

**Developing a Stochastic Model to Predict Cost Overrun due
to the Causes of Projects Delay in Oil Fields Construction
Industry**

تطوير نموذج للتنبؤ بتجاوز التكاليف بسبب تأخر المشاريع في أعمال الإنشاءات
بحقول النفط

by

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Abstract

The criticality of managing projects delay in oil fields construction projects has been exacerbated by the general complexities associated with the sources of projects delay and how varied the impact may be to various stakeholders such as client/owner, contractor, design/consultant and miscellaneous/external groups within the industry. While most of the previous research investigated the causes of project delay in general construction, very little research exists specifically on oil fields construction projects in terms of budget overrun. The main aim of the research is to establish a model that could be used to map the causes of projects delay to the cost overrun in oil fields construction projects and to investigate the variables that contribute to budget/cost overrun. In addition, the author used regression analysis and Monte Carlo simulation to develop a stochastic model to map the causes of projects delay to cost overrun. The research results revealed that poor contractor works was found to have the most significant positive impact in the delay experienced by the projects considered in this work. However, most of the causes of cost overrun were found to follow the Log logistic distribution – a family of distribution associated with projects where the risk increases at the initial phase of the project and decreases later on. Therefore, to minimize cost overrun, the study suggest that those involved in a project's value chain must ensure a smooth execution of project in its early stage so as to limit the high risk associated with the project during in its initial phase. The main contribution of this work, is the research framework which can be used by businesses in oil fields construction industry to model their own factors and help in their decision-making, as opposed to using anecdotal evidence. Finally, the author recommended some areas of the current study that can be developed such as mapping the causes of projects delay to other impacts, such as time overrun success criteria and to increase the number of projects delay in the regression model.

مختصر تنفيذي

ازدادت أهمية إدارة تأخير المشاريع في مشاريع بناء حقول النفط بسبب التعقيدات العامة المرتبطة بمصادر تأخير المشاريع ومدى تنوع التأثير على أصحاب المصلحة المختلفين مثل العميل / المالك والمتعاقد والمصمم / الاستشاري والأسباب الأخرى المتنوعة / غير المرتبطة بأصحاب المصلحة المذكورين.

في حين أن معظم الأبحاث السابقة بحثت في أسباب تأخر المشاريع في الإنشاءات العامة ، إلا أنه لا يوجد سوى القليل جدًا من الأبحاث على وجه التحديد حول مشاريع بناء حقول النفط من حيث تجاوز الميزانية أو التكاليف. الهدف الرئيسي من البحث هو إنشاء نموذج يمكن استخدامه لتحديد أسباب تأخير المشاريع إلى تجاوز التكلفة في مشاريع بناء حقول النفط والتحقيق في المتغيرات التي تساهم في تجاوز الميزانية / التكلفة. بالإضافة إلى ذلك ، استخدم المؤلف تحليل الانحدار ومحاكاة مونت كارلو لتطوير نموذج عشوائي لتحديد أسباب تأخر المشاريع في تجاوز التكلفة. أوضحت نتائج البحث أن أعمال المقاول الضعيفة كان لها الأثر الإيجابي الأكثر أهمية في التأخير الذي واجهته المشاريع التي تمت دراستها في هذا العمل. ومع ذلك ، تم العثور على معظم أسباب تجاوز التكلفة لمتابعة التوزيع اللوجستي - مجموعة التوزيع المرتبطة بالمشاريع حيث تزداد المخاطر في المرحلة الأولية من المشروع وتتنخفض لاحقًا. لذلك ، لتقليل تجاوز التكاليف إلى أدنى حد ، تشير الدراسة إلى أن المشاركين في سلسلة القيمة الخاصة بالمشروع يجب أن يضمنوا التنفيذ السلس للمشروع في مرحلته المبكرة للحد من المخاطر العالية المرتبطة بالمشروع خلال مرحلته الأولية. المساهمة الرئيسية لهذا العمل ، هي إطار البحث الذي يمكن استخدامه من قبل الشركات في صناعة بناء حقول النفط لإدارة عواملها الخاصة والمساعدة في صنع القرار ، على عكس استخدام الأدلة القصصية. وأخيرًا ، أوصى المؤلف ببعض مجالات الدراسة الحالية التي يمكن تطويرها مثل رسم خرائط أسباب تأخير المشاريع إلى التأثيرات الأخرى ، مثل تجاوز معايير النجاح في الوقت وزيادة عدد المشاريع المتأخرة في نموذج الانحدار.

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Chapter 1: Introduction

1.1 Introduction

This chapter illustrates the research problem through introducing the contextual aspects of this research. The chapter further presents the research questions, aims and objectives.

1.2 Background of the study

Delay in oil fields construction projects has been rarely studied over the latest few decades despite its high impact on the economy and development plans of the countries. Many researchers have argued that delay in construction projects in oil fields industry become a global phenomenon and costly problem for all projects stakeholders (Dey 2007; Kazemi *et al.*, 2018; Pham and Hadikusumo 2014; Ruqaishi and Bashir 2014; Salama 2008).

Delay in oil fields construction projects lead to disputes and claims which required effective mitigating strategies to save time and costs and consequently contribute to a country development. According to Kazemi *et al.* (2018), delay in oil and gas construction projects might affect the economic development of oil producing countries, therefore, it is very crucial to analyze the factors causing delay and having mitigating strategies to reduce the duration of delay and saving time and budget.

Recently, Pham and Hadikusumo (2014) gave a comprehensive review on schedule delays in engineering, procurement, and construction petrochemical projects in Vietnam, they noted that

many large-scale petrochemical and oil plants construction projects have been suffered from schedule delays, thus, a clear understanding of the business model and management processes and methods is required to solve the delay problems.

Moreover, Ruqaishi and Bashir (2014) explained that projects delay in oil and gas construction industry might lead petroleum companies to lose trillions of dollars in lost revenue. Authors elaborated more on this topic by illustrating the effect of these failed projects on the economic development of the oil producing countries, which mainly depend on the revenue generated from oil and gas projects such as gas treatment units, oil refinery, and petrochemical plants.

In another study, Salama *et al.* (2008) examined the causes of delay within oil and gas projects in the UAE, authors indicated that delay is common problem in petroleum projects especially in the completion date, which ranges from 5 to almost 20% of the total project duration. Salama *et al.* (2008) explained further that industry experts should expect that rate of delay will increase in the future due to shortage in material, equipment and experienced personnel.

For example, Fallahnejad (2013) explained that fossil fuels will remain as the main energy in the market until 2050 while Iran, UAE, Iraq , Kuwait, Qatar and Saudi Arabia will remain the main oil and gas producers in the region. That's why longer delay in petroleum construction projects at any major producer country will highly affect the development of its economy and financial stability. The author described delay as one of the root causes of conflicts in projects, and that delay lead to time and cost overrun which in most cases contractors pay cost of delay and owners lose huge profits by not being able to sell oil products when market prices are high. The author further studied three fields in literature review to investigate delay causes in Iran gas pipeline construction projects. First field the author studied is the oil and gas. The second filed is public

projects which usually implemented in long duration such as highways and railways. The last field is governmental projects. The author justified the use of the last two fields in literature review to investigate petroleum construction projects is that they all belong to governmental sectors whose management methods, rules and regulations, and organization structures are the same. Therefore, the common projects environments, procurement and management methods would result in common main problems and major causes of delay.

Furthermore, recent evidence indicated that the average cost overrun of 200 public oil and gas projects is 18% with standard deviation of 29% (Rui et al. 2017). Authors who conducted a research investigation into the performance of oil and gas projects described that the error of underestimation is more than the error of overestimation, which lead to non-proper management of projects risks and issues and consequently lead to projects delay.

There is a large volume of published studies identifying mitigation strategies for project delay in civil construction projects and few studies were about oil and gas industry projects, which propose suggestions on reducing the impact of delay on time and cost by planning a proper strategy by completing projects on time. Mitigation strategies to reduce projects cost and minimize delay can be achieved by different techniques such as timely and reasonable procurement, protection of pending or uncompleted work, and rescheduling or cancellation of purchase orders (Bramble and Callahan 1992).

Previous research in oil and gas construction projects in Vietnam has shown that building good relationship with government authorities and environmental authorities can help reduce project approval delays by understanding their requirements and showing the benefits and fruitful outcomes of the projects (Toor and Ogunlana, 2008). Authors illustrated further that familiarity

with approval procedures and understanding local laws and regulations by maintaining historical records and archives of past project approvals and documentations can help to reduce the approval time for project works and tasks which will definitely save some time and cost for project owners.

Furthermore, it has conclusively been shown that recruiting professional and highly qualified and specified site managers for managing projects site operations can reduce not only projects delay, but also defects, disputes and cost overrun (Ruqaishi and Bashir 2014). Authors of former research who conducted their study on the causes of delay in construction projects in the oil and gas industry in the gulf cooperation council countries explained that qualified site managers can assure the quality, safety and security of site operations tasks and processes by allocating the right resources at the right time and location. They noted that proper site managers can assure that each supervisor's responsibilities match their authorities. Additionally, Ruqaishi and Bashir (2014) identified that a clear definition and documentation of project team communication, roles and responsibilities can improve contractors schedule performance and reduce risk of delay from contractors and all project stakeholders.

In another recent study conducted by Rui et al. (2017) who investigated into the performance of oil and gas projects noted that project management team should spend their best effort to understand and quantify the project risks related to unique characteristics of oil projects in order to avoid project cost and time overrun. Although there are many studies emphasized on identifying the causes of projects delay in petroleum construction industry, the researches in mapping the causes of projects delay in oil fields constructions projects to cost overrun remains limited and not clearly presented in the literature.

Moreover, project delays studies in petroleum constructions have been conducted by many authors, however, causes of projects delay in oil fields construction that leads to cost overrun are still insufficiently explored. Therefore, this thesis addresses the need for identifying the causes of projects delay in oil fields construction that leads to cost overrun and to develop a stochastic model to predict cost overrun for the causes of projects delay in oil fields construction which provide a model for business decision makers to accurately estimate the planned cost for projects and minimize the impact of causes of projects delay on projects cost/budget.

1.3 Research aim

The overarching aim of the research was to propose a model that could be used to map and forecast the causes of future project delay in oil field construction projects. Moreover, the research identified causes of project delay in oil field construction and proposed guidelines that could be adopted by senior managers to address the issue of cost overrun on oil field construction projects.

1.4 Research objectives

The above aim was accomplished through the following objectives:

- To identify the main sources, causes and impacts of projects delay in oil fields construction projects.
- To establish the distribution associated with most of the causes of projects delay in the context of cost overrun;
- To propose a regression model that could be used to predict cost overruns; on future oil fields construction projects.
- To propose a Monte Carlo simulation model for deriving the probability of cost overruns due to causes of delay;
- Propose a stochastic model that could be used to map and forecast the causes of future cost overrun in oil fields construction projects.

1.5 Research Questions

The following research questions have been used as a guide to generate data necessary to achieve the aim:

- What are the main sources, causes and impacts of projects delay in oil fields construction projects?
- What are the key causes of projects delay to cost overrun?
- What distribution associated with most of the causes of projects delay in the context of cost overrun?
- What is the most likely cost overrun?

1.6 Novelty of the research

Several studies have identified causes of project delay. However, limited works have investigated those causes in the context of how they affect cost overrun, specifically in oil field construction projects. By modelling the cost overrun in relation to causes of project delay, the researcher has been able to identify the causes of delay that translates into cost overrun, thereby filling a gap that exists in the literature. Consequently, the findings of this work can serve as a foundation for future research works.

In the practical realm, the findings of this work shows that main sources of cost overrun are associated with delays that have to do with consultant, contractors and project owners, while external factors play minimal role in cost overrun. Consequently, by mapping out strategies relating to consultant, contractors and project owners, cost overrun can be minimized during project execution. Also, this work shows that cost overrun in oil field construction is significantly impacted by factors whose risk rate increases initially and decreases later on. Thus, managerial efforts must be channelled to pay particular attention to the early stages of project execution.

1.7 Research methodology

The research methodology has been designed with both positivism and interpretivism philosophies in mind (Bryman and Bell, 2011); this is because the nature of the data from causes of projects delay could either be quantitative and or qualitative. However, this research adopted a quantitative research methodologies May (2011) in order to ensure that data relating to projects delay can be

captured, as explained in chapter three of this thesis section 3.5.1. The most ideal research methods included a critical review of the literature and 55 case studies from oil fields constructions projects from leading oil organisations. It was also important to supplement the data collection methods with a questionnaire applied to the oil fields construction case studies by collecting the views of experts who worked on those projects and estimate the impact of causes of projects delay on cost overrun .Chapter seven includes more details on research design and methodology.

1.7 Theoretical and practical contribution of the research

By modelling the cost overrun in relation to causes of project delay, the author has been able to identify the causes of delay that translates into cost overrun in oil fields construction projects, thereby filling a gap that exists in the literature. Consequently, the findings of this work can serve as a foundation for future research works.

Moreover, the research has contributed towards formalizing the estimation of the impact of the causes of projects delay in oil fields construction projects using a combination of regression analysis and Monte Carlo simulation techniques. According to the formulated research questions, the key research findings and contributions of this investigation are summarized below:

- 1) The research results revealed that poor contractor works was found to have the most significant positive impact in the delay experienced by the oil fields constructions projects considered in this work.
- 2) The researcher developed and validated probability distribution for the most important causes of projects delay (those that correlate with the proxy variable of this research-cost

overrun) which is log-logistic distribution - a distribution whose rate increases initially and decreases later.

- 3) The researcher also conducted a multiple-regression analysis to quantify the association between causes of variation and their impact based on real 55 case studies. The model was used to stochastically estimate the impact of causes of projects delay in oil fields construction projects.
- 4) The major contribution is that the proposed model can be used by businesses to model their own factors and help in their decision-making, as opposed to using anecdotal evidence.

Chapter 2: Theoretical Background – A critical Analysis of Sources and Causes of Projects Delay

2.1 Introduction

This is the literature review section of the thesis. The objectives of this chapter are to identify the causes, sources and impacts of projects delay in oil fields constructions projects by conducting a critical analysis of the existing literature, covered themes and existing literature gaps. It is based on this analysis that the study rationale and value both in literature and empirically is derived. In order to accomplish the objectives of this chapter, it is categorised into different sections namely the characteristic of oil fields projects, brief background of procurement and management processes of oil fields projects, the definition of projects delay, types of delay, previous studies on the causes and factors of delay, grouping causes and factors of projects delay, causes of delay related to the owner/client, contractors, consultant, and causes of delay related to the external factors. Based on the above, existing gaps in the literature are identified to serve as the basis for this research at end of this chapter.

2.1.1 Methodology of the literature review

The author of this research used semi-systematic methodology/approach for this literature review. The semi-systematic methodology for literature review fit the purpose/objective of this chapter by overviewing the research area of the causes, sources and impacts of projects delay, while focusing on peer reviewed research articles to review critical analysis of the existing literature, covered themes and existing literature gaps. Moreover, this approach of literature review can follow

qualitative/quantitative analysis and considered very useful for this research by identifying the common causes and sources of projects delay in oil fields construction projects and propose an agenda for further research in this field (Snyder, 2019). Consequently, the semi-systematic methodology has been adopted for the literature review presented for this work.

2.1.2 Characteristic of oil fields construction projects

Due to its unique characteristics, the oil fields industry differs from all other types of market enterprise starting from the beginning of oil field exploration to service station, therefore, it is important to understand the characteristics and basics of oil fields project from beginning to end and what really differentiate this industry from other types of businesses and identify the links between these characteristics and projects delay. For example, Ogunlana and Dey (2007) noted that special characteristics of oil and gas construction projects such as large capital investment, involvement of many stakeholders, use of complex technology, high environmental and social impact might lead to project risks and delay. According to Ogunlana and Dey (2007); Ruqaishi and Bashir (2014); Seba (2002); Wright (1997); Conroy and Soltan (1997); and Moreau and Back (2000) the characteristics of oil fields projects and the link between them and projects delay are illustrated as following:

- ❖ Oil fields construction projects has a long life cycle, from the preparation of the projects infrastructure, communications and formalizations with the environmental concerned parties, discovery of a petroleum deposit to the first oil barrel, exploration and production activities are spread over several decades and they highly depend on successful construction projects. Five main phases can be distinguished in the life of an oil field

construction project and production organized into two major step, the first step is exploration which takes from 5 to 10 years and includes the following phases such as discovery and evaluation. The other step is production which takes 15 to 30 years and includes development, production and abandonment. This complicated and long life project cycle of petroleum construction projects might be possible reason to create delay at construction project completion in case of delay occurred at any project critical task or action, it might immediately delay the entire project work.

- ❖ To make it more profitable business, oil fields industry business consists of different phases and stages. It starts by exploration phase to find the available oil in the targeted field, and then next phase is the production, where most of the business profits come from and the profits mainly depend on the production cost which varies between oil production countries. For example, the production cost of oil shale barrel in the US (United States) is the most expensive which is estimated about somewhere between \$30 to \$50, while the Saudi oil can be produced as cheap as between \$4 to \$12 per barrel. The third phase is refining processes, where some of the raw oil is reproduced and refined to different useful products such as car fuel, air plane fuel and etc. The fourth phase is transportation requirements of oil fields construction projects, which is the heart of this business that transport and deliver the needed oil to consumers around the world through super heavy marine tanks. The final phase at oil fields construction businesses is prepare and arrange the required infrastructure for marketing, which is mainly organized and planned to find the consumer who pay better prices for large orders.

- ❖ The petroleum industry is not stable business industry, due to many related factors that effecting oil prices and business profits such as political stability, development of renewal resources, environmental issues...etc. Therefore, the key players in this market usually manage oil fields constructions projects as group of two or more investors or partners to maximize the profits of investment and minimize expenses as much as possible. This partnership or joint venture strategy in the investment of oil fields constructions projects help projects partners to reduce the risks involved in these kinds of business environment to minimum level of risks and share the unexpected risks as group and partners of the project. Although business partnership have some benefits to businesses, however, misunderstanding and miscommunication between partners might delay decisions making for urgent project tasks or actions which might consequently delay task or project completion and lead to projects delay for oil fields constructions projects.

- ❖ In oil fields constructions project, the exploration phase is a critical stage of business development process, the outcome of this phase clarify and help to make investment decision on whether to continue investing in such particular oil fields or not, which depends on many factors such as the available reserves of oil in the field, the cost of production as per the fields and reservoir geological and geographical environment, the quality of raw oil, the political stability...etc. The long duration and special conditions of the exploration phase might be another reason for partial agreement between project stakeholders that delay the approval requirements for major infrastructure construction project tasks which require extra funds or labor for completion. All of these factors highly influence oil fields constructions projects and lead to disputes and projects delay.

- ❖ Oil fields investors know that this kind of business take time for return on investment and investors should be patient in order to reach profit margin. For example, the exploration and development of new oil field takes about 10 to 15 years only just to explore, operate and start producing the first oil barrel, and couple of additional years to build and develop a strong marketing reputation in oil market. Therefore, any delay for oil fields construction projects that prepare the required infrastructure for oil exploration and production will delay the required investment on this business and add extra cost on oil fields development projects.

- ❖ As mentioned above, production cost of oil barrel can clearly differentiate between oil productions companies that can absorb and bear the consequences of falling crude oil prices for a long time. Therefore, oil operational companies in countries of low cost production of oil barrel such as Saudi Arabia can easily optimize the operations processes and cope with low oil prices than its competitors of shale oil in the US with very high production cost of oil barrel. Therefore, the production cost of oil barrel and oil prices in the market highly effect the expanding projects of oil fields construction projects and its related sub projects, these influences the decision making process between investors and business partners and it might be another reason for partial agreement between project stakeholders that delay the approval requirements for major oil fields construction project tasks which require extra funds or labor for completion which all depends on the oil prices in the market and the production cost of oil barrel.

From the above literature review of the characteristics of oil fields constructions projects, author noted that petroleum construction projects are almost considered as mega projects, very complicated and required advanced and high-end technologies (Dey 1999). According to Yeo and Ning (2002), big budgets and very skilled human resources are required to invest in this industry. Oil fields construction projects required a detailed and completed scope definition and design to operate successfully, so any poor design or changes on scope during operations may cause project delay and lead to cost overrun (Ruqaishi and Bashir 2014). Another noted from this review is that major oil and gas construction projects mostly required long duration to complete such as 3 to 6 years depending on the size and scope of projects which might highly effect the planning for proper time management. This is happening due to unique nature of some project tasks such as efforts required to gain approval for projects works and access to the protected sites by governments and local authorities. Another reason is the unpredictable time for precise materials delivery date and time from long distance suppliers using large marine carriers to deliver millions of tons of constructions materials (Yeo and Ning 2002). In addition, unexpected weather conditions such storms, heavy rain...etc might be direct causes of delay for some major materials required for oil fields constructions projects and therefore, which lead to projects delay.

Accordingly, this thesis will focus on identifying the most causes of delay that lead to cost overrun in oil fields construction projects. Therefore, the identified characteristics and challenges of oil fields construction projects in this literature review will be very helpful to prove the causation relationships between the sources and causes of projects delay. More details on causation relationships in section 4.4.

2.1.3 Common characteristics and differences between civil construction projects and oil fields construction projects

There have been several studies in the literature reporting the causes of oil construction projects by using multiple cases of civil construction projects and limited research only from the petroleum construction projects (Rui *et al.* 2017) as there are only few studies published from the former one such as (Kazemi *et al.* 2018; Pham and Hadikusumo 2014; Dey 2007; Ruqaishi and Bashir 2014; Salama 2008). This might be due to substantial similarity between civil construction and oil and gas construction industry (Salama *et al.* 2008).

The above researchers studied three fields in literature review to investigate, analyse and identify delay causes in petroleum construction projects. First field the authors studied is the oil and gas. The second field is public projects which usually implemented in long duration such as highways and railways. The last field is governmental projects such as major services construction projects like water, electricity and sewerage services development. The authors justified the use of the last two fields in literature review to investigate petroleum construction projects is that they all belong to governmental sectors whose management methods, rules and regulations, and organization structures are the same. Therefore, the common projects environments, procurement and management methods would result in common main problems and major causes of delay.

While the multiple similarities between oil and gas constructions projects and public and governmental projects have been stated above, the few key differences that uniquely related to oil fields construction projects are: the use of various advanced technologies, long duration that most oil fields construction projects require, and the complexity of designing oil fields construction projects which are developed progressively through the project life cycle (Salama *et al.* 2008). More details on oil fields construction projects life cycle in section 2.1.4.4.

The author of this research adopted the same approach as mentioned above by reviewing and studying published research papers that pointed to petroleum and oil fields construction projects and some of civil construction projects in literature review.

2.1.4 Procurement and management processes of oil fields projects

This section clarifies the civil constructions procurement processes and management in the oil fields industry, covering the definition of procurement, the basic procurement processes, procurement activities, types of projects' contracts, and major stakeholders or players of civil construction procurements processes in oil fields projects.

2.1.4.1 Definition of Procurement

Several attempts have been made to define procurement in literature. Ukalkar (2000) described procurement in detail as following "the needs by the company which identified its requirements from raw materials, products and main resources to produce its own products and services".

Broome (2002) described procurement in the construction industry as "in construction term, what you plan to buy as per your needs and requirements in order to maintain your construction works and assets".

2.1.3.2 Procurement Activities and Contracts in Oil Fields Construction Projects

According to Schramm et al. (2010), proper management of procurement activities and contracts play a critical part of major projects by saving cost and time accordingly. Different range of acronyms is used in oil and gas contracting projects which illustrate in details technically and legally the content of scope or services that are provided by the engineering contractors (EC). Usually, the detailed content of the scope of work indicate the type of contract for EC.

Moreover, for large and big oil construction projects, most clients prefer to assign projects work to one EC who can manage integrated work scope as per the given requirements instead of having multiple EC dealing with projects owner (Schramm et al. 2010). The following list of contract types sorted from the least integrated to the most integrated (Loots and Henchie. 2007; Schramm et al. 2010):

2.1.4.2.1 Contracting Activities

- ❖ EPCM: stands for Engineering, Procurement and Construction management. In this type of contract, the EC executes engineering and implement procurement scope, the EC does not make any orders to purchase or buy goods or services of subcontractors, these are all done by projects owner who fully control the cost risk and can influence the business outcome of EC due to their direct integrated relationship. In EPCm contract, the EC manage projects work on behalf of the owner and service more as adviser between the owner and other project parties such as construction contractors and materials suppliers (Schramm, Meibner, and Weidinger 2010, p. 35; Loots and Henchie 2007).
- ❖ EPC: An acronym for Engineering, Procurement and Construction. In this type of contract, the EC provides all project work to the owner as integrated services, communication and coordination related to the major activities involved.
- ❖ EPCI: Engineering, Procurement, Construction and Installation. This type of contract is different that EPC that EC is highly responsible for installation of the construction materials, tools and equipment as per the given scope of work.
- ❖ EPIC: Engineering, Procurement, Installation and Commissioning. This is the most integrated type of contract where the EC is highly responsible for commissioning the

installations of the constructed works. The EC handover all the project work to the owner who can immediately start his operations.

By reviewing the projects case studies (more details in appendix A), the author noted that most of the oil fields constructions projects fall under EPIC contracts, which means that any delay in the procurement or installation phases of project implementation will highly influence project completion and lead to projects delay. Therefore, projects contractors and owners might invest more than planned budget to avoid late projects completion, and this will consequently lead to cost overrun.

Figure 2-1 shows the typical role of the EC in oil & gas construction project (Berends 2007, pp. 13).

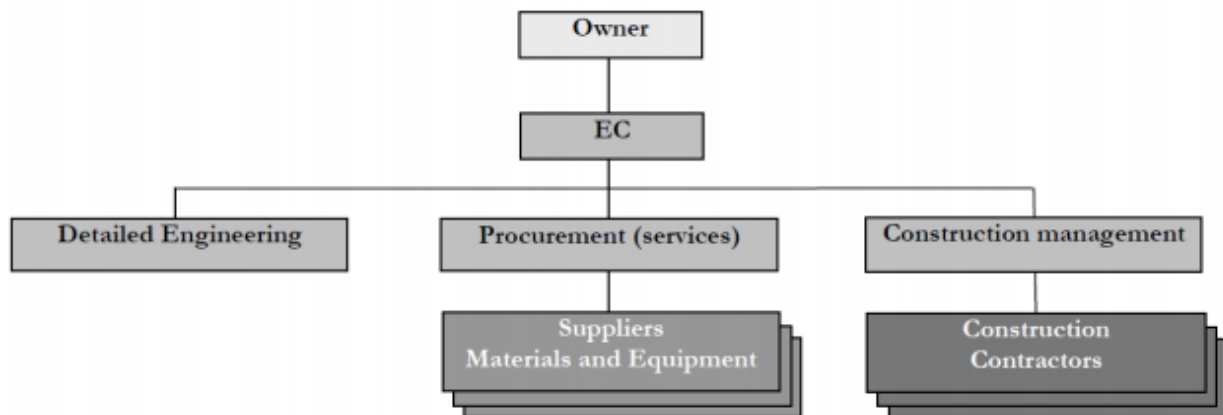


Figure 2-1 typical set-up of large construction project in the oil and gas industry. (Berends, 2007, p. 13)

2.1.4.2.2 Contract Types

EPC projects can vary in different types of contract:

- 1) Cost Plus Fee
- 2) Fixed price, Incentive
- 3) Lump Sum, Fixed Price: All project risk is borne by the EC. The client pays a fixed price for the delivery of the agreed works. The works itself contains engineering, procurement and construction activities.
- 4) Lump Sum Turn Key: A turnkey project also includes operational spares, training etc.

Moreover, researchers noticed link between procurement issues that lead to project delays such as improper selection of contract type; awarding contract to lowest price contractor among technically accepted contractors and poor contract administration (Alzara et al. 2016; Alsharif and Karatas 2016; Abdul Rahman et al. 2009; Assaf and Al_Hejji 2006; A Elaw et al. 2016; El-Razek et al. 2008; Faridi and El-Sayegh 2006; Ibironke et al. 2013; Marzouk and El-Rasas 2014).

2.1.4.3 Major stakeholders of oil fields construction procurements projects

From the previous review of procurement processes and management of oil fields projects and according to Schramm et al. (2010); Loots and Henchie (2007); Seba (2002); Wright (1996), the author of this research study identified the major stakeholders of oil procurement process as following:

1. Users/Clients/Owners (who are mostly governments, which own the natural resources such as oil and gas).

2. Contractors.
3. Consultants/Designers.

2.1.4.4 Projects life cycle of oil fields constructions projects

It is clearly noticed from the literature review that many authors indicated that every and each construction project is unique and different than others, unlike other types of industries where planning and implementation of projects have common characteristics and norms. In oil fields construction, every project is unique. Even if there are similar projects with same design and requirements under constructions, each project will have it is own challenges due to geographical location and environmental conditions (Younis et *al.* 2008; Ibironke et *al.* 2013; Koushki et *al.* 2005; Marzouk and El-Rasas 2014; Odeh and Battaineh 2002; Samarghandi et *al.* 2016). Therefore, it's important to understand the nature of oil fields contracts and changes in contracts development to minimize the impacts of projects delay (Younis et *al.* 2008).

(See Figure 2-2).

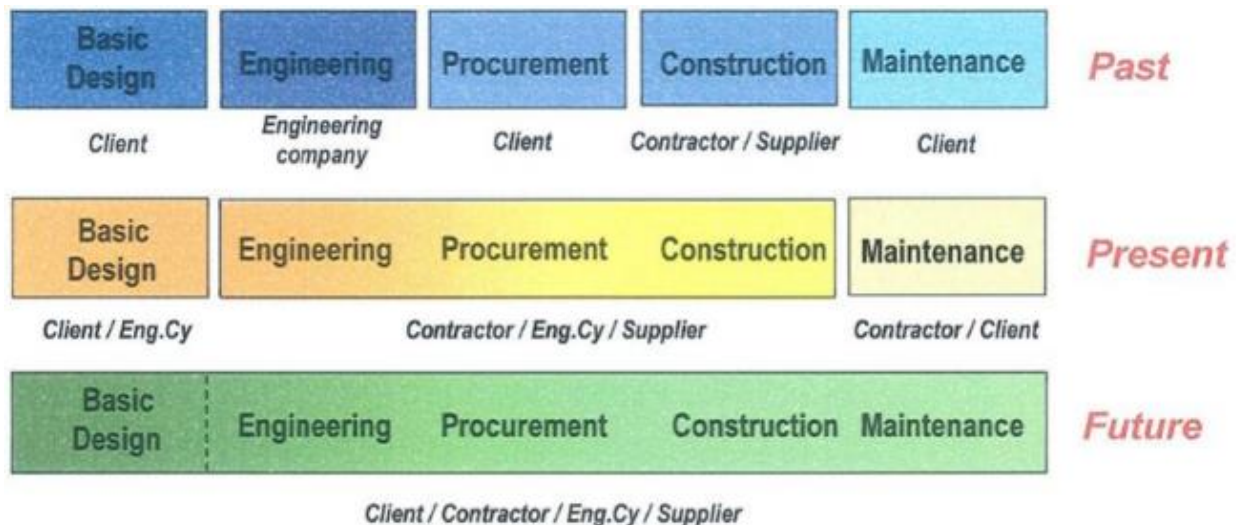


Figure 2-2 Evolution of role division in Oil and Gas contracting (Bakker, 2010, p. 16)

This thesis will focus on identifying the most causes of delay that lead to cost overrun in oil fields construction projects. The identified causes of procurement and management processes along with the causes that related to projects life cycle such as geographical location and environmental conditions of oil fields construction projects found in this literature review will be very helpful to prove the causation relationships between the sources and causes of projects delay for oil fields constructions projects. More details on causation relationships in section 4.4.

2.2 Definition of Project Delay

Researchers in the literature are divided into two groups in terms of defining project delay. Some of them support common definition such as exceeding the time/date mentioned in the project contract and agreed among the major project stakeholders or planned schedule while other authors define delay as exceeding the date of critical tasks/activities of the project. The first group of researchers who prefer a common definition of delay include Arditi et al. (1985 and 1989); Royer (1986); Yates (1992 and 1993); Mendelson (1994); Riad et al. (1991); Chalabi et al. (1984); Bartholomew (1987); Morris et al. (1989); Assaf and Al-Hejji, (2006); Aibinu and Jagboro (2002); Abul Rahman, Takim and Min (2009); Abd El-Razek et al. (2008). The second group who define delay “as the time exceed the date/duration of critical activities and causes delay” include Kraeim et al. (1987); Trauner (1990); Rad (1979); Querns (1986); and Householder et al. (1990). Each group of researchers justified reasons for advocating the definition of delay.

This research attempts to provide a more detailed investigation regarding the causes of delay that

lead to cost overrun specifically in oil fields constructions projects, therefore, based on above literature review, the researcher will adopt the following definition for project delay: Project delay means “The time/duration which exceed the contract completion date or the completion date of critical activities that have been delayed”

The Former definition above cover what both groups of researchers prefer to define delay in projects where in some cases the completion date in the contract/project agreement specify the critical activities and in other cases the contract date is considered as general reference for the project stakeholders.

2.3 Types of Project Delay

According to Arditi et *al.* (1985); and Wa’el Alaghbari (2007)

There are four types of delay as following:

- 1) Excusable delays with compensation
- 2) Excusable delays without compensation
- 3) Non- Excusable delays.
- 4) Concurrent delays.

- 1) Excusable delays without compensation

This type of delay is caused/occurred by unknown event or risk, which is out of the control of all project stakeholders such as contractors, consultants, project owner etc. No one is eligible to be compensated for this type of delay if it happened (Ibbs 1984; Arditi et *al.* 1985; and Kraiem et *al.*1987). Causes, which are under this type of delay, are known, as “Act of the God” such as earthquake, storms, strike etc, which is considered and identified at this study as external causes

of delay.

2) Excusable delays with compensation

Clients or business owner's actions are mainly related to this type of delay. Contractors are always compensated for whatever causes classified as per the contract terms and conditions that both parties agreed about. Examples of these causes are changes in scope, changes in design, late payment, late access/permission to the construction site etc. The author considered this type of delay at this research and identified as clients/owners causes of delay.

3) Non- Excusable delays.

The contractors or sub-contractors cause this type of delay with no responsibility for the clients/owner (Hamzah et al. 2011). The clients are eligible as per the contract terms to claim for the damages that caused delay by the contractors. Events such as failure to provide sufficient resources to the site, late payment for sub-contractors etc. This type of delay is considered for this research and identified as contractors causes of delay.

4) Concurrent Delay

In a different study by Wa'el Alaghbari (2007) another type of delay added called concurrent delay which is more complicated in content than other types of delay mentioned above and mostly happened when more than one factor/causes of delay from different types of delay mentioned above happened at the same time or different periods of project tasks (Hamzah et al. 2011).

Therefore, the goal of this thesis is to find the causes of projects delay that lead to cost overrun in oil fields construction projects, hence , the author of this research will adopt the first three types

of delays that are applicable and used at this study which are excusable delays without compensation, excusable delays with compensation and non- excusable delays.

2.4 Previous Studies on Causes of Projects Delay

This section reviews the literature concerning the causes of projects delay in oil fields constructions projects and identify the top causes of delay in the context of cost overrun. It's being well known among the researchers that the first step of studying the causes of delay is to classify and rank the main causes of the problems which is considered as an important step of analysing and mitigating project delay causes (Yang and Ou 2008; Yang *et al.* 2013). There have been several studies in the literature reporting on the causes of delay in oil and gas construction projects. As per the current literature review, no one can deny that delay in oil fields construction projects are unavoidable and mostly lead to disputes and claims which required effective mitigating strategies to save time and costs and consequently contribute to a country development. According to Kazemi *et al.* (2018), their research results showed that change orders and changes in scope of work by owner, delay in reviewing of documents by consultant, inadequate experience and knowledge and errors during construction by contractor, and low productivity of laborer are famous causes of delay in the oil and gas construction projects. These findings are consistent with findings of past studies by Kazemi *et al.* (2008); Rui *et al.* (2017); Kaliba *et al.* (2009); Ruqaishi and Bashir (2014); Salama *et al.* (2008); which identified that similar above causes are the most expected to cause project delay in petroleum projects. This thesis will focus on identifying the most variables that contribute to the cost overrun in oil fields construction projects. Therefore, the identified

causes of delay in this literature review will be very helpful to consolidate the top causes of delay in terms of cost overrun. More details are discussed in section 2.8.

Recently, Pham and Hadikusumo (2014) gave a comprehensive review on schedule delays in engineering, procurement, and construction in petrochemical projects in Vietnam by using 3 case studies on selected project which are at least 80% completed, they found that lack of effective communication is one of the main causes of projects delay. Research findings by Abdul Rahman *et al.* (2006); Al-Kharashi and Skitmore (2008); Aibinu and Odeyinka (2006); AlNuaimi *et al.* (2013); and Arditi *et al.* (2017) also points towards the poor communication between major stakeholders of petroleum construction projects which lead to project time and cost overrun.

Moreover, Ruqaishi and Bashir (2014) who researched the causes of delay in construction projects in the oil and gas in the gulf cooperation council countries by conducting questionnaire survey, the research results showed that some causes of delay are common and can be a cause of delay in any project in any industry except one cause which is poor interaction between project stakeholders and vendors which is considered to be unique to petroleum construction projects. This is supported by Grant & Christensen (2006); Hossen *et al.* (2015); Kazemi *et al.* (2018); Pham and Hadikusumo (2014); and Yang and Ou (2008) which reveal that the lack of effective interaction between vendors and project stakeholders might cause delay for critical project tasks.

In another study, Salama *et al.* (2008) examined the causes of delay within oil and gas projects in the UAE, authors indicated that delay is common problem in petroleum projects specially in the completion date which ranges from 5 to almost 20% of the total project duration. Salama *et al.* (2008) who conducted their research by using semi-structured interviews followed by a survey,

found that main causes of delay for oil and gas projects are delay in procurement and delivery of materials, inaccurate estimate of materials requirements and poor selection of contractors. This is consistent with the studies of Kaming et al.(1997);Kumaraswamy and Chan (1996);Abdul Rahman et al.(2006);AL-Kharashi and Skitmore (2008);Ahsan et al.(2010);Aziz (2013);Batool and Abbas (2017) which showed that these causes are among the most causes of projects delay in petroleum projects.

For example, Fallahnejad (2013) who conducted a research investigation into the performance of oil and gas projects studied 24 case studies of executed gas pipeline projects which were discussed further with 10 experts from petroleum industry and then ranked by using questionnaire survey to identify the top 10 causes of delay. Author found that imported and client-related materials and contractor's cash flow are among the top causes of projects delay in Iran gas pipeline projects. Similarly, Kaming et al.(1997);Kumaraswamy and Chan (1998);Abdul-Rahman et al.(2006); Abdul-Rahman et al.(2009); Ahsan & Gunawan (2010); Alsharif & Karatas (2016);Alzara et al.(2016);Kazemi et al.(2018); and Pham and Hadikusumo (2014) found that the same causes mentioned by Fallahnejad (2013) lead to projects delay.

Additionally, Ogunlana and Dey (2007) investigated the risk management in oil and gas construction projects in Vietnam by conducting a questionnaire survey and informal interviews with experts from petroleum industry and found that bureaucratic administration systems, poor law implementation and the incompetence of government staff were the main causes of projects delay in Vietnam. Research findings by Mansfield et al. (1994); Ahsan & Gunawan (2010); Aibinu & Odeyinka (2006); Batool and Abbas (2017); Doloi et al. (2012);Fugar (2010); Manavazhi and Adhikari (2002); and Ruqaishi and Bashir (2014) also points towards the same results of Ogunlana

and Dey (2007). The present study is motivated by the need to take into consideration the previous studies conducted on causes of projects delay in oil fields construction projects in the context of cost overrun, in order to develop a realistic model that predict the cost overrun due to the causes of projects delay in oil fields construction projects.

Assaf et al. (1995) investigated on the causes of delay in large construction projects in Saudi Arabia by identifying 56 causes of delay grouped into nine categories reviewed from literature and interviews. The researchers conducted a questionnaire survey to specify and rank the importance of delay causes. The study found that financial related causes are the top ranked by all respondents of the survey who are owners, contractors and consultants. The finding is consistent with findings of past studies by Abdul-Rahman et al. (2006); Abdul-Rahman et al. (2009); Alaghbari et al.(2007); Alnuaimi and Al Mohsin (2013); Batool and Abbas (2017); Doloi et al.(2011); Doloi et al.,(2012); Elawi et al.(2016); Fallahnejad et al.(2013);Fugar (2010); Hamzah et al.(2011);Hossen et al.(2015) which noted that financial related issues are main causes of project delay.

Factors influencing construction time and cost overruns on high-rise projects in Indonesia was attempted by Kaming et al. (1997), the study found that design changes, poor labour productivity and inadequate planning are the most causes of delay in the construction projects in Indonesia.

The study by Al-Khalil and Al-Ghafly (1998), examined the important causes of delay in public utility projects in Saudi Arabia by identifying sixty causes of delay organized into six main groups from literature review and expert interviews. The study found that cash flow problems and financial difficulties by the contractor, difficulties in obtaining permits, and the requirements to select the lowest bidder without regard to prequalification are the most important causes of delay agreed by the concerned parties of the projects such as owners, consultants and contractors. This

is supported by Zou et al.(2007);Yang and Ou (2008);Toor and Ogunlana (2008); Sambasivan and Soon (2006); Samarghandi et al.(2016); Ruqaishi and Bashir (2014) studies which reveal that cash flow problems and financial difficulties by project participants are major causes contributed to projects delay. This thesis attempts to provide more detailed investigations regarding the causes of projects delay in oil fields construction projects in the context of cost overrun, therefore, detailed list of causes of projects delay are used in this research and summarized in section 2.8.

According to Elinwa and Joshua (2001), authors identified twenty-one factors of delay from literature review and interviews from which they found that financing and payment for completed works, improper planning, and underestimation of time/duration for projects are among the most frequent factors of delay in Nigerian construction industry. Elinwa and Joshua (2001) found similar results to those obtained by Zou et al.(2007);Yang and Ou (2008); and Toor and Ogunlana (2008); Sambasivan and Soon (2006); Samarghandi et al.(2016); Ruqaishi and Bashir (2014) in terms of cash flow problems that lead to projects delay and they found similar results to those obtained by Kaming et al.(1997);Abdul-Rahman et al.(2006);Al-Kharashi and & Skitmore (2009); and Arditi et al.(2017); in terms of indicating that causes of delay are due to improper planning of the project.

As highlighted by Aibinu and Jagboro (2002), client related delay is the most significant projects delay causes in Nigeria. The study analyzed the effects of project delay in Nigerian construction industry, it found that time and cost were the most effects of project delay in Nigeria.In addition to work of Aibinu and Jagboro (2002), Aibinu and Odeyinka (2016); Alnuaimi and Al Mohsin (2013);Doloi et al.(2012);A Elawi et al.(2016); Fallahnejad (2013); Fugar et al.(2010); provides another evidences that most of projects delay are due to client related issues.

Material and equipment procurement delays in highway projects in Nepal carried out by Manavazhi and Adhikari (2002), found that the main causes of procurement delays are organizational weaknesses, suppliers' defaults, governmental regulations and transportation delays. This was based on the result of a questionnaire survey, which observed that almost 78% of the highway projects studied delayed due to materials procurement delay. Authors of this study noticed that organizational weaknesses and suppliers defaults is the top cause of procurement delays which is a direct cause of poor management in the supply chain of construction industry. The finding is consistent with findings of past studies by ALZara et al.(2016);Arditi et al.(2017); Samarghandi et al. (2016);Yau and Yang (2012);Pham and Hadikusumo (2014); which are supporting that governmental regulations and transportation delays are causing projects delay.

Frimpong and Oluwoye (2003) researched the significant factors causing delay and cost overruns in construction of groundwater projects in Ghana discovered that financing, microeconomics, natural conditions and materials factors are top causes of delay selected from 49 delay factors grouped into nine categories extracted from literature review. The research studies by Alnuaimi et al.(2013);Alzara et al.(2016); Arditi et al.(2017);A.Assaf and Al-Hejji (2006); Batool and Abbas (2017); also found the same outcomes of Frimpong and Oluwoye (2003).

The study by Koushki et al. (2004) examined the delays and cost increases in the construction of private residential projects in Kuwait. Through a questionnaire survey of 450 randomly selected private residential projects owners/developers in 27 representatives districts of Kuwait, the study found that changing orders, owners financial constraints and owners lack of experience in the construction projects are the main causes of delay which are similar results to those obtained by

Alzara et al.(2016); Arditi et al. (2017); Aziz (2013); Fallahnejad (2013); Hasan et al. (2014) and Ibrionke et al. (2013).

According to an investigation by Assaf, Al-Hejji (2006) on the causes of delay in large construction projects in Saudi Arabia, change order was identified as the most cause of delay by the research participants and major stakeholders of the construction industry projects, i.e., the owner (clients), consultants and the contractor. This research is among the few studies in the literature which identified seventy-three causes of delay categorized into nine major groups/categories of delay factors as following project, owner, contractor, consultant, design, materials, equipment, labors and external. Authors of this study ranked the causes of delay according to their importance; the top five causes of delay were shortage of labors, delay in progress payments by owner, change orders by owner during construction, ineffective planning and scheduling and poor site management and supervision by contractor. Additionally, the groups of delay factors were also ranked according to their importance by all parties of this study, and the top 3 factors were owner related, contractor related and design team related factors respectively. This is supported by Alnuaimi et al.(2013);Alzara et al.(2016);Arditi et al.(2017); Aziz (2013); A Elawi et al.(2016); Fallahnejad (2012);Kazemi et al.(2018);Salama et al.(2008);Ruqaishi and Bashir (2014) studies which reveal that manpower limitations, payments delay and poor site management are among the top list of delay causes.

Lo et al. (2006) showed the common causes of delay in civil engineering projects in Hong Kong by conducting a questionnaire survey for owners, contractors and consultants to rank and prioritize 30 identified causes of delay organized into seven categories collected by literature review. The study found that top six causes of delay are similar to the results of Chan and Kumaraswamy

(1998) which are unforeseen ground conditions, poor site management and supervision, client variations, inexperienced contractor, slow coordination and seeking of approval from concerned authorities, and inadequate contractor resources. Additionally, this was one of the few studies in literature that participants acknowledged their responsibility of some causes of delay, which caused their projects time or cost overrun. In addition, Ruqaishi and Bashir (2014); Salama et al.(2008); Samarghandi et al.(2016); Sambasivan & Soon (2006); Pham and Hadikusumo (2014) showed that inexperienced and inadequate contractor resources causes projects delay.

