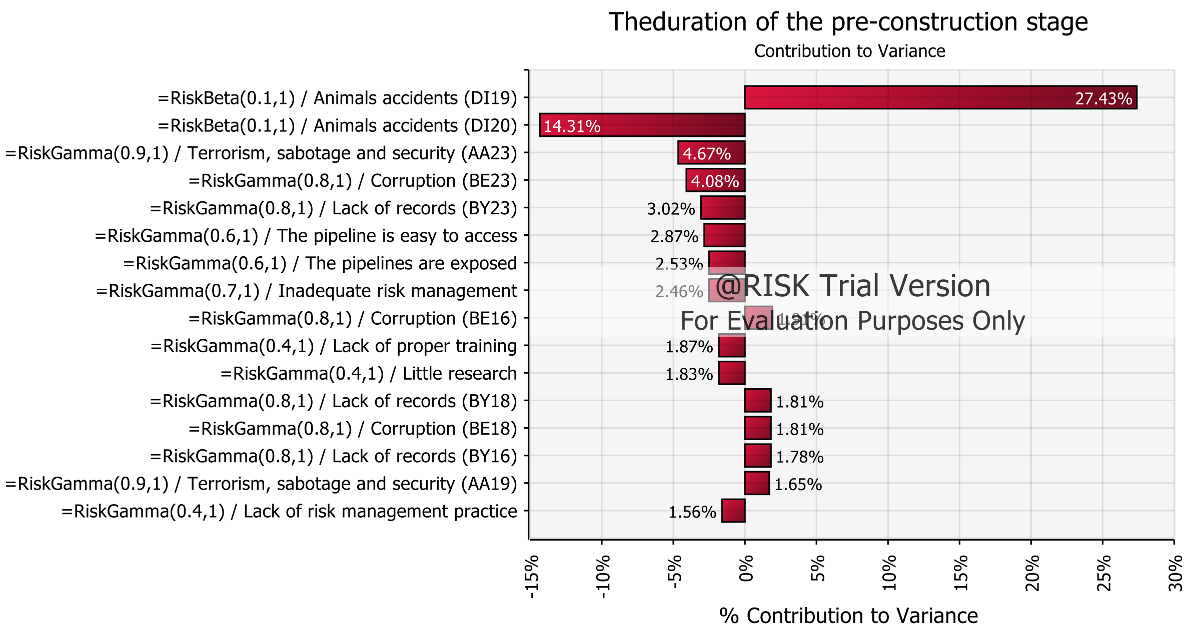


Figure H.35: Tornado-Contribution to variance (Planning and design stage).

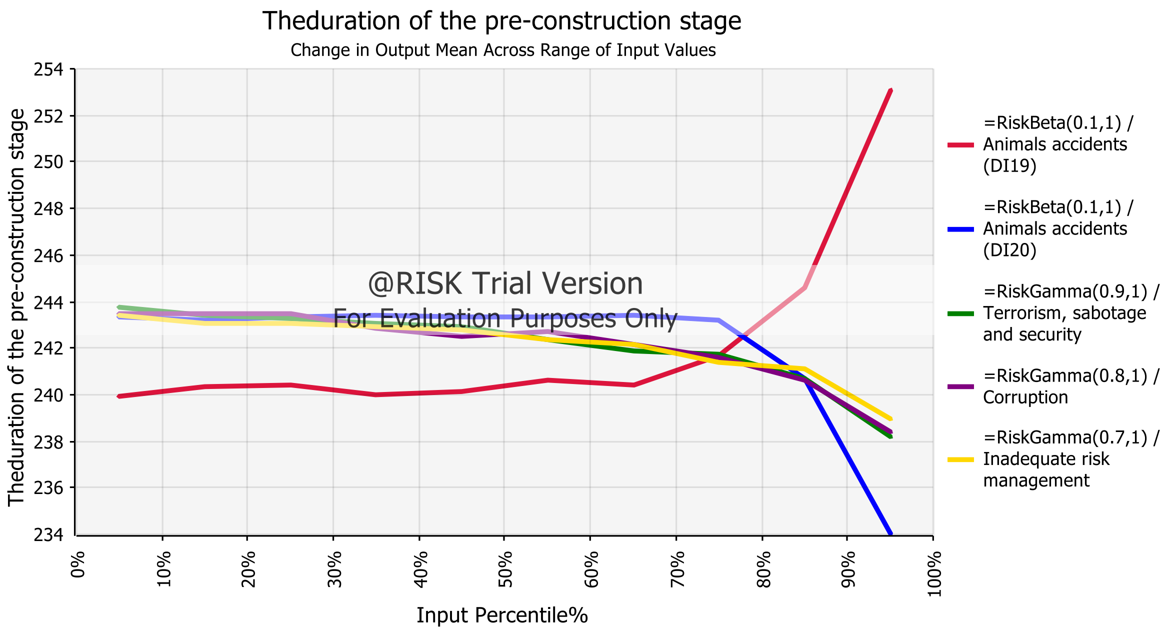


Figure H.36: Spider graph – Change in output mean (Planning and design stage).

H.2.3. The IRFs that affect the duration of the pre-construction stage of the project

The different types of sensitivity tests have confirmed the IRFs that have the highest impact on the duration of the pre-construction stage of the project. These IRFs are limited warning signs; terrorism, sabotage and security; corruption; inadequate risk management; socio-political factors; natural disasters and weather conditions; public awareness; the absence of law towards TPD; lack of appropriatetraining; lack of records; stealing the products and the materials; improper safety regulations; the pipelines are exposed and easy to access; and construction defects, see Figure H.37 to Figure H.42.