Faridi and El-Sayegh (2006) which is one of the few studies published on factors causing delay in the (UAE) United Arab Emirates construction industry indicated that almost 50% of the construction projects in UAE are not completed on their planned completion date due to delay on approvals of drawings, inadequate early planning and slowness of the owners' decision-making process which are rated as the top causes of delay identified by this study. Authors of this research compared the results to other similar studies in terms of geographical location (Middle East) and culture wise (Arab countries) such as Lebanon and (KSA) the Kingdom of Saudi Arabia. This comparison of the studies between the three countries (Assaf et al. 1995) for (KSA) and (Mezhar and Tawil, 1998) for Lebanon noted that the top 10 causes of delay for those former studies are not related for the UAE construction industry.

In another study, Abdul-Rahman et al. (2006) analyzed delays mitigation in the construction industry in Malaysia and found that financial problems, manpower problems and clients influence were among the top causes viewed by the top management, consultants and contractors who participated in a questionnaire survey. The research studies by Omran et al. (2010);Mohammed and Isah (2012); Kaliba and Mumba (2008) also found similar results.

Sambasivan and Soon (2007) has demonstrated ten of the most important causes of delay categorized into eight groups in Malaysian construction industry by conducting a questionnaire survey of 150 contractors, consultants and clients. Those causes of delay had been selected from a list of 28 causes retrieved from literature review. Some of the top ten causes identified by this research are contractor's improper planning, contractor's poor site management, inadequate contractor experience, inadequate client's finance and payments for completed work. This research paper is among a few studies, which had studied the specific cause of delay and its specific impact, while most of the studies in the literature examined whether the causes or the effects of delay on projects.

The significant factors causing delay of building construction projects in Malaysia investigated by Alaghbari et al. (2007), conducted a questionnaire survey of 31 delays factors extracted from a literature review and organized into four main groups such as responsibility - contractors, owners, consultants and external factors. The study found that financial problems and coordination problems were the first and second most important factors of delay respectively.

Preliminary work on excusable and compensable delays in the construction of building projects in Malaysia was undertaken by Yusof et al. (2007) discovered that architect instruction, late information given to contractor, part of nominated sub-contractor or supplier, and failure of the employer to provide access to site are considered as important causes related to clients/owner that caused delay to building projects in the state of Kuala Lumpur Malaysia.

In 2007, Hegab et al. (2007) published a paper in which they described the causes of delay in Micro tunneling projects. Authors of this research categorized the causes of delay into five groups by using actual projects data, which are slurry problems blocking of slurry lines, operations, laser problems such as periodical laser position check, mechanical problems and surface management such as shortage of materials during work.

According to an investigation by Sweis, Abu Hammad and Shboul (2008), financial difficulties faced by the contractor and too many change orders by the owner found as the top causes of delay in constructions projects in Jordan, while weather conditions and changes in government regulations and laws were the least important causes of delay. Authors of this research summarized 40 causes of delay organized into three main groups such as input factors (labor, materials, and equipment), internal environment (contractor, owner, and consultant) and exogenous factors (weather, government regulations). They developed a structured questionnaire survey based on Drewin open conversion system, which is considered one of the few studies in the literature who used this theory as research methodology.

According to Toor and Ogunlana (2008), causes of delay related to designers, clients, contractors and finance categories proved as top of the causes of delay in Thailand construction industry. This study identified 75 causes grouped into 10 categories, which were analysed through a questionnaire survey and then top causes of delay were classified and compared with previous studies in the literature. The former comparison showed some similarities of the top causes between studies with some differences as well due to the special characters of the projects in terms of geo-graphical locations, government support etc. Furthermore, authors refer most causes of

delay to the lack of risk management practices, which reduces the chances of mitigating strategies and anticipating risks before happening.

Yang and Ou (2008) highlights the capability of Structural equation modeling (SEM) of quantifying the causes of delay and the relationship between its factors and its high ability on resolving the problems of delay. The study identified list of 75 causes of delay from 14 studies, and then reduced that former list to 37 after SMEs interviews and discussions with senior industry engineers. Those causes were categorized into six groups as contract, management, human, nonhuman, design and finance related.

Abd El-Razek et al. (2008) noted that financing by contractor during construction, delays in contractor's payment by owner, design changes by owner or his agent during construction, partial payments during construction, and no utilization of professional construction/contractual management are the most important causes of delay as per the final results of their questionnaire survey contributed by contractors, consultants and owners from the Egyptian construction industry. The authors identified nine groups of causes of delay from literature research classified as per their importance starting from financing as the most important group of delay and end by environment as the least important one according to the study results.

Kaliba et al. (2008) researched the cost escalation and schedule delays in road construction projects in Zambia by conducting a literature review, structured interview and questionnaire surveys by 26 respondents. The study found that delayed payments, financial processes and difficulties on the part of contractors and clients, contract modification, economic problems, materials procurement

are the top 5 causes of delays in Zambia's construction industry while the first cause found to be the most critical one of this study.

Abdul-Rahman et al. (2009) found that the top 4 factors leads to project delays in terms of financial factors are Poor cash flow management, late payment, insufficient financial resources and financial market instability respectively. At this research, authors adopted a Delphi technique, and collected data from clients, contractors, bankers and consultants in the construction industry. While the study collected varies suggestions from the respondents on mitigating the causes of financial delays, the authors highly recommended concentrating more research on improving the practices of clients' payment on time to avoid delay on executing works from the contractors in the construction industry. The direct relationship between the main problem and sub problems has been generally investigated. By considering the cash flow management as independent variable, and all the other mentioned factors above as dependent variables, the paper summarized the relationships as following. The greater any of the 4 factors identified above as financial project delay, the greater the cash flow management, and the greater the extent of delay.

Al-Humaidi and Tan (2010) provides in-depth analysis of the work of a fuzzy logic approach to model delays in construction projects using translational models. The authors classified the causes of delay into three categories as following Procedural which consists of managerial, legal, financial and operational, triggering which consists of weather, underground conditions and natural disasters, and enabling which consist of materials, workers and equipment related. The authors of this research paper justified the use of fuzzy set theory to evaluate the occurrence of causes of delay, which cannot be performed using a crisp value as it require to consider the uncertainty of cause of delay.

Omran et al. (2010) noted that owner's slow in decision making is the most significant cause of delay in construction projects in Malaysia which is selected from twenty one factors of delay classified from literature review organized only by three categories such as owner, contractor and consultant related factors of delay. All participants of the research agreed that contractors are highly responsible for projects delay during construction stage.

Exploring delays in victoria-based Australian pipeline projects was investigated by Orangi et al. (2011). Through extensive literature review, interviews with (SMEs) subject matter experts from the pipeline infrastructure and analyzing local case studies, they extracted the top root causes of delay as following design changes, design errors, poor communication and customer/ end-user related issues. Hamzah et al. (2011), reviewed the available literature on the types of delay and the most identified causes of delay on studies published after 2000s. The authors categorized the types of delay mainly into excusable delay which is divided into compensable delays caused by the owner or whoever behave on behalf of the owner, i.e. slow to give instructions, lack of working knowledge, and non- compensable delay caused by "acts of the God" such as flood, snow and fire. However, non-excusable delay caused by contractors such as delay in sub-contractor work. One additional type of delay called concurrent delay had been added to types of delay supported by Alaghbari et. al.(2007).

Yau and Yang (2012) studied factors causing design schedule delays in Turnkey projects in Taiwan by conducting an empirical study of power distribution substation (PDS) projects and found that from 27 delay groups examined independently and selected from literature review, the most important factors were public contending or political environment and tedious review processes of government agencies. Authors clarified that the study results are limited to the (PDS)

projects in Taiwan due to the government policies and rules for organizing such kind of projects in the country and might not occur in other places. In a study which set out to determine causes of delay in Nigeria's construction industry, Mohammed and Isah (2012) found that improper planning, lack of communication, design errors and shortage of supply are top causes of delay that required proper actions plan to mitigate their impacts on construction projects in Nigeria.

In another study, Doloi and Iyer (2012), investigate factors affecting schedule performance in Indian construction projects found that clients influence was one of the most significant group of factors causing delay. The authors compare other studies with similar findings i.e. Iyer and Jha (2005) and Odeh and Battaineh (2002). The researchers identified the causes of delay related to clients influence as late approval on projects processes/requirements, the repetitive changes of design and scope and lack of documentation on change requests. Moreover, authors of this research paper found improper planning as the second significant group of factors causing delay in Indian construction industry. The authors emphasizes on the relation between improper planning and client influence in a way that improper planning of contractors is highly impacted by clients influence. Doloi and Iyer (2012) provided supporting reports on Indian construction for this finding (Ernst and Young 2011).

In 2012, Odeh and Battaineh studied the causes of delay in construction industry in Jordan with traditional type contracts. As per their questionnaire survey, authors identified the top ten important factors that causes delay i.e., owner interference, inadequate contractor experience, financing and payments and labor productivity. The study was based on twenty-eight causes of delay organized into eight categories retrieved from literature research. The weakness of this study is that only contractors and consultants were included at the survey, while the most important

stakeholder of the projects such as clients/owners were not included/questioned as most authors did in the literature review of this topic, which will definitely effect the efficiencies of the final results of this research by excluding the major part of the problem.

In 2013, Alinaitwe, Apolot and Tindiweni published a paper in which they researched the causes of delay and Cost Overruns in Uganda's Public Sector Construction Projects. By deep literature review, 12 factors of delay that occur during the implementation part of construction projects collected at this study, authors ranked the top five causes of delay in Uganda's Public Sector Construction as following: changes to the scope of work, delayed payments, poor monitoring and control, the high cost of capital and political insecurity and instability. The researchers identified a moderate relationship between the causes of delay and causes of cost overrun.

In an analysis of causes of delay in completion of construction projects in Oman, Alnuaimi and Al Mohsin (2013) found that delay in construction projects during 2007-2009 is more than 40% of the project-planned time while the highest rate of delay was about 300% during the same period. Authors analyzed historical projects data and noticed that top causes of delay are related to owner/client. In a different study, González et al. (2013), analyzed the causes of delay and time performance in construction projects found that planning and subcontracts are the most occurring causes of delay and have large impacts on projects duration.

In another study, Yang et al. (2013) observed that change orders and changed scope of the work are most common causes of schedule delay during construction stage based on Taiwan's litigation cases. Authors justified the use of their research approach by identifying causes of projects delay from the reviewed contents of legal cases that this approach is proactively discovering the

problems comparing to the common method in the literature such as surveys and experts interviews.

In a different study, Aziz (2013) examined delay factors in construction projects after Egyptian revolution. The author analyzed the projects data using Relative Importance Index (RII), which are commonly used by other authors in the literature to rank the causes of delay according to their importance, i.e., (Arditi et al.1985;Assaf et al.1995). By doing an extensive literature research and structured interviews with subjects matter experts from the construction industry, the author of this paper identified ninety-nine delay factor, which were categorized into nine major groups. By analyzing the delay factors using (RII), Aziz (2013) identified the top 5 delay factors as following; (1) delay in progress payments (funding problems), (2) different tactics patterns for bribes, (3) shortage of equipment,(4) ineffective project planning and scheduling, (5) poor site management and supervision.

Ibironke et al. (2013) provides in-depth analysis of non-excusable delay factors influencing contractors' performance in Lagos State, Nigeria. By conducting a questionnaire survey with consultants and contractors, authors selected 20 major factors of non-excusable delays out of 57 factors collected from the literature review and classified into eight categories. The research highlight the top five causes of non-excusable delays that highly influence on projects schedule as following change orders, monthly payment difficulties, insufficient amount of equipment, shortage of construction material and construction financial difficulties.

Analyzing delay causes in Egyptian construction projects attempted by Marzouk and EI-Rasas (2013), identified from literature review; forty-three causes of delay categorized into seven groups.

Through questionnaire survey and experts interviews, authors found that there is no difference in feedback from the respondents of the survey such as contractors, consultants and owners in terms of their views of the common causes of delays analyzed at this study. Therefore, authors identified the top three causes of delay in Egyptian construction projects as following finance and payments of completed work by owner, scope changes by owner and effects of subsurface conditions. At this study, a roadmap of prioritizing delay causes groups had been developed and classified as very high, high, medium, low and very low. As per the results of the survey, authors graded the owner related causes as very high and materials related causes as very low which might give some indicators for business owners to better work on mitigation plans on the most causes of delay which will help avoid or minimize the time and cost overrun of delayed projects.

In 2015 Hossen et al. which was among the few studies in the literature dived deeper into the causes of delay by identifying three levels of delay factors through extensive literature research and discussions with (SMEs) subject matter experts in nuclear industry pointed four main factors of delay which are main contractors, utility, regulatory authority, and financial and country factor. Authors of this study who had developed a combined analytic hierarchy process (AHP) and relative importance index (RII) methods to assess the risk of delay qualitatively and quantitatively, found that the top five most important sub-sub-factors, are policy changes, political instability and public intervention; uncompromising regulatory criteria and licensing documents conflicting with existing regulations; robust design document review procedures; redesign due to errors in design and design changes. Some of the research limitations were that involvement of study's SMEs were only from Korean nuclear industry, which do not give real generalization of the results as well as

the developed (AHP) and (RII) model, were not implemented in a real construction project up to the date of publication of the study.

In a different study, Samarghandi et al. (2016) who studied the reasons for delay and cost overrun in construction project in Iran, identified 36 factors of delay and organized into four categories as follow owner defects, contractor defects, consultant defects and law, regulation and other general defects which are collected from expansive literature review and open interviews with experts from construction industry in Iran. In this research, authors selected the most important causes under each category such as lack of attention to inflation and inefficient budgeting schedule related to owner defects, while inaccurate budgeting and resource planning is the most important cause related to the contractor defects. Moreover, inaccurate first drafts and mistakes in technical documents are the most important causes related to the consultants defects, and outdated standard mandatory items in cost lists is the common cause related to law, regulation and other general defects category.

In 2016, Alsharif and Karatas proposed a framework for identifying causal factors of delay in nuclear power plant construction projects. Authors found that productivity, plant support engineering, and design errors/engineering change requests are the major factors of delay among the 13 identified factors of delay from literature review. Researchers have investigated the relationship between the factors of delay in the nuclear power plant projects and found that those factors of delay interrelate with all others. For instance, if the project manager incorrectly update the project schedule, it will definitely lead to wrong estimate of project resources.

A Elawi et al. (2016) studied the case studies of road and bridge projects in Saudi Arabia. Their analysis revealed that causes of delay related to the owners were the highest 53% of the time delays (26 out of 49 projects) which agreed with other studies results that clients influence/owners are among the top factors causing delays (Doloi and Iyer 2012; Assaf and Barhamain 1996). The authors of this study identified 10 factors of delay from literature research, which are organized into four categories as following owner, contractor, and consultant and others. Furthermore, contractor's lack of experience ranked first as the main causes of delay identified from literature review of the (GCC) Gulf Cooperation Countries studies, while difficulties in obtaining work permits ranked last.

In 2016, Alzara et al. reported on minimizing the causes of delay in Saudi Arabian construction project by using (PIPS) the Performance Information Procurement System which identified by a literature review as a mitigation method for the causes of delay. The authors collected the major causes of delay from a case study, which was performed at a University campus in northern Saudi Arabia, and then compared to delay factors on Saudi's construction projects by literature research. Then, nine causes of delay identified because of this comparison as following; late in reviewing and approving design documents, delay in progress payments to contractors which are related to the owner, while poor contractor performance, contractor's lack of qualifications, lack of contractor experience, shortage of manpower are related to the contractor. Moreover, lack of consultancy employees are related to the consultant and material delivery problems and bidder systems identified as causes of delay related to other factors. From the nine causes of delay identified by this research, the authors clearly mentioned that most of the construction projects in Saudi Arabia delayed due to low bidder system.

Recently, Batool and Faisal (2017) gave a comprehensive review on reasons for delay in selected hydro-power projects in Khyber Pakhtunkhwa (KPK) in Pakistan. The authors found that lack of political stability, delay in civil work, delays in release of funds by the Government, bad Law and order situation, project start without proper site investigation and poor project time management are the most causes of delay of Hydro Power projects.

By conducting deep literature review, The author of this study followed the same technique of other authors in literature as mentioned in the study by categorizing the causes of projects delay into four main sources which are clients/owners, contractors, consultants and external factors. This is mentioned in details at section (2.7). Moreover, the author identified and listed the critical causes of delay from the above literature review at section (2.8) and used to compare with the causes of delay documented for the case study projects used at this research.

Although several attempts have been made to study the causes of projects delay in oil and gas construction projects, yet , very few studies have examined the causes of projects delay in the context of cost overrun in oil fields construction projects. This paper attempts to provide a more detailed investigation on to fill the gap of developing a stochastic model to predict cost overrun due to the causes of projects delay in oil fields construction industry.

2.5 Interconnectivity of causes of projects delay

According to Wambeke et al. (2011), it is possible to model the causes of projects delay in construction projects and, once the causes have been abstracted and modelled, they can easily be used to determine the effect they have on the project. Their research work concentrated on variations for time to commence the work (herein called time) as well as the time it could take to

complete it (here in referred to as schedule). Although their research only looked at these two factors, they opined that projects delay were generally impacting construction productivity as well as the general performance of projects (Wambeke et al. 2011), meaning that their analysis of cause and effect from projects delay could be as wide as possible, even if they started with just “time” and “schedule”. While the causes could be limited to a few factors, the overall effect could be as complex as possible and is dependent on the complexity of the project, the structure of the industry, the nature of the project team and the nature of the sub-sector of the industry (Wambeke et al. 2011). Their research explored over 50 possible causes linked to projects delay, from tools to labour, materials to design and site conditions, actual workflow to site management. This shows that causes of projects delay have a serious element of “interconnectivity” – the attribute that could lead to an explanation of how causes associated with projects delay tend to cascade way down the construction process and flow.

2.5.1 Interconnectivity

The issue of interconnectivity between variables that are related to projects delay has been examined from the professionals involved in decision-making to the actual causes of projects delay. For example, Akinsola et al. (1994) opined that designers – engineers or architects – have a major share of responsibility when it comes to causing projects delay. However, Wambeke et al. (2011) viewed interconnectivity as relating to the way the projects are planned for execution, whereby stakeholders could be issuing incomplete information such that they trigger causes, which are then interconnected with other tasks in the project. One of the factors causing interconnectivity, according to Wambeke et al. (2011), is the multitudes of activities that are linked from the word

go on any project such that the completion of some tasks forms the prerequisite for the commencement of others; this implies that the linkage between tasks or activities becomes virtually connected to the impacts caused by projects delay. Therefore, analysis of the interconnections of causes of projects delay with the project outcomes can only be achieved if the inter-correlations can be modelled and analysed in order to see the impact of each individual factor on the other factors and vice versa (Wambeke et al. 2011). This study investigates the interdependency of causes of projects delay through correlation, multiple regression and stochastic modelling (more details discussed in chapter 8).

2.6 Magnitude and impact of projects delay

According to Akinsola et al. (1994), the severity and impact of the causes of projects delay is largely dependent on many variables. Empirical evidence indicated that causes of delay could not easily be compared with one other, they argued (Akinsola et al. 1994). Realistically speaking then, it is not ideal to assess projects delay because of some predetermined magnitude of the causes or the impact they could have; rather, it is vital to examine the sources of such causes and how they can be provided for within the project work environment – see section (2.7). Further discussion on the impact of projects delay is provided in Chapter 3.

2.7 Grouping/Sourcing causes of projects delay

A considerable amount of literature has been published on the causes of projects delay in the construction industry. These studies have primarily concentrated on categorizing the causes of delay into groups/sources such as Nkado (1995); Assaf et al.(2006); Faridi and El-Sayegh (2006);

Hegab et al.(2007); Abd El-Razek et al.(2008); Abdul-Rahman et al. (2009); Al-Humaidi and Tan (2010); Hossen et al.(2015); A Elawi et al. (2016); Alsharif and Karatas (2016);Alzara et al. (2016). Previous research has shown that contractors, consultants and clients/owner who are among the major stakeholders of construction projects are the most frequent sources of projects delays in the literature. Alzara et al. ,(2016) summarized that most causes of delays are categorized into the contractors, consultants and owners in addition to others or external group which are not belongs to them such as bidder system and lack of materials.

The above approach of categorizing the causes of delay is consistent with past studies by Al-Khalil and Al-Ghafly (1998); Abdul-Rahman et al. (2006); Alaghbari et al. (2007); El-Razek et al. (2008); Omran et al.(2010); Yau and Yang (2012); A Elawi et al. (2016); Alzara et al.(2016) and Samarghandi et al. (2016). For this reason, the author of the current study will consider to use this approach for the purpose of this research.

2.7.1 Owner/Client group of causes of projects delay

The client is defined as a party who finances the project (whether that be government, public sector or private) or who orders the construction project for a certain purpose. The client has a large role in initiating changes in projects (Aziz 2013; Jawad et al. 2009 and Alsharif,S. and Karatas,A.2016).

The changes can occur by means of a direct request to alter a contracted work, or through a representative act from the consultant on the client's behalf (Oladapo 2007), whether in the design phases or the following stages (procurement, contractual agreements, implementation/construction phases). The owner also could also be responsible for the project management after the completion.

Alnuaimi et al. (2009) conducted a case study of four construction projects in Oman. Owner-initiated changes were found to be the most common category of causes of projects delay. Likewise, Love & Edwards (2004) reported that owner-initiated changes represent a main source of time and cost overruns. Aziz (2012) put forward 52 different causes of project cost overrun in Egyptian wastewater projects, categorised into four groups according to the change initiator (client/owner, contractor, design/consultant and miscellaneous). After comparing a statistically representative sample, it was found that the owner-initiated category caused the most changes. Likewise, Alsharif and Karatas (2016) considered the client as a major source of projects delay due to uncertain conditions and modification requirements.

On the other hand, Ismail et al. (2012) noted that changes in project plans or scopes by employer, errors and omissions in design, and financial standing of owner/client are also critical parameters governing the projects delay in road construction projects.

On the other hand, it could be considered unrealistic to expect a project to not encounter changes or delay. Alsharif and Karatas (2016) stated that “it is almost becoming a rare thing for a project not to have delay, thus becoming a normal occurrence in all construction projects”. Therefore, the client should expect changes/delay to occur and accept some modifications during the project processes.

2.7.2 Consultant group of causes of projects delay

In the design phase, the main role is played by the designers handling the project. They are responsible for data collection, exposition and visualising the project. They prepare the primary studies and alternative plans, including the technical drawings, quantity estimations, and

contractual clauses, reviewing these until the final shape of the project is agreed. Post-contract, the role of the consultant begins. Enshassi et al. (2010) investigated the causes of projects delay in construction projects in the Gaza Strip. Design changes ordered by the consultant were ranked as the second highest cause of project delay.

The consultant-originated problems causing project delay according to Mohammad et al. (2010) are: design changes, poor designs, problems in contract agreements, complex nature of design, insufficient drawing details, and poor knowledge of materials and methods to be adopted in the smooth execution of a project. More details about causes of delay related to the consultant will be presented in section 2.8.3.

2.7.3 Contractor group of causes of projects delay

The contractor is the party responsible for the implementation of the project within an agreed budget and in compliance with the requirements set out in the contractual agreement. The party responsible for the implementation of the project often sub-contracts sections to other operators. Sambasivan and Soon (2007) researched time delays in construction projects and found that four out of the five top causes for time overruns were attributed to the contractor.

In another study, by Fallahnejad et al. (2013) on delays in Iran gas pipeline construction projects, one of the contributing reasons was the contractor who caused delays in addition to several other causes. Thus, in summary, the contractors originate such project delay because they fail to fulfil certain requirements when carrying out project works, and these are the reasons (Mohammad et al. 2010): lack of involvement, insufficient machinery or equipment, lowly skilled workforce, financial constraints and lack of professionalism.

2.7.4 External group of causes of projects delay

This category refers to causes of projects delay that are not initiated by a party involved in the construction project. This is a wide category that can include a variety of external factors. Enshassi *et al.* (2010) found that external factors affecting the supply chain were the highest cause of project delay. Kaming *et al.* (1997) concluded that an external factor, the weather, was the most prominent cause of project delay in construction projects in Indonesia.

Additionally, the study by Mohammad *et al.* (2010) on building construction projects in Malaysia described some of the reasons for project delay, which include: amendments in government regulations, changes in weather conditions, economic crisis faced by the country, natural disasters, etc.

According to the above-mentioned studies, Table (2-1) provides a summary of the main sources of project delay in oil construction projects.

Table 2-1 Group/Sources of Projects Delay

Group/Source of Projects Delay	Description	Reference
Client	The owner or promotor of the project	Arditi <i>et al.</i> (1985); Alsharif and Karatas (2016); Alzara <i>et al.</i> (2016); Assaf and Al-Hejji (2006); A Elawi <i>et al.</i> (2016); El-Razek <i>et al.</i> (2008); Faridi and El-Sayegh (2006); Hossen

		et al. (2015); Ibironke et al. (2013); Koushki et al. (2005); Marzouk and El-Rasas (2014); Odeh and Battaineh(2002); Samarghandi, et al. (2016); Sambasivan and soon (2007); Sweis et al. (2008); Yau and Yang (2012);
Consultant	Design and cost professional; conceptualize and document project requirements; Include: architect, structural engineer, mechanical and electrical engineer and quantity surveyor.	Samarghandi et al. (2016); Sambasivan and soon (2007); Sweis et al. (2008);Yau and Yang (2012); Alaghbari et al. (2007);Toor and Ogunlana(2008); Abdul-Rahman et al. (2006);Al-Khalil and Al-Ghafly (1999); Assaf et al. (1995);Omran et. al.(2010);Frimpong and Oluwoye (2003); Arditi et al. (1985);Nkado (1995); Yusof et al.(2007), Alnuaimi and Al Mohsin (2013); Kumaraswamy and Chan

		(1998); Hamzah et al. (2011);Alzara et al.(2016);
Contractor	The only other party to the building contract with the client. Carries out the physical construction works.	Alzara et al.(2016); Alsharif and Karatas (2016); Abdul Rahman et al. (2009); Assaf & Al_Hejji (2006); A Elaw et al.(2016); El-Razek et al.(2008); Faridi & El-Sayegh (2007);Ibironke et al. (2013); Marzouk and El-Rasas (2014);Odeh and Battaineh (2002); Samarghandi et al. (2016);
External Factors	not directly related to the project's participants. Include: weather conditions, safety conditions, changes in government regulation, changes in economic conditions, socio-cultural factors, and unforced problems	Faridi and El-Sayegh (2007);Ibironke et al. (2013); Marzouk and El-Rasas(2014);Odeh and Battaineh (2002);Kumaraswamy and Chan (1998); Hamzah et al. (2011);Alzara et al.(2016);

2.8 Detailed causes of projects delay

From the preceding studies, there are different issues that can cause projects delay during the project cycle. These causes can have either a direct or a non-direct impact on project stages negatively. Most often these causes have impeded project success for the project's parties (Frimpong *et al.* 2003) in terms of quality, cost, time or scope. These impacts will be discussed at a later point in Chapter 3 of this thesis. It is difficult to define the aspects of the causes of projects delay, and it becomes more complicated the larger and more complex a task becomes, with more interdependent activities. This requires continuous monitoring of the project's construction and the provision of plans to mitigate or avoid the negative consequences of these causes (Keane *et al.* 2010). These amendments to the project timetable should be carried out with the knowledge of all parties, with good communication to avoid future disagreement, claims or disputes between stakeholders (El-Adawaye *et al.* 2016).

Therefore, for optimum project performance, an effective analysis of projects delay necessitates a complete knowledge of the root causes (Keane *et al.* 2010). Having explored the different sources of projects delay, this section will now seek to offer simple examples of the differing causes of projects delay that can be attributed to each group of causes as categorised in the literature review of section (2.7) of this thesis.

2.8.1 Causes of delay related to the owner/client

The causes of delay related to owners/clients have been widely investigated and more recent studies have confirmed that top causes of delay are related to the owners. For instance, Yusof *et al.* (2007) found that most significant delay from owner is failure to provide required access to construction site. Alzara *et al.* (2016) did a comparison of the case study university's delay factors

in Saudi Arabia with those found in the literature review, and found that late in reviewing and approving design documents and late payments to contractors are the important causes of delay related to the owner in construction projects in Saudi Arabia. The latter is noted as well by Mansfield et al. (1994); Al-Khalil and Al-Ghafly (1999); Frimpong et al. (2003); Assaf and Al-Hejji (2006); Sambasivan and Soon (2007); Sweis et al.(2008).

Assaf and Al-Hejji (2006) analysed the causes of delay in large constructions projects in Saudi Arabia and out 73 problems causes delay for large projects extracted from literature review, authors summarized that some of the top causes of projects delay by owner are change orders and slowness in decision-making process.

A Elawi et al.(2016) investigated the owners' perspective of factors contributing to project delay in Saudi Arabia found that the majority of project delays were caused from the owner's side as compared to contractors, consultants, and other project's stakeholders which clearly highlights the importance of owner as the main sources of projects delays in construction projects. Authors conducted literature review of Gulf Co-operation Countries (GCC) and ranked top causes of delays in the GCC studies found that financial constraints by the owner, design errors/changes, and difficulties in obtaining work permits are most causes by owner. Similar studies conducted by Sambasivan and Soon (2007);Odeh and Battaineh (2002) noted that financial issues and late payments of completed work and unrealistic imposed contracts duration of the construction projects are among the top causes by owner; the latter is noted as well by Arditi et al. (1985); Mansfield et al. (1994); and Frimpong et al. (2003). This means that some owners don't study the project requirements and force unrealistic completion date which resulted into project delay.

According to Ibironke et al. (2013); Toor and Ogunlana (2008); Kaming et al. (1997); Mazher and Tawil (1998); Dlakwa and Culpin (1990); Koushki et al. (2005); Confusing and ambiguous requirements is one of the top causes of delay by owner. This can be clarified that owner who are not aware about project requirements and lack clear targets and goals of the project, most probably will request change orders during project construction which will lead to project time overrun.

Moreover, Samarghandi, et al. (2016) noted that lack of attention to inflation and inefficient budgeting schedule are the most significant delay factors in the owner defects category. Authors who conducted the research in Iran, elaborated further that owners do not pay full attention to the financial reports of inflation rates in the country, and they ignore the real inflation rates during the bidding of the construction projects, which lead to legal cases between them and the contractors.

In addition, lack of cooperation between owners and projects parties and complicated administrative procedures causes delay for construction projects. Faridi and El-Sayegh (2006) noted that excessive bureaucracy and an uncooperative owner causes delay for construction projects in the UAE.

Author of the current study identified the causes of projects delay related to the owner for the purpose of this research by conducting a comprehensive literature review. Table 2-2 below summarized the owners' causes of delay as following:

Table 2-2 Causes of delay related to the owner

#	Causes of projects delay related to the owner	References
1	Lack of knowledge	Arditi et al. (1985); Alsharif and Karatas(2016); Alzara et al.(2016); Assaf and Al-Hejji (2006); A Elawi et al. (2016); El-Razek et al.(2008); Faridi and El-Sayegh (2006); Hossen et al. (2015); Ibironke et al. (2013); Koushki et al. (2005); Marzouk and El-Rasas (2014); Odeh and Battaineh(2002); Samarghandi, et al. (2016); Sambasivan and soon (2007); Sweis et al. (2008); Yau and Yang (2012); Alaghbari et al. (2007); Toor & Ogunlana (2008); Abdul-Rahman et al. (2006); Al-Khalil and Al-Ghafly (1998); Assaf et al. (1995); Omran et al.(2010); Frimpong and Oluwoye (2003); Nkado (1995); Yusof et al.(2007); Alnuaimi and Al Mohsin (2013); Kumaraswamy and Chan (1998)
2	Late in Reviewing and Approving Design Documents	
3	Delay in Progress Payments to Contractors	
4	Delay to furnish and deliver the site to the contractor by the owner	
5	Change orders by owner during construction	
6	Delay in approving shop drawings and sample materials	
7	Poor communication and coordination by owner	
8	Slowness in decision making process by owner	
9	Conflicts between joint-ownership of the project	
10	Unavailability of incentives for contractor for finishing ahead of schedule	

11	Suspension of work by owner	
12	Re-designing	
13	Line services (Utilities and underground services)	
14	Land acquisition	
15	Variation in estimated quantities between designer and general contractor	
16	Excessive bureaucracy in project owner operation	
17	Obtaining permits from municipality	
18	Materials type and specification change during the construction	
19	Unrealistic contract duration imposed by the client	
20	Improper selection of contractors once a mixture of quantitative and qualitative factors are taken into consideration	
21	Lack of attention to inflation	
22	uncooperative owner	

2.8.2 Causes of delay related to the contractors

There have been several studies in the literature reporting on the causes of projects delay related to the contractors. Alsharif and Karatas (2016) found that late proposal from contractor and late decision from owner are the main factors of delay related to the contractors of the projects which generally lead to projects rework and cost overrun. In addition, Contractor's Lack of Qualifications and experience is one of the most frequent cause of delay documented against the contractors in construction industry Alzara et al.(2016) and A Elaw et al.(2016).

Some authors have highlighted that contractors who are causing delay to the projects are handling so many projects contracts at the same time while they have lack of qualified resources to work on those committed projects. For example, Abdul Rahman et al. (2009); Assaf and Al_Hejji (2006) noted that Contractor handles too many projects at the same time while they are financially not stable and strong enough to manage multiple projects until completion.

Moreover, accidents during construction works are one of the causes of delay documented by El-Razek et al.(2008), the author reported that other problems such as shortage in equipment and poor labor productivity caused projects delay by contractors. In another study by Faridi and El-Sayegh (2007), they noted that unsuitable leadership style of construction/project manager resulted in projects not completed on time . This happen when contractors assign unqualified project managers who have less experience in managing mega construction projects which costs millions of US dollars.

According to an investigation by Samarghandi et al. (2016), authors found that lack of knowledge about regulations, using low quality material and inadequate equipment, and adherence to outdated construction methods are some of the contractors' defects. These defects cause real risks to the

construction projects especially when using low quality material in terms of safety of the workers on the construction site and not obeying the local regulation, which resulted into, projects delay.

In addition, Ibironke et al. (2013); Sweis et al. (2008); Odeh and Battaineh(2002) noted that incompetent technical staff assigned to the project and improper technical study by the contractor during the bidding stage are the most important issues by contractors which lead to project delay. This can be elaborated that those selected contractors might underestimated the value/size/importance of the projects, which resulted into poor planning, and improper requirements gathering.

Author of the current study identified the causes of projects delay related to the contractors for the purpose of this research by conducting a comprehensive literature review. Table 2-3 below summarized the contractors' causes of delay as following:

Table 2-3 Causes of delay related to the contractors

#	Causes of projects delay related to the Contractors	References
1	Poor Contractor Performance	Alzara et al.(2016); Alsharif and Karatas (2016); Abdul Rahman et al. (2009); Assaf and Al_Hejji (2006); A Elaw et al.(2016); El-Razek et al.(2008); Faridi and El-Sayegh (2007);Ibironke et al. (2013); Marzouk and El-Rasas(2014);Odeh and Battaineh(2002); Samarghandi et al. (2016); Sambasivan and
2	Contractor's Lack of Qualifications	
3	Lack of Contractor Experience	
4	Shortage of Manpower	
5	Late decision from owner	
6	Late proposal from contractor	
7	Missed milestone/deliverable	

8	Contractor handles too many projects at the same time	soon (2007); Sweis et al. (2008);Yau and Yang (2012); Alaghbari et al. (2007);Toor and Ogunlana(2008); Abdul-Rahman et al. (2006);Al-Khalil and Al-Ghafly (1999); Assaf et al. (1995);Omran et. al.(2010);Frimpong and Oluwoye (2003); Arditi et al. (1985);Nkado (1995); Yusof et al.(2007), Alnuaimi and Al Mohsin (2013); Kumaraswamy and Chan (1998); Hamzah et al. (2011)
9	Contractor's unstable financial background	
10	Contractor's invalid claim	
11	Difficulties in financing project by contractor	
12	Conflicts in sub-contractors schedule in execution of project	
13	Rework due to errors during construction	
14	Conflicts b/w contractor and other parties (consultant and owner)	
15	Poor site management and supervision by contractor	
16	Poor communication and coordination by contractor with other parties	
17	Ineffective planning and scheduling of project by contractor	
18	Improper construction methods implemented by contractor	
19	Delays in sub-contractors work	
20	Inadequate contractors work	

21	Frequent change of sub-contractors because of their inefficient work	
22	Inadequate contractors work	
23	Slow delivery of materials	
24	Lack of database in estimating activity duration and resources	
25	Poor labor productivity	
26	Shortage in equipment	
27	Accidents during construction	
28	Failure/breakdown of equipment	
29	Unsuitable leadership style of construction/project manager	

2.8.3 Causes of delay related to the consultants

Researchers have studied the causes of project delay due to defects of consultants. Samarghandi et al. (2016) indicated that inaccuracies in technical drawings such as electrical or mechanical drawings resulted into change orders and rework and lead to projects delay. A number of studies have found that Preparation and approval of drawings is another issue of consultants that lead to project delay Samarghandi et al. (2016); Sambasivan and soon (2007); Yau and Yang (2012).

Moreover, the late communication and slow response between consultants and other parties of the project such as contractors and owners are documented as other reasons for project delay. Sweis et al. (2008); Sambasivan and soon (2007) and Samarghandi et al. (2016) noted that slow response

by the consultant engineer to contractor inquiries and poor coordination by the consultant engineer with the parties involved lead to project delay.

In another study, Toor and Ogunlana (2008) noted that some consultants didn't follow the local and/or international updated standards for construction engineering and design which resulted into over-design increasing the overall cost and causing projects delay.

Previous studies have reported that quality control and assurance is additional cause of delay by consultants. Researches such as Ibironke *et al.* (2013); Marzouk and El-Rasas (2014); Odeh and Battaineh (2002) reported that consultants who lack standardization and quality assurance and control their efforts resulted in time overrun and projects exceeded official deadline.

Author of the current study identified the causes of projects delay related to the consultants for the purpose of this research by conducting a comprehensive literature review. Table 2-4 below summarized the contractors' causes of delay as following:

Table 2-4 Causes of delay related to the consultants

#	Causes of projects delay related to the Consultants	References
1	Lack of accuracy in reviewing feasibility studies	Samarghandi et al. (2016); Sambasivan and soon (2007); Sweis et al. (2008); Yau and Yang (2012); Alaghbari et al. (2007); Toor
2	Mistakes in technical documents	

3	Inaccuracies in technical drawings such as electrical or mechanical drawings	and Ogunlana (2008); Abdul-Rahman et al. (2006); Al-Khalil and Al-Ghafly (1999); Assaf et al. (1995); Omran et. al.(2010); Frimpong and Oluwoye (2003); Arditi et al. (1985); Nkado (1995); Yusof et al.(2007), Alnuaimi and Al Mohsin (2013); Kumaraswamy and Chan (1998); Hamzah et al. (2011); Alzara et al.(2016); Alsharif and Karatas (2016); Abdul Rahman et al. (2009); Assaf and Al_Hejji (2006); A Elaw et al.(2016); El-Razek et al.(2008); Faridi and El-Sayegh (2007); Ibiro et al. (2013); Marzouk and El-Rasas (2014); Odeh and Battaineh (2002)
4	Tardiness in preparing change orders	
5	Inaccurate first drafts that cause confusion	
6	Ineffective project planning	
7	Delay in updating project status	
8	Having too many unforeseen items in cost lists	
9	Lack of executive experience	
10	Preparation and approval of drawings	
11	quality assurance and waiting time for approval of test and inspection	
12	Waiting time for approval of tests and inspection	
13	Quality assurance/control	
14	Contract management	
15	Poor qualification of consultant engineer's staff assigned to the project	
16	Delay in the approval of contractor submissions by the engineer	
17	Poor coordination by the consultant engineer with the parties involved	

18	Slow response by the consultant engineer regarding testing and inspection	
19	Slow response by the consultant engineer to contractor inquiries	
20	absence of consultant's site staff	
21	lack of experience on the part of the consultant's site staff; (managerial and supervisory personnel)	
22	delayed and slow supervision in making decisions	
23	Impractical design	
24	Lack of standardization in design	
25	Over-design increasing the overall cost	
26	Poor site management and supervision by consultant	
27	Insufficient data collection and survey before design	
28	Un-use of advanced engineering design software	
29	Change of consultant during project execution	

30	Changes in materials types and specifications during construction	
31	Quality assurance and control	

2.8.4 Causes of delay related to the external factors

There is a large volume of published studies describing the causes of delay related to the external factors which are not belong to the three factors mentioned above. Marzouk and El-Rasas (2014);Yusof et al. (2007); Frimpong and Oluwoye (2003); Kumaraswamy and Chan (1998); El-Razek et al.(2008); Hamzah et al. (2011); Arditi et al. (1985); and Samarghandi et al. (2016) noted that bad weather and unexpected natural events such as fire, flood, earthquake, strikes...etc in most cases stop the construction projects and causes damages to the construction sites which require rework and lead to time overrun and over budget.

Another studies by Samarghandi et al. (2016); Alnuaimi and Al Mohsin (2013); Sweis et al. (2008);Sambasivan and soon (2007); and Nkado (1995); indicated that local government pressure and regulations is additional cause by external factor which is effecting the project works not being completed on time. This happened when government regulations changes, then all project parties have to cope with new rules and policies of construction industry and it became a headache and time consuming for project team to fill the official documents and communicate with related government entities to get the proper approvals for projects tasks as per the new regulations and rules.

In a different studies, Yau and Yang (2012);Toor and Ogunlana(2008);Alaghbari et al. (2007) found that external work due to public agencies (roads, utilities and public services),lack of

materials, equipment and tools on the market and transportation delays are among the problems which causes time overrun. These happened when some public services such as water, electric and sewerage services are down due to unforeseen risks, then dependent project tasks on these services stopped immediately which resulted on more project delay.

Author of the current study identified the causes of projects delay related to the external factors for the purpose of this research by conducting a comprehensive literature review. Table 2-5 below summarized the external factors' causes of delay as following:

Table 2-5 Causes of delay related to the external factors

#	Causes of projects delay related to the External Factors	References
1	Bad weather and unexpected natural events	Frimpong and Oluwoye (2003); Arditi et al. (1985);Nkado (1995); Yusof et al. (2007), Alnuaimi and Al Mohsin (2013); A Elaw et al.(2016); El-Razek et al.(2008); Faridi and El-Sayegh (2007);Ibironke et al. (2013); Marzouk and El-Rasas (2014);Odeh and Battaineh (2002);Kumaraswamy and Chan (1998); Hamzah et al. (2011);Alzara et al.(2016); Alsharif and Karatas (2016); Samarghandi et al. (2016); Sambasivan and soon (2007); Sweis et al. (2008);Yau and Yang (2012); Alaghbari et al. (2007);Toor
2	Unexpected subsoil and ground conditions.	
3	Environmental concerns and restrictions.	
4	Slow permit by government/municipality	
5	Loss or damaged by fire, flood and riot and civil commotion	
6	Fluctuations in cost/ currency	

7	Labor Dispute and Strike	and Ogunlana (2008); Abdul-Rahman et al. (2006); Al-Khalil and Al-Ghafly (1999); Assaf et al. (1995); Omran et al. (2010); Abdul Rahman et al. (2009); Assaf and Al_Hejji (2006);
8	Contract Modifications	
9	Transportation Delays	
10	Bidder System	
11	Local government pressure	
12	Problems with neighbours and site conditions	
13	Public resistance or political intervention	
14	external work due to public agencies (roads, utilities and public services).	
15	poor economic conditions (currency, inflation rate, etc.)	
16	Effect of social and cultural factors	
17	Accident during construction	
18	Delay in providing services from utilities (such as water, electricity)	
19	Traffic control and restriction at job site	
20	lack of materials, equipment and tools on the market	

2.9 Mitigating strategies for causes of projects delay

Numerous studies have attempted to identify the mitigation strategies for project delay and propose suggestions on reducing the impact of delay on time and cost by planning a proper strategy to mitigate delay and reduce the cost by completing projects on time. Mitigation strategies to reduce projects cost and minimize delay can be achieved by different techniques such as timely and reasonable procurement, protection of pending or uncompleted work, and rescheduling or cancellation of purchase orders (Bramble and Callahan 1992).

Projects delay in construction industry can be very critical for all construction stakeholders such as owner, consultants and contractors if it is not planned well. Most construction projects involved financial loan which adds extra cost to project delay, in addition to some professional contractors who are time dependent and paid by hours, and some other cost of delay can be the fluctuation in materials prices. So, it is very important to have mitigation strategies in place to reduce the duration of projects delay and save time and cost (Alnuaimi and Al Mohsin 2013).

Several attempts have been made to identify the effective mitigation strategies, which might minimize the duration of delay in construction projects. For example, previous research in oil and gas construction projects in Vietnam has shown that building good relationship with government authorities and environmental authorities can help reduce project approval delays by understanding their requirements and showing the benefits and fruitful outcomes of the projects (Ogunlana and Dey 2007). Authors illustrated further that familiarity with approval procedures and understanding local laws and regulations by maintaining historical records and archives of past project approvals and documentations can help to reduce the approval time for project works and tasks which will definitely save some time and cost for project owners.

Furthermore, it has conclusively been shown that recruiting professional and highly qualified and specified site managers for managing projects site operations can reduce not only projects delay, but also defects, disputes and cost overrun (Ruqaishi and Bashir 2014). Authors of former research who conducted their study on the causes of delay in construction projects in the oil and gas industry in the gulf cooperation council countries explained that qualified site managers can assure the quality, safety and security of site operations tasks and processes by allocating the right resources at the right time and location. They noted that proper site managers can assure that each supervisor's responsibilities matches their authorities. Additionally, Ruqaishi and Bashir (2014) identified that a clear definition and documentation of project team communication, roles and responsibilities can improve contractors schedule performance and reduce risk of delay from contractors and all project stakeholders.

In another recent study conducted by Rui et al. (2017) who investigated into the performance of oil and gas projects noted that project management team should spend their best effort to understand and quantify the project risks related to unique characteristics of oil projects in order to avoid project cost and time overrun.

Abdul-Rahman and Berawi, (2002b) noted that it is better to identify and predict the causes of project delay in the early stages of construction projects which might provide more chances to implement economical solutions and most efficient mitigations plans.

Another study by Alnuaimi and Al Mohsin (2013) noted that owners have to study and plan very well for their construction projects to avoid contractors' problems. Authors advised developing countries to initiate and develop a new strategy of management in construction projects to minimize the delay in public construction projects.

Arditi et al. (2017) at their empirical study provide evidence that there is a relationship between culture and delay and they indicated that understanding of this relationship, owners of construction companies can raise a public awareness and promote an organizational culture that might help to reduce or prevent projects delay.

Moreover, Hasan et al.(2014) and Assaf and Al-Hejji (2006) raised several concerns about the importance of having mitigation strategies to reduce the effect of project delay in construction industry. They suggested that all construction parties such as owners, contractors and consultants should give special attention to the mitigation remedies provided by their study such as: owner who should avoid delay in reviewing and approving of design documents than the anticipated, and contractors should consider that enough number of labors should be assigned and be motivated to improve productivity, while consultants should be flexible in evaluating contractor works.

In addition, Fugar (2010) identified some strategies to reduce the occurrence of projects delay and observed that construction clients must ensure that funds are available or adequate arrangements for funds are made before projects are started and that government authorities must enforce contract provisions which allow contractors to claim interest on delayed payments.

Furthermore, Odeh and Battaineh (2002) proposed that minimizing the project delay requires developing human resources construction industry through proper training and classification of craftsmen, adopting a new approach to contract award procedures by giving less weight to prices and more weight to capacities and past performances of contractors; and adopting new approaches for contracts, such as design-build and construction management-type contracts.

Author of the current study identified the mitigation strategies of projects delay for the purpose of this research by conducting a comprehensive literature review. Table below summarized the

actionable mitigation strategies of projects delay as classified by literature review, which are actions that one can do to reduce project risks and delay; some authors provided mitigation strategies in general and others provided specific mitigation plans related to major stakeholders in the construction industry such as consultants, contractors and owners/clients.

2.9.1 Mitigating strategies of projects delay (in general)

Table 2-6 Mitigating Strategies of Projects Delay (In General)

#	Mitigation Strategies of Projects Delay (In General)	References
1	Protect incompleteness of project by insurance	Alnuaimi & Al Mohsin (2013); Bramble & Callahan (1992); Abdul-Rahman et al. (2006); Arditi et al. (2017); (Fugar 2010); (Nguyen et al. 2004); Aibinu & Jagboro (2002); Al-Rashid & Kartam (2005); Odeh & Battaineh (2002); Ibrionke et al. (2013); Kaliba et al. (2008); Koushki et al. (2004); Lo et al. (2006); Mohammed & Isah (2012); Yusof et al. (2007); Zou et al. (2007);
2	Ensure timely and reasonable procurement	
3	Ensure timely changing or cancellation of purchase orders	
4	Conduct site meeting by seniors and authorized to make decisions	
5	Owners have to study the construction project properly	
6	Developing countries have to develop a new strategy of management in construction projects taking into account the considerations of size, nature, cost, and importance of the project	
7	Understand the relationship between organizational culture and delay	

8	Construction clients must ensure that funds are available or adequate arrangements for funds are made before projects are started.	Kumaraswamy & Chan (2010); Mansfield et al.(1994); Chan & Kumaraswamy (1997);
9	Ensure that the long and bureaucratic processes involved in honouring payments to contractors must be shortened for efficiency and contractors' payments must be honoured as and when they due in strict compliance with the provisions of the contract.	
10	Strictly enforced contract provisions which allow contractors to claim interest on delayed payments to serve as deterrent to clients.	
11	Governments have to revisit and brainstorm the idea of establishing a commercial bank for building and construction so that contractors can have access to credit in times of liquidity difficulties.	
12	Recruit competent project manager	
13	Accurately estimate project time	
14	Project managers have to properly emphasis on past experience	
15	Project team have to use of up-to-date technology	

16	Ensure clear information and communication channels	
17	Include contingency allowance	
18	Hiring an independent supervision engineer to monitor the work	
19	Ensuring timely delivery of materials	
20	Adopt a new approach to contract award procedures by giving less weight to prices and more weight to capacities and past performances of contractors	
21	Adopt new approaches for contracts, such as design-build and construction management-type contracts.	
22	Ensure legislation and good corporate governance	
23	Ensure that comprehensive strategies to be formulated to minimize variations, whether client initiated or consultant initiated, wherever possible. Ensure a clear and thorough client brief is considered the most useful strategy for reducing variations. Contingency allowances may be incorporated for inevitable variations.	

2.9.2 Mitigation strategies of projects delay (owners related)

Table 2-7 Mitigating Strategies of Projects Delay (owners related)

#	Mitigation Strategies of Projects Delay (Owners Related)	References
1	Pay progress payment to the contractor on time because it impairs the contractors' ability to finance the work.	Assaf & Al-Hejji (2006); Hasan et al.(2014); Koushki et al.(2004); Marzouk & El-Rasas (2013); Sambasivan & Soon (2006);
2	Minimize change orders during construction to avoid delays.	
3	Avoid delay in reviewing and approving of design documents than the anticipated.	
4	Check for resources and capabilities, before awarding the contract to the lowest bidder.	
5	Have a contingency plan to be used in the case if any unforeseen events happen to avoid suspension of work.	
6	Made collaborative decisions Instead of making individually.	
7	Involve services' authorities in the planning and design phases.	

8	Involve the land's owners in the planning and design phase for land acquisition, understand and accommodate their needs, and reimburse them generously in return of their land.	
9	Include specification of a realistic duration in the contract for the contractor to execute the project.	
10	Choose a consultant to the project with sufficient experience in the field of work and has a good reputation	
11	Make sure tender documents are complete, clear and free of errors and/or contradiction	
12	Hire an experienced contractor in the field of work who has a good reputation	

2.9.3 Mitigation strategies of projects delay (contractors related)

Table 2-8 Mitigating Strategies of Projects Delay (contractors related)

#	Mitigation Strategies of Projects Delay (Contractors Related)	References
1	Should assign enough number of labors and motivate them to improve productivity.	Assaf & Al-Hejji (2006); Hasan et al.(2014); Marzouk & El-Rasas (2013); Sambasivan & Soon (2006);
2	Should manage financial resources and plan cash flow by utilizing progress payment.	
3	Continue processes during construction and match with the resources and time to develop the work and to avoid cost overrun and disputes.	
4	Assign administrative and technical staff as soon as project is awarded to make arrangements to achieve completion within specified time with the required quality, and estimated cost.	
5	Give more attention to planning phase and spend more time and money for it.	
6	Develop human resources through continuous training programs.	

7	Assign sufficient number of labours that should be motivated to enhance their productivity.	
8	Minimize the effect of summer restriction on time, contractor should let the workers do their job during night or early morning, or to work extra hours in return of over time.	
9	Provide labors with timely breaks to overcome the effect of hot weather. Such breaks will enhance the labors' productivity and quality of work.	
10	Choose experienced subcontractors with good reputation	
11	Develop a good system for site management and supervision also develops effective planning and scheduling for the project	

2.9.4 Mitigation strategies of projects delay (consultants related)

Table 2-9 Mitigating Strategies of Projects Delay (consultants related)

#	Mitigation Strategies of Projects Delay (Consultants Related)	References
1	Review and approve design documents, if any delay caused by the consultant engineer in checking, reviewing	Assaf & Al-Hejji (2006); Hasan et al.(2014); Marzouk

	and approving the design submittals prior to construction phase, could delay the progress of the work; Use punishment system to be applied for any employee who is slow in reviewing and approving changes requested by owner.	& El-Rasas (2013); Sambasivan & Soon (2006);
2	Should be flexible in evaluating contractor works. Compromising between the cost and high quality should be considered.	
3	Develop staff through training courses and workshops.	
4	Employ competent, experienced and qualified engineers in order to do their jobs effectively.	
5	Establish a control system to handle, control, and evaluate variation orders, initiated by the owner	

2.10 Key research problems identified from the reviewed literature

A careful study of the literature reveals that the causes of projects delay in oil fields construction projects had not been thoroughly investigated. Moreover, this research attempts to provide clear understanding of causes, sources and impacts of delay on oil fields construction projects which is very essential to identify the causes of delay that leads to cost overrun in oil fields construction projects.

Although several attempts have been made to study the causes of projects delay in oil and gas construction projects, yet, very few studies have examined the causes of projects delay in the context of cost overrun in oil fields construction projects. This thesis attempts to provide a more detailed investigation on to fill the gap of proposing a model to predict cost overrun due to the causes of projects delay in oil fields construction industry.

It should be noted from the above literature review that limited studies are available on investigating the causes of delay in oil fields construction projects, and this has motivated the present study to investigate the distribution associated with most of the causes of projects delay in the context of cost overrun and to establish a Monte Carlo simulation model for deriving the probability of cost overruns on future oil filed construction projects.

2.11 Chapter summary

Chapter 2 focuses mainly on the literature review to identify areas of prior scholarship to prevent duplication and identify gaps in research. This chapter basically categorized the sources of projects delay in oil fields construction projects that leads to cost overrun into four main sources, which are projects owners, consultants, contractors, and external sources. This is very essential step to shape the conceptual framework of this research later in chapter 4. In addition, this chapter has demonstrated the causes of projects delay related to procurement and management processes, identified characteristics and challenges of oil fields construction projects along with the causes that related to projects life cycle such as geographical location and environmental conditions of oil fields construction projects found in this literature review will be very helpful to prove the causation relationships between the sources and causes of projects delay later in section 4.4 of this research.

Moreover, this chapter has demonstrated the gaps of research identified from the reviewed literature and provide proposed mitigation strategies on reducing the impact of delay on time and cost by planning a proper strategy to mitigate delay and reduce the cost by completing projects on time. Next chapter will undertake an examination of the processes of modelling projects delay and the possible impacts of having projects delay on oil fields construction projects.

Chapter 3 – Assessing the Impacts of Projects Delay on Project

Outcomes

3.1 Introduction

The objective of this chapter is to conduct a thorough review of existing literature to assess reported impacts of project delays on project outcomes.

There are many causes that lead to projects delay and have critical impact on construction time and cost overrun (Kaming *et al.*1997). They found that impact of project delay on cost overrun was higher than time overrun on high-rise construction works in Indonesia. In Oil and Gas industry, it has been found that projects delay had a high impact to these petroleum projects leading to major cost and time overrun on the mega projects (Omran *et al.*2010). Ogunlana *et al.* (2007) found that projects delay might occur not only during one phase of the project, but during all phases of the project. This should be highly considered by project managers when planning for construction and preconstruction phases concurrently and the later should be given equal important as the former due to their impact on the total cost and time overrun at later project phases which are much higher than expected (Omran *et al.*2010).

Moreover, researchers found that negative impacts of projects delay outweigh positive impacts in construction projects, therefore effective mitigating strategies need to be taken to prevent/reduce impacts of the project delay as much as possible such as maintaining professional project management practices by certified projects managers (Mohammed and Isah 2012)- more details on mitigating strategies can be found in chapter 2 at section 2.7. Researchers identified and studied 4 factors in Nigeria's construction industry that impact delay on construction projects such loss of

interest by the stakeholder, blacklist by authorities, waste of time and money, and declination of reputation (Mohammed and Isah 2012). They found that loss of interest by the stakeholder was ranked as the most important factors, which have impact in constructions projects delay.

This chapter, therefore, seeks to critically examine the impacts of projects delay on project success. By exploring the impacts of projects delay, it is argued that projects delay has a number of possible consequences; therefore, understanding its impacts and causes might help reducing the cost and time overrun of projects delay, thereby justifying the necessity of this research. It proposes the use of a systematic approach to modelling the impacts of managing projects delay on a typical project.

3.2 Assessing the impacts of projects delay

Delay in oil fields construction projects is becoming real phenomena these days and is affecting all major parties of constructions projects such as clients, contractors, and consultants in terms of financial problems, litigation, business reputation etc. Therefore, previous studies have primarily concentrated on assessing the impacts of projects delay and exploring mitigation strategies to reduce the impacts of projects delay on time and budget/cost (Gajare *et al.* 2014; Arditi *et al.* 2017; Fugar 2010; Nguyen *et al.* 2004; Aibinu and Jagboro 2002; Al-Rashid and Kartam 2005; Odeh and Battaineh 2002).

As highlighted by some researchers below, time and cost overrun have highest impact on projects delay. Aibinu and Jagboro (2002), analyzed the effects of project delay in Nigerian construction industry, and found that time and cost were the most effects of project delay in Nigeria. In addition to work of Aibinu and Jagboro (2002), Aibinu and Odeyinka (2016); Alnuaimi and Al Mohsin

(2013);Doloi *et al.*(2012);A Elawi *et al.*(2016); Fallahnejad (2013); Fugar *et al.* (2010); provides another evidences that the highest impact of projects delay are time and cost overrun.

Alnuaimi *et al.* (2009) conducted a case study of four construction projects in Oman. Owner-initiated changes were found to be the most common category of causes of projects that have critical impact on projects delay. Likewise, Love and Edwards (2004) reported that owner-initiated changes represent a main source of time and cost overruns. Aziz (2012) put forward 52 different causes of project cost overrun in Egyptian wastewater projects, categorised into four groups according to the change initiator (client/owner, contractor, design/consultant and miscellaneous). After comparing a statistically representative sample, it was found that the owner-initiated category caused the most changes that lead to time overrun as high impact of project delay. Likewise, Ndiokubwayo and Haupt (2009) considered the client as a major source of projects delay due to uncertain conditions and modification requirements, which result into some impact of delay such as high cost overrun of final project completion. More specifically, Assaf, and Al-Hejji, (2006) specified that the stage where the client most often requested modifications to a project was the design phase as a main reason of delay and impacted the final project cost to increase more than expected.

It's very important that project managers consider adding a contingency buffer as extra cost or time to the planned projects budget and duration. Enshassi *et al.* (2010) illustrated that when work is planned few organisations would embed risk of unplanned changes in the plan of works as contingency plan which might add extra 10-20% of the project planned cost/duration; however, the reality is that as work flows some changes becomes inevitable. This shows that initially projects are perceived to be developed perfectly within the schedule and budget limits; however, when some causes lead to projects delay, projects experience schedule overruns, budget growths, cost

overruns, difficulties in the attainment of specified standards of quality and many more negative impacts too numerous to itemise and control (Enshassi *et al.* 2010).

The relationship between location and impact of project delay has been widely investigated (Gunathilaka *et al.* 2013; Enshassi *et al.* 2010). Project stakeholders need to be aware about the geographical location of the projects, which is considered an important factor that have impact on project delay due to some government policies on the access or use of materials in the construction areas. For example, Enshassi *et al.* (2010) found that contractors and project managers sometime have difficulty to immediately access to construction areas without proper security clearance and long procedures of checking and documentation reviews for every site visit. Researchers found that other factors such as the procurement method used, the level of engagement with professional consultants, market conditions, as well as the susceptibility to international financial market are some of the factors that have been crucial to triggering projects delay.

The commencement of projects delay that has been highly contested in oil fields construction and engineering projects based on the belief that changes in scope might be inevitable due to varied site conditions; however, delays, suspensions and acceleration are said to instigate projects delay A Elawi *et al.*(2016); therefore, the management of such factors is seen as the starting point for the classification and modelling of projects delay. This shows that if there is deviation, alteration, addition or indeed any omission from that which was agreed from the start, it can be classed as a good reason for unexpected changes that might lead to projects delay Alnuaimi and Al Mohsin (2013). However, the impact of such delay cannot easily be classed as impacting only intended targets such as scope; rather, it can spontaneously impact any element of the project (Enshassi *et al.* 2010).

Alnuaimi *et al.* (2010) explained that, generally speaking, projects delay emanates from the need to respond to the necessity of changes in scope, alterations in the material quantities, any errors appearing in the design or any changes triggered by the unit rates in the cost of elements. They argued that it is not good enough for an organisation to accept the inevitability associated with delays; rather, it has to ensure it can analyse the scope of the job in order to itemise the sources and types of requests, and evaluate if the requests are linked to any errors in the design – real or imaginary (Alnuaimi *et al.* 2010). Detailed analysis of the sources of projects delay can lead to an appreciation of the instruments necessary for the issuance of the projects delay (Elinwa and Joshua 2001). For example, many projects rely heavily on the traditional roles of project stakeholders, as assigned by the contract. Therefore, if the circumstances change they find it challenging to analyse every contractual clause and assess the optimal strategy to manage projects delay (Samarghandi *et al.* 2016). This means that the overall interpretation of the contractual relations between project stakeholders has been seen as a major factor in the management of projects delay, not only with regard to who is responsible of projects delay and what the consequences could be, but also in creating a working environment that can map the causes and the effects of unexpected changes so that confusions can be avoided (Abdul-Rahman *et al.* 2006). One way of achieving a balance between projects delay and necessary changes is to allow for a contingency amount in the contract – say 5 to 20% of the contract sum (plus or minus) to hedge against possible change orders (Al-Kharashi and Skitmore 2009); however, this might not be an ideal strategy because there is a possibility that the organisation could fail to map all the possible effects of projects delay. It is difficult to pinpoint and predict what the stakeholders' behaviour would be when the project commences; for example, the design could be complete yet the construction planning could be wrong; or the financial base to support the procurement of lead items might not be in place because

the contract may not have been agreed and signed in good time; this makes it difficult to speculate as to the causes and impacts of project delay.

3.2.1 Effects of projects delay

According to Alnuaimi *et al.* (2013); Alzara *et al.* (2016); Arditi *et al.* (2017); A. Assaf and Al-Hejji (2006); Batool and Abbas (2017); Arain and Pheng (2005), noted that effects of projects delay can be managed easier when categorizing them in proper groups. Some of the effects that they examined are as follows:

- As mentioned above in section (3.2), when adding contingency buffer, projects delay can be affected without necessarily impacting the overall project schedule; this effect relies on the use of the float in plans so as to achieve changes that have no impact on the overall schedule;
- Projects delay can lead to cost escalations due to unexpected changes. This could be due to scope changes, or costs of changes due to additions and/or alterations;
- It had been clearly found that some organisation recruit other professionals as contractors with limited contract duration as per the projects needs/requirements of human resources/experts to execute the work on the project, which can be visible – either for good or otherwise – especially if the project is highly complex;
- The changes to the project can lead to changes in the overhead expenses due to the paperwork changes, claims review and general administration costs required to facilitate the projects delay;

- It is had been found that projects delay can result in delays to the processing of payment for particular stakeholders. Moreover, this could eventually influence progress on the project;
- Researchers found that quality could be compromised if any quality standards of project implementation had been changed, especially if the work has been changed tremendously;
- With changes, productivity is expected to wane;
- Depending on the procurement method used, it is possible that work will not start on any procurement of products or services due to the understanding that changes have been made.

If the works have started and changes have been made, there is a high likelihood that reworks and demolitions would inevitably be part of the package that the stakeholders have to manage. This could affect other factors such as cost and delivery schedule as well as the quality standard.

Construction as a business relies heavily on logistics and reverse logistics; therefore, project delay have the propensity to impact logistics for materials, equipment and tools (Koushki *et al.* 2004).

There is an intangible element of reputational damage to the brand in the event that delays have caused other impacts. The major issue with reputational damage is that it can negatively affect the competitiveness of the business (Ibironke *et al.* 2013).

The management of safety and welfare for the site can be complex because of the changes brought about by projects delay, especially as they would have to be resourced (Hasan *et al.* 2014);

There can be professional acrimony from the stakeholders and blame-game could be inevitable because of disputes relating to the manner in which projects delay have been triggered and or managed;

There is a potential for disputes related to the need for additional payment to the contractor because of the effect of projects delay (Assaf and Al-Hejji 2006). Handling the need for additional payment

can be a source of conflict to parties to the contract because some parties could be seen to favour projects delay for as long as they benefit from such delay.

Delays in the overall schedule can be an issue in many projects because all the above-stated factors would eventually lead to a delay in the delivery of the project.

Even though the list of effects from projects delay cannot be exhaustive, Ibbs *et al.* (2007) were of the view that they need to be quantified to see if they can be managed. They opined that quantification of the impacts of changes to projects could offer a basis upon which the management of changes can be anchored. The quantification process for projects delay could lead to a clear establishment of the causal linkages between factors so that any losses in productivity or that establishment of responsibilities can be minimised (Ibbs *et al.* 2007). Once the factors have been accrued cumulatively it may be possible to assess their ranking and identify how critical some factors are to the project, hence creating an overall impact assessment of projects delay on the project's key performance indicators. The suggestion to quantify projects delay and assess the causal linkages was not considered as a finite process; rather, Ibbs *et al.* (2007) recognised constraints associated with uncertainties, risks, professional judgement and general inefficiencies caused by the structure of the industry as well as the structures of the organisations involved in the project development process.

The discussions in this section provide the various causes of project delay associated with time and cost overrun in different construction projects as well as mitigating strategies. Some of the causes identified herein form the basis of this research in terms of causes of delay associated with project owner, contractor, consultant and external factors.

3.3 Impact of projects delay on time

Researches such as Ibironke *et al.* (2013); Marzouk and El-Rasas (2014); Odeh and Battaineh (2002) reported that consultants who lack standardization and quality assurance and control their efforts resulted in time overrun and projects exceeded official deadline.

Other studies by Samarghandi *et al.* (2016); Alnuaimi & Al Mohsin (2013); Sweis *et al.* (2008); Sambasivan and soon (2007); and Nkado (1995); indicated that local government pressure and regulations is additional cause by external factor which is effecting the project works not being completed on time. This happened when government regulations changes, then all project parties have to cope with new rules and policies of construction industry and it became a headache and time consuming for project team to fill the official documents and communicate with related government entities to get the proper approvals for projects tasks as per the new regulations and rules.

Time is the most important factor in oil fields construction projects. Yogeswarn *et al.* (1998) investigated the occurrence of excusable time extensions during construction projects in Hong Kong. Through analysis of data gathered from 67 construction projects it was found that, out of the projects that were completed late (85% of projects surveyed), 76% had excusable delays and 20% had non-excusable delays. Wambeke *et al.* (2011) focused their research on the causes of projects delay in concrete slab production and the subsequent impacts of these delays. The study concluded that the identification, study and reduction of delay would result in significant increases in productivity. However, while coming to these conclusions the study did not propose any strategies to reduce projects delay based on the data they gathered.

It could also be argued that, if the management team can identify areas that are of high concern to their organisation, or project or business so that they can react to these areas, that would bring better results (Oladapo 2007).

According to Oladapo (2007, p.35), the main issues behind projects delay tend to be the “nature of the business of construction”; factors such as the complexity of a project, uncertainty within the oil fields construction industry, the process of delivering the oil fields or petroleum infrastructure, and the fragmentation of the business entities assigned to the delivery of the construction project are but some of the pertinent attributes that compound causes of delay (Sweis *et al.* 2008).

The implications are that weaker oil prices present fiscal challenges for the oil and gas companies (Carrillo 2005); however, some projects have been allowed to continue despite the fiscal challenges (Al-Ghamdi 2016). In such a case, changes to any attribute of the project has the potential to compound other factors, and this would lead to the increase in constraints that management have to deal with at any point in time.

Therefore, it can be argued that cost and schedule should be used as the main causality of project delay. Thus, modelling the impact of projects delay on project outcomes will allow decision-makers to assess the consequences and develop mitigating strategies.

Based on the above, it is established that time is a critical factor in the completion of a construction project and failure to mitigate delays and factors that could lead to time overrun has negative impact on a project’s performance.

3.4 Impact of projects delay on cost

According to Ibironke *et al.* (2013); Toor and Ogunlana (2008); Kaming *et al.* (1997); Mazher and Tawil (1998); Dlakwa & Culpin (1990); Koushki *et al.* (2005); Confusing and ambiguous requirements from projects owner who are not aware about project requirements and lack clear targets and goals of the project, most probably will request changes during project construction which will lead to project time and cost overrun.

In another study, Toor and Ogunlana (2008) noted that some consultants did not follow the local and/or international updated standards for construction engineering and design, which resulted, into over-design increasing the overall cost and causing projects delay.

It has long been established that projects delay brings indirect costs to a project (Bower 2000). However, the issue has been to establish a way in which factors causing projects delay could be modelled and linked to indirect costs. Bower (2000) argued that many organizations are able to model the direct impacts of projects delay to scope; however, the indirect impacts are the most difficult to isolate and model because projects delay do not only cause stoppages and restarts, they lead to loss of productivity, constraints in reprogramming, loss of any rhythm in the work process, unbalance the work teams, and lead to a cascade of changes in the way reports are done or the documentation is prepared for reporting purposes. In other words, there are factors that are overly sensitive to projects delay; however, the significance of the projects delay varies from project to project and factor to factor. The only uniformity in the impact has been its unpredictability and the assessment of its severity (Bower 2000). For example, when there are time-related factors with projects delay these can be related to the affected tasks; however, issues such as recalculation of

the network schedule for construction, overheads costs and time-related charges such as the liquidated and ascertained damages would have to be dealt with too (Bower 2000). This also implies that reworks, standing time for subcontractors, changes in cash flow as well as the possibility of costs related to loss of earnings would equally be triggered indirectly (Bower 2000). The other key dimension could be the way human resources are allocated at head office, the management of time, as the site as well as the head office would be negatively impacted (Bower 2000).

Arain *et al.* (2005) sought to provide information for a detailed exploration of the potential effects of projects delay in building projects. It was found that the most common impact of projects delay was an increase in the total project cost, followed by an increase in contractor revenue. The study proposed the following measures to combat unwanted changes that lead to projects delay: involving professionals in the design process, effective and constant communication, and thorough briefing for the contractor.

Moreover, accidents during construction works add extra cost to projects as documented by El-Razek *et al.* (2008), the author reported that other problems such as shortage in equipment and poor labor productivity caused cost overrun by contractors. In another study by Faridi and El-Sayegh (2007), they noted that unsuitable leadership style of construction/project manager resulted in projects not completed within planned budget.

Amoatey *et al.* (2015) investigated the reasons for delays in Ghanaian state housing construction projects and their impacts. The authors concluded that the major impact of construction delays is directly on both cost and time of the project, hence affecting the quality as a whole. In a similar investigation, Ibbs *et al.* (1997) studied the quantitative influence of project change in terms of

size issues. The authors concluded that the greater the changes in a project, either at the design stage or construction, or even between them, the more the costs are degraded. Therefore, the fewer the changes in a project, the smaller the cost overruns. The research assumes that the causes of projects delay will have a major impact on the cost overruns of oil fields construction projects. From the foregoing, it is established that time and changes to project execution lead to cost overrun causing projects to exceed their working budget.

3.5 Modelling of projects delay

There have been several studies in the literature reporting on experimental investigations to explore the complexity of oil fields constructions projects and the variety of efforts of categorizing projects delay by adopting theoretical and systematic methods (Ruqaishi and Bashir 2014; Samarghandi *et al.* 2016; Arain and Pheng 2007; Alsharif and Karatas 2016).

According to Ruqaishi and Bashir (2014), the management of projects delay in oil fields construction projects largely depends on how are the projects team organized and qualified with requirements gathering and key information analysis and categorization. They argued that, because petroleum projects have complex sets of variables, an organisation could use a theoretical model as a method of categorising projects delay (Ruqaishi and Bashir 2014). Their argument has been based on the premise that, for ease of management of projects delay, they need to be modelled, meaning that the manager would need to find a way of modelling the attributes of the changes starting with causes and linkages as well as the possible impacts on the project. The rationale for

taking such a stance was that effective management of projects delay relies heavily on developing a systematic approach; otherwise, the changes data could overwhelm managers, who are likely to over simplify the response to projects delay (Samarghandi *et al.* 2016). Despite the complexity associated with projects delay, Arain and Pheng (2007) were of the view that they could model them using three main steps – firstly, by undertaking detailed screening of the causes of projects delay; secondly, by assessing the likely alternatives so that projects delay can be avoided; and, thirdly, by reviewing areas that are dominant in a project. They further illustrated that deploying a systematic model for managing changes can turn their perceived negative impacts into a positive force that takes advantage of the opportunities of projects delay while minimising their negative impacts (Arain and Pheng 2007). In other words, they opined that efficiencies in the management of changes are realisable if there is a systematic method of screening and identifying them with a view to understanding their attributes (Alsharif and Karatas 2016). The only downside to the proposed model is that it was based on a theoretical framework – one that is centred on non-quantitative variables in developing the model. This meant that, even if the model was clear, it was not possible to maintain consistency in the way that data related to projects delay could be modelled. This weakness could be improved if there was a way of creating consistency – hence the need to introduce numerical analysis mechanisms.

3.5.1 Quantitative modelling approaches

Numerous studies have attempted to explain the possibilities of using quantitative approaches to model causes for projects delay (Hsieh *et al.* 2004; Arain and Pheng 2007). Modelling that is based on quantitative data has the potential to allow for further statistical analysis or to generate patterns of correlation (or lack of) between sets of data obtained from the projects delay under review

(Arain and Pheng, 2007). When one compares the approach, using qualitative data for modelling projects delay that was proposed by Arain and Pheng (2007) with the use of quantitative data, it can be noted that decision-making is possible in either strategy; however, if the emphasis is on effective decision-making, the general understanding of projects delay cannot be helpful. For example, Arain and Pheng (2007) felt that, if the project manager looks at a database of experiences with delays, their understanding of projects delay would have a significantly positive influence on the decision-making process. While past experiences form an essential part of communication and documentation of decision-making on projects delay (Arain and Pheng 2007), there could be a need to undertake a detailed analysis of the meaning behind the data so that relationships, if any, can be established; hence creating patterns that are necessary to increase the potential of making correct decisions (Hsieh *et al.* 2004).

In trying to categorize the sources of projects delay on a typical project in Taipei, Hsieh *et al.* (2004) searched local databases to categories sources of projects delay. They generally found the following: (i) that planning and design were highly rated because they caused inconsistencies in information such as site conditions and insufficient specifications. These factors impacted decision-making; (ii) that ground conditions were also highly rated because most projects contained insufficient data about the ground conditions, meaning that changes had to be ordered at the time of construction; (iii) insufficient safety preparations mainly because the conditions had changed, hence the safety provisions became insufficient – forcing changes in the construction approach; (iv) they also found that natural incidents such as floods or typhoons were actively creating projects delay for projects because they triggered the need for temporary works; (v) the legal framework for making and implementing change orders was high rated as a source; (vi) management hierarchy in any project that acted as an authority to issue changes was a highly rated

factor; (vii) when there is pressure to commission a project and be able to transfer it to the owner, there are sources of delays; (viii) when there are stakeholders lobbying about the need for changes so that the neighborhood could be protected. This tended to cause changes in the design and planning process, especially if there was poor stakeholder engagement. (ix) The authors opined that there was a category that can be classed as “miscellaneous” because the factors in it can be organized in one group.

While the classification of factors triggering projects delay could help in the decision-making process, the most important issue is how to rate the causes in terms of the patterns based on the likelihood that one of these factors could materialize in a particular project. This way, decision-makers could use the statistical model in determining how best to stem the negative impact of possible projects delay and be able to maximize the opportunities.

Previous studies have primarily concentrated on using various quantitative models and different modelling methods have been proposed to analyze projects delay in oil fields constructions projects. However, there is no rule of thumb that one method can fit all or there is the best method that can be internationally used (Lyulina *et al.*,2015). There are multiple modelling methods used for delay analysis and each of them has its own advantages and disadvantages for research investigation as per the available resources.

According to Toor and Ogunlana (2008), they used a questionnaire survey to identify and rank the causes of delay related to designers, clients, contractors and finance categories proved as top of the causes of delay in Thailand construction industry. This study identified 75 causes grouped into 10 categories, which were analysed through a questionnaire survey and then top causes of delay

were classified and compared with previous studies in the literature. The former comparison showed some similarities of the top causes between studies with some differences as well due to the special characters of the projects in terms of geo-graphical locations, government support etc. Furthermore, authors refer most causes of delay to the lack of risk management practices, which reduces the chances of mitigating strategies and anticipating risks before happening.

Yang and Ou (2008) highlights the capability of structural equation modelling (SEM) of quantifying the causes of delay and the relationship between its factors and its high ability on resolving the problems of delay. The study identified list of 75 causes of delay from 14 studies, and then reduced that former list to 37 after SMEs interviews and discussions with senior industry engineers. Those causes were categorized into six groups as contract, management, human, nonhuman, design and finance related.

Al-Humaidi and Tan (2010) provides in-depth analysis of the work of a fuzzy logic approach to model delays in construction projects using translational models. The authors classified the causes of delay into three categories as following Procedural which consists of managerial, legal, financial and operational, triggering which consists of weather, underground conditions and natural disasters, and enabling which consist of materials, workers and equipment related. The authors of this research paper justified the use of fuzzy set theory to evaluate the occurrence of causes of delay, which cannot be performed using a crisp value as it require to consider the uncertainty of cause of delay.

Farnum and Stanton (1989) described regression analysis (RA) as a powerful numerical tool for prediction of the functional interrelations between a dependent variable (Y) and one or more independent variables ($X_1, X_2, X_3, \dots, X_m$). This is used to find out the best-fit representation for the relationship that is present in the data sample. However, the nature of this relationship may

take several forms extending from simple to multiple regressions and from linear to non-linear relations.

Moreover, some published studies described Monte Carlo simulation (MCS), which has been an essential tool and remains instrumental in management science and modelling delay analysis in constructions projects (Hossen *et al.* 2015) . Authors defined MCS in different ways depending on the use of researches/systems, however, the majority of them agree on the concept of using MCS to optimize/improve the decision making process based on highly accurate estimation of results/outcomes (Banks, J. *et al.* (2001);Gheorghe (2012); Pham and Hadikusumo (2014).

By conducting the systematic literature review above by reviewing several modelling methods used in the time and cost overrun in the construction industry, the author of the current study will adopt the use of the regression analysis techniques to develop regression models that can help in the mapping process of the causes of project delay to cost overrun in oil fields construction projects. The author will adopt as well the use of the application of stochastic modelling using Monte Carlo simulation techniques using the developed regression models, which is very helpful to estimate the cost overrun accurately and because of their robustness in the context of this study. More details on this illustrated in chapters 5,6,7 and 8.

3.6 Chapter summary

This chapter has articulated how causes of projects delay can lead to consequences for project success in terms of time and cost. It was found that projects delay issued by the owner of the project rank highly in terms of the impact on project success. The review also found that, at the

institutional level, the most-cited effects for projects delay included changes in project costs, progress schedules that were changed due to delays, increase in overhead costs. Also, the review establishes a cause-effect relationship between time and cost overrun wherein failure to complete a project according to its planned timeline leads to project budget overrun. Therefore, the significance of the projects delay is tested at the “impact” phase to see how they affect the smooth operations of the project, the institution or the business at large. Since most, if not all, projects in oil fields construction industry are procured by the public sector; this research is of vital importance to identify the association between causes of projects delay and project success criteria which is the cost.

Chapter 4: Research Conceptual Framework

4.1 Introduction

In this chapter, the conceptual framework of this research is presented to identify the important causes of project delays associated with project owner, contractor, consultant and external factors based on theoretical data available from the literature. Also, the link between these causes and budget overrun is considered to select only those that exhibit a direct relationship with budget overrun.

This chapter presents the research conceptual framework used to derive and guide this research. This chapter consist of the following sections: the conceptual framework: general background, the research conceptual framework.

4.2 The Conceptual framework: General background

A conceptual framework (CF) is defined as explanaltion of the research content either graphically, or in narrative form, the main things to be studied – the key factors, concepts or variables and the presumed relationship among them (Miles and Huberman 1984). Leshem and Trafford (2007) emphasis on the importance of using the conceptual framework in doctoral thesis and examination processes by providing a map of theories and issues related to the research content and problems and by providing the following benefits in the research process: Leshem and Trafford (2007):

- Modelling relationships between theories

- Reducing theoretical data into statements or models
- Explicating theories that influence the research
- Providing theoretical bases to design, or interpret, research
- Creating theoretical links between extant research, current theories, research design, interpretations of findings and conceptual conclusions.

According to Trafford and Leshem, (2002a, b), doctoral thesis which used conceptual framework to explain and guide the research variables and issues are more likely to pass viva exams from the first time, or with minor changes as per the vivas and examiner reports. Moreover, using conceptual framework is an important aspect for doctoral candidates to assure that they reached doctorateness in their thesis (Leshem and Trafford 2007).

Leshem and Trafford (2007) indicated that using conceptual framework at doctoral thesis will help candidates to respond to the examiners questions such as:

- What was the wider theoretical significance of that reading?
- Why was the research designed in that way?
- What is the conceptual significance of the evidence?
- Why does the thesis make a contribution to knowledge?

4.2.1 Methodology for conceptual framework

The methodology adopted in this thesis is to identify the causes of budget overrun associated with project owner, contractor, consultant and external factors based on what has been widely reported in the literature. These identified causes are then evaluated to see if they have a direct or indirect relationship with budget overrun. Causes with indirect relationship are discarded so as to ensure validity of the finding of this work, thus, only those causes that exhibit a direct relationship with budget overrun are considered in this thesis.

4.3 Research conceptual framework

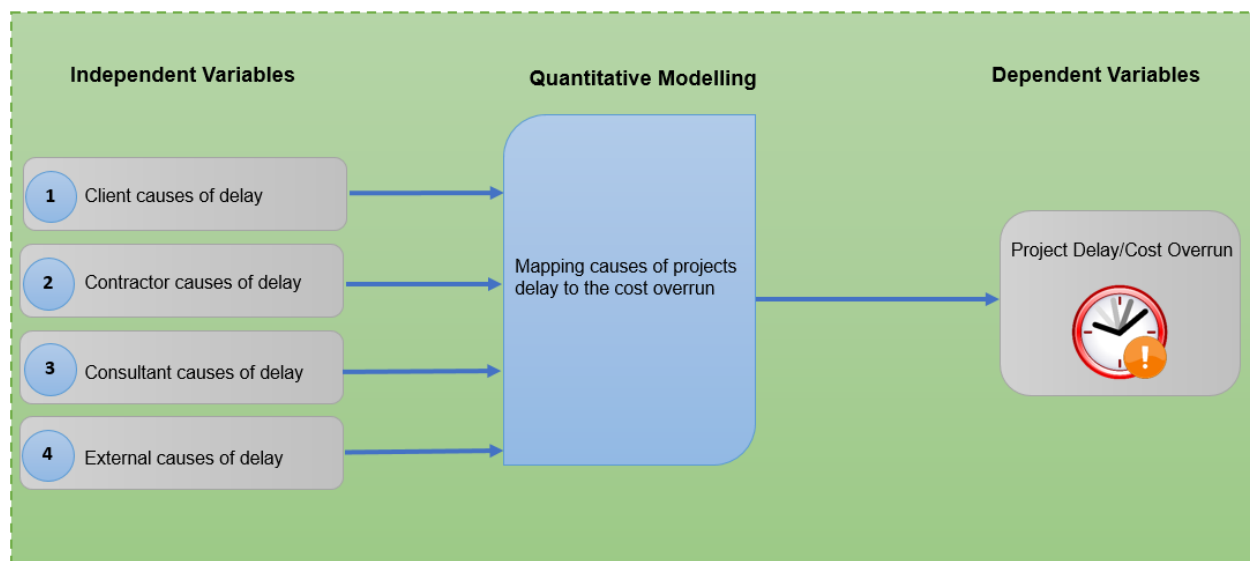


Figure 4-1 Conceptual framework

The framework shown in figure 4-1 above is created based on the findings from previous chapter on the theoretical background. As can be seen the framework is made up of four independent constructs which are client causes of delay, contractor causes of delay, consultant causes of delay and external causes of delay, and one dependent construct which is project delay/cost overrun.

Each one of the mentioned constructs will be measured based on several variables. These variables are chosen from literature. In addition, framework describing the relationship among different constructs will be developed as will. Each of studied constructs may have direct relationships with projects delay. In addition, there may be relationships among these constructs, which leads to indirect relationships between them, and projects delay. Based on conducted literature review, the most reliable framework for this research is based on direct relationship between each construct and projects delay as presented in figure 4-1.

The conceptual model will explain how the research dependent and independent variables are linked conceptually to achieve the research outcomes. It's expected in this chapter that all research questions and hypothesis are developed. The conceptual model will also help in adopting an appropriate data analysis methodologies. Moreover, the conceptual framework will assist in designing the data collecting methods.

4.3.1 Independent variables

4.3.1.1 Client causes of delay

A client, user or owner in the construction industry is a person or company for whom a project is carried out with full control on the project and is responsible for funding the project costs and payments. The clients have control on assessing, evaluating and selecting the proper consultants/designers and contractors for the construction project (Arditi *et al.*1985).

In addition, there are many causes of delay related to client's category, as per the conducted literature review, the most important causes have been identified in chapter 2 and here are some of them:

#	Causes of projects delay related to the client
1	Lack of knowledge
2	Late in Reviewing and Approving Design Documents
3	Delay in Progress Payments to Contractors
4	Delay to furnish and deliver the site to the contractor by the owner
5	Change orders by owner during construction

Table 4-1 Causes of projects delay related to the client

4.3.1.2 Contractor causes of delay

Contractor is a person or company who is responsible to carry out, execute and control the major construction work or sub works of the construction projects or supply labour and materials according to construction work requirements (Marzouk and El-Rasas 2014)..

In addition, there are many causes of delay related to contractor category, as per the conducted literature review; the most important causes have been identified in chapter 2 and here are some of them:

Table 4-2 Causes of projects delay related to the contractors

#	Causes of projects delay related to the Contractors
1	Poor Contractor Performance
2	Contractor's Lack of Qualifications
3	Lack of Contractor Experience
4	Shortage of Manpower
5	Late decision from owner

4.3.1.3 Consultant causes of delay

Consultant is a person or company who is responsible to any design task or work related to construction project. Consultants may take role of designing part or whole of the project which will contain all specifications and drawing related needed by contractors to carry out the construction project (Assaf and Al-Hejji 2006).

- Architects;
- Engineers;
- Surveyors;
- Contractors carrying out design work (Design, Build and Operate);
- Specialist suppliers.

In addition, there are many causes of delay related to consultant category, as per the conducted literature review; the most important causes have been identified in chapter 2 and here are some of them:

#	Causes of projects delay related to the Consultants
1	Lack of accuracy in reviewing feasibility studies
2	Mistakes in technical documents
3	Inaccuracies in technical drawings such as electrical or mechanical drawings
4	Tardiness in preparing change orders
5	Inaccurate first drafts that cause confusion

Table 4-3 Causes of projects delay related to the consultants

4.3.1.4 External causes of delay

There is a large volume of published studies describing the causes of delay related to the external factors which are not belong to the three independent variables mentioned above.

Group of authors such as Samarghandi *et al.* (2016); Alnuaimi and Al Mohsin (2013); Sweis *et al.* (2008); Sambasivan and soon (2007); and Nkado (1995) indicated that local government pressure and regulations is additional cause by external factor which is effecting the project works not being completed on time. This happened when government regulations changes, then all project parties

have to cope with new rules and policies of construction industry and it became a headache and time consuming for project team to fill the official documents and communicate with related government entities to get the proper approvals for projects tasks as per the new regulations and rules.

In addition, there are many causes of delay related to external category, as per the conducted literature review; the most important causes have been identified in chapter 2 and here are some of them:

#	Causes of projects delay related to the External Factors
1	Bad weather and unexpected natural events
2	Unexpected subsoil and ground conditions.
3	Environmental concerns and restrictions.
4	Slow permit by government/municipality
5	Loss or damaged by fire, flood and riot and civil commotion

Table 4-4 Causes of projects delay related to the external factors

4.3.2 Dependent variable

4.3.2.1 Project cost/budget overrun

Each of studied constructs may have direct relationships with projects cost. In addition, there may be relationships among these constructs, which leads to indirect relationships between them, and projects cost. Based on conducted literature review, the most reliable framework for this research is based on direct relationship between each construct and projects delay as presented in figure 4-1.

4.4 The causation relationship between projects delay and cost overrun in oil fields constructions projects

There have been several studies in the literature reporting on the causation between projects delay and cost overrun in oil fields construction projects. Pham and Hadikusumo (2014) gave a comprehensive review on schedule delays in engineering, procurement, and construction in petrochemical projects in Vietnam by using 3 case studies on selected project which are at least 80% completed, they found that lack of effective communication is one of the main causes of projects delay that lead to cost overrun and financial problems for project owners. In another study, Salama *et al.* (2008) examined the causes of delay within oil and gas projects in the UAE, authors indicated that delay is common problem in petroleum projects specially in the completion date which ranges from 5 to almost 20% of the total project duration. Salama *et al.* (2008) who conducted their research by using semi-structured interviews followed by a survey, found that main causes of delay for oil and gas projects are delay in procurement and delivery of materials, inaccurate

estimate of materials requirements and poor selection of contractors. The author noted that the more delay occurred in petroleum projects, extra cost will be required to added in the budget of those delayed projects. This is consistent with the studies of Kaming *et al.*(1997);Kumaraswamy and Chan (1996);Abdul Rahman *et al.*(2006);AL-Kharashi and Skitmore (2008);Ahsan *et al.*(2010);Aziz (2013);Batool and Abbas (2017) which indicated that any delay in oil and gas construction projects, will consequently lead to cost overrun, and the impact of delay on the cost will depend on the duration of the time overrun/delay. Therefore, higher duration of delay will add high cost overrun to the projects.

Based on the above literature review, author of this study can prove that a causation relationship existed between projects delay and cost overrun in oil fields construction projects. This is because it has been established that a change in a project's completion schedule incurs additional costs to the planned budget of the project, thereby leading to budget overrun. The prove of a causation relationship between projects delay and cost overrun in oil fields construction projects is important to shape the chapter 7 of this study, research design and methodology.

Therefore, having discarded the causes of project delay with indirect relationship with budget overrun, the research strategy adopted fits into the conceptual framework explained in this chapter. This provides a reliable avenue that ensures the validity of the findings of this research.