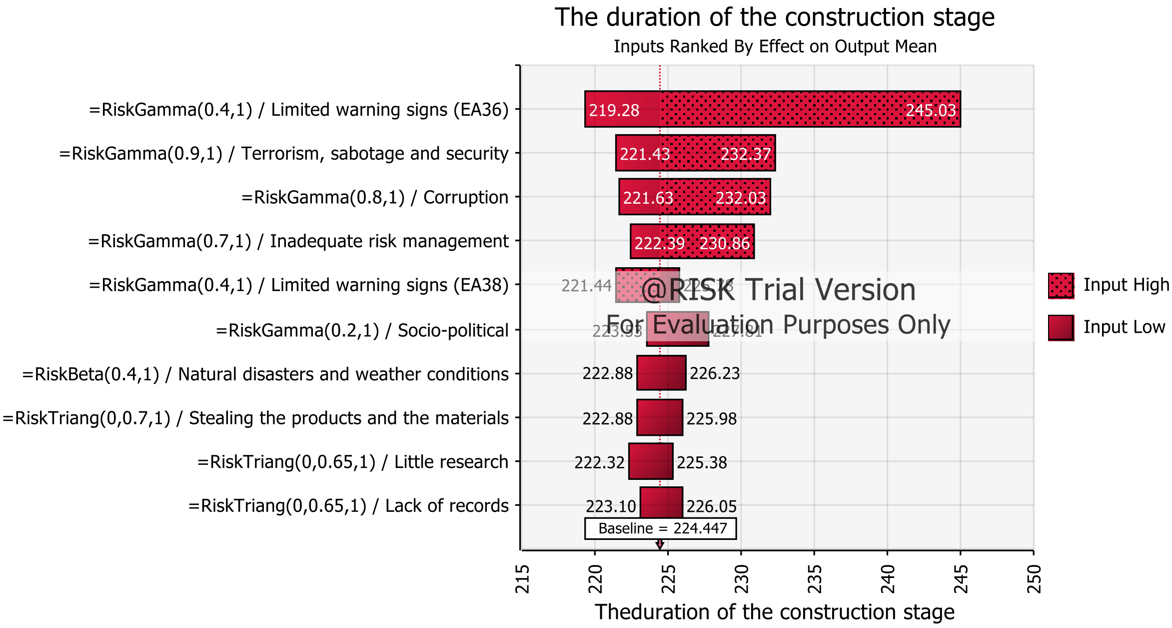


Figure H.37: Tornado-Change in output mean (Pre-construction stage).

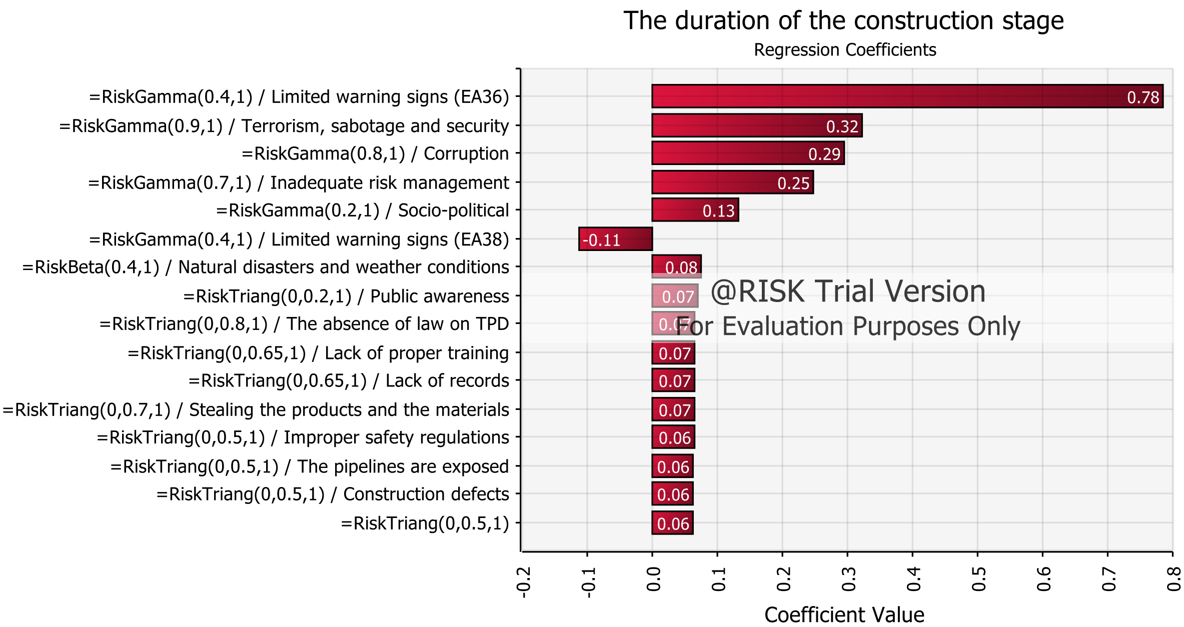


Figure H.38: Tornado-Regression coefficients (Pre-construction stage).

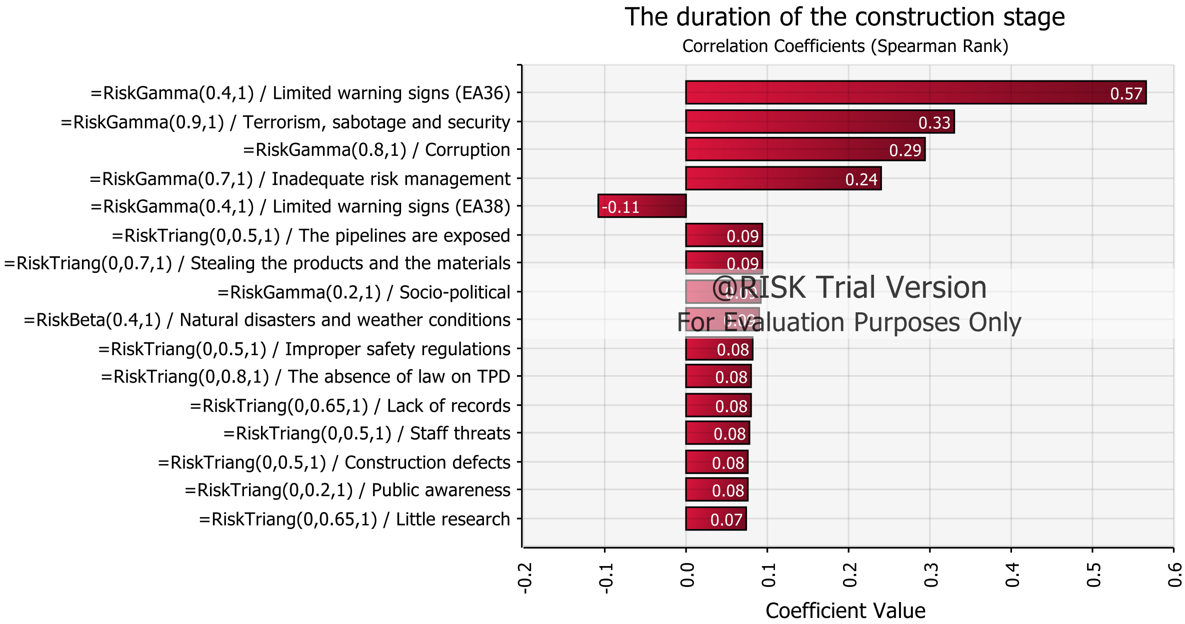


Figure H.39: Tornado-Correlation coefficients (Pre-construction stage).

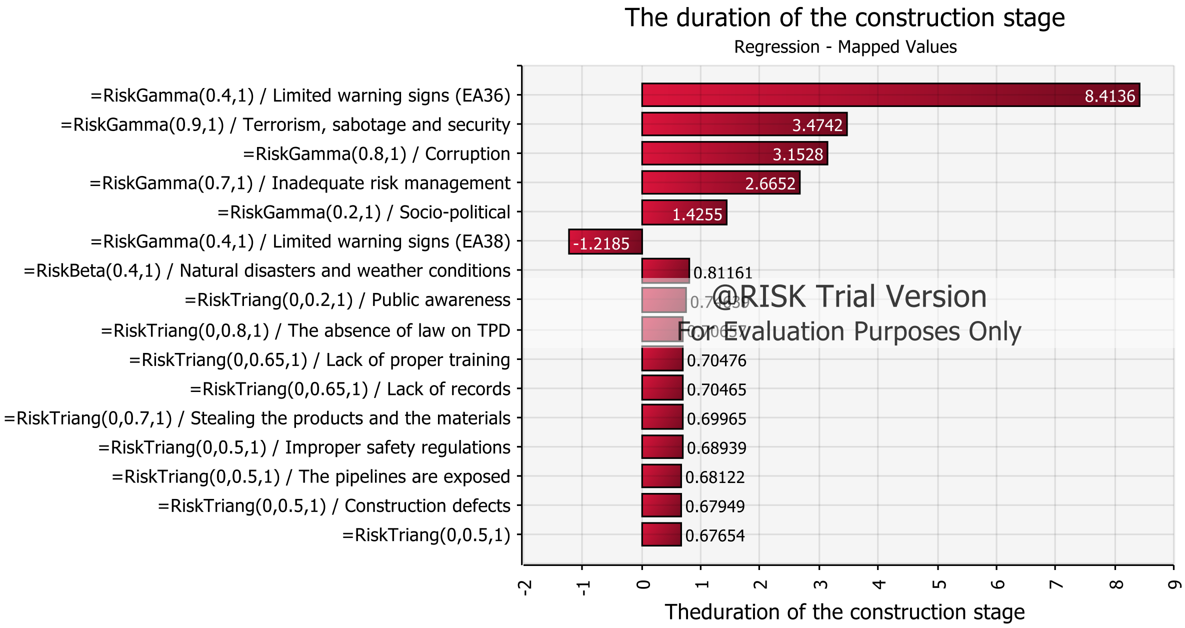


Figure H.40: Tornado-Regression mapped values (Pre-construction stage).

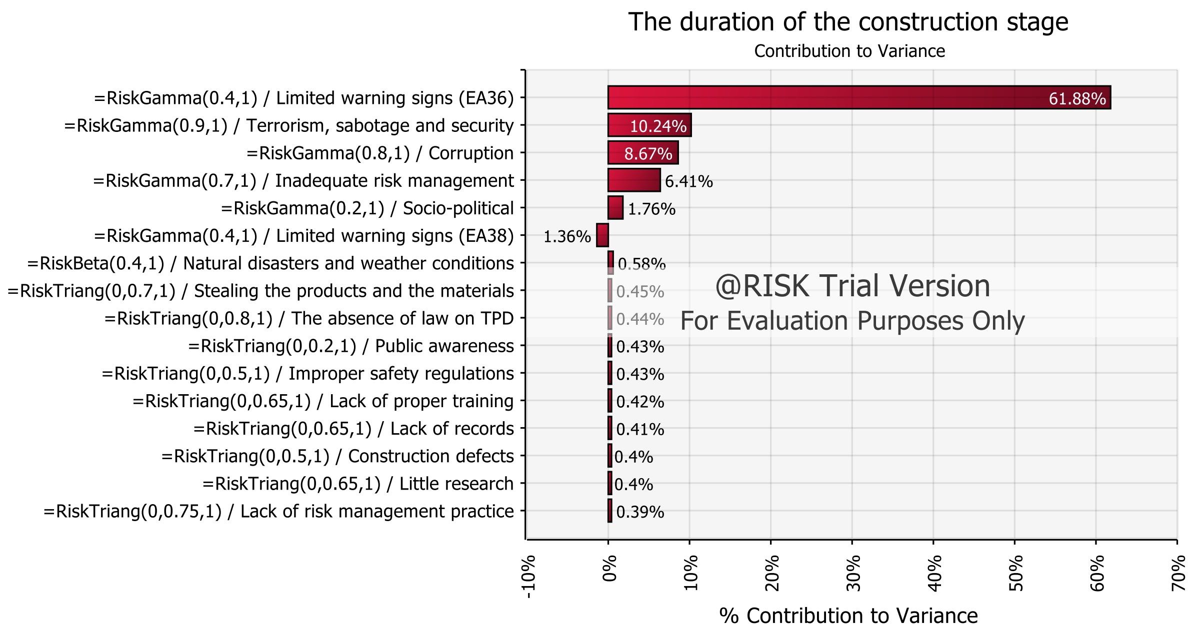


Figure H.41: Tornado-Contribution to variance (Pre-construction stage).