4.5 Chapter summary

This chapter presented a conceptual framework for this research by considering the causes of project delay relating to project owner, contractor, consultant and external factor based on

available literature. These four (4) categories of causes of project delay serve as the dependent variable for the quantitative model which is to be employed to provide an estimate of a project's budget overrun. Generally speaking, causes of project delay have a direct and indirect relationship with budget overrun, only those with direct relationship have been singled out to form the basis of the study to be conducted in this thesis. This is to ensure the reliability and validity of the findings of this thesis.

Chapter 5: Regression Analysis

5.1 Background

In this chapter, a detailed description of regression analysis is presented to provide readers with the theoretical background required for the understanding of interpretation of results obtained in the regression model developed in this thesis. Also, the assumptions that must be fulfilled by any regression model are described and the procedure for determining if these assumptions are fulfilled is outlined.

This chapter presents an overview of the regression analysis (RA) while the next chapter will present Monte Carlo simulation (MCS) applied in the present study because the knowledge of RA and MCS are important for an understanding of how to numerically assess the influence of projects delay on the cost of construction projects in the oil fields construction industry. This chapter presents an overview of the regression analysis (RA) while the next chapter will present Monte Carlo simulation (MCS) applied in the present study because the knowledge of RA and MCS are important for an understanding of how to numerically assess the influence of projects delay on the cost of construction projects in the oil fields construction industry. By providing a detailed summary of the statistical tool employed and its justification, readers with no prior background of RA and MCS can easily comprehend the content and finding of this thesis. Furthermore, the detailed summary provided in this chapter can serve as a reference note to future studies in this subject area (mapping the causes of projects delay in oil field construction projects).

According to Mueller *et al.* (1997, 1986), the prediction of project cost can be achieved using various performance ratios; however, the explanation was rather too simplistic to be of real value

and that was due to the lack of consideration of the complexities involved in the construction projects such as the ground realities at a project site and the dynamic and interconnectivities between all the stakeholders of the constructions projects during the implementation/execution phase of the projects.

Numerous studies have attempted to explain the importance of having ability to predict/forecast the targeted numbers/goals for long-term events. Having that ability of prediction based on historical data, will help the decision makers to make better decisions that will highly effect the business needs and requirements to achieve the organization/company targeted goals/objectives (Madsen *et al.* 2006; Fellows and Langston 1987). Authors suggested that RA can be used for these purposes which involves the use of information related to one or more variables to work out the predictions about another one; thus, this makes regression analysis a most powerful tool to be used in projecting and predicting future values of desired variable quantities.

Many researchers have argued that using MCS and regression methods can significantly increase the project estimation accuracy, because such models permits accurate estimation for longer forecasting periods (Fellows and Langston 1987). Consequently, efficient cost monitoring and control of building construction projects is truly facilitated by the application of regression methods. In particular, RA is an appropriate tool for developing practical and user-friendly models; therefore, the application of RA techniques was adopted for this present research.

Therefore, in this chapter a theoretical overview of RA based on open literature is presented. This includes the basic assumptions of regression and the theoretical limitations of the analysis, and

estimating the quality of RA. In particular, the influence of factors (causes of delay by a wide variety of sources) on the project cost is analyzed using RA methods.

5.2 Description of regression analysis

Farnum and Stanton (1989) described RA as a powerful numerical tool for prediction of the functional interrelations between a dependent variable (Y) and one or more independent variables (X1, X2, X3,.....,Xm). This is used to find out the best-fit representation for the relationship that is present in the data sample. However, the nature of this relationship may take several forms extending from simple to multiple regressions and from linear to non-linear relations.

In a simplified regression model, one independent variable (X) and another dependent variable (Y) are used. In contrast, the relationship between one dependent variable (Y) and a set of various independent variables (X1, X2, X3,.....,Xm) is dealt with in a multiple regression model. The following are the forms of the relationship between the dependent variable (Y) and independent variable(s) (X1, X2, X3,.....,Xm) that are divided into linear and non-linear.

1. Linear:

$$Y=BX+C \quad (5.1)$$

Where 'C' is the intercept and 'B' is the slope.

2. Logarithmic:

$$Y=B\ln X+C \text{ (5.2)}$$

Where 'C' and B are constants and 'ln' is the function of the natural logarithm.

5.3 RA relationships:

A relationship, or what is commonly called correlation, is defined as the degree of the affiliation between two or more variables, and this measure establishes the level to which values of the variables show linearity or proportionality to each other.

In regression analysis, correlation value is known as the correlation coefficient or coefficient of determination R, which describes the linear relationship between two variables. The value of the R is ± 1 , while its sign shows the direction of the relationship. The absolute value of the R represents the strength of the relationship; thus, the larger the value, the stronger the relationships between the related variables in the correlation matrix. In a case when R is squared, the resulting value is known as the coefficient of determination, i.e. R^2 .

The R^2 is measured as one criterion which is applied to assess the goodness of fit of a regression equation, and it shows the percentage of the variance in the dependent variable described by the independent variable(s).

In other words, it can also be understood as the proportionate decrease in error in approximating the dependent when the set of independents is known. The following equation is used to compute the value of R^2 :

$$R^2 = \left(1 - \frac{ESS}{TSS}\right) = \frac{RSS}{TSS}$$

(5.3)

To account for the independent variables (m) in the regression model and the sample size (n), an adjusted determination coefficient (R_{adj}) is usually calculated by using the following equation:

$$R_{adj}^2 = 1 - \left\{ (1 - R^2) \frac{n - 1}{n - m - 1} \right\}$$

(5.4)

The proportion of the variation is measured from R^2 in the dependent variable that was expressed by variations in the independent variables, whereas R_{adj}^2 determines the proportion of variance in the dependent variable that was expressed by variations in the independent variables (Gupta 2000). Moreover, in this regard, the following crucial points to be noted are:

i. When $R^2=0$, this means the data shows a poor fit with the regression model; this implies that the developed equation does not express any relation between the dependent and independent variable(s).

ii. In contrast, when $R^2=1$, this means the data shows a perfect fit to the model.

iii. General, it is known that the larger the value of R^2 , the better the model fits the data (Sincich 1996).

Moreover, the values of R^2 and R are not good enough to exhibit the acceptability of the overall relationship expressed by the regression line. In this connection, a test of importance that compares the expressed variance to the unexplained variance is needed; this test is obtained from the F-statistic which is defined in equations 5.5 to 5.6 in sub-section 5.4.2.

The calculated value of the F-statistic is matched up with the proper entry in a table of the F-statistic values in order to gain confidence-level data.

5.4 RA Value/or quality evaluation

The goal of RA is to express the variations in the forecasted dependent variable values by working out the best regression coefficient B_i values that can reduce the sum of the squares of these deviations. The aim of examining the quality of the regression is to find out how well the developed regression equation expresses the relationship between the dependent and independent variables. Similarly, the goal of regression in this study is to estimate the influence of causes of projects delay on cost overrun (see Chapter 8). In order to assess the regression quality, some of the following measures and diagnostic tests are used in the current research and described below.

5.4.1 Deviations in RA (ANOVA)

Several researchers have suggested using the model goodness of fit (ANOVA) to make sure that the developed model expresses the deviations in the dependent variable (Gupta 2000). The information generated from this test is used to confirm the significance of the generated model in

estimating the cost of overrun due to causes of projects delay. The contents of the measures taken in the analysis of variation in order to test the importance of a set of regression coefficients are shown in Table 5.1.

ANOVA					
Source	<i>DF</i>	Sum of Squares	Mean Squares (Variance)	F-statistic	Sig.
Regression	m	RSS	$MSR = \frac{SSR}{m}$	$F = \frac{MSR}{MSE}$	
Residuals	$n - m - 1$	ESS	$MSE = \frac{SSE}{n - k - 1}$		
Total	$n - 1$	TSS	--		

Table 5-1 Measure to Test Regression Coefficients

5.4.2 Fitting goodness test (F-test)

In cases where the regression equation is to be used for multiple regression, then the choice of the right one to use can be assessed by means of the F-statistic test, which can be calculated by using either of the following equations:

$$F = \frac{\frac{\sum(Y_i - \bar{Y})^2}{m - 1}}{\frac{\sum(\hat{Y} - Y_i)^2}{n - m}}$$

(5.5)

$$F = \frac{\frac{R^2}{m-1}}{\frac{(1-R)^2}{n-m}}$$

(5.6)

Where ‘m’ is the number of coefficients and ‘R²’ is the determination coefficient.

The significance of the R is obtained using the F-test which is the similar crucial testing as for R². Also, it is exactly the same test that was developed for assessment of the regression model as a whole.

Thus, the 'significance' of the model shows the model's goodness of fit and entails whether the model can be or cannot be approved to express a relationship between the dependent and independent variables.

Characteristically, if the obtained value of 'significance' is <0.01, then the model is said to work or be confident at 99%, and likewise, if the 'significance' value drops, i.e. <0.05, then the model is said to be significant at 95%.

Some researchers have mentioned that, if the 'significance' value is <0.10, then the model is not significant enough to fit the data or no reliable relationship can be obtained between the dependent and independent variables (Gupta 2000).

The fundamental principle is that the lower the obtained 'significance' value, the better the fitting goodness of the model and consequently the more able the model is to express the relationship between the dependent and independent variables.

5.4.3 Importance of variable relationships

The null and alternative hypothesis tests are used to assess the significance of the relationship between the dependent and independent variables as expressed by the following equations:

$$H_0 : B_1 = B_2 \dots \dots \dots = B_m = 0$$

(5.7)

$$H_1 : \text{At least one } B_i \neq 0$$

(5.8)

The null hypothesis (H0) indicates that there is no linear relationship between the dependent variable and the complete set of independent variables. In contrast, the alternative hypothesis (H1) confirms that at least one coefficient of regression is not equal to zero.

In general, these hypotheses can be verified by utilizing the F-test, as mentioned earlier in Table 5.1. Therefore, if the 'significance' is <0.05 , then the model is counted as being considerably better than would be expected by chance and thus the null hypothesis, which exhibits a non-linear relationship of the Y to the independent variables, is abandoned. Thus, this test is used in this study to determine the level of contribution that each cause of delay makes to the cost overrun.

5.4.4 Sum of squares evaluations

The following variation procedures are important in order to develop how well the independent variable(s) ($X_1, X_2, X_3, \dots, X_m$) forecast the dependent variable (Y) in a regression model to be used.

i. The Total Sum of Squares (TSS) is a measure of the overall deviations in the dependent variable Y_i values more or less from their mean $\bar{Y}$. It should be noted that the TSS does not take into consideration the effects of the independent variables X_i , and is determined by applying the following formula, (5.9) :

$$TSS = RSS + ESS \sum_{i=1}^n (\hat{Y}_i - \bar{Y}_i)^2$$

ii. The Expressed or Explained Sum of Squares (ESS) is the amount of the TSS that could be described by the model. It is highly attributable to parameters other than the relationship between Y_i and X_i , while ESS considers the effects of independent variable X_i that is assessed by using the following formula (5.10):

$$ESS = TSS - RSS \sum_{i=1}^n (\hat{Y}_i - \bar{Y}_i)^2$$

iii. Moreover, the Regression Sum of Squares (RSS) determines the decrease in variation owing to the influence of independent variable(s) and is known as the explained variation. Thus, this type of variation is attributable to the relationship between the dependent and independent variables Y_i and X_i , respectively, and is determined using the following expression (5.11):

$$RSS = TSS - ESS \sum_{i=1}^n (Y_i - \bar{Y}_1)^2$$

Where, $\bar{Y}_1$ is the original value of the dependent variable for the i th case, and Y_i is the regression forecast of the i th case as well.

Therefore, the variation measures RSS, TSS and ESS in the RA are also depicted in Fig (5-1):

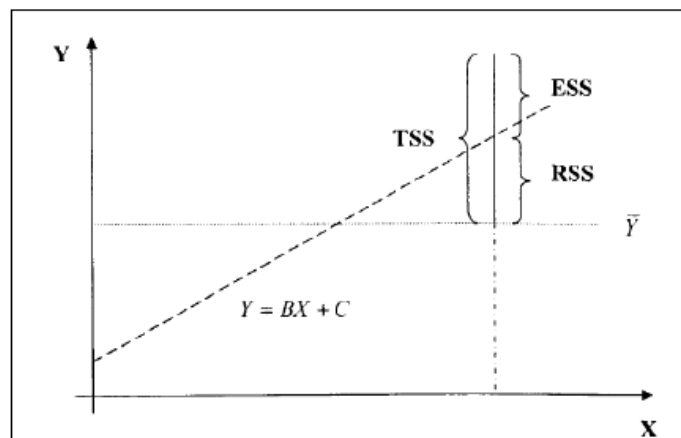


Figure (5-1): The measure of variations in regression

5.4.5 RA deviations and residuals

In the next sections, the simple and multiple regression expressions 5.22 and 5.23 respectively are the abstract models and exhibit *some* aspects of the reality, because it is not completely practical to establish a regression model that takes into account 100% of all aspects. Therefore, an error or

a residual term (e) is involved in the model to compensate for the fact that a regression model does not yield some parts of the real phenomenon or process.

Moreover, the residual value can also be described in terms of the deviation of a particular point from the graph or plot of regression line.

Therefore, both the simple and multiple regression expressions (5.12 and 5.13) can take the following forms with inclusion of the residual element:

$$(\hat{Y} = BX + C + e)$$

(5.12)

$$(\hat{Y} = B_1X_1 + B_2X_2 + \dots + B_mX_m + C + e)$$

(5.13)

Where Y is the actual value of the dependent variable and ‘ e ’ is the error owing to variables other than the independent one involved in the model. This means that, the more the independent variables are involved in the regression model, the smaller the error in the expected values of dependent variable Y .

Some researchers have cautioned against including several independent variables in the regression model, since it brings complexity and increased cost to the analysis (Madsen et al. 2006; Wheelwright 1984).

The standard of parsimony needs the inclusion of the smallest value of independent variables in the regression model and at the same time requires as small a range of error values (e) as possible.

The residuals were defined to be the difference between an i th observed value of a dependent variable Y_i and its corresponding fitted, actual value $\hat{Y}_i$ for the given independent variables $(B_1X_1+B_2X_2+\dots+B_mX_m)$ that were involved (Madsen et al. 2006).

$$e = (\hat{Y} - Y_i)$$

The limitations of the error (e) were identified, which must be met prior it beings safe to utilize the simple and multiple regression expressions having no error term in the format explained in equations 5.22 and 5.23; such restrictions are summarized in the following points (Wheelwright 1984):

- i. The error ‘ e ’ mean value must be equal to zero.
- ii. In order to smooth the consequences of the large number of variables that affect Y but are not placed in the regression equation, the residuals must be distributed.
- iii. In order to remove the possible autocorrelation, the residuals must be kept random and independent from one another.
- iv. Also, the variance of the residuals must be constant within the whole range of the achieved observations.

Moreover, the statistic required to examine the typical error of the estimate of the established regression model is known as the Standard Error of Estimate (SEE), and it determines the scattering of the dependent variables’ estimate around its mean and is computed using the following equation, 5.14:

$$SSE = \sqrt{\sum_{i=1}^n e_i^2 / (n - (m + 1))}$$

Where, ‘ n ’ denotes the number of observations in the sample data set, m is the value of independent variables involved in the regression expression, and ‘ e ’ is the elemental error value or residual.

The computed value of the *SEE* is matched to the mean of the forecasted values of the dependent variable(s). In the cases when the *SEE* value obtained is $> 10\%$ of the mean, then it is considered high.

The usefulness of the fitted regression model may be estimated by plotting the residuals against the X_i of the relevant descriptive variable. However, if the fitted model is an appropriate representation of the data, there will be no apparent relationship between the standardized residuals and the relevant independent variable. Thus, if such a condition is true, the homoscedasticity assumption is not desecrated or violated.

5.4.6 Effects of testing in rA (t-test)

Established models of simple and multiple regressions stipulate the most appropriate linear relationship required to produce a prediction of the Y values.

It should be noted that these expressions or equations do not, however, by themselves allow a manager to take confident decisions without answering questions about the significance of the regression equation itself and the calculated coefficients.

On the other hand, the involvement and the significance of each independent variable X_i can be estimated using the t-statistic test, which determines the null and alternative hypotheses about the population of the corresponding coefficients of regression B_i , which is described in the following equations, 5.15 and 5.16:

$H_0: B_i=0$ (showing that there is no relationship) (5.15)

$H_1: B_i \neq 0$ (showing that there is a relationship) (5.16)

The statistic required in assessing the significance of a regression coefficient, i.e. the 'Standard Error' of such a coefficient, SEB is computed by applying the following equation, 5.17:

$$SE_{B_i} = \frac{\sqrt{\frac{\sum(\hat{Y}_i - Y_i)^2}{(n-2)}}}{\sqrt{\sum(X_i - \bar{X})^2}}$$

(5.17)

Thus, the t-statistic can be computed by using the following equation, 5.18:

$$t = \frac{B_i}{SE_{B_i}}$$

(5.18)

Where:

B_i = Coefficient of regression of independent variable X_i

SE_{B_i} = Typical error of the regression coefficient B_i

The t-statistic tracks a t-distribution with $(n-m-1)$ degree of freedom (DF), where 'n' is the number of observations in the data sample, and 'm' is the value of independent variables involved in the RA.

To examine the involvement and the significance of an independent variable X_i in a multiple regression model, the null and alternative hypotheses of expressions 5.17 and 5.18 should be verified.

For a chosen level of significance and a certain degree of freedom a t-statistic is computed; the null hypothesis is then either approved or rejected accordingly.

The extent of confidence that can be kept in the regression coefficient B_i depends on the acquired 'significance value' of the forecast; the following points express the types of significance of the estimated B_i value or number:

- i. In the cases when the 'significance' value is < 0.05 , then the approximation of B_i can be anticipated to be true with a 95% confidence level.
- ii. In the cases when the 'significance' value is > 0.05 and < 0.10 , then the B_i estimate can be presumed to be true with a 90% confidence level.
- iii. In the cases when the 'significance' value is > 0.10 , then the B_i estimate is not reliable and is known to be insignificant statistically.

Moreover, the theory of an approach of developing confidence intervals provide a range of values within which the estimation of B_i coefficients with a certain confidence level is permitted.

Thus, a 95% confidence level interval would be the range within which a regression analyser or a project professional is 95% sure that the true value of the regression coefficient B_i will be determined.

Therefore, the foundation for creating the confidence interval for a specific estimate value is the standard error of forecast (SE_f) and can be computed by using the following expressions:

$$SE_f = \left(\sqrt{\frac{\sum(\hat{Y} - Y_1)^2}{n-2}} \right) \left(\sqrt{1 + \frac{1}{n} + \frac{(X_f - \bar{X})^2}{\sum(X_1 - \bar{X})^2}} \right) \quad (5.19)$$

The confidence interval for the estimate of B_i is given by:

$$B_i - 2(SE_f) \quad \text{to} \quad B_i + 2(SE_f) \quad (5.20)$$

Consequently, supposing the pattern of the estimate data remains the same at the prediction stage; therefore, the manager would be 95% sure actual values of the B_i projected values would lie within ± 2 standard errors from the predicted number.

Indeed, this is because equation 5.19 is a standard deviation of the regression plot multiplied by an adjustment that takes into account the sample size and the distance of the predictor variables from their mean numbers.

5.5 RA methods

In any RA, the initiation point is the assumption that a basic relationship is present between a predictor or independent variable(s) and a response or dependent variable (s). This relationship can be described in some functional ways. Therefore, with regard to this present study, the variation percentage of cost of the project can be assessed and modelled by a general input/output relation in the following form:

$$Y = f(X_1, X_2, X_3, \dots, X_m)$$

(5.21)

Where:

X is the foreseeable input characterized by the factor that influences the parameters (cost) affecting the project due to variation orders of construction projects,

Y is the response input characterized by the percentage of project-influencing parameters/experts survey-questionnaire (cost) because of a particular factor, X, or several factors, X to X_m, and

m is a number factor of 'X' that affects the 'Y' factors.

It is worth noting that the relation between input and output is examined by the RA tool, where the percentage of cost in a construction project is predicted as a system that is controlled by a set of effective factors or variables.

Indeed, if the complete set of independent factors (or variables) affecting the project cost is known at some point in time during the project construction phase, it should be possible to envisage the dependent variable/factors described represented by the percentage (cost, time, etc.) of the project. However, the nature of the numerical relationship between the independent and dependent variables can take either of the following two types:

5.5.1 Simplistic form of RA

The interpretation of the simple regression becomes easy when the supposed functional relationship takes into account one projected dependent variable and one independent variable, X. Thus, the simple regression formula takes the following form, as presented in (5.22):

$$Y = BX + C$$

Where B is the value of the regression coefficient which represents the amount the projected dependent variable Y changes (or variations) when the independent variable X changes by one degree or unit.

The coefficient B denotes the slope of the regression line; thus, the larger its value, the steeper the slope and the greater the likelihood of the predicted dependent variable changing (difference or variation) for each unit/degree change in the value of the independent variable.

On the other hand, the value of the regression constant C is obtained where the estimated regression line intercepts the y -axis in the graph plotted. Thus, this is the value that the expected dependent variable Y will be when the value of the independent variable is zero.

Once the values of (B) and (C) are obtained from a sample data of relevant values of X and Y , the factors can be utilised in equation 5.22 to calculate the Y values for any given values of the X .

5.5.2 Multiple form of RA

The multiple regression is similar to simple RA in principle; however, the methods of interpretation are different when the assumed functional relationship involves the relationship between one predicted dependent variable, Y , and a number of independent variables ($X_1, X_2, X_3, \dots, X_m$) that are influencing the Y outcome.

Moreover, the principles of simple regression are employed in multiple regressions to predict the Y values for various sets of the X values by the following equation, 5.23:

$$Y = B_1X_1 + B_2X_2 + \dots + B_mX_m + C$$

(5.23)

Where Y is the forecasted dependent variable, the B s are the corresponding coefficients of regression for the corresponding X variables (independent), and C is the regression intercept constant with the y -axis.

5.6 RA inadequacy and restriction

A best-fit regression line and equation can be used and calculated for any bivariate set of points, but, if the slope of the regression line needs to be verified if positive or if it needs to be applied to forecast an outcome, some crucial key assumptions or conditions must exist.

For the development of the multiple linear regression models, the following four basic regression assumptions were taken into consideration. These constraints can be verified by observing the residuals. It should be noted that the residual is the difference between an actual Y_i and a predicted value $\hat{Y}_i$ of an available dependent variable.

5.6.1 RA supposition 1: normality

It is mandatory to distribute the residuals normally; outliers (something that lies outside the main boundary) are key indicators that show that the distribution is not normal. Significantly larger data sets that include 100 or more observations tend to normality and RA can be sustained.

In order to find out if there is a problem, a second analysis is run without the outlier(s); if the output or result is similar to the first analysis, then the outliers are not considered a problem, and thus the actual analysis is presumed to be fine.

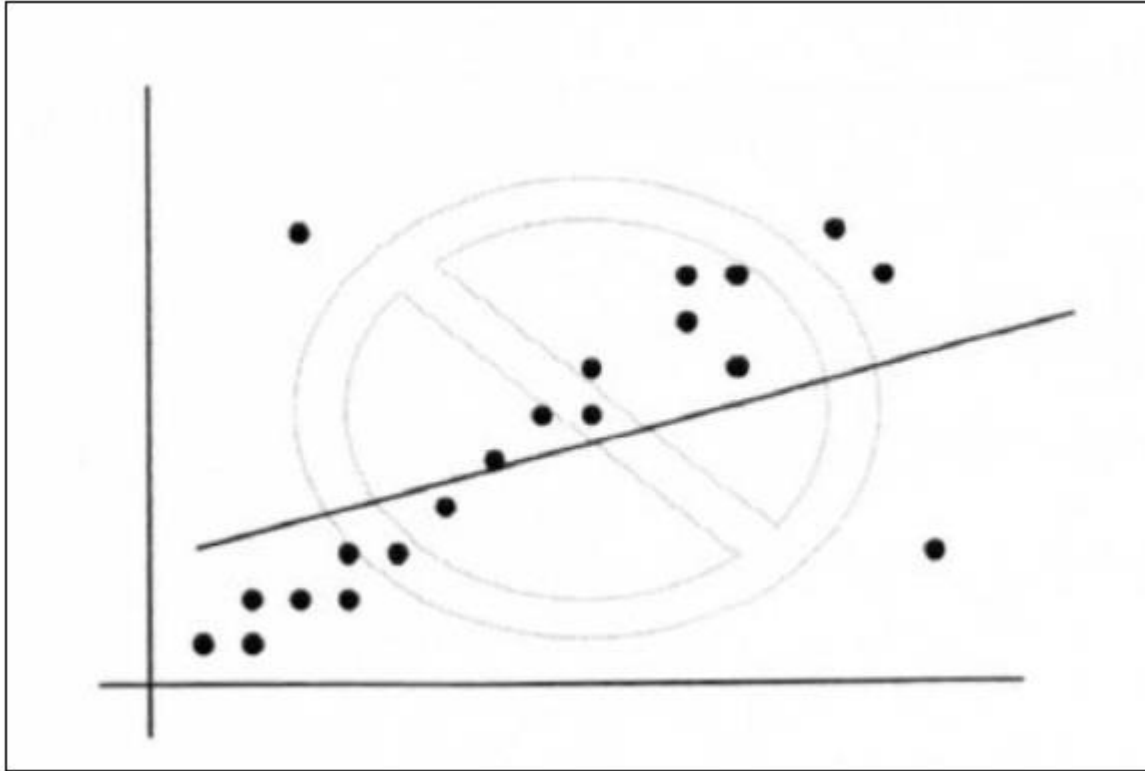


Figure 5-1: The regression assumption, i.e. normality

A typical property of the normal distribution (ND) is that 68% of all its observations lie within a range of a ± 1 standard deviation (SD) from the mean value, and a range of ± 2 SD includes 95% of the scores.

Also, ND observations that have a standardized value of < -2 or $> +2$ have a relative frequency of $\leq 5\%$.

The standardized values are defined as the numbers by which a value is described in terms of its difference from the mean value, divided by the estimated or calculated SD.

5.6.2 RA supposition 2: homoscedasticity

In this case, the assumptions need the residuals to be distributed randomly all over the range of the predicted dependent, or the residuals should have a constant variance: variation around the line of regression kept constant for entire values of X_i . It means that Y_i changes by the same degree or amount when X_i is a low value as when X_i is a high value. However, if data ‘fans-out’, the variance is not a constant number; in this situation, the Y variable should be changed and instead $\log(Y)$ is examined.

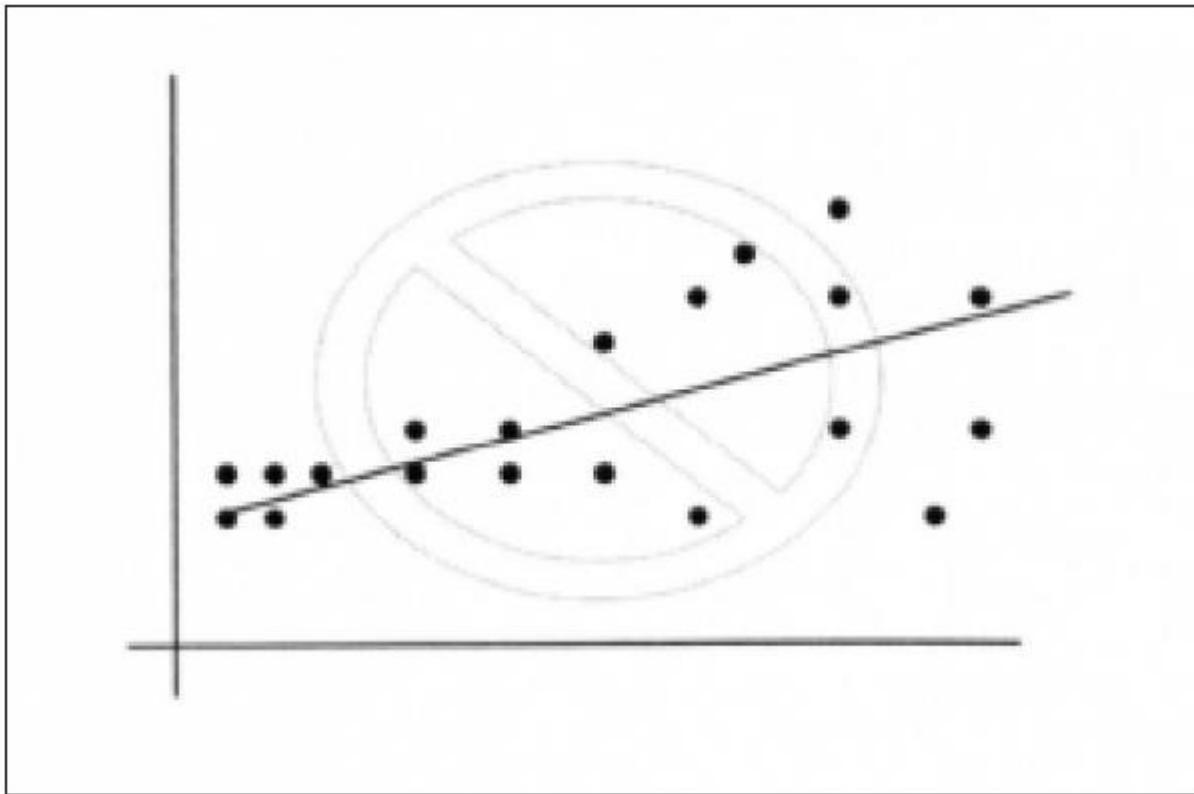


Figure 5-2: The RA assumption, i.e. homoscedasticity

Moreover, the outliers are a kind of violation of homoscedasticity, and they are handled or arranged by being removed from the assessment and described on a different basis. In contrast,

transformations including operations, for instance, logarithmic, inverse and the square root may be utilised to pull outliers in (see Fig. 5-2).

5.6.3 RA supposition 3: independence

It is necessary that the residuals should be independent of each other. Whilst it is not usually possible to observe lack of independence, a scatter graph is a good tool. If subsequent points (with respect to the x-axis) tend to be either above or below the regression line, the analysis should not be sustained (see Fig. 5-3).

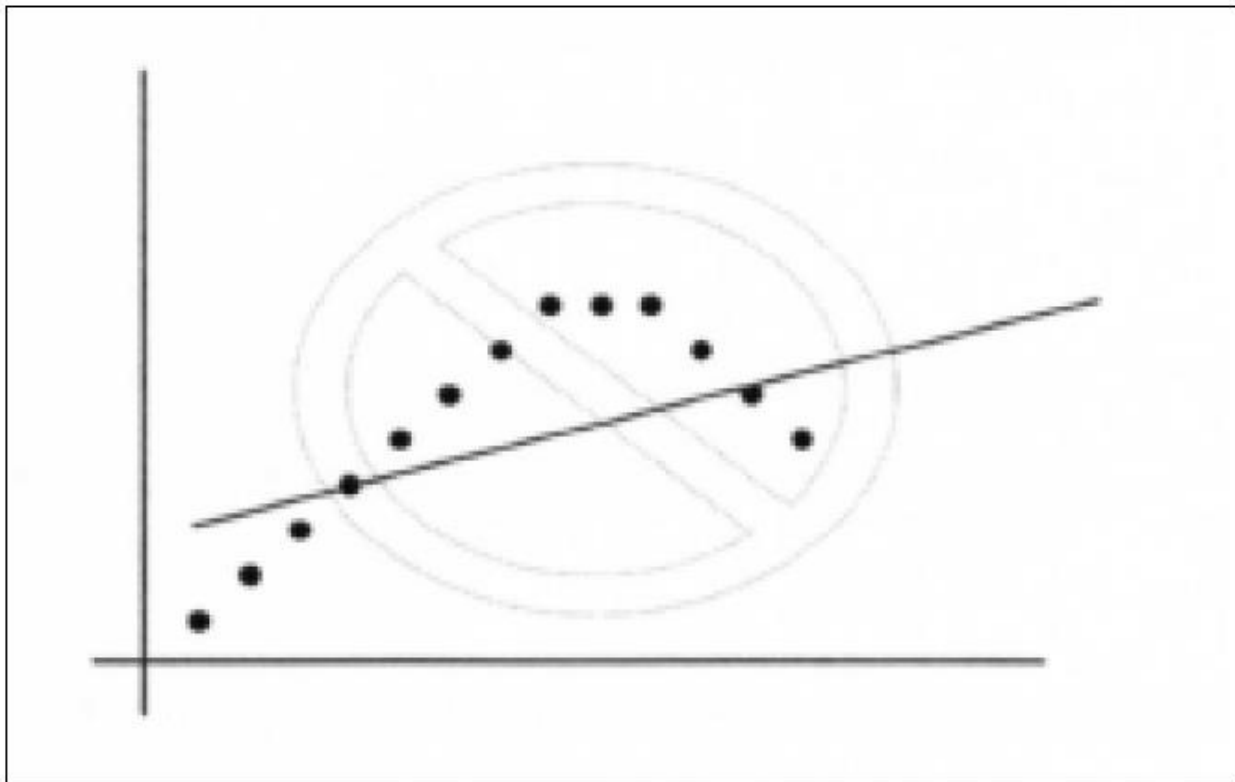


Figure 5-3: The RA assumption, i.e. independence.

The contravention of this supposition of RA exists when an autocorrelation effect takes place among subsequent residual observations.

5.6.4 RA supposition 4: linearity

In this case, the assumption needs the relationship between the dependent and independent variable(s) to be linear. However, some variables could be completely related in a non-linear fashion; in such a situation, a curvilinear model may be a better fit and should be assessed.

If data is clumped on one side of the plot, it should be probed effectively by regressing $\log Y$ vs $\log X$ (see Fig. 5-4).

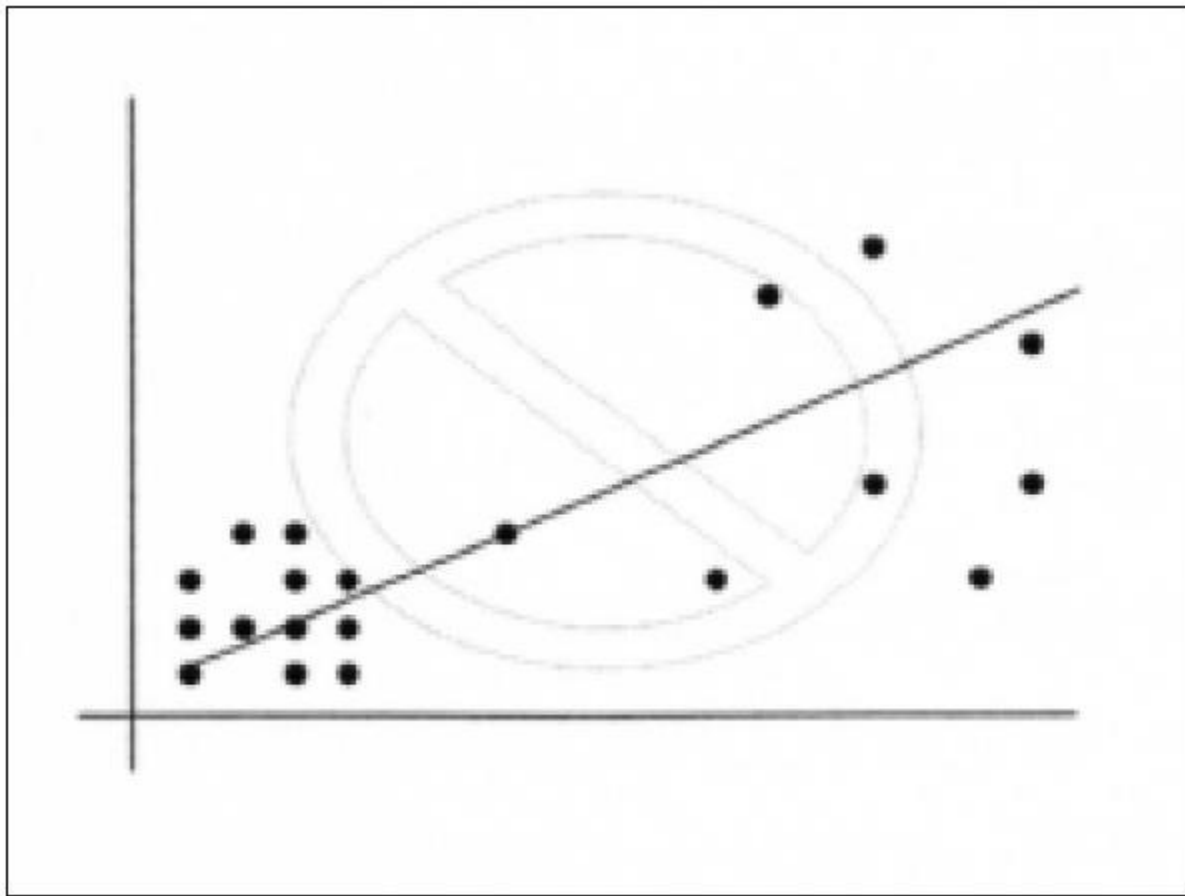


Figure 5-4: The RA assumption, i.e. linearity

Moreover, the transformations including logarithmic, square root and inverse ($x = 1/$) are occasionally used to force all variables into a normal distribution. Transformations correct or approve a positive skew distribution, whilst powers correct a negative skew distribution.

In general, non-linearity is not an issue of concern in the RA when the SD of the dependent variable is more than the SD of the residuals.

For RA, the following are the most important considerations that need to be accounted for precisely:

- i. RA is applied in situations when a relationship can be reasonably assumed or is known to exist between the variables to be modelled.
- ii. It is favored, although not mandatory, for the relationship between the variables to exhibit the linearity. In certain transformations, it may be used to solve problems of nonlinearity and uneven variances.

It is highly preferable to know the exact form of regression curve from theoretical consideration, because the analysis of the regression parameters C and B_i relies on the equation of the regression curve to be fitted.

Unprocessed values of C , B_i , and R^2 are not enough to enable a model to be confidently used for prediction; they have to pass some specific tests of desired importance.

- v. All predictor factor X_i whose relevant regression coefficients, B_i , are considerably different from zero should be involved in the regression model to minimize the residual error.

vi. It is important to allow periodic reviews of the fundamental relations between the regression parameters or variables to make sure that they have not altered. The model has to be amended accordingly whenever the relationships are observed to have changed.

5.7 Multiple regression in steps

Stepwise multiple regressions are the approaches utilized for calculation of a general least squares regression in stages. In stage one, the independent best correlated with the dependent is involved in the equation, whereas, in the second stage, the outstanding independent with the highest partial correlation with the dependent is involved in the equation.

Therefore, this process is continual, at each stage partialling for previously included independents, until the addition of a remaining independent does not raise the value of R^2 by a considerable amount or until all variables are included. Otherwise, the process can work backwards by beginning with all the independent variables involved in the regression expression, and then starting to remove one independent variable at a time until the removal of one makes a considerable difference to the value of R^2 .

5.8 The use of RA

The following sub-sections comprehensively summarize the practical use of RA (Wheelwright 1984).

5.8.1 Difficulties in design

This step involves defining the dependent variable(s) to be estimated and described, and the identification of the independent variable(s) influencing the dependent variable(s).

5.8.2 Economic choices and related indicators

Similar to the one described previously, this step includes the identification of those variables or factors that can perhaps affect the regression process and deciding on those that can reasonably be involved in the equation. This step depends on the acquired historical sample data as well as the data related to the future stages.

5.8.3 Initial testing of multiple regression

This includes the application of all the acquired sample information of the dependent and independent variable(s) to verify some regression equations in order to determine the results that can be acquired. A useful output of such verifications is the establishment of a simple correlation matrix.

5.8.4 Matrix of correlations' study

This step selects the variables to be involved in the regression expression or equation order to augment the forecast of the dependent variable(s). The choice of dependent variables whose simple correlations are not so close to ± 1 will help to escape the problem of multicollinearity. A useful result or output of this step is the establishment of a number of alternative regression expressions that can be verified further.

5.8.5 Decision making among individual regressions

In this step, the determination of the coefficients of the alternative regression expressions are made in step 4, and verifying the significance of each regression formula or expression, their regression coefficients, and their standard errors of prediction to examine the regression equation whose dependent variables have a more considerable impact on their dependent variable.

The correctness or confidence level of the selected regression formula can then be enhanced by increasing its R^2 value through the inclusion of additional dependent variables in a stepwise method.

5.8.6 RA assumption validity checks

This step utilises the Durbin-Watson test to examine the nature of the residuals for the selected equation(s) to test their satisfaction of the properties described in this section, and any regression formula that fails the Durbin-Watson test is not to be approved or trusted as a basis for predicting.

5.8.7 Forecast preparations

This step includes the chosen regression equation (that has a significantly high value of R^2), satisfies the assumptions of regression, and fulfils/meets the significance tests in order to determine predictions of the dependent variable.

5.8.8 Enhancing understanding by RA

This step involves the analysis of the predictions and the regression coefficients to illustrate the circumstances and allow a better understanding.

5.9 Complications in RA application

In the section, the main problems or difficulties associated with the application of the RA are described. In general, there are two most important issues in the application of regression analysis; these are known as:

- i. Autocorrelation and
- ii. Multicollinearity

5.9.1 Estimation of autocorrelation

This type of problem usually occurs when the residuals are not randomly distributed and follow a definite or systematic pattern. In contrast, if the residual values are drawn into plots and it is recognised that the residuals are not independent, the Durbin-Watson (D) factor can be utilized to verify the occurrence of autocorrelation.

The theoretical background of this test is obtained from the work of Madsen *et al.* (2006), who described it statistically in the following equation:

$$D = \frac{\sum_{i=1}^n (e_i - e_{i-1})^2}{\sum_{i=1}^n e_i^2} \quad (5.24)$$

Where,

n is the number or value of observations, and

e is the residual number or value at time t.

Because of the problem of acquiring the exact distribution of the D-statistic, Durbin and Watson discovered bounds that can be utilized as critical values.

The value of the Durbin-Watson D coefficient can vary between 0 and 4. A value of 2 shows no autocorrelation, whereas 0 describes the positive autocorrelation; finally, a value of 4 denotes negative autocorrelation.

In the cases when the calculated value of the D is between 1.5 and 2.5 then there is no autocorrelation and the regression model can be confidentially utilized for estimating, subject to it passing other verifications of significance. Therefore, the decision rule for the Durbin- Watson test is described in the following relation (Wheelwright 1984):

*If $(1.5 < D < 2.5)$ then the analyses are independent and the
regression expression is approved*

In the situations when autocorrelation is available, the generalized least squares estimation (GLS) is applied in the analysis rather than the customary ordinary least squares (OLS). In iteration (0) of (GLS), the estimated (OLS) residuals are applied to examine the error covariance matrix. At that point in iteration (1), (GLS) estimation decreases the sum of squares of the residuals weighted by the inverse of the sample covariance matrix.

5.9.2 Estimation of multicollinearity

Multicollinearity is defined as the intercorrelation of the independent variables, which is regarded as one of the major issues in the adoption of multiple regressions.

It has been mentioned by some authors that multicollinearity takes place when some of the independent variables are highly correlated with each other and, in such cases, the values of the regression coefficients for the correlated variables may vary drastically depending on which variable is involved in the model (Sincich 1996).

Moreover, the simple correlations can denote something about multicollinearity, but the desired method of determining multicollinearity is to regress each independent variable on all the other independent variables in the expression or formula.

5.9.2.1 Endurance

Tolerance is determined as $(1-R^2)$ for the regression of that independent variable on all the other independents, overlooking the dependent ones. Thus, there will be as many tolerance coefficients as there are independents.

It should be noted that, the higher the intercorrelation of the independents, the more the tolerance will tend to zero. In the cases when tolerance is < 0.20 , an issue with multicollinearity is specified. If the tolerance is near to zero, there is high multicollinearity of that variable with other independents and thus the B_i coefficients will not be stable. Moreover, the higher the multicollinearity, the lower the tolerance, and the greater the standard error of the regression coefficients.

This is because 'tolerance' is a fragment of the denominator in the formula for computing the confidence limits of the regression coefficients.

5.9.2.2 Inflation factor of variance (VIF)

A method for determining the collinearity by applying the variance inflationary factor (VIF), which is the reciprocal of the 'tolerance' and is calculated for each independent variable, can be shown by the following formula (Berenson & Levine 1996):

$$VIF_i = \frac{1}{1 - R_i^2}$$

(5.25)

Where (R_i) is the coefficient of multiple determination of the independent variable (X_i) with all other (X) variables.

Therefore, when VIF is high, there is high multicollinearity and variability of the B_i coefficients. The values of VIF that are appearing above 4 suggest a multicollinearity problem. In addition, if the computed VIF_i of the independent variable X_i roughly equals one, it is safe to presume that there is no correlation between the independent variables.

Some authors have noted that, if the computed VIF_i of the independent variable X_i surpasses 10, this shows that the correlation between this independent variable and the other independent variables is too big (Berenson & Levine 1996).

5.10 Application of RA in the construction industry

RA is extensively applied as a marketing research tool (Jain and Sigman 1996) and has been demonstrated to be valuable in many areas of construction management, for instance, the prediction of the duration of a construction project (Chan and Kumaraswamy 1999).

In particular, the application of RA to construction projects is investigated in this study; the following practical sequence steps were adopted:

- i. First, examining the project objectives: this includes budgeting, durations, etc., and performance models were used to examine the various sets of response and predictor variables related to each of the intended objectives.

ii. Clearly defining the relationships that exist between different variables and identifying those that needed to be either predicted or described.

iii. Taking decisions on the regression models to adopt from theoretical knowledge or via an initial graph or plot of relevant data from both past and present operations.

iv. Applying the approved tests to validate the chosen model.

v. Applying the validated models to determine the necessary forecasts.

Furthermore, the fundamental concepts of RA presented in this section were used on the acquired construction projects' data to exhibit the quantitative trends and relationships between utilization levels of the recognized independent factors and construction, cost outputs.

When such trends and relationships are calculated for the main operations at the start of a project, they can be applied to forecast the manner in which total budget, schedule and physical progress of the project will be influenced by present decisions, resource mixes or operational approaches. Thus, regression models could be adopted in construction projects to manage the overall programme and budget, and examine the future course of action for project progress, costs, etc.

In particular, the RA is an important when it is to be used on data from construction projects whose system processes, unlike manufacturing operations, have neither a uniform state nor repetitive cycles. However, this present research, which focuses more on the construction stage of projects, the cross-sectional trends of the data at different stages of a construction operation or project may

differ, which is a parameter that needs to be taken into consideration when using RA in construction projects.