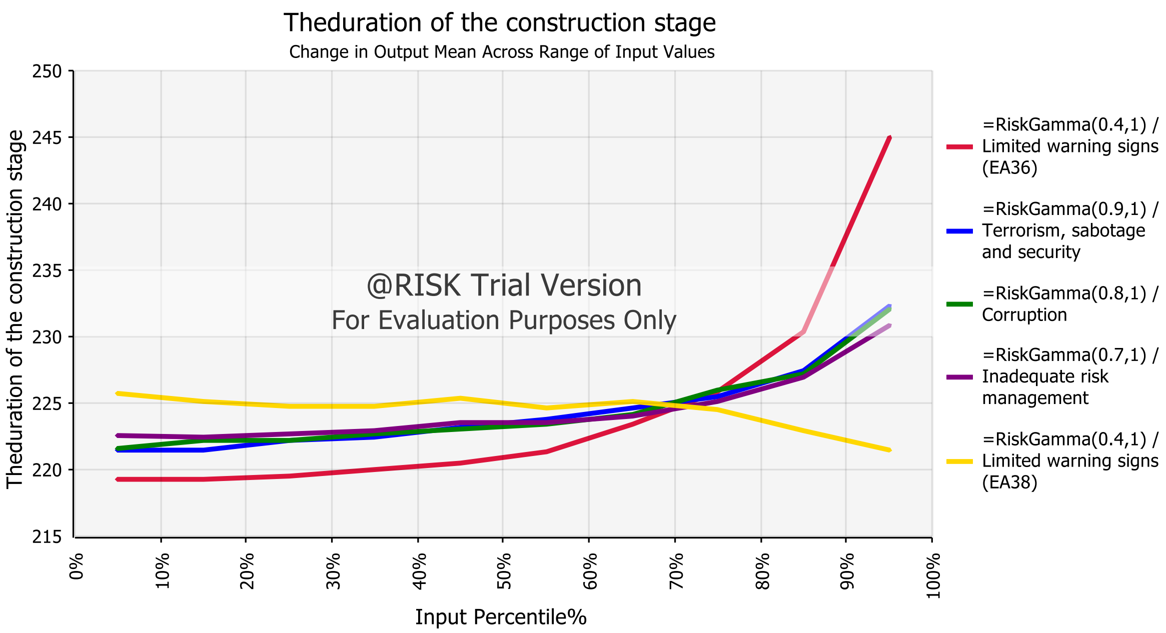


Figure H.42: Spider graph – Change in output mean (Pre-construction stage).

H.2.4. The IRFs that affect the duration of the construction stage of the project

The different types of sensitivity tests have confirmed the IRFs that have the highest impact on the duration of the construction stage of the project. These IRFs are limited warning signs; terrorism, sabotage and security; corruption; inadequate risk management; socio-political factors; natural disasters and weather conditions; public awareness; the absence of law towards TPD; lack of appropriatetraining; lack of records; stealing the products and the materials; improper safety regulations; the pipelines are exposed and easy to access; and construction defects, see Figure H.43 to Figure H.48.

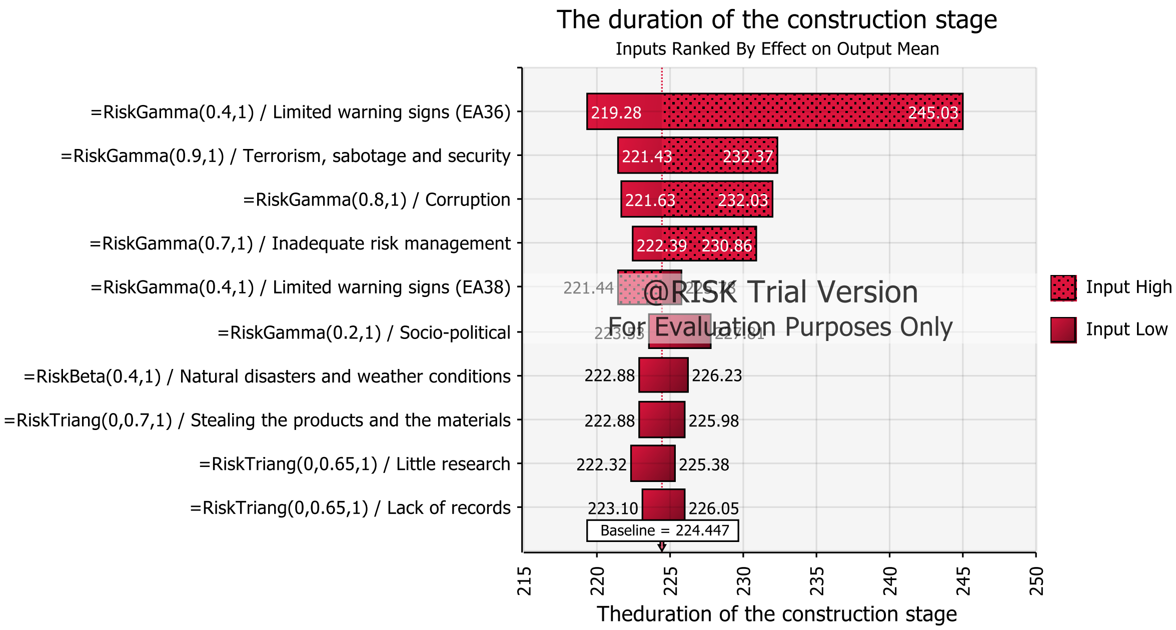


Figure H.43: Tornado-Change in output mean (Construction stage).

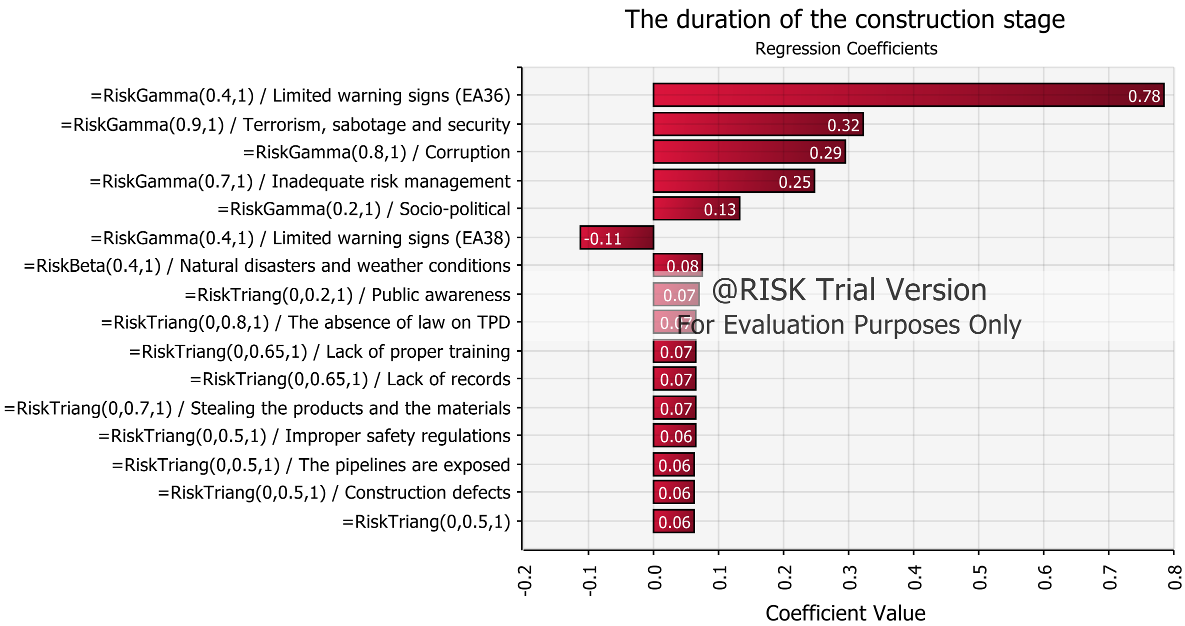


Figure H.44: Tornado-Regression coefficients (Construction stage).