To do so, there are two possible methods, as illustrated in the following bullet points:

- i. Creating from historical information, various sets of regression expressions for the stages (or control points) of construction operations, so the suitable set may be adopted to make clear and simple predictions.
- ii. Using a progress factor (p) taken from the construction budget or schedule (depends on whether time or cost is the subject of control) in the regression formula as presented below. The ‘ p ’ is simply the proportion (e.g. 80% = 0.80 in terms of either cost or duration) of the operation in a project that has been fulfilled to the stage at which the estimate was made.

$$Y = \frac{B_1X_1 + B_2X_2 + \dots + B_mX_m + C}{p}$$

Whilst the previously discussed methods may overcome the possible lack of repetitive cycles in construction data and smooth the lack of uniformity in the system process (by altering the ‘ p ’ value in relation to work progress), the reliability of the second approach can only be established through extensive empirical tests, which are beyond the scope of the present research.

5.11 Merits of RA

It has been demonstrated in the above sections that RA is a useful tool; in summary, the following are its merits or advantages:

- i. RA can be utilized with descriptive or underlying predictors as well as with time variables, thus facilitating predictions of the dependent variable to be made in a wider range of circumstances.
- ii. RA applies quite straightforward and simple statistical models to determine and measure relationships, and thus requires little knowledge of statistics.
- iii. In RA, the volume of data and amount of calculation needed is moderate in comparison to that needed by other statistical models. Hence, it is a relatively cheaper approach to apply for required computations.
- iv. Multiple RA enables a number of different relationships to be hypothesized and verified easily with the assistance of statistical computer software, for example, SPSS.

5.12 Justification for adopting regression analysis method

The author of this study decided to adopt the use of regression analysis due to its simplicity, ease of interpretation and reliability of identifying the causes of delay with significant impact on a target variable and is well established in the literature. In addition, regression analysis (RA) is a powerful numerical tool for prediction of the functional interrelations between a dependent variable (Y) and one or more independent variables ($X_1, X_2, X_3, \dots, X_m$) (Farnum and Stanton 1989). Moreover, having that ability of prediction based on historical data, will help the decision makers to make better decisions that will highly effect the business needs and requirements to achieve the organization/company targeted goals/objectives (Madsen *et al.* 2006; Fellows and Langston 1987). Authors suggested that RA can be used for these purposes which involves the use of information related to one or more variables to work out the predictions about another one. Other than the merits of RA highlighted above based on previous works, when many independent variables are

considered as is the case in this thesis, regression analysis provide an avenue for piece-wise selection of only the important variables without compromising the predicting power of the developed model. Also, with regression analysis, data transformations, normalization, polynomial fitting, etc can be employed to arrive at the best model. These justifications makes regression analysis the most powerful tool to be used in projecting and predicting future values of desired variable quantities.

5.13 Chapter summary

It was clearly noticed in this chapter that the future behavior of the system can be forecasted using RA as an explanatory tool that can be applied to recognize the system trends and relationships between wide varieties of components in a system so that the potential behavior of any system can be predicted.

Adoption of the characteristic regression framework allows the problems of cost and duration progress in construction projects to be monitored, in order to exhibit quantitatively the trends and relationships between utilization levels of construction cost outputs. This shows that RA can be adopted in the oil fields construction industry to facilitate efforts in monitoring the projects delay and, in particular, control of petroleum construction projects during construction. This can be achieved by administering the overall programme and budget, and pre-determining the future course of their progress by estimating the manner in which they would be influenced by the recognized affecting factors.

Moreover, approaches to formulating and answering the problems using regression models have been outlined along with essential regression assumptions, thoughts, and derivations of the least squares equations, determining variations in RA, evaluating the suitability of the fitted model, determining autocorrelation and working out multicollinearity.

Chapter 6: An Overview of Monte Carlo Simulation and Sensitivity Analysis

6.1 Introduction

In this chapter, theoretical background on Monte Carlo simulation, its fundamental terminologies, description, process and commonly encountered probability distributions are presented to form a basis for the understanding of the work presented in this thesis. Also, presented in this chapter is the justification of the use of Monte Carlo simulation in the context of this thesis and based on existing literature.

This chapter will illustrate the conceptual background of the Monte Carlo Simulation (MCS) and sensitivity analysis, which were used to process the information and data collected in this research. There is a large volume of published studies describing MCS, which has been an essential tool and remains instrumental in management science. Authors defined MCS in different ways depending on the use of researches/systems, however, the majority of them agree on the concept of using MCS to optimize/improve the decision making process based on highly accurate estimation of results/outcomes. Banks, J. *et al.*(2001);Gheorghe 2012; defined MCS as "imitation of the functionality of a process/system from the real world over time" while Schiefer, J *et al.*(2007) defined this concept in other way as "a computer experiment using a simplified model of an operating system in the framework of its evolution over time aimed at better understanding and improving it."

6.2 Monte Carlo simulation terminology

In this section, it is imperative to understand the fundamental terminology or definition of MCS; although it has been in existence for several decades, it is only currently that a wide variety of

practitioners have shown a renewed interest in the subject, in particular for risk analyses applications (Nichols 1994; Whitford 1997).

At first, the term 'Monte Carlo' was taken from the city name of Monaco which is renowned for its casinos, which are its main attractions; these casinos run 'probability-based' games, e.g. roulette wheels, slot machines and dice.

Likewise, MCS techniques randomly choose values to generate situations of a modelled problem. The computer software collects these values from within a fixed range of numbers which are chosen to fit a probability distribution such as the very well-recognized 'bell curve' or a linear distribution, for instance, or other type of probability distribution. A random value is selected each time by the computer software during the simulation process, a new situation is developed and an answer or explanation to the modelled problem is generated.

Moreover, MCS is a sort of spreadsheet simulation that adopts a stochastic method to answer mathematical problems. The word 'stochastic' means that it uses random values or numbers and probability statistics to acquire forecasts, or, as is illustrated in some research works, stochastic processes are the methods that run over a time in a probabilistic means (Abraham and Wirahadikusumah 1999).

It has been pointed out that simulation models are logical explanations of the interrelationships among the components of a decision problem (Evans 2000). It should be noted that the word 'simulation' is applied to any analytical method meant to imitate a real-life situation; thereafter, it facilitates a better understanding of the outcome or product, etc., to be designed.

Moreover, it has been further demonstrated that simulation methods are applied especially in situations when other analyses are mathematically complex or too difficult to execute (Evans 2000).

6.3 Description of MCS operation

According to Evans (2000) understanding the following steps are important in developing MCS model:

Formulating the Problem: in order to have a robust simulation study, in this step it is important to have a systematic performance that is very well measured, verified and evaluated.

Developing a Logical Model: To execute the simulation model on spreadsheet, this step will define the key events and actions that will occur in the system.

Specifying Probabilistic Assumptions: the probabilistic assumptions are required to run the simulation model. This can be achieved by assigning probability distributions of the input variables.

Implementing the Model: This step include a computer application that will execute/implement all essential calculations in order to examine the distribution of the model's output data.

Additionally, probability distribution functions can describe the values for all the uncertain variables in the spreadsheets. Thus, the chosen probability distribution is dependent on the conditions of the involved variables; these distribution types are illustrated in section 6.5.

6.4 Main components of the MCS process

According to (Gheorghe 2012), most of the Monte Carlo applications consists of major basis, which are main elements of MCS techniques, described as following:

Probability Distribution Functions: Probability distributions are used to express the uncertainties in the variables involved in the spreadsheet model.

Random Number Generator: This deals with the accessibility of a source for generating samples of random values for the uncertain variables involved in the spreadsheet model in order to predict the result.

Sampling Rule: This deals with a prescription of sampling random values from the particular probability distributions for each uncertain variable involved in the spreadsheet form.

Scoring/or Tallying: The results of the random trials or samplings are gathered into overall tallies in a suitable manner to create the intended desired results.

Error Estimation: The error estimation is applied to obtain a forecast of the statistical error (variance) as a function of the number of tests to facilitate the decisions on the desired best-fitted distribution to the actual forecasted data or results.

Moreover, a better understanding of these aforementioned main components of MCS techniques and their correct application enables a good basis to be made in order to construct a range of Monte Carlo techniques.

6.5 Probability distribution functions

The proper statistical name for a frequency distribution created from a set of values is a probability distribution. In each distribution function, a different type of probability distribution is illustrated, whilst the easiest functions are those that take opinions stipulating the minimum, most likely or maximum possible value for the uncertain input variables, such as the ‘UNIFORM’ or the ‘TRIANGULAR’ distribution functions. Reasonably complex distribution functions incorporate arguments relevant to the distribution, for example, the ‘BETA’ distribution function.

In the following tasks, these distribution functions are used:

- 1) Describing probability distributions
- 2) Describing simulation outputs
- 3) Applying recurring simulation results to the spreadsheet

After literature review, it was noted that there is no rule of thumb of which is the best method of selecting a probability distribution that best fit data.

It should be remembered that the process of choosing a probability distribution can occasionally present difficulties to the modelling professional. This is because there is no definite procedure in the literature that has been demonstrated to be the precise method for conveying the correct distribution to fit data.

However, it is helpful to know that the software used to perform MCS in this study, @Risk, can automatically empower the correct choice of distribution for a set of given data. Nevertheless, a labour-intensive methodology of choosing the best-fit distribution for a specific data set is suggested by some authors (Flanagan and Norman 1993).

The following are the steps involved in such a conventional/manual approach to select an appropriate distribution for a data set:

- i. Listing the entire data known about the variable and the limits encompassing them.
- ii. Developing an understanding of the fundamental types of probability distribution(s) and functions.
- iii. Selecting the distribution that best illustrates the variable under observation.

This precise conceptual method seems to underestimate the skill and perception needed in modelling the correct and accurate distributions, which needs a wide range of techniques.

The most common types of probability distribution functions used at this research modelling in cost modelling, and parameter descriptions about both the required and optional arguments are described for each function type in the format used in @Risk in the following sub-sections.

6.5.1 Weibull distribution

The argument Risk Weibull(alpha, beta) creates a Weibull distribution in @Risk with the shape parameter 'alpha' (a) and a scale parameter 'beta' (b), where the parameter values 'alpha and beta' must be greater than a zero.

The Weibull distribution is a nonstop distribution, whose shape and scale differ significantly, which depends on the input argument values. The Weibull distribution is important to investigations that are related to life cycles, life expectancy, deterioration of elements and future forecasting. Some authors have mentioned that the Weibull distribution was documented as the most appropriate distribution for the simulation of the cost of electricity predictions in the health sector, e.g. hospital buildings (Kirkham *et al.* 2002).

This distribution is known to be a part of a group of distributions that presume the properties of several other distributions. For instance, in addition to others, it can be applied to model the exponential and Rayleigh distributions.

The parameters defined in the argument term of the distribution function command the form that the distribution gains. For example, when the value of the shape parameter is equal to a 1.00, then the Weibull distribution is equal to the exponential distribution, in this case.

6.5.2 Extreme value distribution

The argument RiskExtValue(a,b) stipulates an extreme value distribution in @Risk with location parameter 'a' and shape parameter 'b', where the value of 'b' ought to be greater than a zero.

The extreme value distributions are frequently applied to model the minimum or maximum value among a large set of independent, evenly distributed random values presenting the measurements.

In extreme value distribution which is when skewed to the left and its common shape remains the same for all parameter values. The locality parameter ‘a’ shifts the distribution along the real line, and the scale parameter ‘b’ enlarges or shrinks the distribution (Gheorghe 2012).

The extreme value distribution is frequently applied to model extreme happenings, such as flood size, maxima of stock market indices over a given year and gust velocities encountered by airplanes. In addition, it is also frequently applied in reliability verification, for instance, in order to present the distribution of failure times for electric circuits, as mentioned in previous studies by Hahn and Shapiro (1967).

6.5.3 Log-logistic distribution

The argument RiskLoglogistic(gamma, beta, alpha) stipulates a log-logistic distribution in @Risk with location parameter ‘gamma’, shape parameter ‘alpha’ and scale parameter ‘beta’; the values of alpha and beta ought to be greater than a zero.

The loglogistic distribution was demonstrated to be a suitable tool for modelling the risk of decompression sickness (DeS) caused during high-altitude flights or extravehicular activities in space (Kannan *et al.* 1998).

6.5.4 Exponential distribution

The argument RiskExpon(beta) stipulates an exponential distribution in @Risk with an input of a beta value that is equal to the mean of the distribution.

It should be noted that the exponential distribution is interrelated to the discrete distribution, Poisson. Its application principally lies in the modelling of random points in time (Kulkarni and

Horn 1995). For instance, the distribution could be utilized to model the probabilities that the structure of a building may fail at a certain extent.

Moreover, the exponential distribution unveils a special characteristic which some call ‘memoryless’, which means that time does not affect the future events.

6.6 Limitations of MCS

MCS is a probabilistic technique that is a widely accepted tool by building construction professionals owing to its simplicity or its straightforward means of probabilistic cost forecasting and risk analysis. Nonetheless, it has been observed that all simulation techniques in general and MCS in particular have not been extensively applied in the construction business for construction risk management (Akintoye *et al.* 1998, Akintoye and MacLeod 1997).

Indeed, the authors described various reasons for the limited application of the MCS by construction professionals (Akintoye *et al.* 1998, Akintoye and MacLeod 1997):

- i) Inadequate knowledge of the simulation procedures.
- ii) Time constraints and lack of data and knowledge.
- iii) Uncertainties regarding the adoption of these simulation techniques.
- iv) A significant need to have knowledge and trustworthy project data to ensure confidence in the output results.
- v) Some construction projects are not outsized or bulky enough to permit the use of these techniques.
- vi) A large number of the risks are contractual; hence, they are usually better managed by using experience gained from prior projects.

vii) A degree of sophistication is present in these techniques which does not permit precise knowledge of the project's performance.

viii) Also, there is a direct need to establish the statistical distributions for a variety of cost components involving their arithmetic means and standard deviations, which is yet to be developed precisely.

6.7 Justification for adopting Monte Carlo simulation method

The author of this study decided to use Monte Carlo simulation (MCS) for the stochastic modelling due to its ability to provide an understanding of the probability distribution of each cause of project delay, and consequently allows the evaluation of risk associated with project cost overrun as a result of a changes in the dependent variables. Also, MCS gives not just the result of what can happen but also the likelihood of each outcome but provides secondary results such as the sensitivity analysis of the target variable to each of the input distributions. By evaluating the sensitivity of project success outcomes based on the foreseen causes of projects delay, impact of causes of project delays on cost overrun can be determined. Also, through scenario analysis dominant risk factors can be identified. Moreover, some published studies described Monte Carlo simulation (MCS), an essential tool and remains instrumental in management science and modelling delay analysis in constructions projects (Hossen *et al.*2015) . Another reason to adopt MCS is that it is proved as good method to optimize/improve the decision making process based on highly accurate estimation of results/outcomes (Banks, J. *et al.*2001;Gheorghe 2012; Pham and Hadikusumo 2014). Finally, consistency of the results obtained via Monte Carlo simulation helps to justify accuracy of the regression model developed in this thesis

6.8 Chapter summary

This chapter present the related concepts Monte Carlo simulation (MCS) applied in the present study due to the importance of MCS knowledge of how to numerically assess the influence of projects delay on the cost of construction projects in the oil fields industry. Chapter 8 will provide more details on practical applied approaches of RA and MCS, which are based on these theoretical concepts.

Chapter 7: Research Design and Methodology

7.1 Introduction

This chapter details the design and methodology of this research. The objectives of this chapter are to justify the research strategies and methods related to data collection and analysis. It is based on this chapter where the researcher select and justify the type of data needed for this research, methods , ways, procedures used for collection of data, and tools or methods used to analyze data.

A large and growing body of literature has investigated the research design and methodology in the social science. According to Saunders *et al.* (2009), most of the authors noted that the researcher has to justify the reasons for undertaking the research, which is a systematic process that someone undertakes in order to find out something about an issue or problems of concern to themselves. As highlighted by Easterby-Smith *et al.* (2004), the researcher has to make sure that a clear research design can be created by relaying on systemized process of research which will help the researcher to determine his/her philosophical positioning on the research.

In this research, the main issue has been to establish a mechanism (or model) that could produce tangible results regarding how to undertake an analysis of causes and factors of delay in construction of oil fields projects, and their impacts on projects success criteria. However, before collecting primary information about project successes , it was visualized that a research design had to be developed so that the research could improve the available sources of information. Therefore, this chapter undertakes a theoretical approach to research in general starting with an

explanation of the research philosophy, research methodology and research methods as well as a justification for the selected philosophy, research methodology and research methods.

Previous studies have primarily concentrated on using a questionnaire survey to address the issue of projects delay from different points of view (Arditi et al. 1985; Alsharif & Karatas 2016; Alzara et al. 2016; Assaf & Al-Hejji 2006; A Elawi et al. 2016; El-Razek et al. 2008; Faridi & El-Sayegh 2006; Hossen et al. 2015; Ibironke et al. 2013; Koushki et al. 2005; Marzouk & El-Rasas 2014; Odeh & Battaineh 2002; Samarghandi, et al. 2016; Sambasivan & soon 2007; Sweis et al. 2008; Yau & Yang 2012; Alaghbari et al. 2007).

That is why this research will adopt this method which falls in line with the quantitative research methodology (Bryman & Bell 2011), and which in turn aligns with the use of both positivism and interpretivism as the guiding research philosophy. According to the above literature review, the author of this research decided to use a questionnaire survey as primary data collection from the experts who worked on case studies projects, as well as historical records of case studies as secondary data for this research.

7.1.1 Description of research ethics

As highlighted by Meltzoff 2008, it is essential for every research to consider the ethical issues throughout the research process starting from the planning and designing phase of the research, asking and in dealing with the participants, analysing and reporting the data, and finally presenting the research results.

Therefore, the researcher of this thesis considered ethical issues in this research by taking into consideration confidentiality and privacy of research participants who are protected by remains

completely anonymous. Another ethical issue was considered during the analysis of the data, by selecting the most appropriate statistical test rather than one that is less suitable but appears to yield more favourable results (Meltzoff, 2008). Moreover, the research avoided the transgression in data processing by considering the assumptions of statistical techniques and tests used in data processing and analysis such as normality and homogeneity of variance and other well-known techniques to improve the validity and efficiency of data collection, analysis and results. More details in chapter 8.

7.2 Consideration for the ideal philosophy for this research

Easterby-Smith *et al.* (2004) has demonstrated that the researcher has to define his/her research philosophy before conducting the research and this will help to make better decision when choosing the research design, data collection approaches and will develop self-esteem in the collected data for the research.

Another study by Saunders *et al.* (2009) noted that researcher's decision on selecting the ideal research design and data collection approaches is determined by their views and understanding of research concepts and knowledge and how these two interchange in order to solve the natural curiosity that human beings possess.

Numerous studies have attempted to explain that researchers can save a lot of time and resources doing their studies by reviewing the available research philosophies and methodologies that they can use to conduct their research and this will reduce the possibility of adopting a research approach that might not add value to the research process (Easterby-Smith *et al.* 2002; Bryman

and Bell 2011; Bryant 1985; May 2011). For this research, four main philosophical approaches might have been applicable: (1) positivism, (2) empiricism, (3) realism and (4) interpretivism.

7.2.1 Positivism

Bryant (1985) and May (2011) summarized that positivism is the believe and understanding of things around us in terms of natural science. May (2011) noted that researches are not considered valid and effective if they are not tested and investigated as per the basics and rules of business research.

Bryman and Bell (2011) and May (2011) proposed that positivism is a philosophy that promotes a deep understanding of a phenomenon by conducting a detailed research of an issue or problems which helps clarify more information on possible solutions or clear understanding of the complexity of the situations that creates the problems. This means that researchers can dig into details by investigating the current issue using different tools and techniques to test, observe or predict the real causes of making the issue or problems. According to May (2011), unless the research contents and results are governed by scientific research rules and procedures, the whole research work is not considered trustworthy.

From literature review above, the author noted that this philosophy is important for researcher whose aim is to analyze projects delay in oil fields construction projects and their impacts on projects success criteria. However, not all the information needed to deal with such an analysis can be obtained if a researcher takes a positivist philosophy only. Causes of project delay are not the only situations that need objective data, there are also issues of subjective influence of the data; hence the reliance on positivism alone may not be ideal for this research.

7.2.2 Empiricism

According to Bryman and Bell (2011), empiricism is a philosophy that depend on the information and tested knowledge that generated by experience. According to the former authors, this philosophy allows researchers who are not able to answers research questions from the literature to depend on the physical evidences that is not available by social science. This is what Frege (2005) explained further that empiricism is more of observations and experimentation of data analysis that depends on the evidence of understanding the process of something from simplicity to complexity.

According to May (2011) who is similarly adding to what above authors explained, that empiricism is a philosophy which depends on the reality and experience, this is how the analysed data of the research related to the researcher who figured it out.

Many researchers have argued that the main difference between positivism and empiricism is that positivism is a theory driven philosophy where the researcher conduct his/her research using current theory or develop new theory by collecting the required data to support the selected theory, while the empiricism philosophy is totally different as it's not theory based and the research data can be collected without depending on any theory (May, 2011; Bryman and Bell, 2011 ;Bulmer 1982).The similarity between positivism and empiricism is that they both need objectivity whereby the researcher can detach themselves from the social world where they are researching by ensuring that they are independent of the data and that the analysis is devoid of personal opinion (May, 2011). This is why empiricism tends to be achieved through experiments (Bulmer 1982); the result being that the results need no fashion when presenting them (Marsden 1982). As a result, empiricism removes any form of flamboyance and superficial elements (Bhaskar 1989); rather, it concentrates on substance, which can be useful to reason with (May 2011). For this research, the

process of assessing the perceptions of the impact of projects delay on construction projects in the oil fields industry with a particular focus on cost of the project could do with empiricism; however, there has been a theory set for the issue, which was developed using a literature review. This means the data to be obtained will be based on the literature review that was cardinal in setting the theory; hence, the philosophy of empiricism has been seen as inappropriate for this research.

7.2.3 Realism

According to Saunders *et al.* (2009), realism is a philosophy that depends on the believe that researchers are social experimenters who analyses the conditions of the phenomena based on their related knowledge so they can find out answers for their questions from a realistic point of view. This implies that the way the researcher behaves and the way they treat a social issue can be linked to their basic knowledge (Bhaskar 1989); making them realistic about the research.

May (2011) observed that when researchers considered the philosophy of positivism, they don't start their research works until they make sure that the issue or problems of the research are valid and deserves the research efforts, otherwise, their researches will be considered faulty. The same author further explained that realism allows researchers who have concrete experience independently deliver a solid solutions on the issue of the research by referring to their realization and experience. According to Bhaskar (1989), it is possible to use empirical realism if the researcher has empirical data appropriate for the research, or critical empiricism if there is an element of precision with regard to the knowledge supporting realism. Because of the need to have a deeper knowledge about the subject matter in order to form a basis for realism, it was seen to be inappropriate for this research because the knowledge needed would be too vast and specialised to apply realism realist philosophy to the full. Therefore, this philosophy would not be ideal for examining the impact of projects delay in oil fields construction industry.

7.2.4 Interpretivism

According to Bryman and Bell (2011), interpretivism is a philosophy that allows researchers to work with people who are effected by or effecting the research data and observing how the collected data being realized by people which might influence the overall outcome of the research.

Therefore, there is an element of belief that interpretivism does not only promote a review of the data like a natural science would do; rather, the researcher allows for the influence of the people that may occur in the research process. The researcher needs to provide leadership regarding the data required for the research as well as how to analyses the data, with a high likelihood that the researcher would have to unravel the human relations as social entities of the society (May 2011). Bryman and Bell (2011) opined that the nature of interpretivism is that it can allow the researcher to analyse the theory or literature and collect data so that it can be analysed in a more transparent manner. Interpretivism is therefore essential if the researcher needs to gather deeper meaning from respondents without being restricted to a single form of data.

7.2.5 Justification for adopting positivism and interpretivism

For the research to gather data necessary for modelling the causes and impact of projects delay factors on construction oil fields projects, it can be argued that there is a need to use both positivism and interpretivism. As illustrated from the literature review above, the philosophy of positivism would allow for objectivity in the development of the theory for the research; therefore, the data obtainable from the research based on positivism would largely be quantitative, and this could be useful in the current research. Secondly, there is a need for explanation of the results (Saunders *et al.* 2009); in such a case, a more interpretivist philosophical stance is needed in order to extract deeper meanings of the phenomena causing projects time overrun. Interpretivism is necessary to which could be useful in explaining the meaning behind the data.

7.3 Philosophy of knowledge

Researchers can have varied levels of belief about how valuable knowledge is and eventually this could affect how the process of knowledge creation and addition could be interpreted (Saunders *et al.* 2009; Bryman and Bell 2011). Therefore, the three philosophies of knowledge need clarification before the approach to the research can be examined.

7.3.1 Epistemology

According to the Wikipedia online dictionary, epistemology addresses such questions as "What makes justified beliefs justified?"; in like manner, Bryman and Bell (2011) noted that any issue relating to epistemology refers to the way the knowledge has been considered as an acceptable issue or not. If the knowledge is based on assumptions, then there is a possibility of evaluating the level of credibility that could be attached to it (Taylor *et al.* 2009). It implies that, where knowledge is concerned, the way in which it is developed would require a rigorous engagement with various subject matters and the ability to use data in order to arrive at a consensus so that the information can be considered as knowledge (Bryman and Bell 2011). Therefore, the value of epistemology in this research lies in the way the knowledge creation has been systematized in order to allow for the integration of methodological approaches with a view to accommodating various epistemological positions a researcher could take (Bryman and Bell 2011).

7.3.2 Ontology

The philosophy of ontology concentrates on the researcher's view of the nature of existence knowledge within social entities (Bryman 2012). How a person understands what exists and the nature of existence can have a profound impact on their perception of knowledge creation and/or the nature of structuring the knowledge-creation process (Crotty 1998; Healy and Perry 2000). If

the researcher has a solid base in objectivism or subjectivism, they could design their research process based on the ontological standing that they have adopted (Saunders *et al.* 2009). This could eventually lead to the way the researcher designs the research itself (Creswell & Plano-Clark 2007). By examining what it means to exist, researchers are delving into deeper ways of understanding the importance of the knowledge being sought so that they can design how best to respond or deal with that knowledge. This is an important philosophy in this research because it highlights the need to understand the existence of cost and factors that are external to the business or the consultants as they deal with causes of projects delay in the oil fields construction industry.

7.3.3 Axiology

According to Saunders *et al.* (2009), every researcher has values of their own, and these values could influence the way they conduct their research. Axiology is a philosophy that assesses the role of the researcher's values as they conduct the research (Smith and Thomas 1998); things like ethics and personal values would influence the decisions made in the research process as well as how the data or results can be interpreted by the researcher (Somek and Lewin 2005). If the individual has personal values that contradict the results of the research, it could be difficult for them to bring out conclusive evidence, as the data would demand (Klenke 2008). For this research, the process of identifying and modelling the factors influencing projects delay is vital to the construction industry of oil fields; therefore, the philosophy of axiology is vital in the sense that it allows the research to be conducted in such a way that it can be devoid of the influence of personal values.

7.4 Approaches to reasoning behind the research process

Saunders *et al.* (2009) noted that the approach to the research is also determined by the way a researcher reasons about it. This means that, if the researchers develop a process before they undertake the research, the results would have to be assessed against the theory (Bryman and Bell 2011). Similarly, if the researcher has no theory from the onset and relies heavily on the information gathered prior to development of a theory, then the researcher would have adopted a different approach to reasoning (Bryman and Bell 2011); the full details are herein explained in 7.4.1 and 7.4.2.

7.4.1 Inductive theory of reasoning

Bryman and Bell (2011) described inductive theory that researchers can develop theories from their observations on research topics on unknown direction of thinking and assumptions. Bryman and Bell (2011) further argued that if the researchers have a topic in mind they can explore it, and then develop a theoretical explanation of the topic after they have collected data and analysed it.

The conclusions from such a process are based on inferences that can be deduced from the observations. While inductive reasoning is ideal in some research projects (Saunders *et al.* 2009), it could be difficult to apply in the current research on the causes of projects delay on oil fields construction projects with a particular view of cost of the project. It would imply that the research had been started by observation only, and that issues of projects delay in the industry were only stumbled upon. This would then have meant that the researcher had to deal with issues of projects delay in an unknown direction of argument. In such a case, it could be possible to agree with Bryman and Bell (2011), who noted that inductive reasoning is not an easy way to conduct research, and that if the research is qualitative in nature it can become more difficult to handle the

data. Therefore, this approach to the research has been discounted because it does not apply to the situation. It could equally delay the research process because the focus would not have been made clear from the onset.

7.4.2 Deductive theory of reasoning

Saunders *et al.* (2009) identified that deductive is the opposite of inductive reasoning in the research process. Bryman and Bell (2011) explained that this approach of research is meant to begin with a research theory that set a border for the research topic and then depends on the researcher's observation of topic under research which can later outline the final results and conclusion. Therefore, researchers could use their curiosity to develop a theory of some sort about an issue; after creating the theory, the process of observation can be designed and the data from the said observations can be collected (Saunders *et al.* 2009). It is also possible that, at the theory phase, the researcher could hypothesise what they feel would be the causal relationship between issues or what the outcome could be (Bryman and Bell 2011). At the data collection phase, it is possible to generate qualitative and/or quantitative data, or the data could also be empirical in nature (Bryman and Bell 2011). The results could then be useful for the establishment of the hypothesis or to prove or disapprove the theory that may have been created prior to the commencement of the research (Saunders *et al.* 2009). From the above literature review, author of the current research noted that deductive reasoning is ideal for the research on the causes of projects delay on oil fields construction projects with particular view of cost of the project; this is because the research started with an assessment of what could be the causes of projects delay. Having developed the theory, it was possible to develop the arguments for and against the many factors that have been identified as being critical to the resolution of projects delay.

Overall, it can be observed that the adoption of either deductive reasoning or inductive reasoning is considered to be the researcher's choice, not a hard and fast rule that has been established in the realm of research (Bryman and Bell 2011). The researcher has a prerogative to choose the approach they feel would work well for them. In the case of this research project, it was prudent to use deductive reasoning as a way of creating a direction in the research.

7.5 Research strategy or methodology

According to Bryman (2012), the research methodology is the main design for how the researcher will implement the research as per the selected philosophical knowledge of research for this study which are (positivism and interpretivism); the philosophical standing for how knowledge is added as well as the reasoning for the research (deductive) (Saunders *et al.* 2009). There are three main strategies that can be used for research, Bryman (2012) stated: qualitative research methodology, quantitative research methodology or mixed methodology – which allows for the use of both qualitative and quantitative methodology at once.

7.5.1 Qualitative research methodology

According to Bryman and Bell (2011); Silverman (1993), qualitative research methodology is a strategy that relies heavily on the qualitative type of data such as words, signs and symbols that cannot easily be expressed using numbers; and that the manner in which they are captured could include the contextualization of the research process to allow for social interaction (May 2011). As a result, Easterby-Smith *et al.* (2002) felt that using a qualitative research methodology allows for the collection of words and not numbers so that the analysis could include the context in which the words were uttered and the purpose of sharing them. This approach to research is suitable for the interpretivism form of philosophy whereby the examination of the social world can be

expressed in many ways other than the numbers alone (Bryman and Bell 2011). The overall distinction between qualitative and quantitative methodology is that researchers take the opinion that qualitative methodology does not rely on numerical data as the main driver for primary information; rather, it allows for non-numerical data to take centre stage.

7.5.2 Quantitative research methodology

Quantitative research methodology is a strategy that concentrates on collecting quantitative-related data from the research process so that the numbers therein can be used to analyse and paint a picture of what information can be obtained from the data (Bryman and Bell 2011). The researcher would have to design the data collection mechanisms that would allow quantitative data to be central to the data collection and analysis process (Saunders *et al.* 2009). The influence of the quantitative research methodology is felt in the way the data collection system is organized (May 2011); it means that the researcher could set up experiments, numerical readers or counting mechanisms in order to apportion the weighting of the factors against each other. It is also possible that texts and notes can be used to collect the quantitative data therein, as explained by Bryman and Bell (2011). In the case of this research, it is possible to generate the quantitative numbers from the quantitative methods used at this research, which are regression analysis and Monte Carlo simulation.

7.5.3 Justification for adopting quantitative research methodology

Quantitative research is mostly conducted in the social sciences using the statistical/quantitative methods to collect quantitative data from the research study (more details on quantitative methods used on this study illustrated at chapter 3). In this research method, researchers use mathematical structure/outline and theories to answer the research questions (Bryman and Bell 2011).

The content of quantitative research and studies are more elaborative, therefore, researches might be investigating on research questions while trying to be more objective. The results of this research method are more logical, statistical and reliable due to unbiased concepts of data (Bryman and Bell 2011).

The researcher could gather the information based on documentation, literature, interviews and surveys in order to understand the reasons behind the data (Bryman and Bell 2011). The researcher could use quantitative mechanisms to gather data that could be useful in testing the hypothesis or approving a theory. In such a situation, quantitative data becomes essential (May 2011). The issue of projects delay and the assessment of what factors contribute to their causation could be analysed in depth if there was a possibility of designing the research under the philosophy of positivism and interpretivism so that quantitative data could be captured. It can also be argued that, for deeper analysis of factors such as cost of the project, there is a need to adopt quantitative research methodology because this research strategy could be useful in the research (Bryman and Bell 2011). It was therefore justified to adopt a quantitative research methodology for this research because the research demands the use of numerical data to refine the analysis of the research results.

7.6 Research processes available for the research

There are many research methods that can be useful to the research; however, not all were adopted here because of the nature of the subject area and the theory created from the literature. Below is a general overview of the research methods used at this study (also called data collection methods).

7.6.1 Electronic email survey (questionnaire)

Having decided to use the electronic email survey at this research to collect the experts' feedback on the impact of delay on cost overrun of the project case studies used at this research. It is noted that use of questionnaire will be easier, faster and cheaper approach of collecting the secondary data from the projects experts who are living at different geographical locations. Therefore, it is important to know about this method of data collection. It has been recognized that an electronic email survey is a cost-effective method of data collection by a well-written questionnaire survey. The survey consists of a set of questions submitted to project-relevant professionals/parties in order to gain statistical information. Trespalacios and Perkins (2016) explained that questionnaire email surveys are ideal for large sample sizes or samples received from a large geographical area, and they cost less than a telephonic survey and they take faster to complete. In addition, interviewers are not involved in electronic email surveys, thus avoiding interviewer bias, and there is no possibility of questioning respondents for more comprehensive information. A wide variety of other approaches for gaining information is highlighted in the open literature reviews; these include:

1. Literature reviews: this involves reviewing most of the accessible material resources such as papers, annual reports, magazines, journals and any published data. This is an economical approach but may not yield the required information in time.

2. Interaction with field experts and gatherings at seminars to collect information that is not available publicly, or may be too recent to be obtained in open literature. Indeed, this method can be significantly valuable; however, it is vastly subjective and might not be representative as a whole.

3. The focus group approach is utilized to investigate people's ideas, perceptions or opinions and behaviours to validate new approaches or products. In general, this method is costly, time consuming, and may not provide information that is representative of all group members.

4. Interviews with a wide variety of people can be conducted to acquire in-depth and broad information (e.g. by one-to-one interviews or possibly group interviews). As described earlier, this is also a time-consuming and costly method of data collection.

5. In the cases when personal opinions are required, telephonic surveys have been found to be useful. Large sample size surveys are easily conducted using this approach.

6. Another useful tool is the e-mail and internet surveys that are effectively utilized to collect data. These methods are fast and cost effective; however, they may not be representative because of the demographical profile that the internet covers. In addition, data biases may be a factor that needs to be taken into account.

Moreover, several other authors (Trespacios and Perkins 2016; Lewin-Jones and Mason 2014) have pointed out that email questionnaire surveys has been found to be effective, fast, sufficient and favoured approaches for obtaining the information necessary for the present type of research investigation; thus, they were utilized in this study to collect primary data from experts who worked on the case studies projects used at present research and provide their opinion on the risk impact survey via emails. Further details of these methods are given in the following sub-sections.

7.6.1.1 Advantages and disadvantages of using a questionnaire survey

A questionnaire is defined to be a set of questions devised to generate the specific data required for fulfilment of a study's research goals (Parasuraman *et al.* 1991). It is the fastest way of acquiring the statistical information or data in a most effective manner. The survey involves distributing the designed questionnaire to respondents who are willing to participate, and collecting the completed survey forms for the desired research investigations.

A written questionnaire has several merits/advantages and demerits/disadvantages in comparison to other evaluation methods. This has been described by several investigators (Bloom; Nayar, 1972, Dawson, 2009; Burns and Burns, 2008). The following is a summary of their findings on questionnaire-type surveys:

Advantages

The following are the advantages of the written questionnaire survey:

- The respondents are allowed to freely respond with answers to the questionnaire without interference of any kind;
- A questionnaire survey allows anonymity, which leads to enhancement of the response rate and may increase the possibility that responses reflect genuine views;
- A questionnaire is less intrusive than telephonic or personal queries because it can be easily distributed, either by mail or hand to hand;
- If questionnaire is properly designed, it can address a vast number of issues and questions in a more effective way and with the likelihood of a high response rate;
- A questionnaire is an inexpensive and efficient mode of data collection, in particular, for investigations involving large sample sizes and covering large geographic localities. In

cases when the number of questions in the survey are increased, it becomes even more cost effective and comprehensive;

- The data obtained from a questionnaire survey can be easily analysed. It does not require complicated analytical tools; rather, it could be done using commonly adopted computer software packages.
- A questionnaire is a uniform set of questions distributed to each respondent; this permits closed-form questions to be asked, to standardize the responses, which can facilitate an effective interpretation of the data from a small to a large number of respondents.
- A questionnaire is a commonly known approach to collecting specific information with which respondents are quite familiar, and thus it does not make them uneasy (apprehensive).

Disadvantages

- The following are the disadvantages or demerits of the written questionnaire survey:
- A questionnaire survey can be misrepresented if the respondent is not the person to whom it was sent. This is because it is possible for several copies of the questionnaire survey to be delivered to unrelated or irrelevant respondents;
- In certain circumstances, a questionnaire becomes inappropriate or unsuitable for evaluation if a follow-up is required, since it does not offer flexibility;
- It can be misleading if the questions are not designed correctly;

- The data collected in a questionnaire survey are not high quality in comparison to alternative methods, e.g. interviews or meetings. This is because the lack of personal interaction has numerous impacts on the type of questions being asked. However, a questionnaire requesting factual data will possibly not be influenced by the lack of personal contact;
- A questionnaire survey may have a low response rate, consequently reducing the confidence level in the findings. However, an appropriately designed questionnaire may yield an enhanced response rate.

7.6.1.2 Justification for the use of questionnaire survey

The questionnaire survey was adopted in this research because it provides cheap and efficient way of obtaining large amounts of information required for this thesis from 45 experts who worked on the case studies projects used for this research work. Another reason is that the data required for this research from those experts can be collected relatively faster because the experts who are in different countries do not need to be physically present to complete the questionnaire surveys. Moreover, as mentioned in the advantages of questionnaire survey, it allows for anonymity, which encourage all targeted experts to fairly estimate the impact of risk/cause of delay on cost overrun related to their projects.

7.6.2 Case study

Having decided to use the historical case studies of construction projects in oil fields industry as part of secondary data used in this research, it is important to know about this of data collection. A case study, according to Voss *et al.* (2002), is a primary research method that allows the researcher to observe a phenomenon and be able to ask questions in any way permissible so that

they can obtain answers relating to their concerns or research issues. The process of gaining data from a case study could be through observation, or by interviewing or by using a series of questions (Voss *et al.* 2002; Yin 2009). However, the researcher is not allowed to take part in the phenomenon that they are researching because doing so would defeat the case study; it would imply that the research is taking the form of an action-related research. If the researcher were to participate, they would have to marry the process of obtaining data and analysis whilst participating, and this can be difficult (Coughlan and Coughlan 2002). In the event that the research data to be gathered using a case study has been based on historical data, it is possible for the researcher to plan and construct questions so that they can assess the performance of the phenomenon as presented by the historical information that they gather. For example, Smith *et al.* (2004) used a case study in their research by preparing the case adequately through identification of which industry they could target and an assessment of how the problems would be studied. After that, they were able to develop an assessment of a design and build procurement system in a residential housing development (Smith *et al.* 2004). They also made sure that they had developed a set of criteria that would be assessed; for instance, they selected the contracts and management performance as well as factors within the company and how they impacted on the process of design and build (Smith *et al.* 2004). The lesson from their work has been that being decisive about the factors to assess in a case study can lead to better results (Smith *et al.* 2004; Voss *et al.* 2002; Yin 2009). Other important factors include, but are not limited to, ‘sufficiency’ of resources and adequacy of time to deal with all the data from the case study, as well as the time it could take to adequately analyse the data with regard to the research issues under review (Yin 2009).

7.6.2.1 Some of the merits of using a case study

1. The ability to gather a comprehensive set of data about an issue, and that the data can be very rich and deeper in quality and content (Naoum 2007);
2. There is a possibility to engage as many participants as possible using a critical approach to what they do, as the researcher can interview them and probe them as deeply as possible (Learmonth 2006);
3. It is possible to use other forms of testing and analysis within the case study, meaning that questions can be asked, observations can be made, and interviews can be undertaken without impacting the data collection process (Fellows and Liu 2008);
4. During the case study, the ideas can easily be adapted in order to ensure that the research can be conducted properly, and the intended target can be assessed (Yin 2009).

7.6.2.2 Some of the demerits of the case study

1. Even if case studies can allow critical thinking about a phenomenon, it can be difficult to arrive at clear answers, hence failing to create a causal relationship between variables at times (Learmonth 2006; Voss *et al.* 2002);
2. In most cases, a lone researcher can undertake a case study (Yin 2009); in such a case, it can be difficult for the individual to follow all the leads whose data may be necessary for the research (Fellows and Liu 2008);
3. If the researcher is overwhelmed by the bulky primary data, they can easily become biased towards their beliefs and perceptions about the phenomenon under research (Naoum 2007);

4. There can be poor application of scientific research principles if the researcher has not been able to master such (Naoum 2007); there is a major weakness for case studies relating to the difficulty of generalization of results from a case study (Voss *et al.* 2002).

For this research, it was important to adopt case studies to form part of the verification process of how organizations respond to the impact of projects delay on oil fields construction projects with a particular view of cost of the project. Case studies have been essential in construction research (Naoum 2007; Fellows and Liu 2008); therefore, it was foreseen that the use of case studies could complement other research methods in the assessment of factors causing delay in oil fields construction projects.

7.6.2.3 Generalisation, validity and reliability of case studies

Researchers have to fully consider the demonstration of generalization, validity and reliability of case studies when integrating them into useful knowledge as a base of a field of a study. It's very crucial that these three concepts are considered when establishing a research based on case studies (Rowley 2002; Zainal 2007).

Researches stated that contribution to the theory is an important step when considering generalization of the case studies. It has been illustrated that case studies generalization is not statistical overview of the data, but another way of comparing experimental results of the case studies with earlier developed theories in a logical simplification of data. It is well known that the more the number of case studies available to support the proposed theory, the more consistency and replication will be given to the proposed theory.

7.6.2.4 Difference between single case study and multiple case studies

It is important that researchers clearly differentiate between single case and multiple case design needs. Single case studies are mostly used as preliminary and pilot test in multiple case studies. It has been indicated that single case studies can be better used if the case is considered special as per the research theory used and as per the researcher justification.

Researchers indicated that the more cases used to start a research theory, the more robust the research results will be. The use of multiple cases is similar to multiple experiments, and there is no minimum or maximum number of cases that must be used. Researchers have to carefully select cases if they are targeting to reach a theoretical replication for prediction purposes, which produce different outcomes, or literal replication if they aim to produce similar results (Rowley 2002).

7.6.2.5 Data collection and case study questions

Data collection should be guided by a case study protocol, which should

Include the following conditions:

1. An overview of the case study project.
2. Field procedures, such as use of different sources of information, and access arrangements to these sources.

Researchers should be able to differentiate between case study questions in terms of its use as following:

1. Questions related to specific interviewees and used for documents investigation/review.
2. Questions asked for individual case study.
3. Questions asked for multiple cases studies.

There are multiple sources that researchers can find evidences on case studies. Such as public records, monthly reports, interviews, historical records and participation observation. Researchers can use different approaches to examine those evidence sources. Each of those sources has its pros and cons (Rowley 2002). At current study, the author adopted the approach of using the historical records of projects in oil fields construction projects. More details illustrated at Appendix A.

The following are three key principles of data collection that need to be considered:

1. Triangulation – is one of the best method of evidence sources of case studies as it can be collected from multiples sources.
2. Case Study Database – a well-organized database may be considered as strength to the research paper or student thesis/dissertation. As instance, this include the collection of the evidence sources and cases notes stated by researchers, support documents related to cases, interview notes or transcripts, analysis reports of the cases/evidence.
3. Chain of evidence: The researcher have to plan and maintain a clear and detailed list of evidences related to cases studies by following proper citation of documents and interviews.

7.6.2.6 Case study analysis

Researchers stated that there is no one way procedure that should be followed for the analysis of case study, however, best practices of case study analysis should fill in the following conditions (Rowley 2002):

1. The analysis makes use of all of the relevant evidence
2. The analysis considers all of the major rival interpretations, and explores each of them.
3. The analysis should address the most significant aspect of the case study
4. The analysis should draw on the researchers' prior expert knowledge in the area of the case study, but in an unbiased and objective manner.

As illustrated at above sections, the author of current study adopted the use of historical projects in oil fields construction as case studies and part of the secondary data of this research. Moreover, the author adopted the use of electronic email survey to collect part of the primary data of this research from experts who worked/are still working on those projects and rate the impact of delay on cost overrun.

7.7 General information about respondents/projects experts (impact of delay causes survey)

The research primary data was extracted from a risk impact probability survey that was designed to accommodate as many respondents as possible in order to receive a wider range of opinions that can then offer reliable conclusions from the research. However, it was difficult to ascertain the actual number of construction professionals, clients and project managers that worked on projects cases used for this research. Therefore, a list of 45 experts has been selected to participate at this survey based on the database information related to the roles and responsibilities of project team

members who worked on those projects cases. The researcher was able to select only 45 projects experts as they were the only available projects leaders during the time of conducting this research, and they worked on the list of 55 oil fields constructions projects used as case studies for this research and they are capable to estimate the impact of the cause of delay on cost overrun related to their completed projects. Moreover, the researcher of this thesis was able to find only 55 projects in oil fields constructions projects that were not completed on time and had cost overrun. More details on case studies projects and questionnaire survey on appendix section 11.2.1 and 11.2.2 respectively.