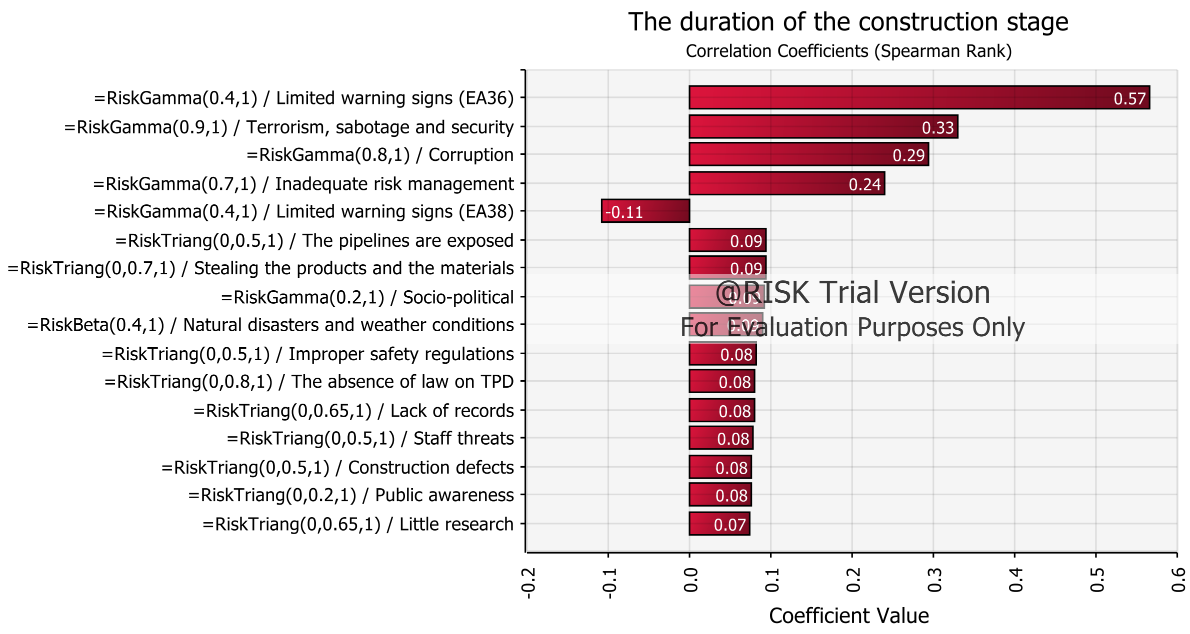


Figure H.45: Tornado-Correlation coefficients (Construction stage).

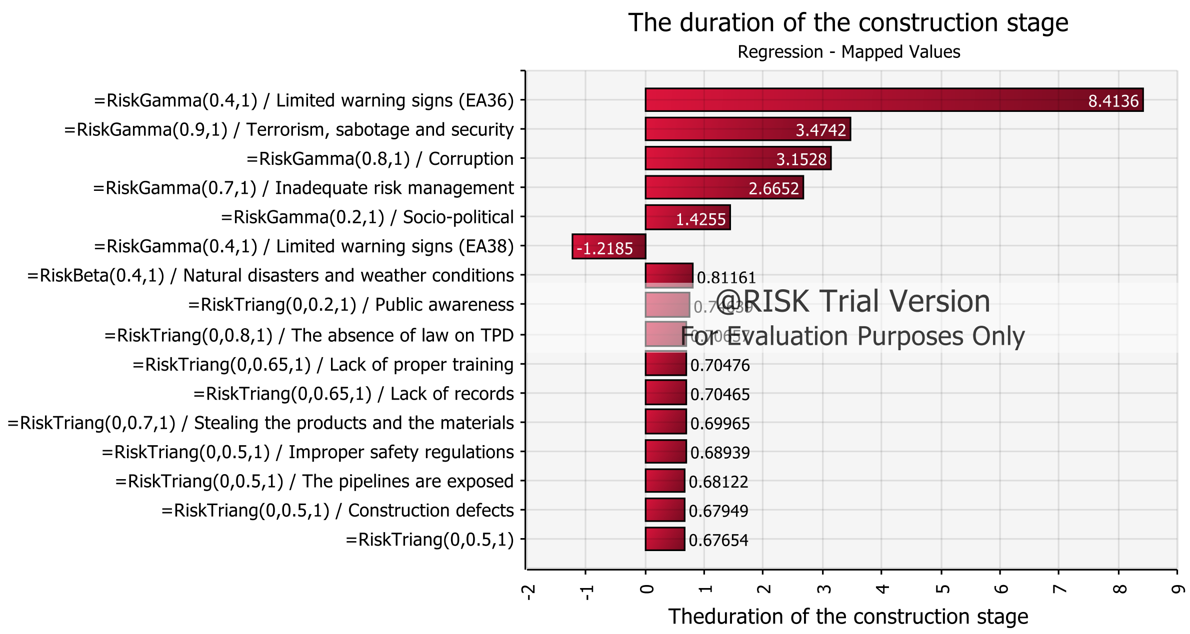


Figure H.46: Tornado-Regression mapped values (Construction stage).

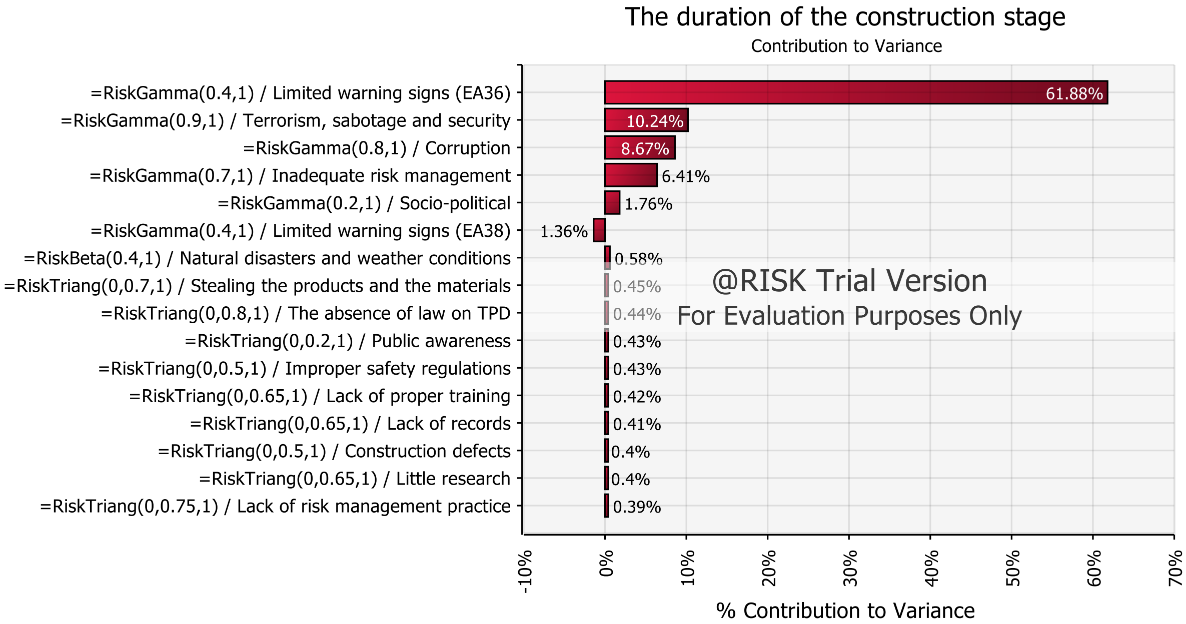


Figure H.47: Tornado-Contribution to variance (Construction stage).

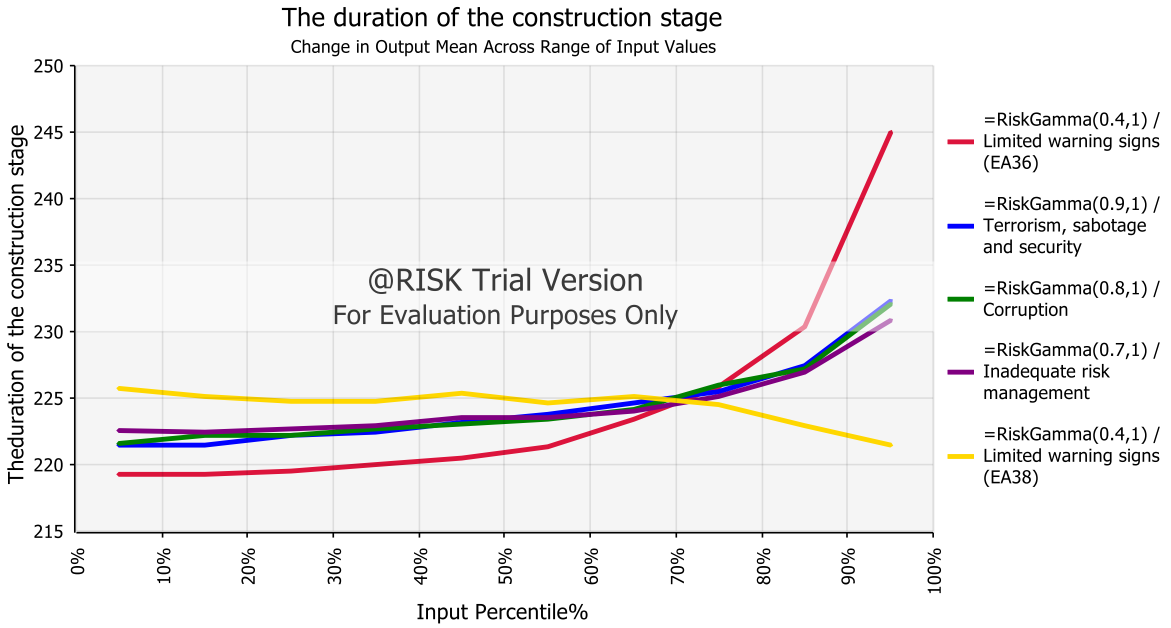


Figure H.48: Spider graph – Change in output mean (Construction stage).

H.2.5. The IRFs that affect the duration of the post-construction stage of the project

The different types of sensitivity tests have confirmed the IRFs that have the highest impact on the duration of the post-construction stage of the project. These IRFs are terrorism, sabotage and security; stealing the products and the materials; corruption; the absence of law towards TPD; inadequate risk management; the weak ability to identify and monitor the threats and IRFs; the pipelines are exposed and easy to access; limited warning signs;

improper safety regulations; leakage of sensitive information; public awareness; and Threats to staff, see Figure H.49 to Figure H.54.

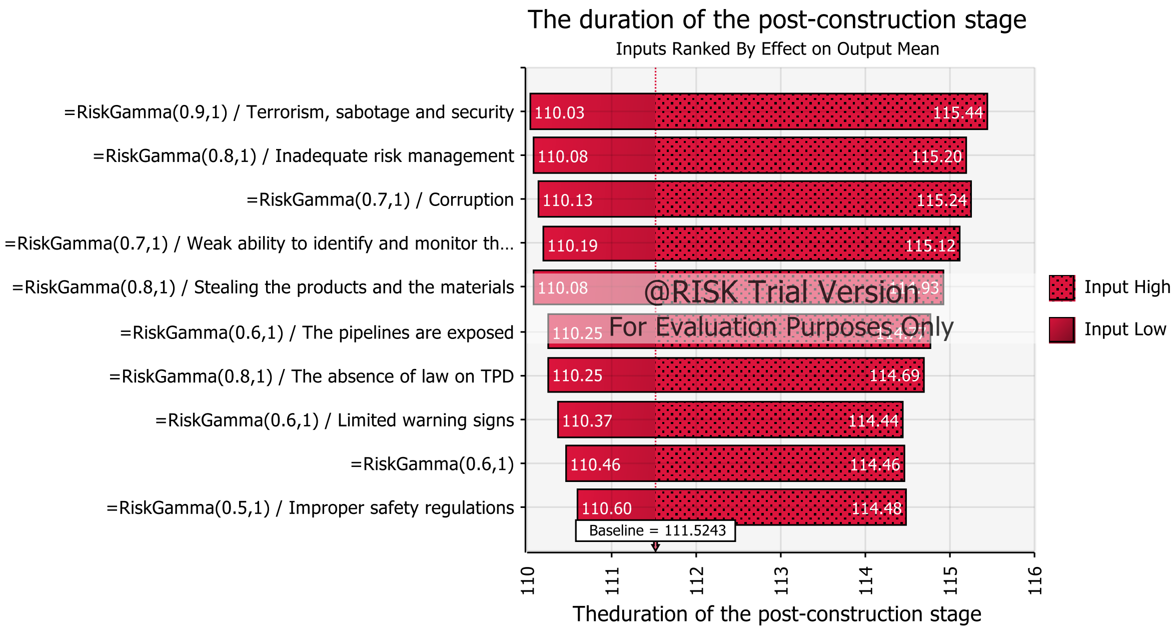


Figure H.49: Tornado-Change in output mean (Post-construction stage).