7.7.1 Selective (or stratified) sampling technique

There was a good possibility of using a stratified sampling technique whereby the researcher had to design proper approaches of case study data collection, first, by requesting information from potential participants and, secondly, to choose the participants to use in the research (Naoum 2013). The author of this research adopted the second approach, which was possible due to the available historical records and archived projects information and details on experts who worked/are still working on those projects used as case studies at this research. Therefore, the researcher of this thesis was able to select only 45 experts who were available during the time of conducting this research.to estimate the impact of the cause of delay on the cost overrun of the project.

7.7.2 Design of the causes/impact survey and data coding

The primary objective of the causes' impact survey was to examine how various groups of projects experts could rate the causes of delay that have the potential to cause delay to any project in terms of cost. Each section of the sample had a set of factors gathered from projects cases and summarized in table form so that the respondents rate them in accordance with their perceptions using probability impact distribution (See appendix B for more details).

7.8 Question coding for the case studies

Having decided to use case studies as part of the secondary data collection, it was imperative to try to systematize the process of data collection at the time of data collection (Yin 2009). Voss *et al.* (2002) advised the planning for how the data was to be collected from the case studies had to take place prior to the data collection. The driving factor for planning the implementation of the data collection through case studies was the need to use them at the causes impact survey discussed at section 5.7.2. This meant that there was a need to code the area of questioning from the case studies and be able to cover the owners, consultants, contractors and external factors. From the onset, the data collection from the case studies was designed to gather as much general information about the projects as was permissible. The main criterion was that projects were taken from the oil fields construction projects in the Arabian Gulf and South East Asia-SEA. They had to either be funded by or belong to both public and private sectors. The total number of projects used on this research was 55 projects normalized by their unit of measurement into square meters.

1. **Case studies projects:** includes 55 projects normalized by square meter M2.

7.9 Question coding for case studies projects

7.9.1 Question coding for projects owner

There were 14 main causes of delay that were identified and linked to and triggered by project 'owner' or project sponsors. The list of causes – herein called variables linked to owners – is not exhaustive as such; rather, it covers issues that have been identified as fundamental to these research case studies. The 14 causes were abbreviated as follows: BPO1Cost to BPO14Cost, as summarized in Table 6-1. This implies that on the questionnaire respondents were asked to rate the causes of delay using probability/impact matrix in terms of degree of risk on cost overrun from (1% to 72%).

Although the factors were labelled BPO1Cost to BPO14Cost, it did not mean that the first one was more highly rated than the second one; meaning that the order in which the causes were listed in table 7-1 did not have a bearing on the relative importance they had within the research. All causes were of equal importance to the research and each one had the same likelihood of appearing at any position in the table.

Table 7-1: Codes and descriptions of causes of delay related to the Projects Owner

Code	Causes of Delay caused by Projects Owners
BPO1Cost	Delay in Reviewing and Approving Design Documents by owner
BPO2Cost	Delay to furnish and deliver the site to the project manager by the owner
BPO3Cost	Conflicts between business partners of the project

BPO4Cost	Some changes in materials types and specifications during construction works not being specified in the detailed site plan
BPO5Cost	Delay in approving project drawings by owner (local government projects council)
BPO6Cost	Delay in Progress Payments to Contractors
BPO7Cost	Conflicts between business partners related to major tasks achievement
BPO8Cost	Too much bureaucracy in project owner management
BPO9Cost	Delay in decision making by owner for some change requests
BPO10Cost	Slow communication and coordination by owner
BPO11Cost	Contract Modifications
BPO12Cost	Delayed and slow supervision in making decisions by owner
BPO13Cost	Uncooperative owner
BPO14Cost	Delay in preparation and approval of drawings by owner

7.9.2 Question coding for contractors

A separate set of questions were needed in order to assess the causes of delay caused by contractors who worked on those projects. Therefore, a set of causes against which the probability/impact matrix was to be evaluated were developed from the case studies. The 11 causes were abbreviated

as follows: BCT1Cost to BCT11Cost, as summarized in Table 7-2. Therefore, each question could be rated using the same probability/impact matrix so that there was consistency in the way respondents were being surveyed about the issue. In this case, consistency could allow for comparative analysis of the responses (Black 2010).

Table 7-2: Codes and descriptions of causes of delay related to the Contractors

Code	Causes of Delay caused by Contractors
BCT1Cost	Contractors handles multiple projects at the same time
BCT2Cost	Poor communication and coordination by sub-contractors with other project parties
BCT3Cost	Delays in sub-contractors work
BCT4Cost	Poor contractors work
BCT5Cost	Frequent change of sub-contractors because of their inefficient work
BCT6Cost	Rework due to errors during finishing construction tasks
BCT7Cost	Conflicts in sub-contractors schedule in execution of project
BCT8Cost	Conflicts between contractors and other parties (consultant and owner)
BCT9Cost	Shortage of experts resources during hazards or emergencies
BCT10Cost	Contractor's unstable of financial background
BCT11Cost	Poor site management and supervision by contractor

7.9.3 Question coding for consultants

The questionnaire for consultants had questions that were coded as follows: BCN1 Cost to BCN11 Cost, as summarized in Table 7-3. The set of questions for consultants were needed to form the basis for analyzing projects delay in oil fields construction projects, and their impacts on project success criteria; hence, the coding of key causes that the consultants could trigger was necessary.

Table 7-3: Codes and descriptions of causes of delay related to the consultants

Code	Causes of Delay caused by Consultants
BCN1Cost	Poor site management and supervision by consultant
BCN2Cost	Poor coordination by the consultant engineer with the parties of the project specially with local authorities
BCN3Cost	Quality assurance requirements by local governments and waiting time for approval of test and inspection
BCN4Cost	Inaccuracies in technical drawings such as infrastructure services and power load on electric power station
BCN5Cost	Unclear first drafts of pipeline connections between both fields that cause confusion between contractors and sub-contractors
BCN6Cost	Delay obtaining permits from local authorities
BCN7Cost	Delay in preparing change orders by sub tasks consultant

BCN8Cost	Change of sub consultant during project execution
BCN9Cost	Slow response by the consultant engineer regarding testing and inspection
BCN10Cost	Lack of experience on the part of the consultant's site staff
BCN11Cost	Delay in the approval of contractor submissions by the engineer

7.9.4 Question coding for external factors

A similar approach was taken for questions that were considered to be centered to external causes. The 12 factors were abbreviated as follows: BEF1Cost to BEF9Cost, as summarized in Table7-4. Like the other coded factors, there was no preference for any factor to be listed before the other on Table 7-4; any factor could have been listed in any order.

Table 7-4: Codes and descriptions of causes of delay related to the external factors

Code	Causes of Delay caused by External Factors
BEF1Cost	Accidents during construction
BEF2Cost	Unproper safety strategy
BEF3Cost	Traffic control and restriction at job site
BEF4Cost	lack of some materials, equipment and tools on the market during economic crises

BEF5Cost	Late delivery of some core materials
BEF6Cost	Issues related to environmental concerns by local authorities
BEF7Cost	Delay at line services maintenance (water and electricity)
BEF8Cost	Extra work related to solve public services such as roads, utilities
BEF9Cost	Bad weather and unexpected natural events during the mid of construction tasks

7.10 Data modelling

This research uses several integrated steps to develop the stochastic model for analyzing the delay in oil fields construction projects. The causes of delay analysis process can be explained more clearly through the following steps:

Step 1:

As illustrated before, causes impact survey was used to collect data about the impact of the causes of delay in oil fields construction projects. To eliminate the potential bias arising from respondents' opinions, the questionnaire survey was sent to participants who were experts and worked on those projects. This primary data was then fed back into SPSS data and analyzed as described in Chapter 8, in addition to the secondary data extracted from projects case studies.

Step 2:

The results from step 1 are used to derive the regression to model the cost overrun of delay. Regression modelling techniques have been used extensively in the construction industry to model

construction cost. Chapters (5 and 6) reviewed the techniques used for this purpose. This research employed the following equation:

$$Y_i = \beta_0 + \sum_{i=1}^n \beta_i R_{pi} + \alpha$$

Where:

Y_i = the value of the dependent variable, i.e., cost of projects delay

β_0 = constant

β_i = the weight of the independent variable

R_{pi} = Delay factors

α = error

This work used a multiple linear regression model to quantify the relationship between costs of projects delay, as proxy of cost overrun, as a dependent and its independent variables (causes of delay); Chapter 8-Modelling results provides further details.

Step 3:

In this step, the causes of delay that were deemed important in predicting the cost overrun by the multiple regression equation are selected for probability distribution fitting. By fitting a theoretical distribution to the data, the specified distributions should be less sensitive to random fluctuations between different observations. A series of theoretical distribution functions were applied to fit the data collected from the questionnaire survey. Statistical tests such as the Andersen test are used to select the best-fit distributions. These distributions are then used in @Risk software to perform Monte Carlo simulation.

Step 4:

Monte Carlo simulation is considered one of the most powerful techniques for stochastic modelling. The technique is considered important in capturing the uncertainties in the model constructs. In this study, all of the dependent and independent variables are considered to have a high uncertainty. Thus, Monte Carlo simulation is used to capture the variability that may exist in each of the study constructs. Inter-relationship between cost overrun from case study projects and causes of delay is captured through the linear equations developed in step 3. The simulation process will generate the cost of delay. This process will be explained more clearly in Chapter (8-Modelling) of this thesis.

Step 5:

The results generated from step 4 are subjected to analysis to determine the nature of the resulting probability distributions. Thus, empirical distributions are defined for the simulated data. The process of identifying and confirming the distribution of the best-fitting distributions is necessary because it can provide several benefits including knowing the upper and lower limits of risk affects events. Several statistical techniques are used to compare and analyze the results. The study uses correlation coefficient, PP plots, Andersen test and descriptive statistics. Plots and charts are also used to observe the variability of output from the simulation. The steps to derive the model are shown in the following figure, Figure 7-2.

- 1 Collecting primary data from causes impact survey in terms of cost/duration overrun. SPSS is used to analyze the data.
- 2 Using a multiple linear regression model to quantify the relationship between costs of variation, as a proxy of cost overrun, as a dependent and its independent variables (causes of variations).
- 3 Statistical tests such as Andersen test is used to select the best-fit distributions by using @Risk software to perform Monte Carlo simulation.
- 4 Inter-relationship between cost overrun from case study projects and causes of delay is captured through the linear equations developed in step 3. The simulation process will generate the cost of delay.
- 5 Identifying and confirming the distribution of the best-fitting distributions to provide several benefits including knowing the upper and lower limits of risk impact events by using several statistical techniques such as correlation coefficient, PP plots and Andersen test.

Figure 7-2: Projects Delay Modelling Process (Tasks 4 and 5 from the research structure)

7.11 Validity of data, modelling and results

This thesis will focus on identifying the most variables that contribute to the cost overrun in oil fields construction projects. Therefore, the data employed in this research which came from secondary sources and was retrieved from archives and based on historical records and documents involving the projects under study, will be very helpful to ensure validity of data for the purpose of this research. Moreover, the data were analysed and presented by using descriptive statistics where the percentages of the projects' cost and duration-overrun figures were calculated for each project case study. More details in chapter 8.

In order to develop a realistic model that predict the cost overrun due to the causes of projects delay in oil fields construction projects., the data were normalized by dividing the total budget by

the total surface area to obtain the budget overrun per square meter. This procedure made it possible to make comparisons between the various projects. Thus, it can be seen from the normalized data discussed in chapter 8, that there are no outliers in the data, thereby indicating data validity. Furthermore, the regression model developed using the normalized data fulfilled all the Gauss Markov assumptions (Non-collinearity between the dependent variables, normality of the error terms and Homoscedasticity). Also, the developed model gave a very high R-square value of 86.2% and the estimated budget overrun per square meter obtained with sets of test data applied to the regression model showed excellent accuracy. All these confirm validity of the modelling procedure. With stochastic evaluation of the developed regression model via Monte Carlo simulation, the author was able to identify the distributions associated with factors that greatly impact budget overrun per square meter. A comparison between the results obtained in this work and those of similar studies in the literature were in conformity with one-another. This demonstrates the validity of the results. Based on the foregoing, the data employed in this study, the modelling procedure and the results are confirmed to be reliable and valid.

7.12 Chapter summary

For research on modelling the causes of projects delay in oil fields construction projects, it is vital to consider the use of both positivism and interpretivism as the guiding research philosophy. Secondly, the appreciation of the impact of the causes of delay could only be analyzed by creating a theory based on the literature review as well as the research questions, meaning that the research adopted a deductive approach. Because the research needs to use both primary and secondary data, it was inevitable that a questionnaire survey comprised of various sections was required, in order to address the issue from many angles and used as primary research data. The adopted research

method falls in line with the quantitative research methodology (Bryman and Bell 2011), which in turn aligns with the positivism and interpretivism philosophy. The chapter concludes that circumstances beyond the researcher's control were instrumental in the decision to use a questionnaire survey as well as a case study. It was also possible to develop a dedicated set of projects cases information from the case study as secondary data. Coding the causes of projects delay prior to their use was vital in order to ensure that the data to be collected could easily align with that collected with other research methods. Finally, the data modelling process was summarized in five steps.

Chapter 8: Modelling Results

8.1 Introduction

In this chapter, data preparation, modelling process and interpretation of results from both the regression analysis and Monte Carlo simulation are presented. The developed regression model is evaluated to ensure that none of the assumptions of regression analysis are violated and test data is employed to evaluate the accuracy of the model. Furthermore, Monte Carlo simulation is employed to fit the best probability distribution associated with the causes of project delay and in assessing the variability of BgtOvrrunM2 based on the developed regression model and obtained probability distributions.

8.2 The modelling methodology process

For this research to implement the modelling theory articulated in chapter (7) it was important to explain the key steps that were taken, as summarized in Figure 8-1, and as the following steps:

- i. Step 1, there was a need to undertake the identification of the causes of projects delay and project success criteria within the oil fields construction industry;
- ii. Step 2, secondary information has been collected from historical oil fields construction projects used as case studies for this research, and there was a need to undertake the collection of primary information from experts who work on those projects used as case studies for this research.

iii. Step 3, involved the examination of the correlation within the data that was used in order to investigate the strength and direction of the relationships between the causes of projects delay and project success criteria. This was necessary in order to identify the most influential independent variables, and then investigate their relationships with the dependent variable (project success represented by cost overrunM2). Details from this exercise are presented in section (8.4) of this chapter;

v. Step 4: Having analyzed the correlation between variables it was considered as not enough to assess the meaning behind the results. It was therefore important to use SPSS in order to find the optimum multiple regression equation that maps the cause of projects delay to project success proxy cost overrun. The regression modelling is presented in section 8.5 of this chapter;

vi. Step 5: The validity of the generated optimum regression model assumptions was checked. Assumptions concerning the linear regression model are discussed in section 8.7.

vii. Step 6: The generated model was tested and validated using data obtained from five projects implemented in oil fields construction projects that were not used in the development process of the regression model. See section 8.8 for details and discussion on the results from the testing.

viii. Step 7: After the model was calibrated and tested, the stochastic Monte Carlo simulation technique was used in order to examine the fitness of the developed regression model in systems that are more complex where a system can be sampled in a number of random configurations to generate data that can be used to describe the system as a whole. This process is presented in this chapter.

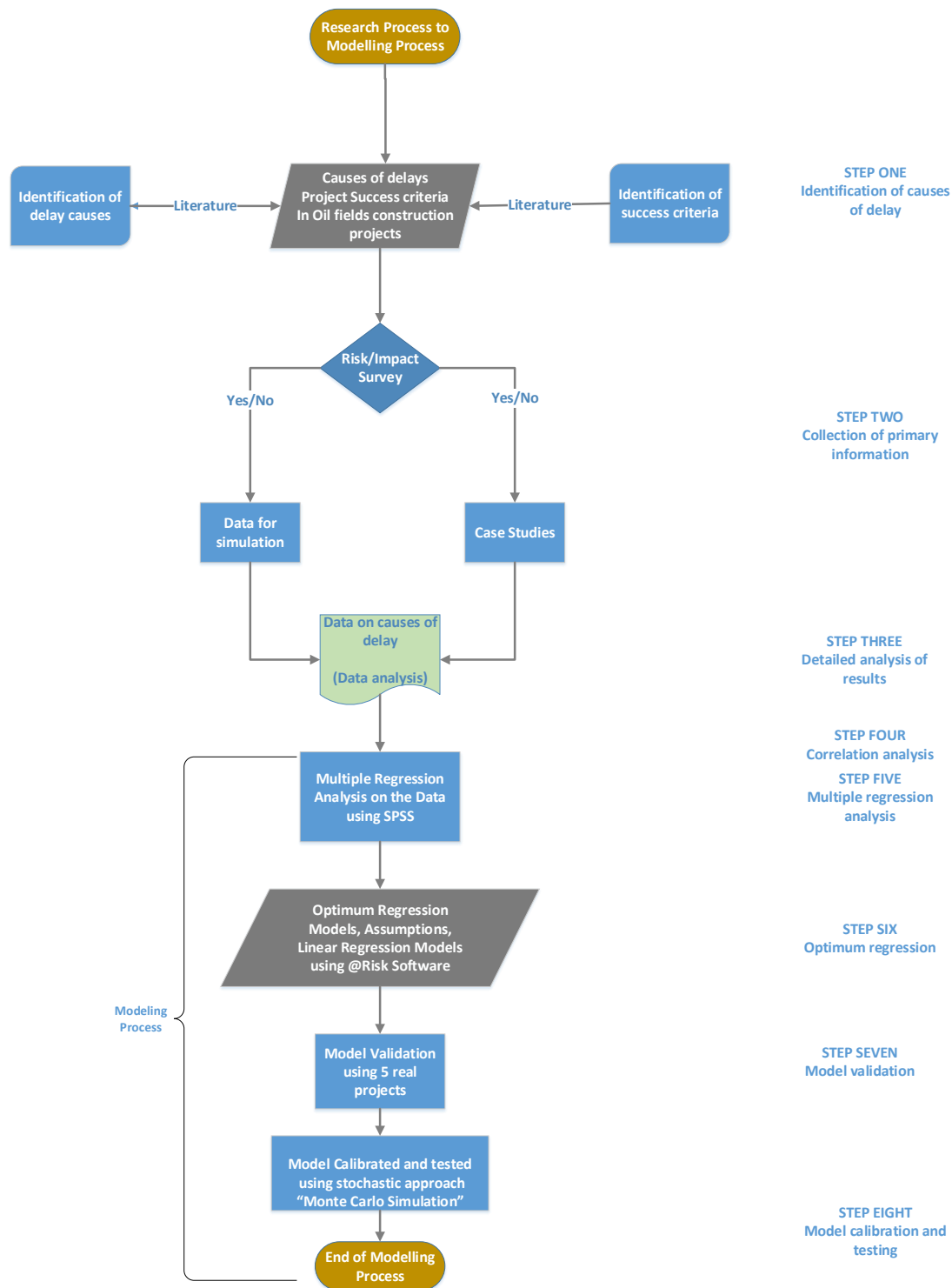


Figure 8-1 Abstraction of the research process combined with the modelling of project factors using @Risk software

8.3 Case study data presentation and analysis

This research collected secondary data from 55 projects. The data format is designed with the aim of obtaining general background information about the project cost, duration of the construction, size of the project, type of project and how a particular project is affected by the causes of delay, and the causes of delay for each project. The raw data of the projects is shown in Appendix A. The descriptive statistics of the projects data is shown in Table (8.1) where it can be seen that the cause of project delay have their mean spreading from 0.531 to 0.3371 in the case of BCT9Cost to BCT4Cost, respectively. The percentages of the projects' cost and duration-overrun figures were calculated for each project case study.

Table 8-1 : Results for Descriptive Statistics

#	Construct	Mean	Std. Deviation	#	Construct	Mean	Std. Deviation
1	BgtOverrunM2	56.4364	96.85016	25	BPO2Cost	.2935	.12929
2	BCT1Cost	.2593	.10825	26	BPO3Cost	.2587	.13163
3	BCT2Cost	.1036	.05810	27	BPO4Cost	.1017	.10031
4	BCT3Cost	.1009	.05140	28	BPO5Cost	.0962	.06682
5	BCT4Cost	.3371	.12223	29	BPO6Cost	.3205	.15968
6	BCT5Cost	.0686	.04629	30	BPO7Cost	.1105	.09140
7	BCT6Cost	.2960	.10409	31	BPO8Cost	.0981	.06773
8	BCT7Cost	.1165	.05417	32	BPO9Cost	.2902	.12560
9	BCT8Cost	.2151	.11744	33	BPO10Cost	.1051	.09562
10	BCT9Cost	.0531	.03958	34	BPO11Cost	.2902	.09180
11	BCT10Cost	.0711	.04379	35	BPO12Cost	.0651	.04550
12	BCT11Cost	.2964	.10860	36	BPO13Cost	.1351	.11643
13	BCN1Cost	.3298	.13075	37	BPO14Cost	.3255	.14694
14	BCN2Cost	.2085	.11314	38	BEF1Cost	.3171	.12070
15	BCN3Cost	.2024	.11873	39	BEF2Cost	.2929	.13765
16	BCN4Cost	.1173	.09898	40	BEF3Cost	.2153	.13422
17	BCN5Cost	.1545	.09845	41	BEF4Cost	.0785	.05086
18	BCN6Cost	.0898	.05658	42	BEF5Cost	.0925	.08703
19	BCN7Cost	.0987	.05288	43	BEF6Cost	.2304	.12170
20	BCN8Cost	.2895	.11188	44	BEF7Cost	.0698	.04201
21	BCN9Cost	.0901	.05384	45	BEF8Cost	.2880	.10733
22	BCN10Cost	.0960	.07551	46	BEF9Cost	.3051	.16819
23	BCN11Cost	.2862	.09752				
24	BPO1Cost	.2727	.13736				

The duration for the 55 projects are presented in Figure (8-2), which shows that 2 projects had a contract duration of over 60 months, meaning that in real terms the projects were estimated to be about 5 years – plus or minus a few weeks. The shortest duration for the case study was slightly below 33 months – about two years and a half contract duration.

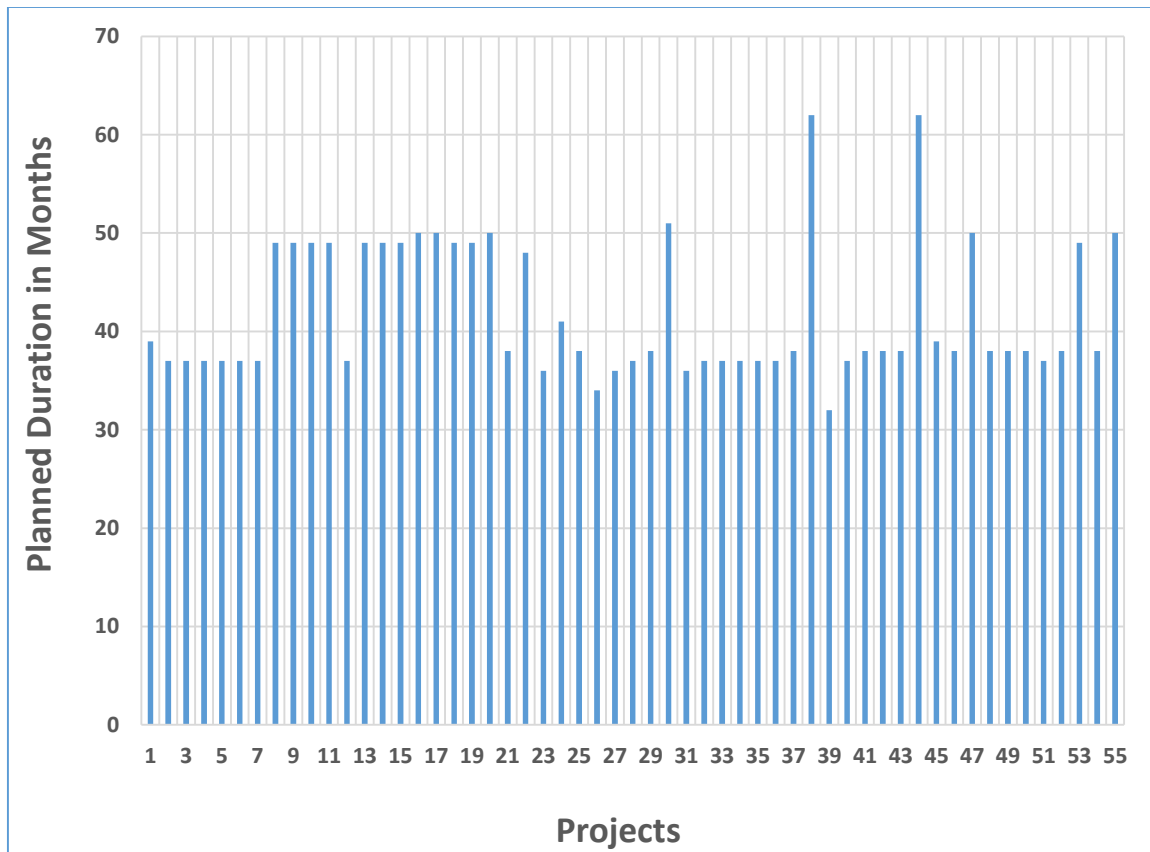


Figure 8-2 Planned Duration for 55 projects - Months

Adopting a comparative analysis of projects with different durations has a likelihood of distorting the meaning behind the data. For instance, a project with one-year duration cannot easily be compared with one with a duration of 5 years because their structure could be totally different, hence making the comparative analysis of the data a bit weaker.

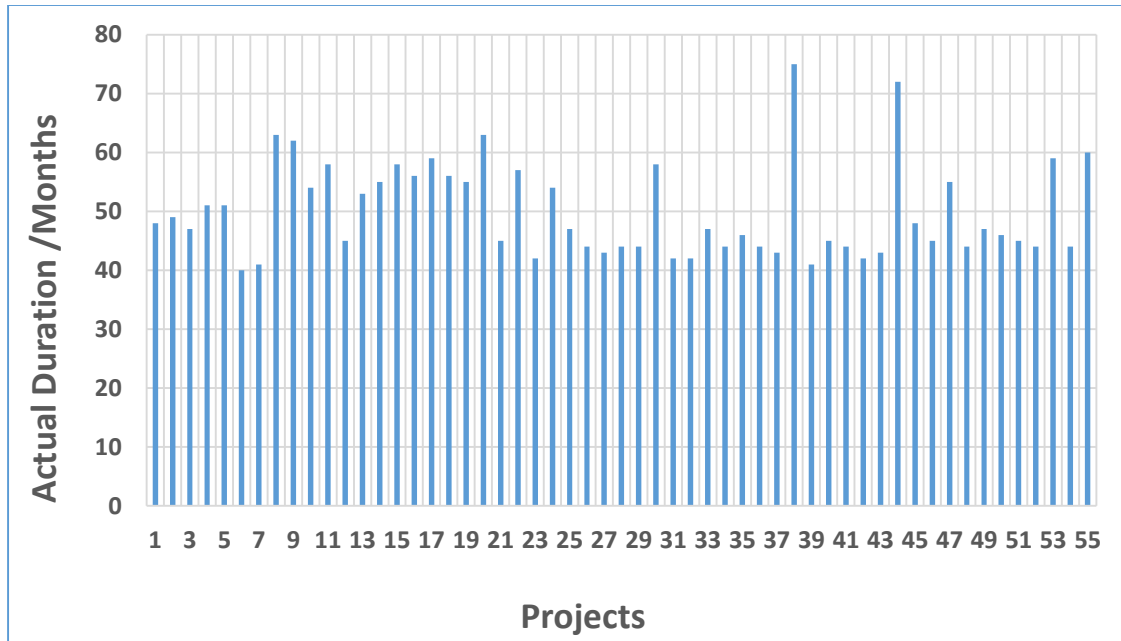


Figure 8-3 Actual Duration for 55 projects

The percentage of duration from the case study is computed using the following simple equation (8.1). This meant that data from the 55 projects was categorized into estimated duration and actual duration in order to establish the final duration of the project at the time of the research.

$$\text{Duration Overrun} = (\text{Actual Duration} - \text{Planned Duration})$$

Equation 8-1: Equation for estimating the Duration overrun for the 55 case study projects

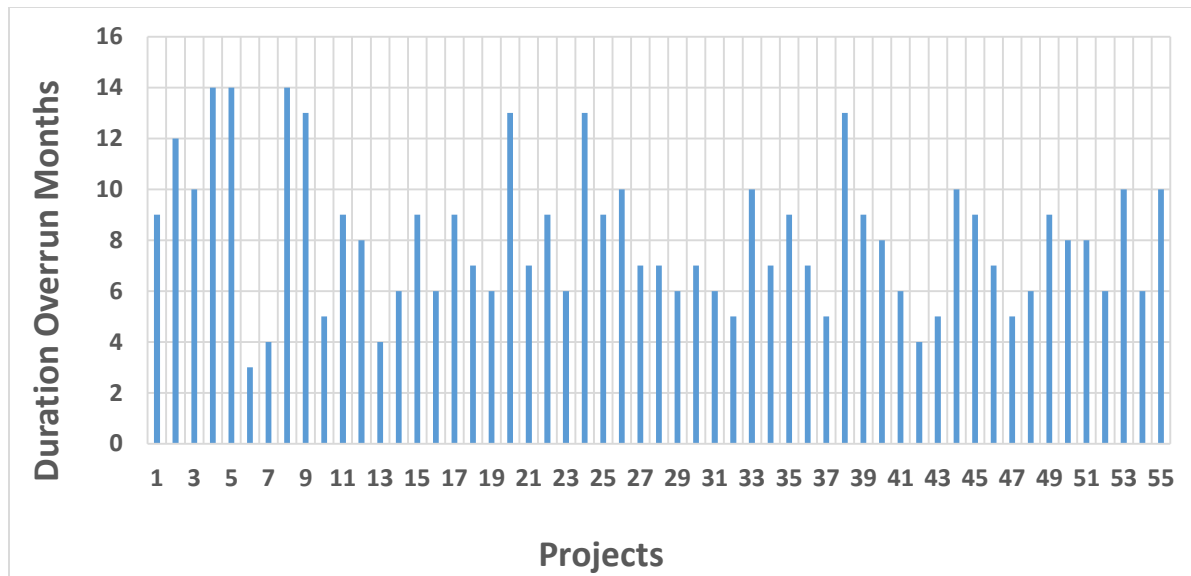


Figure 8-4 Duration Overrun for 55 projects – Months

Figure (8-4) above showed that 8 projects (2,4,5,8,9, 20,24, and 38) had highest duration overrun between 12 – 14 months, while 4 projects (6,7, 13 and 42) had the lowest duration overrun ranged between 2-4 months. All other projects (43 projects) had duration overrun fit in the range between 4-10 months. This figure clearly illustrate that projects delay was series issue for those projects used as case study for this research.

Equation 8.2 below depicts the processing of data from the 55 case studies in order to arrive at the percentage of project duration overrun.

Equation 8-2 Percentage of project duration overrun

Equation 8.2

$$\text{Percentage of Duration Overrun} = \frac{\text{Duration Overrun}}{\text{Planned Duration}} \times 100\%$$

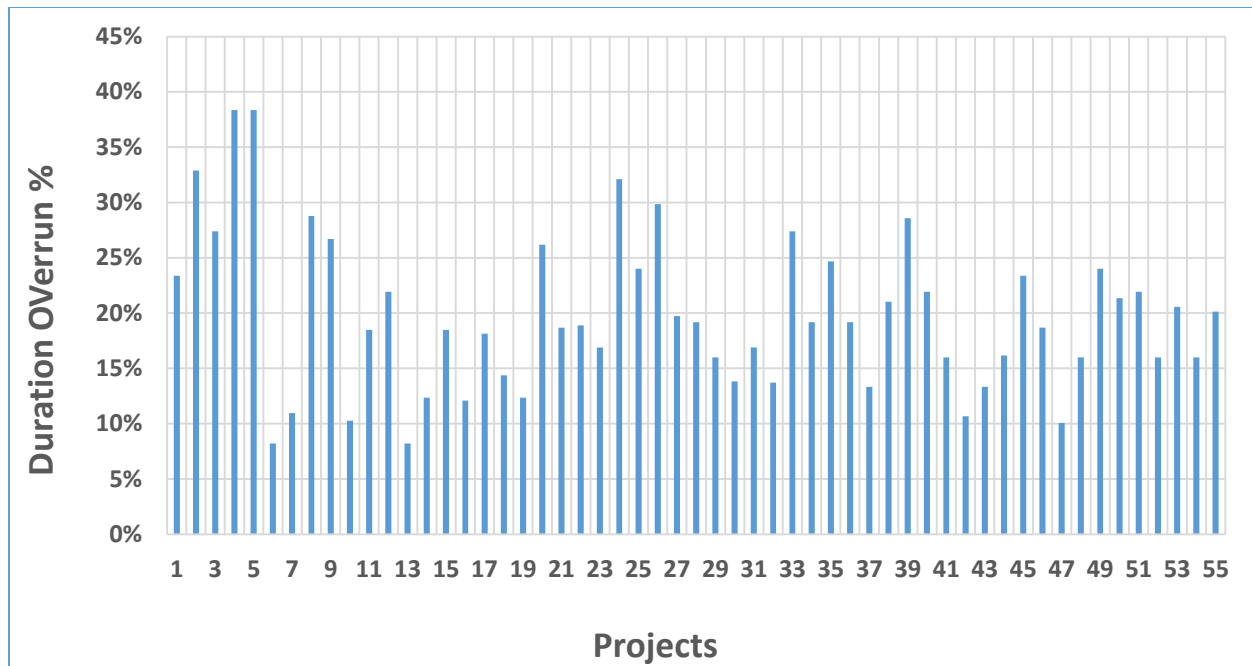


Figure 8-5 Percentages of Duration Overrun for 55 projects

Instead of presenting project duration overrun against the actual schedule for each case study, it was prudent to standardize the data by adopting an approach that can create duration overrun as a percentage of the actual duration. By so doing, project duration overrun as a percentage of overall duration creates data that make projects comparable.

The data presented in figure (8-5) also shows that there were (2) projects that had overrun by above 35%; and only (2) projects had an overrun of less than 10%. Moreover, (30) projects were between 15% and 25%; and (7) projects were between 25% and 30%, while other projects were between 10% and 20%. Based on this information, it can be argued that duration overrun has been a serious issue for the projects used in the case study.

Another cardinal issue to assess was the cost of each project. Figure (8-6) summarizes the profile of planned costs/budgets for the 55 projects. Notice, though, the cost of projects 8 and 54 are 3

times more than the cost of projects 21,46,50 and 55, making it difficult to undertake a meaningful analysis.

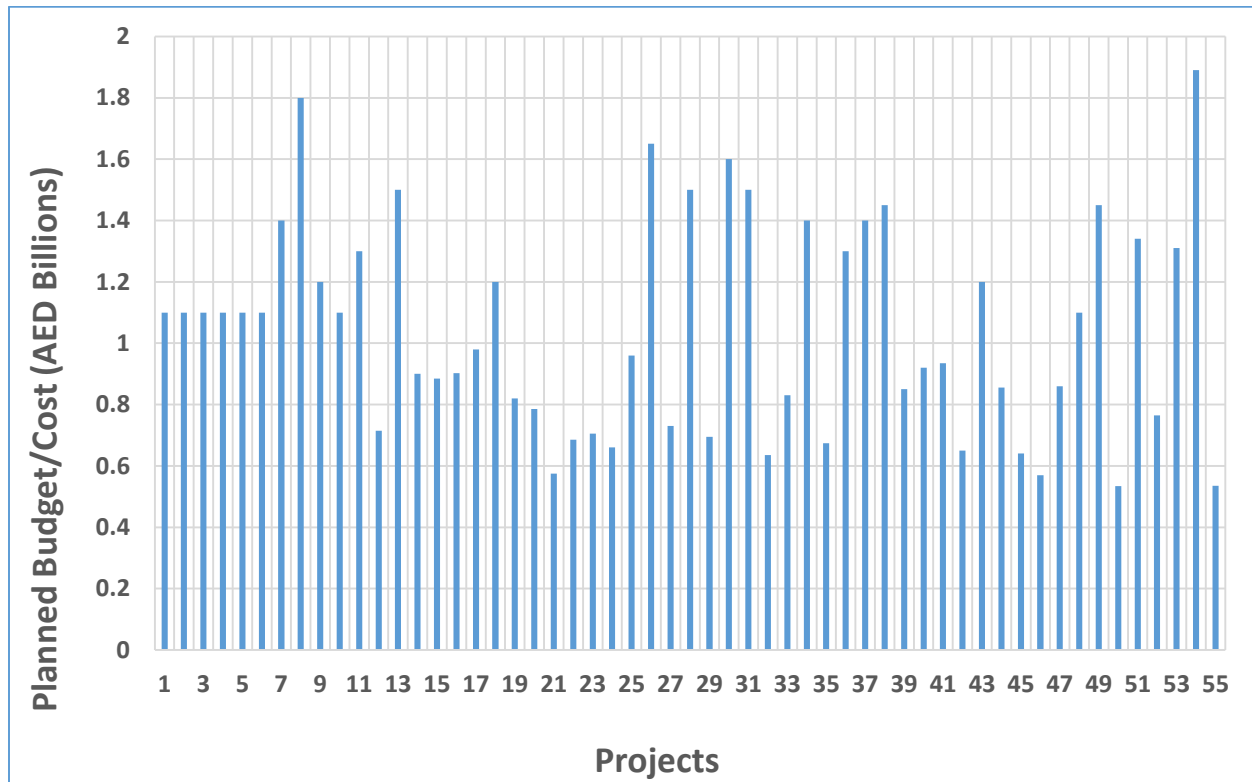


Figure 8-6 Planned cost/budget for 55 projects

Therefore, it was reasoned that if the cost values are used as reported there could be a distortion in the equation terms that will represent the relations between causes of projects delay, and that the variables causing cost variations could be difficult to pinpoint. Thus, the costs were normalized using the surface area of each project using equation 8-3.

Equation 8-3 Estimated cost per M2 = Estimated cost/Project surface Area.

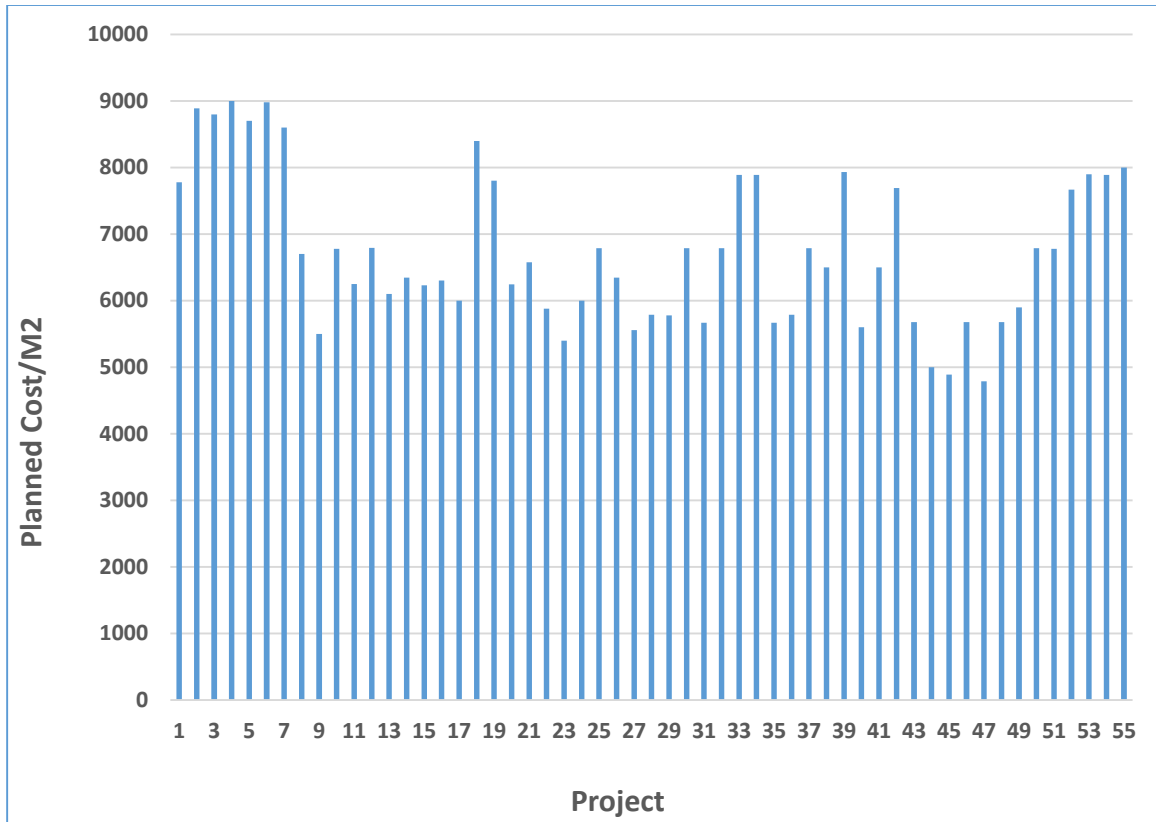


Figure 8-7 Planned cost/budget (AED thousands) for 55 projects normalized per M²

Figure (8-7) presents information after cost normalization using equation (8.3) where cost is normalized per square meter of the project, making the projects more comparable. It can be clearly observed that the cost per meter square for the majority of projects are fluctuated between AED 5000 to 9000 while only few projects are slightly below AED 9000 which are project 2 to 7. However, there are only two projects slightly below AED 5000 which are projects 45 and 47. Moreover, only 10 projects their cost per square meter are between AED 7000 and 8000 which are projects (1,19,33,34,42,52,53,54 and 55).

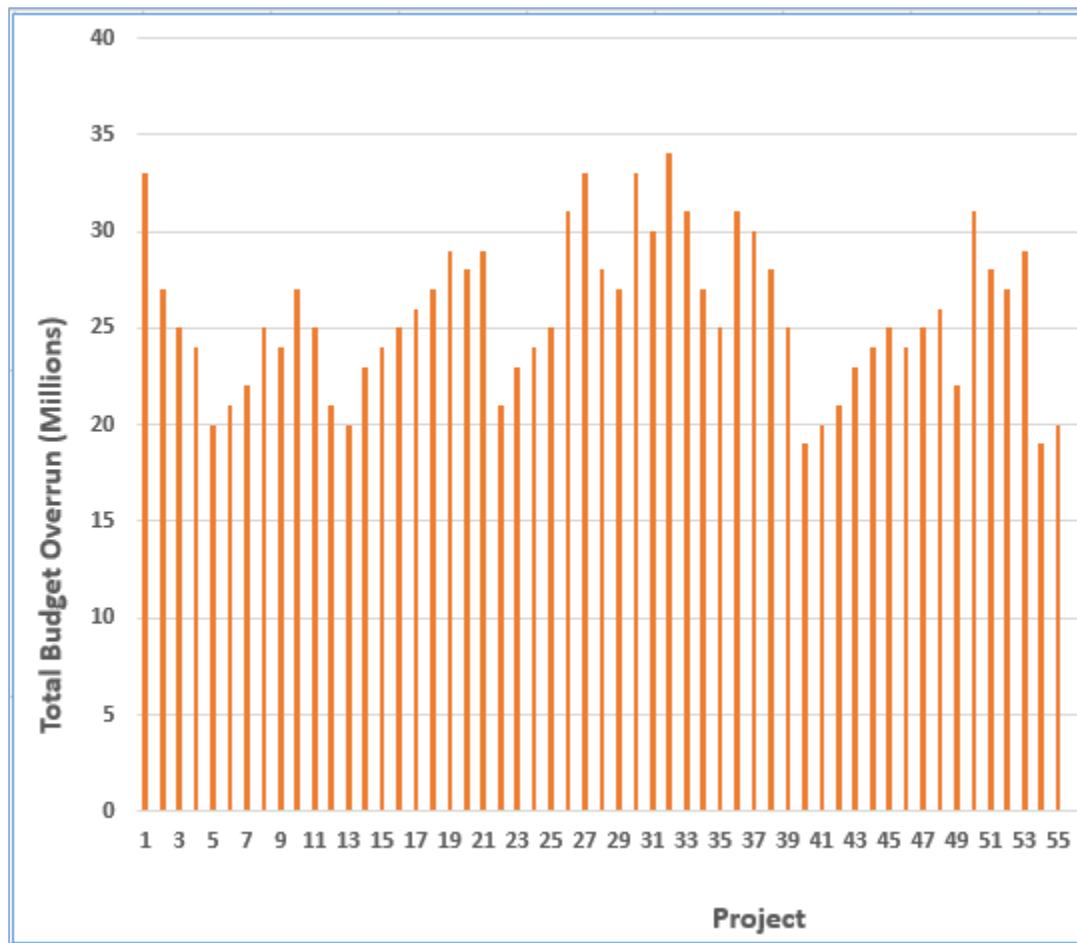


Figure 8-8 Total Cost/budget overrun for all 55 projects calculated as per the following equation:

Equation 8-4: Budget Cost Overrun

Equation 8.4: Budget Cost Overrun= Planned Budget – Actual Budget

From figure (8-8)above, it is noticed that there is only about 16 million difference between the lowest and highest cost overrun, projects 40, 54 are the lowest that are about 18 million for both and they are the only two projects that are below 20, and project 32 is the highest that is 34 million. Only 8 projects are above 30 million which are projects 1,26,27,30,33,36,37 and50. Moreover, all other projects are fluctuated between 20 to 30 million.