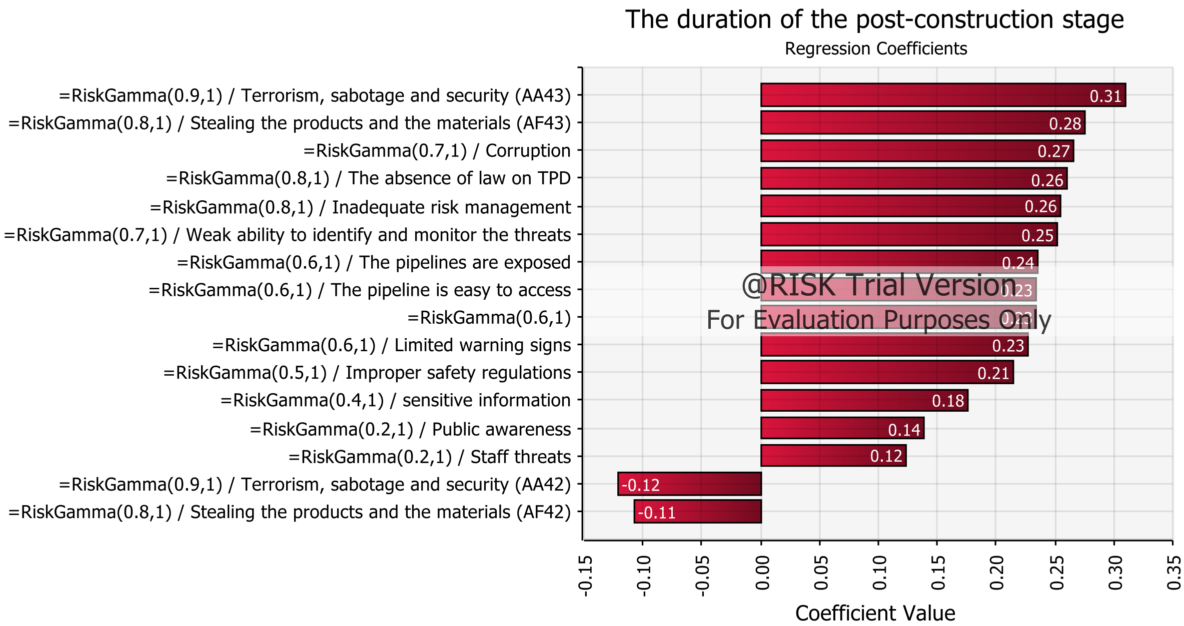


Figure H.50: Tornado-Regression coefficients (Post-construction stage).

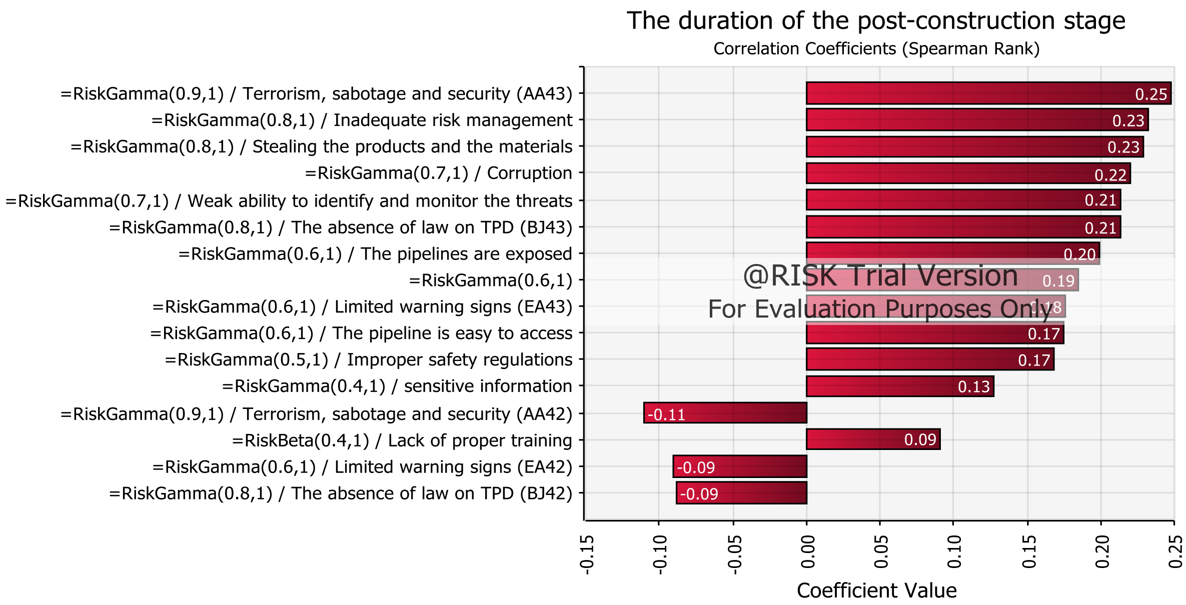


Figure H.51: Tornado-Correlation coefficients (Post-construction stage).

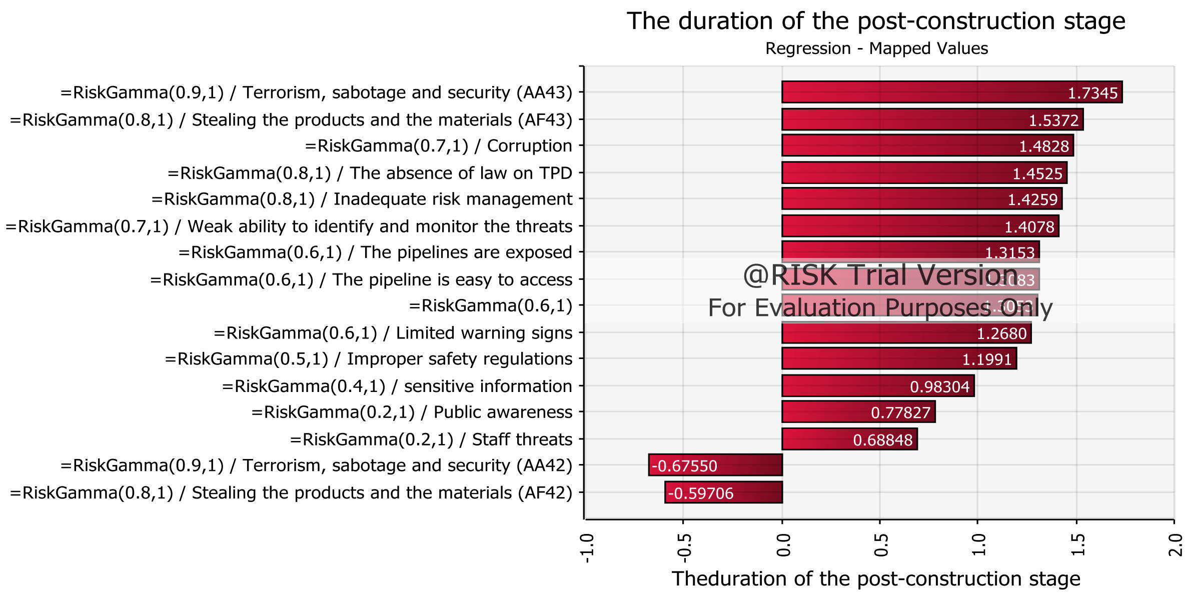


Figure H.52: Tornado-Regression mapped values (Post-construction stage).

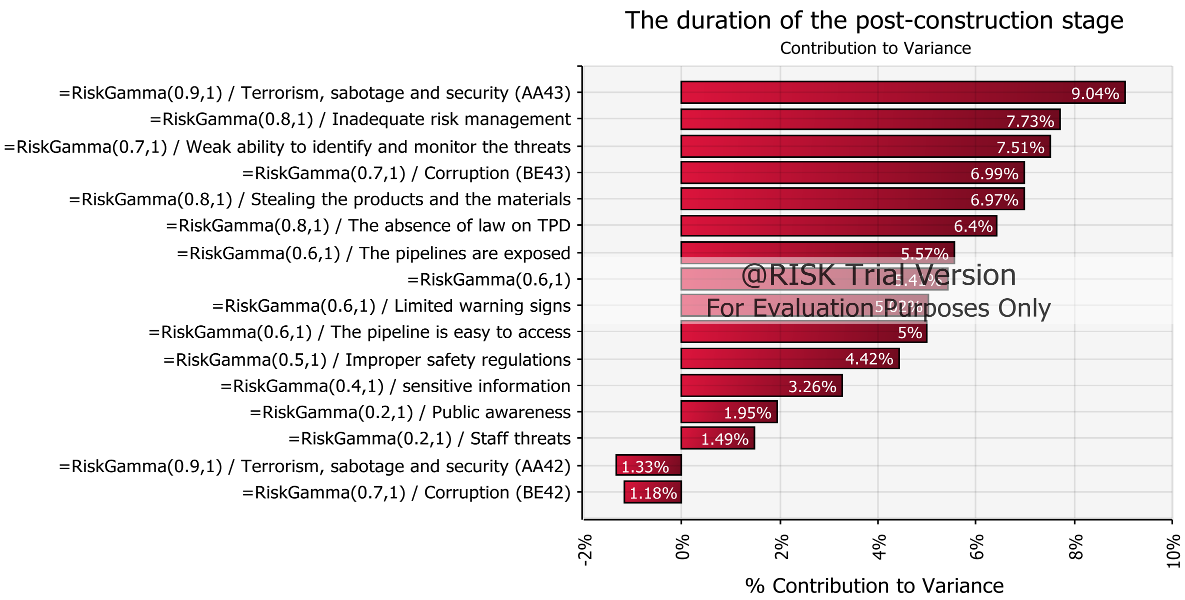


Figure H.53: Tornado-Contribution to variance (Post-construction stage).

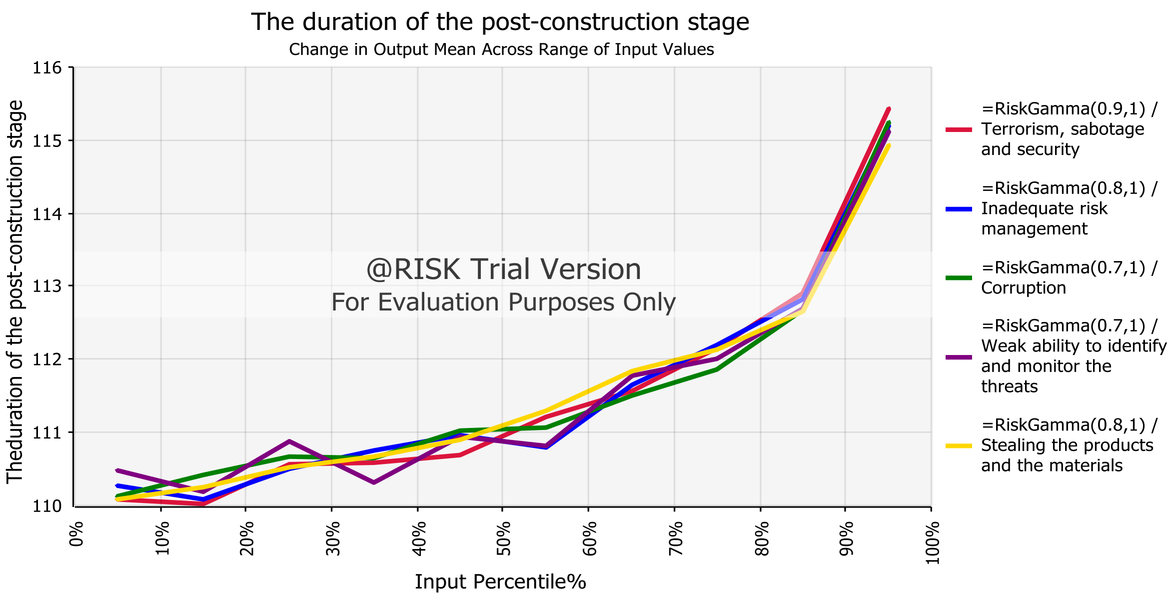


Figure H.54: Spider graph – Change in output mean (Post-construction stage).