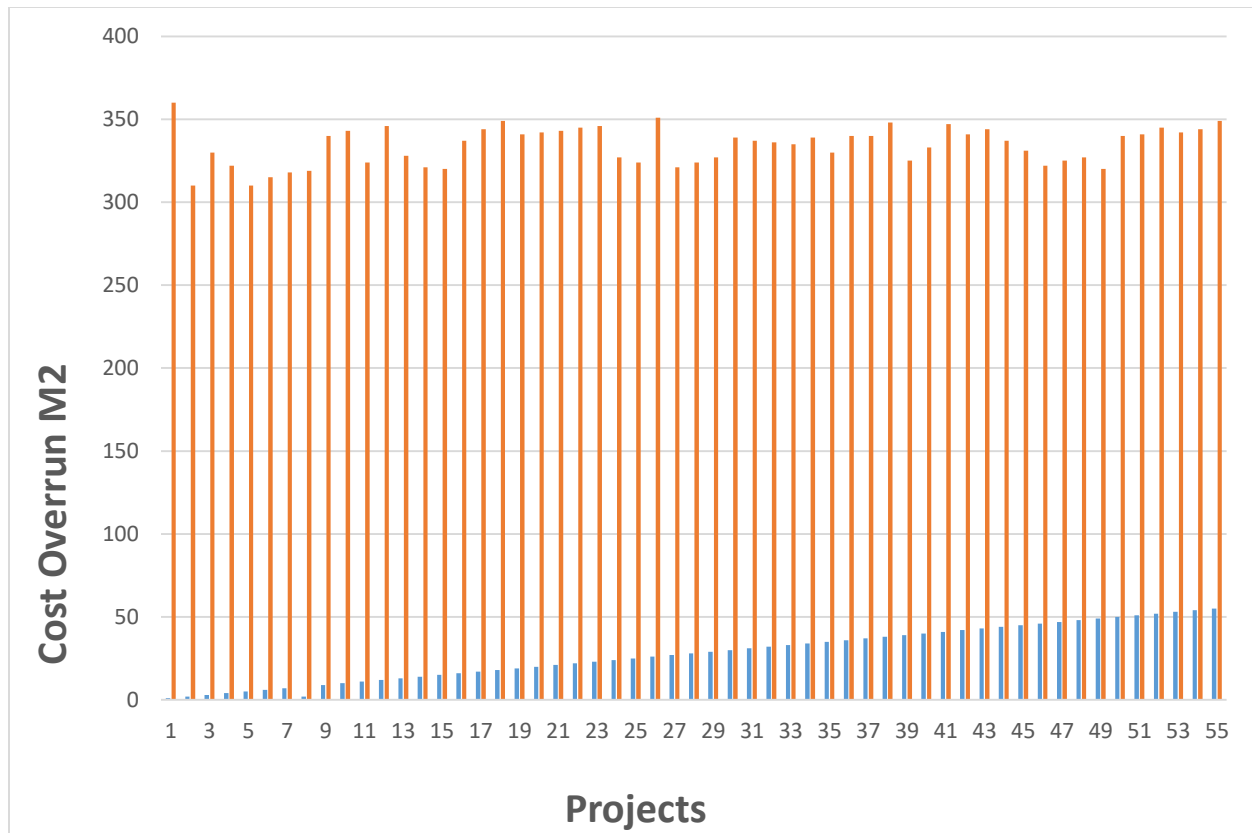


Figure 8.9 cost/budget overrun of 55 projects normalized per M²

The figure (8.9) shows the cost overrun per M² by using the following equation:

Equation 8-5: Cost Overrun per M²

Equation 8.5: Cost Overrun per M²= Total cost overrun/Total Surface Area

The figure (8.9) shows that project 1 had the highest cost overrun per M² which is 360 while lowest cost overrun per meter square is project 2 which is about 310. Majority of projects ranged between 310 to 360 while only two projects are slightly above 350, which are projects 1 and, 26.

The author of this study used above graphs in this research to summarize a large data set of 55 case studies projects in visual form and estimate key values of used data at a glance. Most of the above graphs are important to understand the data used at this research in this chapter, however,

the most important one is figure 8.9, which is used as research independent variable (cost overrun per meter square) in regression analysis and Monte Carlo simulation.

8.4 Data preparation and selection of significant causes of budget overrun

8.4.1 Data preparation

The data used in the analysis presented in this chapter consist of primary data (experts estimation of the impact of delay on cost overrun of the projects case studies) and the secondary data was the historical records of oil fields construction projects. The primary data was collected using questionnaires in which project experts assigned percentages scores to the impact of delay on the project's cost overrun, while the secondary data came from the projects case studies details (sample of the questionnaire template is illustrated in Appendix B). There are 55 projects with 45 respondents working/worked as project managers/sponsors and technical experts.

Starting with the secondary data, this study aims to obtain a regression model which explains the variation in budget overrun per M2 (dependent variable) considering the approved budget per M2 and percentage duration overrun (independent variables) to see if further improvement in the explanatory power of a model to predict BgtOverrunM2 is achievable, the causes of budget overrun are employed in developing the regression model. To achieve this aim, the linear relationship between the dependent and independent variables is accessed and the result shown in figures 8-10.

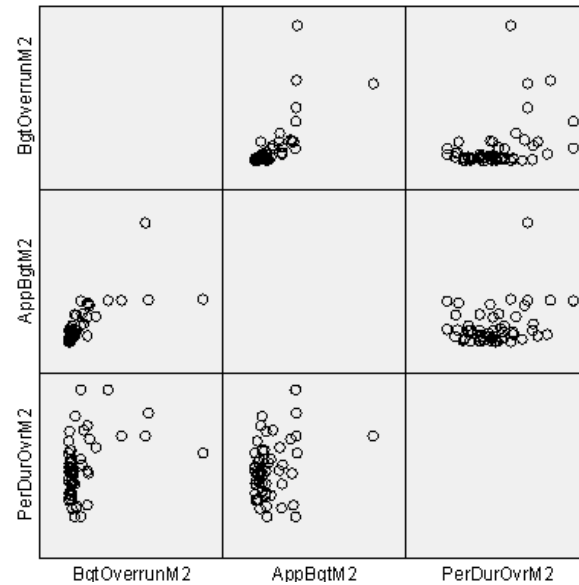


Figure 8-10: Scatter plot of dependent and independent variables (raw data)

As can be observed from the scatter plot (first row), there is limited linear relationship between the dependent and independent variables (especially BgtOverrunM2 and PerDurOvrM2). This is further confirmed by obtaining the correlation coefficient between the dependent and independent variables of which the result is presented in Table 8-2 where the weak correlation between BgtOverrunM2 vs PerDurOvrM2 and AppBgtM2 vs PerDurOvrM2 is highlighted.

Correlations

		BgtOverrunM2	AppBgtM2	PerDurOvrM2
BgtOverrunM2	Pearson Correlation	1	.700**	.386**
	Sig. (2-tailed)		.000	.004
	N	55	55	55
AppBgtM2	Pearson Correlation	.700**	1	.323*
	Sig. (2-tailed)	.000		.016
	N	55	55	55
PerDurOvrM2	Pearson Correlation	.386**	.323*	1
	Sig. (2-tailed)	.004	.016	
	N	55	55	55

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 8-2: Correlation coefficient of dependent and independent variables (raw data)

Also, the result obtained for the regression model using the raw data is provided in table 8.3.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.720 ^a	.518	.499	68.52859	.518	27.929	2	52	.000

a. Predictors: (Constant), PerDurOvrM2, AppBgtM2

Table 8-3: Summary of regression model results using raw data.

From the results, it can be observed that the model can explain approximately 50% of the variations in Budget Overrun per M2 caused by changes in Approved Budget per M2 and Percentage Duration Overrun per M2. The low explanatory power of this model can be attributed to the limited linear relationship between the dependent and independent variables. To improve the explanatory power of this model, data transformation is applied to the data.

It is important to state that the use of data transformation in improving the explanatory power of a regression model, is well established in the literature (Dolby 1963; Naylor 1963; Box & Cox 1964). Commonly employed transformations are: log transformation, square root transformation, angular transformations, power transformations, etc. After applying these transformations to the raw data, the natural logarithm transformation was later employed in this work since it gives the best improvement in linear relationship between the dependent and independent variables. Specifically, the data that has been transformed are those of Budget Overrun per M2 and Approved Budget per M2.

An assessment of the linear relationship between the dependent and independent variables in their transformed state is shown in Figure 8-11.

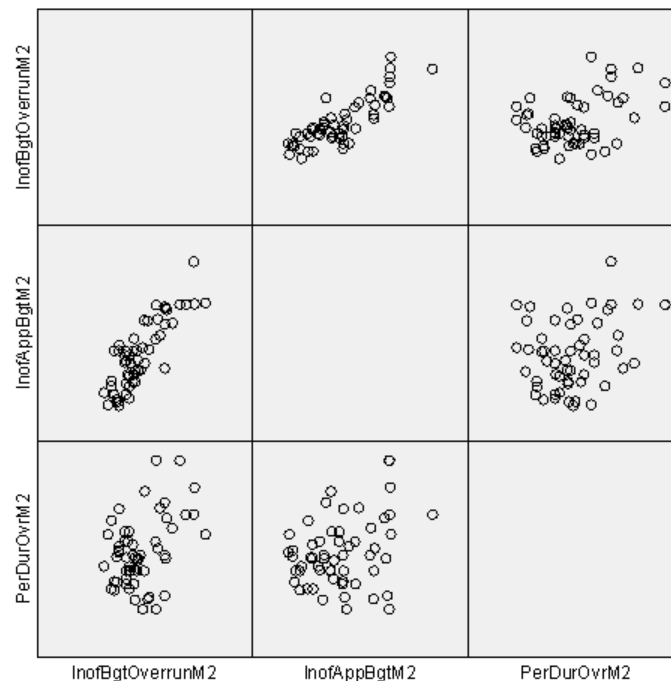


Figure 8-11: Scatter plot of dependent and independent variables (with data transformation)

Comparing the top cell of the scatter plots in figures 8-10 and 8-11, it can be observed that the linear relationship between the dependent and independent variables has been significantly improved. This is also confirmed from the correlation coefficient of the transformed variables in Table 8-4.

Correlations				
		InofBgt OverrunM2	InofAppBgtM2	PerDurOvrM2
InofBgtOverrunM2	Pearson Correlation	1	.834**	.410**
	Sig. (2-tailed)		.000	.002
	N	55	55	55
InofAppBgtM2	Pearson Correlation	.834**	1	.304*
	Sig. (2-tailed)	.000		.024
	N	55	55	55
PerDurOvrM2	Pearson Correlation	.410**	.304*	1
	Sig. (2-tailed)	.002	.024	
	N	55	55	55

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 8-4: Correlation coefficient of dependent and independent variables (transformed data)

Comparing the results in Tables 8-2 and 8-4, data transformation increased the correlation coefficient between BgtOverrunM2 and AppBgtM2 from 0.700 to 0.834 and BgtOverrunM2 and PerDurOvrM2 from 0.386 to 0.410.

Using the transformed data, the result of the regression model is provided in table 8-5.

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.849 ^a	.722	.711	.58818	.722	67.395	2	52	.000

a. Predictors: (Constant), PerDurOvrM2, InofAppBgtM2

Table 8-5: Summary of regression model results using transformed data.

Therefore, with the transformed data, the explanatory power of the regression model increased from 49.9% to 71.1% (an improvement of 42.5%).

8.4.2 Selection of significant causes of budget overrun

Using all the 45 variables considered as causes of budget overrun in the regression model will overcomplicate the modelling process. Therefore, it is reasonable to remove those variables that have minimal effect on the variability of budget overrun. By so doing, a number of significant causes which explains the variation in budget overrun to a large extent can be obtained. This work aims to utilize less than 50% of the independent variables (at most 22 out of the 45 causes). Therefore, the degree of linear relationship between the causes and dependent variable is examined.

Table 8-6 shows the 22 variables that show sufficient linear relationship with budget overrun.

Factors	BudgetOverrunM2	Factors	BudgetOverrunM2
BCT3Cost	0.123	BCN10Cost	0.272

BCT4Cost	0.388	BCN11Cost	-0.168
BCT6Cost	0.194	BPO6Cost	0.145
BCT7Cost	-0.163	BPO7Cost	0.363
BCT10Cost	0.161	BPO10Cost	-0.312
BCT11Cost	-0.106	BPO12Cost	0.304
BCN1Cost	-0.198	BPO13Cost	-0.351
BCN3Cost	0.259	BPO14Cost	-0.011
BCN7Cost	-0.306	BEF2Cost	0.330
BCN8Cost	0.131	BEF3Cost	-0.123
BCN9Cost	-0.041	BEF7Cost	0.302

Table 8-6: Summary of correlation coefficient of significant causes of BudgetOverrunM2

From Table 8-6, the following observations are made about the significant causes of budget overrun.

1. Twelve independent variables were found to have positive relationship with budget overrun with the best and least correlated variables to budget overrun having correlation coefficients of 0.388 and 0.123 for BCT4Cost and BCT3Cost, respectively.
2. Ten independent variables were found to have negative relationship with budget overrun with the best and least correlated variables to budget overrun having correlation coefficients of -0.351 and -0.011 for BPO13Cost and BPO14Cost, respectively. It is important to stress that the necessity and relevance of these variables will be evaluated later

in this work when obtaining the regression model for this project (see Modelling Result subsection 8.6).

It is also important to access the degree of correlation between the independent variables so as to be guided on the possibility of having a problem of multicollinearity in the model obtained with the selected causes. Thus, the correlation matrix for the selected variables is provided in Tables 8-7 and 8-8.

The following observations are made about these correlation coefficients:

1. The strongest positive relationship among the independent variables exist in BPO10Cost vs BPO13Cost, with a correlation coefficient of 0.678.
2. The strongest negative relationship among the independent variables exist between BCN9Cost vs BCT6Cost, with a correlation coefficient of -0.378 .

The strong relationship between the variables BPO10Cost and BPO13Cost may cause the model to suffer from the problem of multicollinearity, weather they impact the model or not will be diagnosed later in this work (more details at section 8.7.1).

Correlations

		BCT3Cost	BCT4Cost	BCT6Cost	BCT7Cost	BCT10Cost	BCT11Cost	BCN1Cost	BCN3Cost	BCN7Cost	BCN8Cost	BCN9Cost
BCT3Cost	Pearson Correlation	1	.146	.195	-.204	.133	-.033	.184	.515**	-.228	-.055	-.146
	Sig. (2-tailed)		.287	.153	.134	.334	.810	.179	.000	.093	.690	.288
	N	55	55	55	55	55	55	55	55	55	55	55
BCT4Cost	Pearson Correlation	.146	1	.210	-.033	.149	-.081	-.042	.363**	-.119	-.054	.014
	Sig. (2-tailed)	.287		.124	.809	.279	.556	.762	.006	.388	.697	.922
	N	55	55	55	55	55	55	55	55	55	55	55
BCT6Cost	Pearson Correlation	.195	.210	1	-.257	-.165	.031	-.065	.318*	-.106	-.189	-.378**
	Sig. (2-tailed)	.153	.124		.058	.229	.820	.637	.018	.442	.167	.004
	N	55	55	55	55	55	55	55	55	55	55	55
BCT7Cost	Pearson Correlation	-.204	-.033	-.257	1	-.093	.239	.271*	-.155	-.182	-.071	-.095
	Sig. (2-tailed)	.134	.809	.058		.500	.079	.046	.259	.184	.607	.493
	N	55	55	55	55	55	55	55	55	55	55	55
BCT10Cost	Pearson Correlation	.133	.149	-.165	-.093	1	.094	-.092	.066	.141	-.020	.003
	Sig. (2-tailed)	.334	.279	.229	.500		.493	.502	.633	.306	.887	.982
	N	55	55	55	55	55	55	55	55	55	55	55
BCT11Cost	Pearson Correlation	-.033	-.081	.031	.239	.094	1	-.178	-.328*	-.168	-.079	.108
	Sig. (2-tailed)	.810	.556	.820	.079	.493		.194	.015	.219	.564	.434
	N	55	55	55	55	55	55	55	55	55	55	55
BCN1Cost	Pearson Correlation	.184	-.042	-.065	.271*	-.092	-.178	1	.213	-.093	.137	-.114
	Sig. (2-tailed)	.179	.762	.637	.046	.502	.194		.119	.500	.319	.409
	N	55	55	55	55	55	55	55	55	55	55	55
BCN3Cost	Pearson Correlation	.515**	.363**	.318*	-.155	.066	-.328*	.213	1	.193	.074	-.262
	Sig. (2-tailed)	.000	.006	.018	.259	.633	.015	.119		.158	.593	.054
	N	55	55	55	55	55	55	55	55	55	55	55
BCN7Cost	Pearson Correlation	-.228	-.119	-.106	-.182	.141	-.168	-.093	.193	1	-.119	-.045
	Sig. (2-tailed)	.093	.388	.442	.184	.306	.219	.500	.158		.388	.747
	N	55	55	55	55	55	55	55	55	55	55	55
BCN8Cost	Pearson Correlation	-.055	-.054	-.189	-.071	-.020	-.079	.137	.074	-.119	1	.458**
	Sig. (2-tailed)	.690	.697	.167	.607	.887	.564	.319	.593	.388		.000
	N	55	55	55	55	55	55	55	55	55	55	55
BCN9Cost	Pearson Correlation	-.146	.014	-.378**	-.095	.003	.108	-.114	-.262	-.045	.458**	1
	Sig. (2-tailed)	.288	.922	.004	.493	.982	.434	.409	.054	.747	.000	
	N	55	55	55	55	55	55	55	55	55	55	55

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 8-7: Correlation coefficient for independent variables (1)

Correlations

		BCN10Cost	BCN11Cost	BPO6Cost	BPO7Cost	BPO10Cost	BPO12Cost	BPO13Cost	BPO14Cost	BEF2Cost	BEF3Cost	BEF7Cost
BCN10Cost	Pearson Correlation	1	.027	-.231	.208	-.169	.240	.166	-.165	-.199	.136	.331*
	Sig. (2-tailed)		.845	.090	.127	.218	.078	.227	.229	.145	.321	.013
	N	55	55	55	55	55	55	55	55	55	55	55
BCN11Cost	Pearson Correlation	.027	1	.144	-.171	.129	-.036	.067	.135	-.244	-.123	-.097
	Sig. (2-tailed)	.845		.294	.211	.349	.792	.625	.325	.072	.372	.479
	N	55	55	55	55	55	55	55	55	55	55	55
BPO6Cost	Pearson Correlation	-.231	.144	1	-.013	.237	.275*	-.013	-.280*	.222	-.134	.172
	Sig. (2-tailed)	.090	.294		.924	.081	.042	.927	.039	.103	.328	.208
	N	55	55	55	55	55	55	55	55	55	55	55
BPO7Cost	Pearson Correlation	.208	-.171	-.013	1	-.257	.324*	-.292*	-.024	.283*	-.095	-.078
	Sig. (2-tailed)	.127	.211	.924		.058	.016	.031	.859	.036	.492	.571
	N	55	55	55	55	55	55	55	55	55	55	55
BPO10Cost	Pearson Correlation	-.169	.129	.237	-.257	1	-.064	.678**	-.183	-.143	-.127	.057
	Sig. (2-tailed)	.218	.349	.081	.058		.641	.000	.180	.298	.357	.677
	N	55	55	55	55	55	55	55	55	55	55	55
BPO12Cost	Pearson Correlation	.240	-.036	.275*	.324*	-.064	1	-.182	-.218	.175	-.204	.267*
	Sig. (2-tailed)	.078	.792	.042	.016	.641		.183	.110	.200	.135	.049
	N	55	55	55	55	55	55	55	55	55	55	55
BPO13Cost	Pearson Correlation	.166	.067	-.013	-.292*	.678**	-.182	1	-.062	-.349**	.035	-.056
	Sig. (2-tailed)	.227	.625	.927	.031	.000	.183		.650	.009	.800	.686
	N	55	55	55	55	55	55	55	55	55	55	55
BPO14Cost	Pearson Correlation	-.165	.135	-.280*	-.024	-.183	-.218	-.062	1	-.178	-.076	-.101
	Sig. (2-tailed)	.229	.325	.039	.859	.180	.110	.650		.194	.582	.462
	N	55	55	55	55	55	55	55	55	55	55	55
BEF2Cost	Pearson Correlation	-.199	-.244	.222	.283*	-.143	.175	-.349**	-.178	1	-.077	-.118
	Sig. (2-tailed)	.145	.072	.103	.036	.298	.200	.009	.194		.577	.392
	N	55	55	55	55	55	55	55	55	55	55	55
BEF3Cost	Pearson Correlation	.136	-.123	-.134	-.095	-.127	-.204	.035	-.076	-.077	1	-.044
	Sig. (2-tailed)	.321	.372	.328	.492	.357	.135	.800	.582	.577		.751
	N	55	55	55	55	55	55	55	55	55	55	55
BEF7Cost	Pearson Correlation	.331*	-.097	.172	-.078	.057	.267*	-.056	-.101	-.118	-.044	1
	Sig. (2-tailed)	.013	.479	.208	.571	.677	.049	.686	.462	.392	.751	
	N	55	55	55	55	55	55	55	55	55	55	55

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 8-8: Correlation coefficient for independent variables (2)

8.5 Modeling the impact of causes of delay on the budget of the projects

As explained in chapter 2 literature review, most experts in the construction of oil fields highlights the importance of early identification of causes of projects delay to avoid the impact of delay on projects success criteria as defined in this study. Assessing the effect of projects delay will help in minimizing the work disruption and cost escalation. To model the relationship between cost/budget overrun and causes of projects delay, this research proposes to use multiple regression (explained at chapter 5). This study uses statistical analysis of key variables to derive a model and its components. It is a method by which user can make estimates for a key variable using historical data from causes of delay case studies. This method of modelling is widely used in the construction sector and in particular for cost and duration forecasting (Boussabaine and Kirkham 2005; Lyulina *et al.*2015 and Yang *et al.*2009,).

Equation 8-6 is utilized in this work to represent the general input/output relationship used in modelling the variations in budget overrun.

Equation 8-6 General input/output relationship

$$f(c) = \beta_0 + \beta_1 c_1 + \beta_2 c_2 + \cdots + \beta_n c_n \quad (8.6)$$

Where $f(c)$ is the budget overrun as a function of the significant causes $(c_1, c_2, \dots, c_n)$. Also, β represents the coefficients of the regression model.

In estimating the values of β , commonly employed techniques are:

1. Forward selection
2. Stepwise selection

3. Backward selection

This work has employed and implemented the backward selection method using SPSS software. The backward selection method where the variables with the most statistically insignificant effect on the model fit are eliminated until the model cannot be improved any further. Its advantage over forward and stepwise selection methods is that it starts by fitting the model with all the specified variables then deletes insignificant ones. Unlike in forward and stepwise selection where the model fitting starts with a single variable after which addition of other variables take place

8.6 Modeling results

To model the impact of variation in budget overrun, the 22 significant variables identified in section 8.4.2 are employed as independent variables. Using the SPSS software, an F-value of 0.01 and 0.05 was specified as the inclusion and exclusion threshold, respectively, for the significant variables. Table 8-9 shows the variables that were removed at different stages of the simulation where it can be seen that apart from the first model, a variable was removed from every other model.

Variables Entered/Removed^a

Model	Variables Entered	Variables Removed	Method
1	BEF7Cost, BCT10Cost, BEF3Cost, BPO14Cost, BPO13Cost, BCT7Cost, BCN11Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCT4Cost, BCN9Cost, BPO7Cost, BPO10Cost, BPO6Cost, BCN3Cost	.	Enter
2	.	BPO14Cost	Backward (criterion: Probability of F-to-remove >= .050).
3	.	BPO7Cost	Backward (criterion: Probability of F-to-remove >= .050).
4	.	BCN11Cost	Backward (criterion: Probability of F-to-remove >= .050).
5	.	BCT4Cost	Backward (criterion: Probability of F-to-remove >= .050).
6	.	BPO13Cost	Backward (criterion: Probability of F-to-remove >= .050).

a. All requested variables entered.

b. Dependent Variable: BgtOverrunM2

Table 8-9: The different stages of backward selection method.

The associated model results obtained at different stages of the simulation is presented in Table 8-10.

Model Summary^a

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.958 ^a	.918	.862	35.93242	.918	16.377	22	32	.000	2.044
2	.955 ^b	.913	.857	36.57763	-.006	2.196	1	32	.148	
3	.950 ^c	.903	.846	37.95618	-.010	3.611	1	33	.066	
4	.946 ^d	.895	.838	39.02224	-.009	2.994	1	34	.093	
5	.943 ^e	.889	.834	39.51104	-.006	1.908	1	35	.176	
6	.938 ^f	.881	.826	40.44474	-.009	2.769	1	36	.105	

a. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO14Cost, BPO13Cost, BCT7Cost, BCN11Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCT4Cost, BCN9Cost, BPO7Cost, BPO10Cost, BPO6Cost, BCN3Cost

b. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO13Cost, BCT7Cost, BCN11Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCT4Cost, BCN9Cost, BPO7Cost, BPO10Cost, BPO6Cost, BCN3Cost

c. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO13Cost, BCT7Cost, BCN11Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCT4Cost, BCN9Cost, BPO10Cost, BPO6Cost, BCN3Cost

d. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO13Cost, BCT7Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCT4Cost, BCN9Cost, BPO10Cost, BPO6Cost, BCN3Cost

e. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO13Cost, BCT7Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCN9Cost, BPO10Cost, BPO6Cost, BCN3Cost

f. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BCT7Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCN9Cost, BPO10Cost, BPO6Cost, BCN3Cost

g. Dependent Variable: BgtOverrunM2

Table 8-10: Summary of regression model results.

1. From the result in Table 8-10, it can be observed that the explanatory power (adjusted R-square) of the model decreases as the number of independent variables decrease. Also, the (R-square change) is negative in models 2 to 6. This implies that the removal of any variable from the model is counterproductive to the explanatory power of the model. Therefore, we can conclude that the 22 variables selected to explain the variation of budget overrun are significant and none of them is redundant as far as the selected model (model 1) is concerned. It is important to stress that the 10 variables with negative coefficient are necessary within the regression model because they give the model its high explanatory power of 86.2%, however, they are not relevant causes of budget overrun because increasing any factor in project delay cannot cause a decrease in the project's budget overrun and vice-versa.

Also, the ANOVA result presented in Table 8-11 shows that all the models (model 1-6) are statistically significant since their p-values are less than 5%.

ANOVA^g

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	465201.1	22	21145.504	16.377	.000 ^a
	Residual	41316.431	32	1291.138		
	Total	506517.5	54			
2	Regression	462366.1	21	22017.432	16.456	.000 ^b
	Residual	44151.461	33	1337.923		
	Total	506517.5	54			
3	Regression	457534.7	20	22876.735	15.879	.000 ^c
	Residual	48982.824	34	1440.671		
	Total	506517.5	54			
4	Regression	453221.8	19	23853.779	15.665	.000 ^d
	Residual	53295.735	35	1522.735		
	Total	506517.5	54			
5	Regression	450317.1	18	25017.617	16.025	.000 ^e
	Residual	56200.415	36	1561.123		
	Total	506517.5	54			
6	Regression	445993.8	17	26234.929	16.038	.000 ^f
	Residual	60523.738	37	1635.777		
	Total	506517.5	54			

- a. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO14Cost, BPO13Cost, BCT7Cost, BCN11Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCT4Cost, BCN9Cost, BPO7Cost, BPO10Cost, BPO6Cost, BCN3Cost
- b. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO13Cost, BCT7Cost, BCN11Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCT4Cost, BCN9Cost, BPO7Cost, BPO10Cost, BPO6Cost, BCN3Cost
- c. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO13Cost, BCT7Cost, BCN11Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCT4Cost, BCN9Cost, BPO10Cost, BPO6Cost, BCN3Cost
- d. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO13Cost, BCT7Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCT4Cost, BCN9Cost, BPO10Cost, BPO6Cost, BCN3Cost
- e. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BPO13Cost, BCT7Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCN9Cost, BPO10Cost, BPO6Cost, BCN3Cost
- f. Predictors: (Constant), BEF7Cost, BCT10Cost, BEF3Cost, BCT7Cost, BCN7Cost, BCN8Cost, BPO12Cost, BCN1Cost, BCN10Cost, BCT11Cost, BCT6Cost, BCT3Cost, BEF2Cost, BCN9Cost, BPO10Cost, BPO6Cost, BCN3Cost
- g. Dependent Variable: BgtOverrunM2

Table 8-11: Summary of analysis of variation of the regression model results.

Accordingly, with the 22 significant variables, the selected model in this work (model 1) has an explanatory power of 86.2%. About 14% of the variation which this model cannot explain can be attributed to factors such as the other variables that were not included in the model or some natural random variations.

Overall, explanatory power the selected model is considered adequate. However, there is need to ensure that this model satisfies the assumptions of multiple linear regression. This is discussed in detail in sections 8.7.1 and 8.7.2.

8.7 Significance of the estimated coefficients

A representative of the weight or contribution of each of the 22 significant variables to the estimation of BgtoverrunM2 is the estimated coefficients (B). The result of the B-value for each of the independent variable is presented in Table 8-11. From the table, it can be observed that all the coefficients except that of BPO14Cost (p-value = 0.148) are significant at 10% significance level. At 5% significance level, the coefficients of BPO13Cost and BCN11Cost are also not significant with p-values of 0.063 and 0.082, respectively. This implies that at 95% confidence interval (5% significance level), 19 out of the 22, translating to 86.4% of the selected causes are good predictors of bgtoverrunM2.

Interestingly, irrespective of the level of significance, the coefficient of the intercept (B-value = 839.937) is significant since its p-value = 0.000. A possible interpretation of this B-value is that the mean value of bgtoverrunM2 in the absence of any of the causes of budget delay is 839.937. Also, the result in Table 8-11 shows that 7 causes of project delay contribute positively to bgtoverrunM2, while the remaining 16 causes contribute negatively. Specifically, BCT10 Cost

with B-value = 1227.796 contributes the highest and BCN7Cost with B-value = -1529.319 contribute the least.

The conclusion drawn from this result is that the variables with positive coefficient will increase the bgtoverrunM2 while those with negative coefficient are necessary but not relevant causes in this study. Therefore, managerial efforts should aim to reduce the effect of the variables with high positive coefficient. This will help in keeping the amount of bgtoverrunM2 at its barest minimum.

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1 (Constant)	839.937	111.384		7.541	.000	613.056	1066.819					
BCT3Cost	814.179	211.994	.432	3.841	.001	382.362	1245.996	.123	.562	.194	.201	4.965
BCT4Cost	-126.500	59.592	-.160	-2.123	.042	-247.885	-5.115	.388	-.351	-.107	.451	2.219
BCT6Cost	-319.476	88.600	-.343	-3.606	.001	-499.947	-139.004	.194	-.538	-.182	.281	3.557
BCT7Cost	-355.513	123.937	-.199	-2.868	.007	-607.965	-103.062	-.163	-.452	-.145	.531	1.885
BCT10Cost	1227.796	175.354	.555	7.002	.000	870.612	1584.980	.161	.778	.354	.406	2.466
BCT11Cost	-524.564	73.070	-.588	-7.179	.000	-673.402	-375.725	-.106	-.785	-.362	.380	2.634
BCN1Cost	-369.444	50.474	-.499	-7.320	.000	-472.256	-266.633	-.198	-.791	-.370	.549	1.821
BCN3Cost	-665.592	127.579	-.816	-5.217	.000	-925.462	-405.721	.259	-.678	-.263	.104	9.596
BCN7Cost	-1529.319	187.432	-.835	-8.159	.000	-1911.107	-1147.532	-.306	-.822	-.412	.243	4.109
BCN8Cost	208.662	65.484	.241	3.186	.003	75.275	342.049	.131	.491	.161	.445	2.245
BCN9Cost	-710.055	142.500	-.395	-4.983	.000	-1000.319	-419.791	-.041	-.661	-.252	.406	2.462
BCN10Cost	667.643	118.914	.521	5.614	.000	425.423	909.863	.272	.704	.283	.297	3.372
BCN11Cost	-118.620	66.152	-.119	-1.793	.082	-253.367	16.127	-.168	-.302	-.091	.575	1.740
BPO6Cost	-448.255	86.868	-.739	-5.160	.000	-625.200	-271.310	.145	-.674	-.261	.124	8.047
BPO7Cost	-194.586	93.406	-.184	-2.083	.045	-384.847	-4.324	.363	-.346	-.105	.328	3.048
BPO10Cost	-572.602	110.603	-.565	-5.177	.000	-797.894	-347.311	-.312	-.675	-.261	.214	4.678
BPO12Cost	546.817	170.955	.257	3.199	.003	198.592	895.042	.304	.492	.161	.395	2.530
BPO13Cost	-149.108	77.564	-.179	-1.922	.063	-307.101	8.885	-.351	-.322	-.097	.293	3.411
BPO14Cost	-84.275	56.873	-.128	-1.482	.148	-200.121	31.571	-.011	-.253	-.075	.342	2.921
BEF2Cost	152.071	48.867	.216	3.112	.004	52.533	251.609	.330	.482	.157	.528	1.892
BEF3Cost	-565.927	76.872	-.784	-7.362	.000	-722.510	-409.345	-.123	-.793	-.372	.225	4.452
BEF7Cost	1099.205	199.037	.477	5.523	.000	693.779	1504.630	.302	.699	.279	.342	2.924

a. Dependent Variable: BgtOverrunM2

Table 8-12: Results for the estimated coefficients extracted from the selected regression model.

8.7.1 Multicollinearity diagnostics

The phenomenon of multicollinearity arises when there is strong linear relationship between the independent variables. This is not desired in a regression model as it negatively impacts the correct interpretation of the regression coefficients. Also, multicollinearity inflates the variance of the regression coefficients and makes them very sensitive to minor changes in the model parameters causing the coefficients to vary substantially when variables are added or deleted from the model.

To diagnose the problem of multicollinearity, common approaches employed are:

1. Correlation coefficient (r),
2. Variance inflation factor (VIF),
3. Variance proportion and condition index

There is no rule of thumb as to the threshold statistic that constitutes multicollinearity in any of these methods. However, according to what is found in some literature, this work has considered a correlation coefficient greater than 0.8 (Tuffery 2011), a VIF greater than 10 (Kutner et al. 2005) and at least two variances proportions above 0.9 for any given condition index that exceeds 30 (Hair 2003).

From the results presented in tables 8-7 and 8-8, the strongest correlation occurs between the variables BPO10Cost and BPO13Cost with a correlation coefficient of 0.68, which is less than the threshold of 0.8. However, the use of correlation coefficient for multicollinearity diagnostic is not sufficient as multicollinearity can exist even when the correlation coefficient between the independent variables are low. Therefore, the use of VIF and condition index is adopted in this work.

Using the VIF results in Table 8-12, BCN3Cost has the highest VIF value of 9.596 (less than the threshold of 10). Also, using the condition index and variance proportion, it can be observed from table 8-13 that in both cases where the condition index exceeded 30 (30.914 and 107.639, however, none of the variance proportion (0.48 and 0.68) exceeded the threshold of 0.9 (Hair 2003). Therefore, we conclude that there is no evidence to suggest the existence of multicollinearity in the selected model

Collinearity Diagnostics																									
Model	Eigenvalue	Condition Index	Variance Proportions																						
			(Constant)	BCT 3 Cost	BCT 4 Cost	BCT 6 Cost	BCT 7 Cost	BCT 10 Cost	BCT 11 Cost	BCN 1 Cost	BCN 3 Cost	BCN 7 Cost	BCN 8 Cost	BCN 9 Cost	BCN 10 Cost	BCN 11 Cost	BPO 6 Cost	BPO 7 Cost	BPO 10 Cost	BPO 12 Cost	BPO 13 Cost	BPO 14 Cost	BEF 2 Cost	BEF 3 Cost	BEF 7 Cost
1	1	18.090	1.000	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	2	.930	4.411	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.04	.00	.04	.00	.00	.00	.00
	3	.738	4.950	.00	.00	.00	.00	.00	.00	.00	.01	.00	.00	.02	.03	.00	.00	.01	.00	.01	.00	.00	.01	.00	.01
	4	.507	5.972	.00	.00	.00	.00	.00	.01	.00	.00	.01	.01	.00	.01	.00	.01	.01	.01	.06	.00	.01	.01	.02	.01
	5	.437	6.431	.00	.02	.00	.00	.00	.00	.00	.00	.01	.00	.00	.04	.00	.00	.08	.00	.00	.02	.00	.00	.02	.01
	6	.379	6.911	.00	.00	.00	.00	.01	.00	.00	.00	.03	.00	.01	.01	.00	.03	.00	.00	.02	.01	.00	.05	.01	
	7	.310	7.638	.00	.01	.00	.00	.05	.08	.01	.00	.01	.00	.03	.01	.00	.00	.00	.01	.00	.01	.00	.00	.01	
	8	.244	8.603	.00	.00	.00	.00	.01	.19	.01	.00	.00	.00	.02	.07	.00	.00	.01	.01	.03	.01	.01	.00	.00	.00
	9	.223	9.003	.00	.00	.02	.01	.04	.00	.01	.05	.00	.06	.00	.01	.00	.02	.01	.02	.00	.01	.00	.03	.00	.02
	10	.179	10.064	.00	.00	.03	.00	.01	.00	.00	.02	.00	.01	.00	.01	.05	.01	.00	.01	.14	.00	.02	.08	.00	.04
	11	.168	10.376	.00	.00	.00	.01	.00	.02	.00	.01	.01	.00	.00	.02	.04	.03	.02	.02	.01	.06	.05	.01	.02	.15
	12	.146	11.140	.00	.00	.00	.00	.00	.00	.00	.07	.00	.00	.01	.03	.15	.00	.01	.07	.01	.02	.00	.02	.19	.03
	13	.131	11.730	.00	.02	.00	.00	.02	.00	.00	.07	.00	.02	.01	.01	.00	.00	.02	.00	.06	.12	.10	.00	.03	.10
	14	.108	12.932	.00	.03	.03	.01	.15	.04	.00	.00	.00	.01	.01	.13	.00	.04	.00	.22	.00	.07	.00	.00	.06	.02
	15	.092	13.986	.00	.07	.00	.06	.03	.10	.00	.10	.00	.05	.09	.03	.03	.00	.00	.04	.00	.04	.03	.00	.00	.01
	16	.079	15.096	.00	.02	.08	.00	.00	.01	.15	.05	.00	.00	.01	.08	.07	.01	.02	.01	.12	.00	.12	.05	.03	.01
	17	.065	16.658	.00	.02	.06	.00	.18	.01	.05	.01	.03	.03	.01	.01	.00	.16	.01	.00	.13	.10	.20	.00	.03	.10
	18	.055	18.214	.00	.00	.09	.05	.05	.00	.03	.07	.06	.02	.28	.07	.08	.02	.01	.01	.00	.00	.03	.01	.07	.05
	19	.036	22.314	.00	.00	.49	.14	.13	.04	.22	.04	.01	.00	.06	.19	.02	.03	.00	.05	.00	.00	.01	.03	.04	.06
	20	.034	22.949	.00	.01	.01	.19	.18	.01	.05	.29	.01	.04	.06	.02	.08	.04	.03	.08	.07	.04	.02	.33	.23	.03
	21	.026	26.175	.00	.02	.02	.01	.01	.14	.02	.03	.01	.06	.18	.09	.20	.56	.10	.01	.34	.02	.33	.25	.00	.03
	22	.019	30.914	.01	.48	.01	.00	.11	.04	.19	.00	.45	.04	.25	.02	.12	.00	.09	.05	.01	.06	.01	.00	.12	.05
	23	.002	107.639	.99	.29	.16	.51	.01	.30	.25	.18	.40	.61	.00	.16	.09	.03	.68	.27	.16	.22	.00	.21	.07	.18

a. Dependent Variable: BgtOverrunM2

Table 8-13: Condition index and variance proportion and multicollinearity diagnostic

8.7.2 Examining residuals

Three necessary conditions of multiple regression analysis that must be fulfilled by the error terms (residuals) of the selected model are: zero mean value, homoscedasticity and normality of error

terms. The result of the residual statistics is presented in table 8-14 where it can be seen that the residuals have a mean of zero.

Residuals Statistics ^a					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-26.7002	514.4828	56.4364	92.81614	55
Residual	-70.51242	54.98767	.00000	27.66079	55
Std. Predicted Value	-.896	4.935	.000	1.000	55
Std. Residual	-1.962	1.530	.000	.770	55

a. Dependent Variable: BgtOverrunM2

Table 8-14: Residual statistics

To assess homoscedasticity and normality of residual, this work employed the use of scatter plot, histogram and P-P plot. Homoscedasticity is a phenomenon in which the residuals have an equal scatter (no pattern) around a reference line. When this is not the case, the problem of homoscedasticity exists with the residuals having an increasing spread around the reference line. The implication of homoscedasticity is that there is correlation between the error terms. This will cause the regression coefficients to be less precise as estimators. A visual assessment of the relationship between the dependent variable (bgtoverrunm2) and residuals of the selected model is presented in figure 8-12 where no pattern can be observed in the scatter plot of the residuals. Therefore, we conclude that the residuals are homoscedastic in nature.

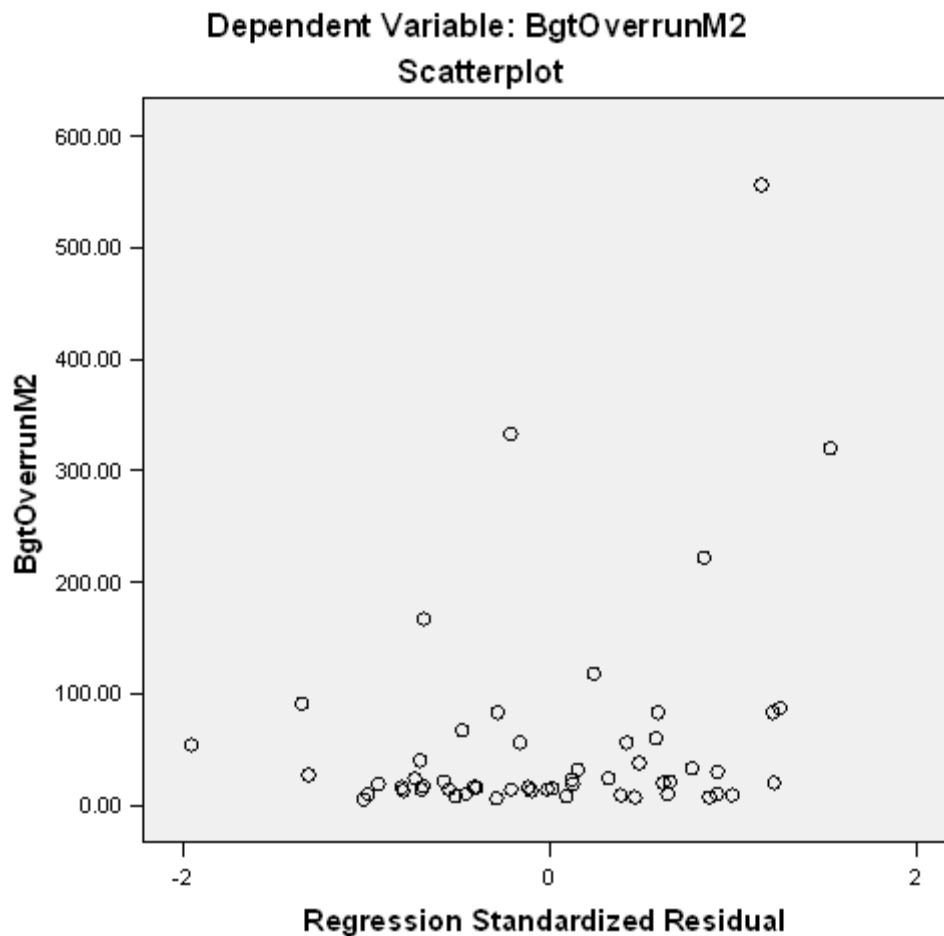


Figure 8-12: Scatter plot for residuals from the selected model

The histogram in figure 8-13 and P-P plot is figure 8-14 are used to assess the normality of the residuals. In the histogram plot, it can be seen that the error terms follow a normal distribution. Also, these error terms follow the straight line as can be seen in the P-P plot. Therefore, the assumption of normality is not violated in the selected model.

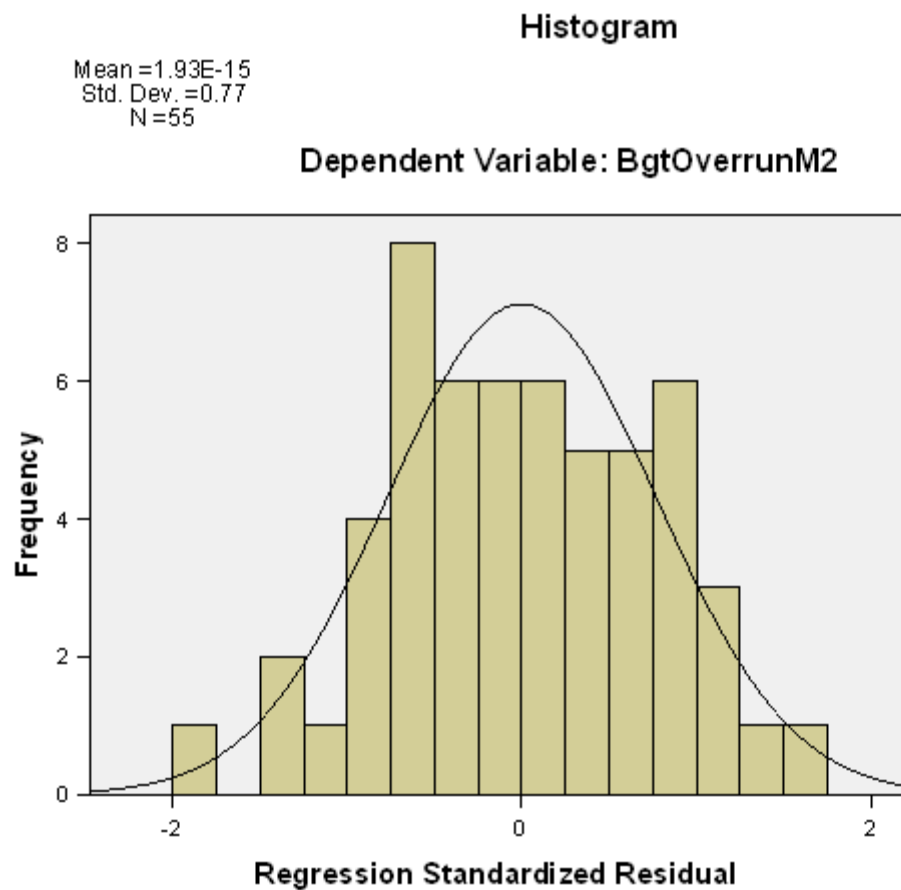


Figure 8-13: Histogram of the frequency of standardized residuals

Normal P-P Plot of Regression Standardized Residual

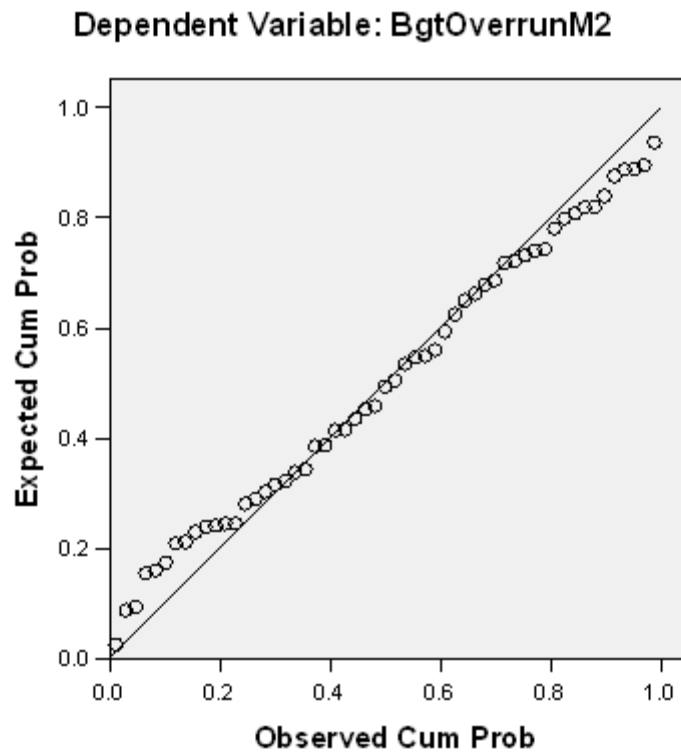


Figure 8-14: Normal P-P plot of regression standardized residuals for the dependent variable

8.8 Model validation

To validate the selected model, five cases were obtained and used in the regression equation. A plot of the actual and model predicted bgtoverrunM2 is displayed in figure 8-15 where it can be seen that the model has a very high accuracy in predicting the bgtoverrunM2 for the first project. In projects 2 and 3, there exists a slight difference between actual and model predicted bgtoverrunM2.

The model gives a negative estimation of bgtoverrunM2 in projects 4 and 5 contrary its actual positive value in both cases. A possible reason for such model estimation is that the significant

causes of bgtoverrunM2 with negative estimation coefficients have higher weight in both projects compared to those causes with positive estimation coefficients. For instance, in projects 4 and 5, the causes of bgtoverrunM2 with the highest weight was BPO6Cost with an estimation coefficient of -448.255.

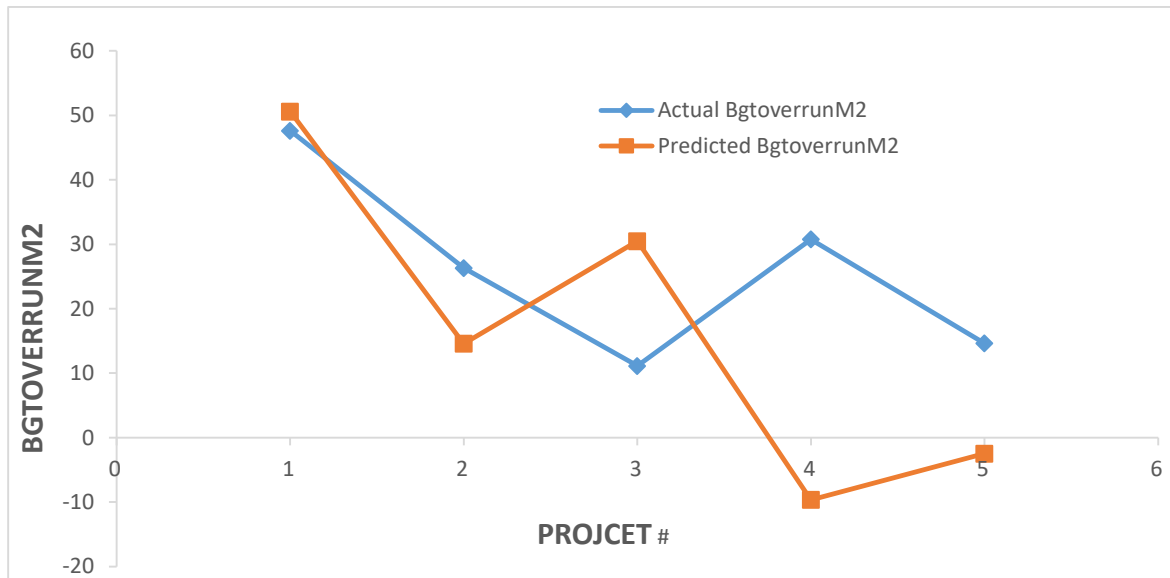


Figure 8-15: Comparison between actual and model predicted bgtoverrunM2

Accuracy of the model as a whole is assessed using the mean absolute deviation (MAD). The choice of approach is primarily due to its ability to provide an intuitive interpretation of the model's relative error. The MAD equation is given in Equation 8.7.

$$MAD = \frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}_i| \quad (8.7)$$

Where:

y_i = actual budget overrunM2,

$\hat{y}_i$ = the predicted budget overrunM2,

n = total number of cases

Project #	Actual	Predicted	Absolute error
1	47.61905	50.58134	2.962292381
2	26.31579	14.57767	11.73811947
3	11.11111	30.4851	19.37398889
4	30.76923	-9.66344	40.43267077
5	14.63415	-2.47426	17.10840634
MAD			18.32309557

Table 8-15: Result of the first test cases using MAD equation

The result obtained using equation 8.7 for the 5 projects is presented in table 8-15. Accordingly, MAD equation suggests that the model exhibits an average error of 18.32%. Therefore, it can be concluded that the model's average accuracy is above 80%.

8.9 Summary of the regression modelling

In this chapter, selecting and mapping the causes of *bgtoverrunM2* has been carried out using multiple regression analysis. Of the 45 causes identified, 22 were considered significant and utilized as independent variables in the regression model. The model equation used to predict *bgtoverrunM2* is presented in equation 8-8 based on the estimation coefficients obtained from regression analysis.

$$bgtoverrunM2 = 839.937 + 814.179 * BCT3Cost - 126.5 * BCT4Cost - 319.476 * BCT6Cost - 355.513 * BCT7Cost + 1227.796 * BCT10Cost - 524.564 * BCT11Cost -$$

$$\begin{aligned}
& 369.444 * BCN1Cost - 665.592 * BCN3Cost - 1529.319 * BCN7Cost + 208.662 * \\
& BCN8Cost - 710.055 * BCN9Cost + 667.643 * BCN10Cost - 118.62 * BCN11Cost - \\
& 448.255 * BPO6Cost - 194.586 * BPO7Cost - 572.602 * BPO10Cost + 546.817 * \\
& BPO12Cost - 149.108 * BPO13Cost - 84.275 * BPO14Cost + 152.071 * BEF2Cost - \\
& 565.927 * BEF3Cost + 1099.205 * BEF7Cost \quad (8.7)
\end{aligned}$$

Equation 8-7 model equation used to predict bgtoverrunM2

The following are the statistical tests and conditions of multiple linear regression fulfilled by the above equation.

- i. F-statistic was obtained as 16.377 and with a p-value of 0.000 (Sig. < 0.05)
- ii. Adjusted R^2 was 0.862
- iii. Standard error of the estimate was 35.93242
- iv. All the regression coefficients were statistically significant at 10% significant level, except that of BPO14Cost
- v. Problem of multicollinearity was non-existent
- vi. Assumptions of normality and independence of error terms were not violated
- vii. Assumption of homoscedasticity was not violated

In summary, none of the main assumption of regression were violated. Therefore, equation 8.8 can be used to stochastically simulate the impact of each cause of variation on bgtoverrunM2.

8.9.1 Monte Carlo simulation

The theory behind Monte Carlo simulation was reviewed in Chapter (6). This section presents the methodology adopted in the application of stochastic modelling using Monte Carlo simulation techniques on the developed multiple regression equation reviewed in Chapter (5). The aim of this exercise is to obtain information on project success (in this case, project budget/cost overrun percentage) based on best-fitted probability distributions for all possible output results from the simulation process. Monte Carlo simulation was used in the current research study to analyse the change in the dependent variable (percentage of budget/cost overrun) based on the developed regression model. The simulation process was conducted by repeatedly calculating output values for the dependent variable based on defined randomly selected input values for the independent variables (i.e., causes of projects delay; for the purpose of this exercise, the causes of projects delay are assumed to be uncertain). The output is generated as a probability distribution for the dependent variables, because of the random sampling of the independent variables, which can provide estimation that is more accurate for the decision makers and optimize project success in oil fields construction projects.

The process adopted for conducting Monte Carlo simulation is described in figure 8-17 and summarized in the following steps:

- i. The regression model was entered in an Excel spreadsheet format using the risk analysis software @Risk;
- ii. Each independent variable of the developed regression model was represented in @Risk by the best probability distribution generated from the case studies.

- iii. Monte Carlo simulation was used to repeatedly sample random values from each of the independent variables or causes of projects delay. The simulation was conducted to include the number of optimum iterations that were reported in the literature;
- iv. The output value was tracked as probability distributions. The results were presented as graphs, histograms and descriptive statistics;
- v. The model is also tested for sensitivity and robustness in order to determine the most influential input variables on the dependent construct.

The result from the above simulation process can be helpful for decision makers to optimize the design and construction of projects in oil fields constructions industry. They will use such a model in testing the sensitivity of project success outcomes based on the foreseen causes of projects delay.

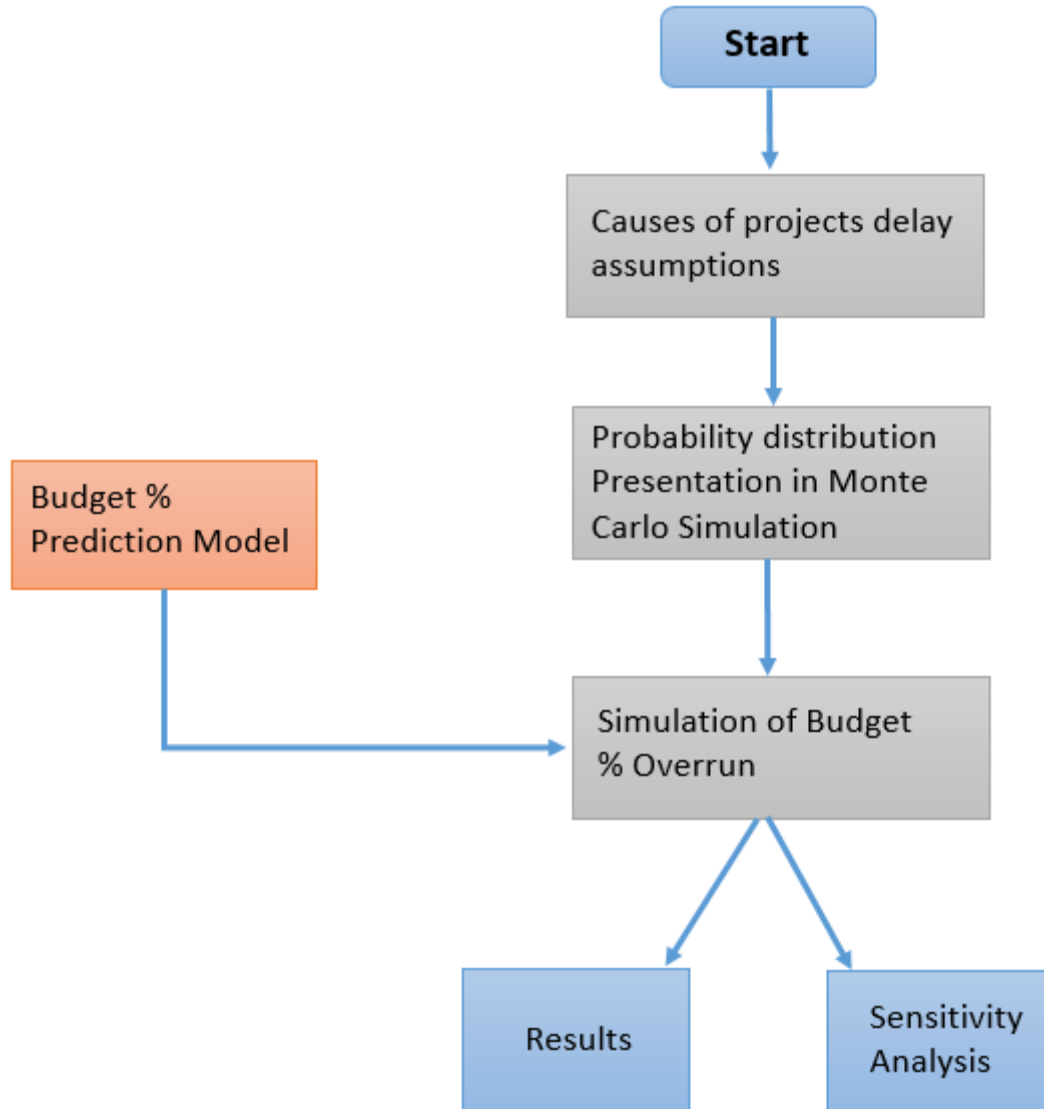


Figure 8-16: The simulation development process

8.9.2 Defining the probability distribution of the input variables

As explained before, the data used to drive the modelling was extracted from 55 case studies; and for each input variable, a theoretical probability distribution was fitted. As shown in chapters 4, the dependent variable (y) and independent variables (x) were quantified by a rating scale and then normalized. Thus, all input values are in the range between 0 and 1. There are many forms and

types of pre-defined probability distribution functions that may be used to fit the case study data. In this research, @Risk software was used to find the best theoretical distribution that fit each input variable. The software used to model the theoretical distribution employs in excess of 40 continuous distributions to identify the highest-ranked theoretical representation of each input variable.

For each input variable, the data sample from the case studies sample was analysed in the simulation software to find the best theoretical probability distribution to the actual data set. The @Risk software was used to conduct the fitting process. This was necessary in order to choose the distribution that has parameters closest to the original data set. Various distribution fits were investigated for their suitability to represent the input variables. Each distribution is tested and ranked using statistical goodness-of-fit tests. The following testes were used at table 8-17:

- ☐ Chi-squared statistic
- ☐ Anderson-Darling statistic
- ☐ Kolmogorov-Smirnov statistic

The distribution that was ranked first by Kolmogorov-Smirnov was selected. In addition to the above tests, several graphs were used to visually assess the fitness of the selected theoretical distributions:

Density histogram/cumulative curve: permits a visual comparison of the fit between the theoretical distribution and original data set.

Probability-Probability (P-P) plot: permits a visual inspection of the linearity fit between the plot of the P-values of the original data distribution against the P-values of the fitted. If the two are similar, one expects the two lines to be superimposed on each other.

Quantile-Quantile (Q-Q) plot: permits comparison between the percentile values of the original data distribution and the percentile values of the fitted distribution.

8.9.2.1 BCT3Cost

Figure 8-17 demonstrates the fit comparison for BCT3Cost, while figure 8-18 and figure 8-19, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Weibull distribution best fits the data. This distribution is widely employed in reliability assessment of engineering projects to determine project failure rates. Furthermore, figure 8-17 shows that the 90.0% and 93.9% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-18 and 8-19, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Weibull distribution of BCT3Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.0913	0.0909

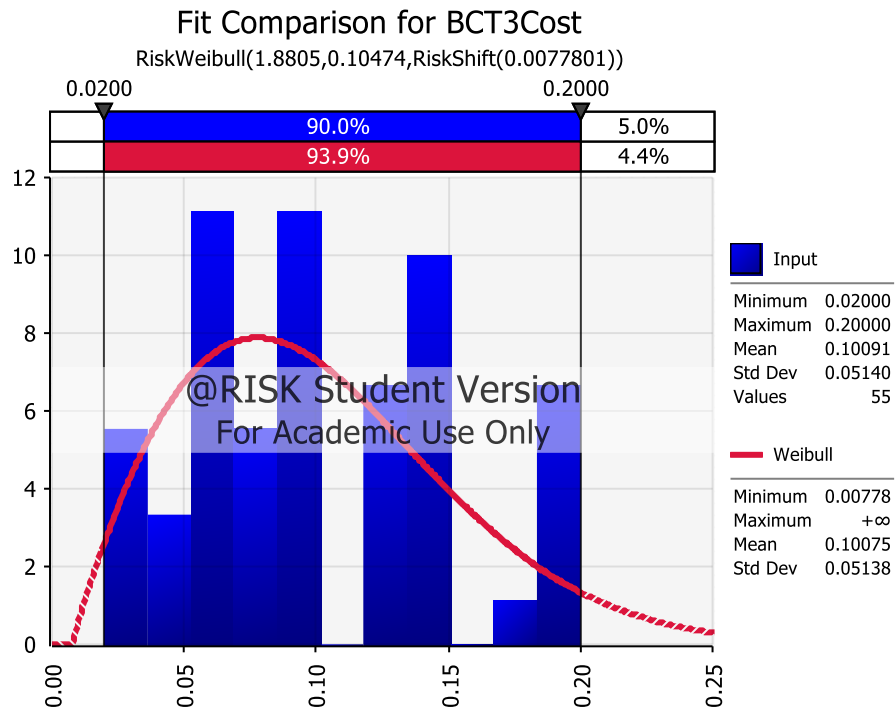


Figure 8-17: Fit comparison for BCT3Cost

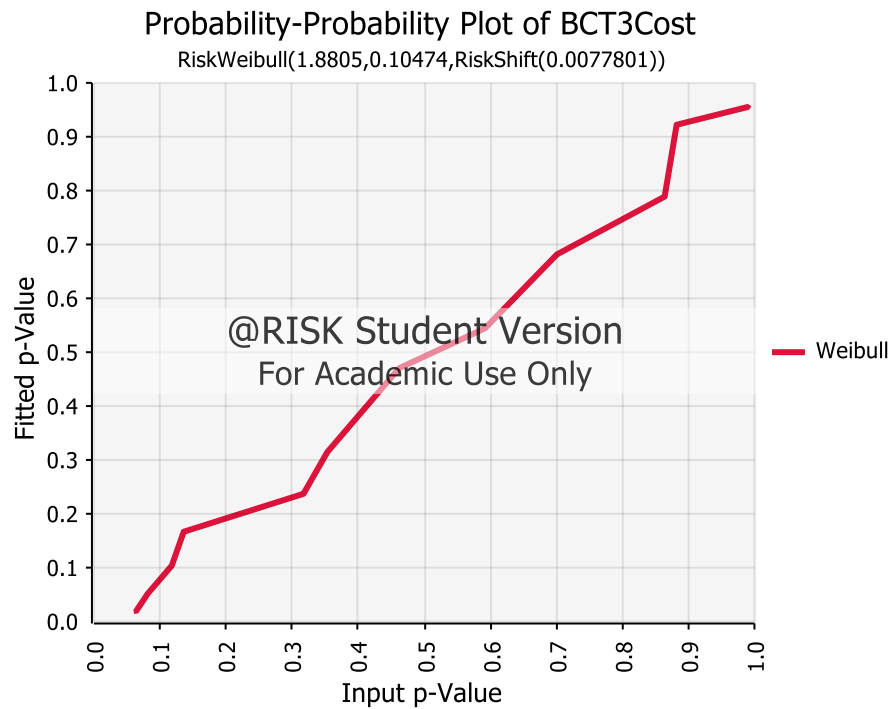


Figure 8-18: Probability-to-Probability plot for BCT3Cost

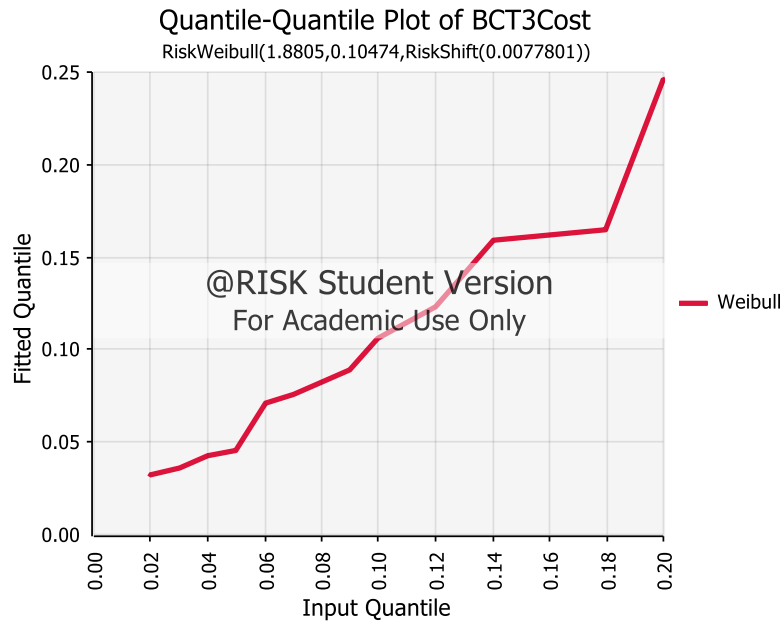


Figure 8-19: Quantile-to-Quantile plot for BCT3Cost

8.9.2.2 BCT4Cost

Figure 8-20 demonstrates the fit comparison for BCT4Cost, while figure 8-21 and figure 8-22, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analysed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Extreme value (ExtValue) distribution best fits the data. This distribution is widely employed to determine tail risk in the finance of a project. Furthermore, figure 8-20 shows that the 90.0% and 90.3% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-21 and 8-22, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Extreme Value of BCT4Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1650	0.0000

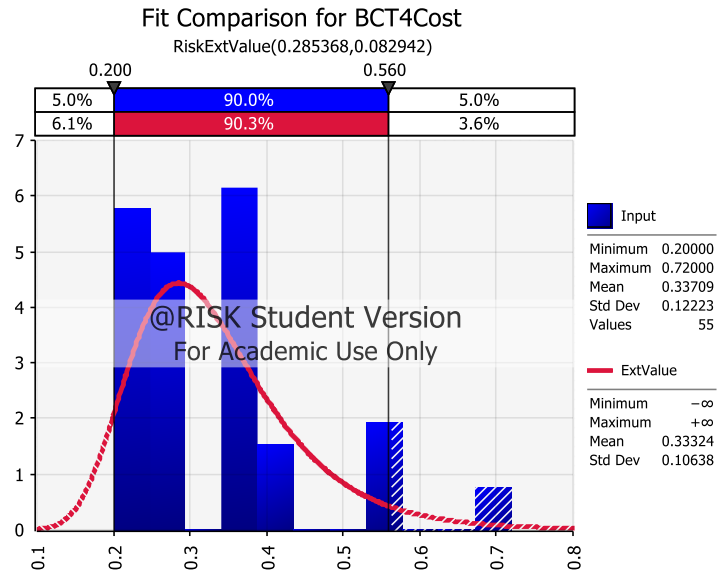


Figure 8-20: Fit comparison for BCT4Cost

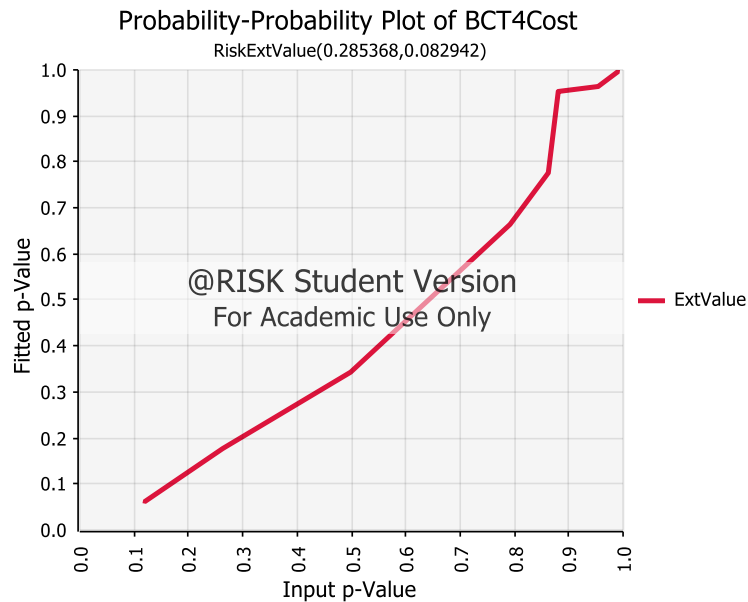


Figure 8-21: Probability-to-Probability plot for BCT4Cost

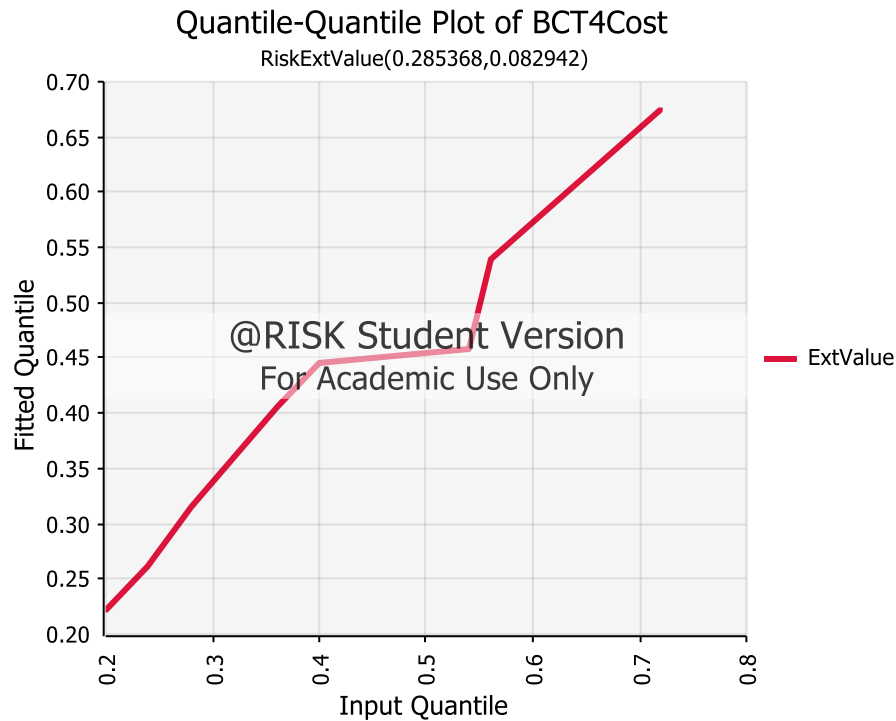


Figure 8-22: Quantile-to-Quantile plot for BCT4Cost

8.9.2.3 BCT6Cost

Figure 8-23 demonstrates the fit comparison for BCT6Cost, while figure 8-24 and figure 8-25, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analysed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Log logistic distribution best fits the data. This distribution is widely employed in survival assessment of events whose rate increases initially and decreases later. Furthermore, figure 8-23 shows that the 90.0% and 95.2% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-24 and 8-25, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Log logistic distribution of BCT6Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1879	0.0000

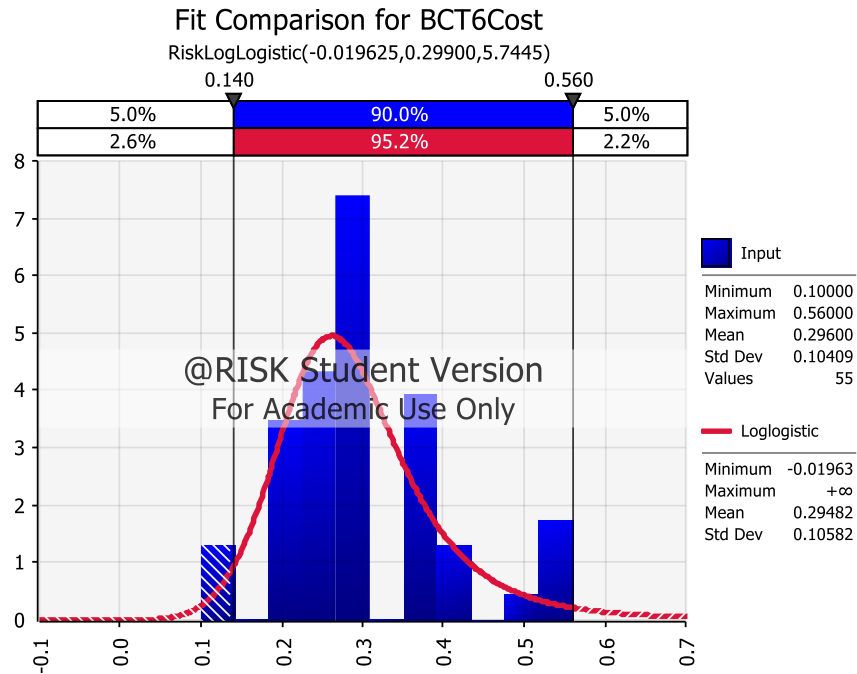


Figure 8-23: Fit comparison for BCT6Cost

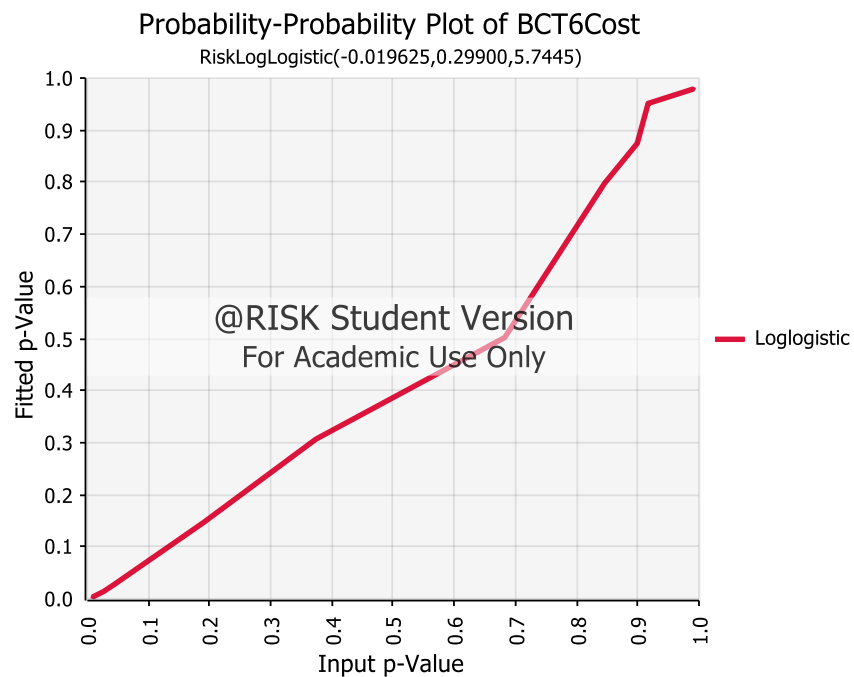


Figure 8-24: Probability-to-Probability plot for BCT6Cost

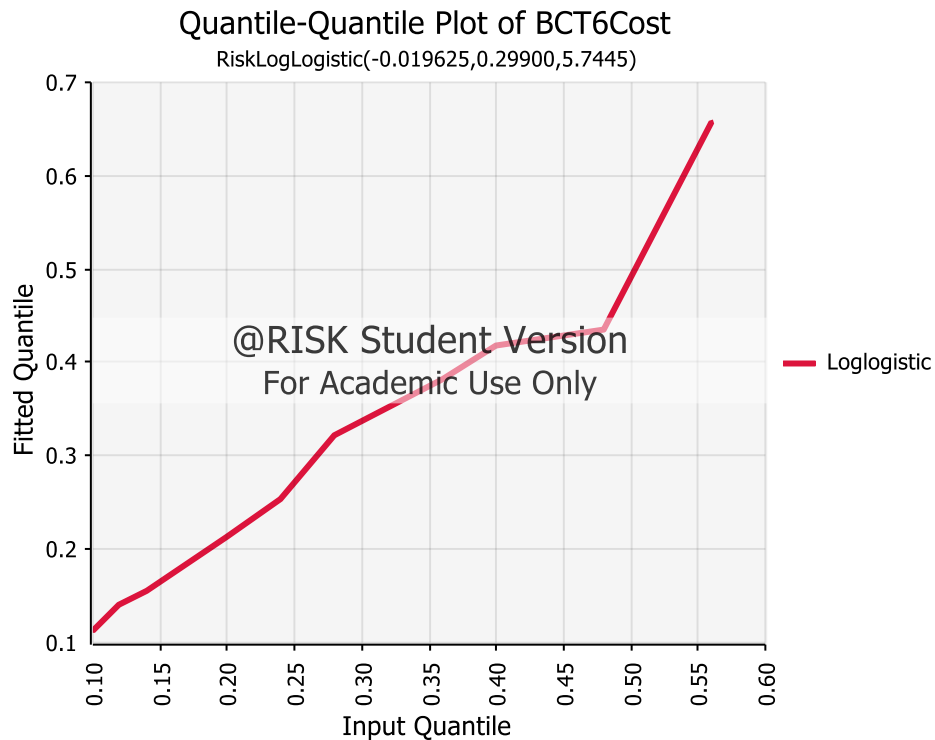


Figure 8-25: Quantile-to-Quantile plot for BCT6Cost

8.9.2.4 BCT10Cost

Figure 8-26 demonstrates the fit comparison for BCT10Cost, while figure 8-27 and Figure 8-28, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Extreme value (ExtValue) distribution best fits the data. This distribution is widely employed to determine tail risk in the finance of a project. Furthermore, figure 8-26 shows that the

90.0% and 85.5% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-27 and 8-28, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Extreme Value of BCT10Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1197	0.0000

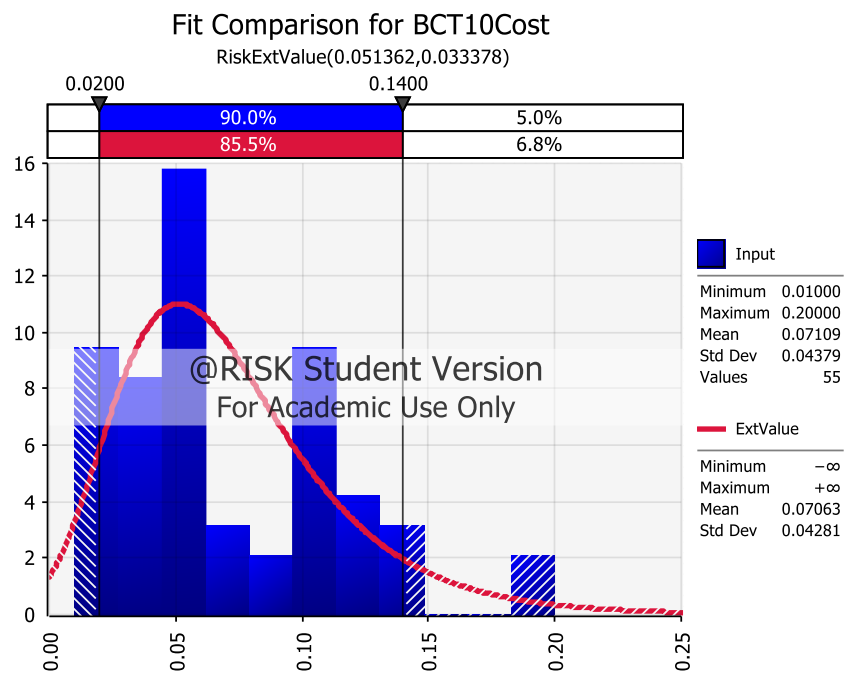


Figure 8-26: Fit comparison for BCT10Cost

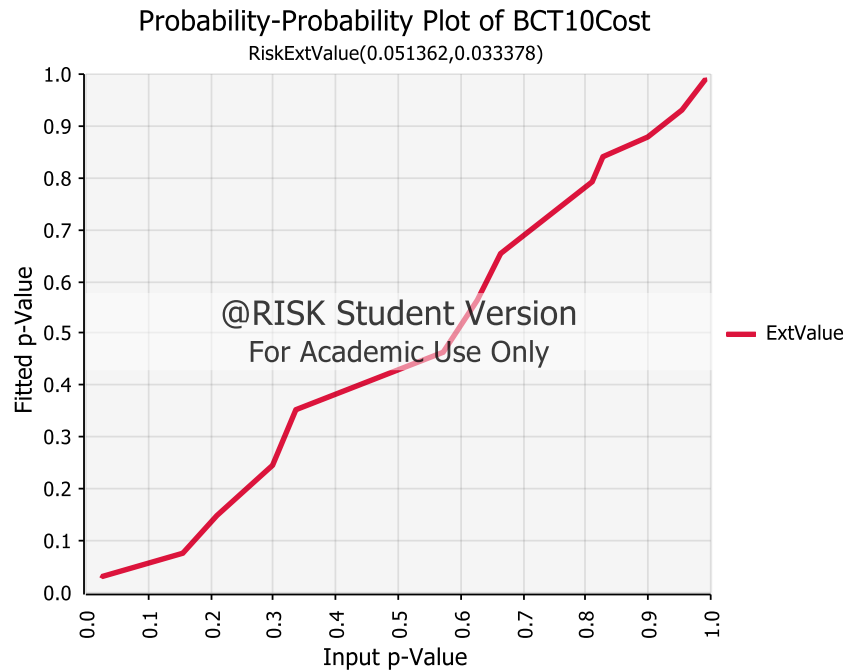


Figure 8-27: Probability-to-Probability plot for BCT10Cost

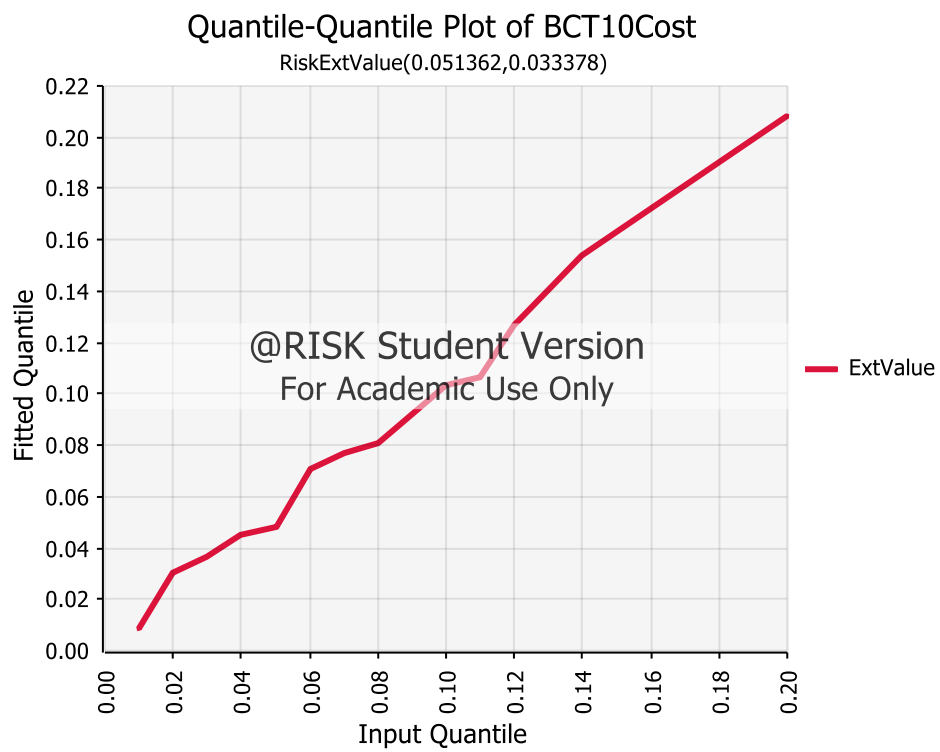


Figure 8-28: Quantile-to-Quantile plot for BCT10Cost

8.9.2.5 BCN3Cost

Figure 8-29 demonstrates the fit comparison for BCN3Cost, while figure 8-30 and figure 8-31, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Extreme value (ExtValue) distribution best fits the data. This distribution is widely employed to determine tail risk in the finance of a project. Furthermore, figure 8-29 shows that the 90.0% and 87.6% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-30 and 8-31, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Extreme Value of BCN3Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1140	0.0000

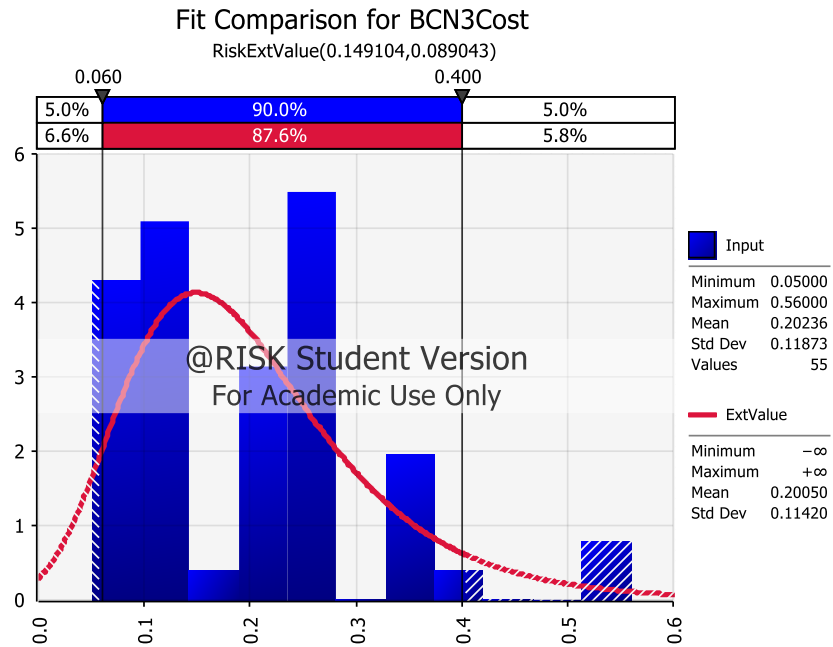


Figure 8-29: Fit comparison for BCN3Cost

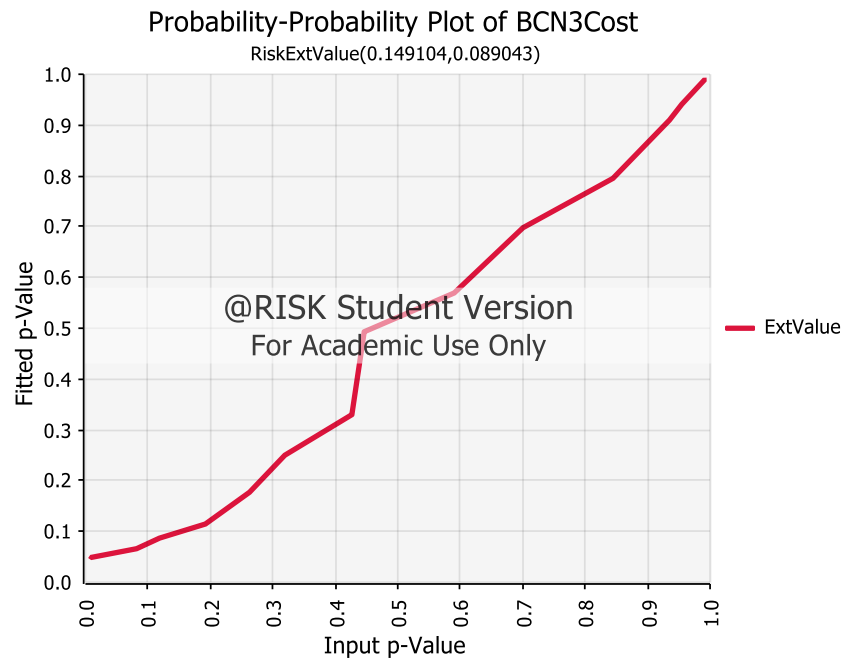


Figure 8-30: Probability-to-Probability plot for BCN3Cost

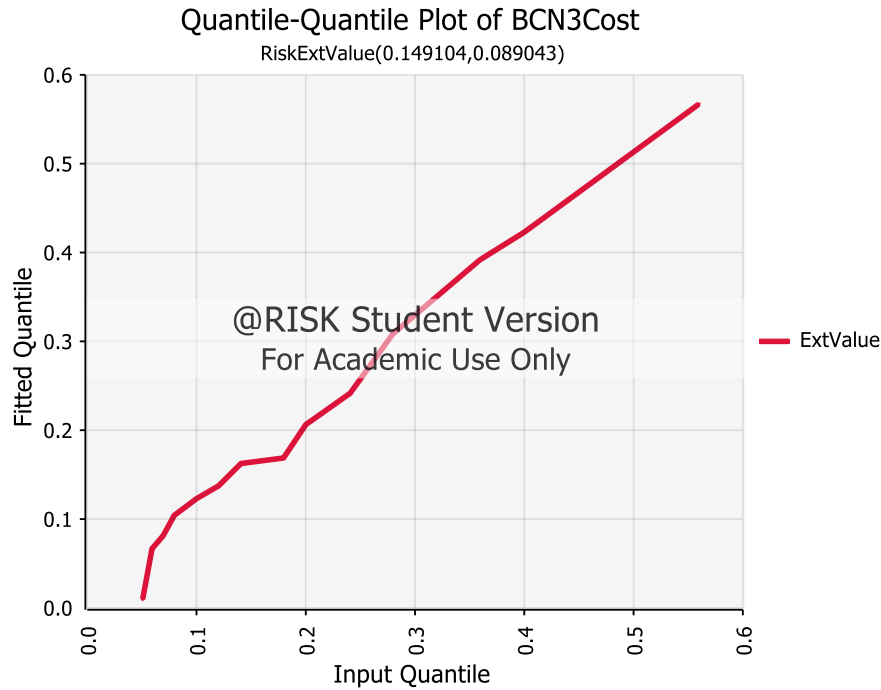


Figure 8-31: Quantile-to-Quantile plot for BCN3Cost

8.9.2.6 BCN8Cost

Figure 8-32 demonstrates the fit comparison for BCN8Cost, while figure 8-33 and figure 8-34, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Log logistic distribution best fits the data. This distribution is widely employed in survival assessment of events whose rate increases initially and decreases later. Furthermore, figure 8-32 shows that the 90.0% and 95.3% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-33 and 8-34, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Log logistic distribution of BCN8Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1372	0.0000

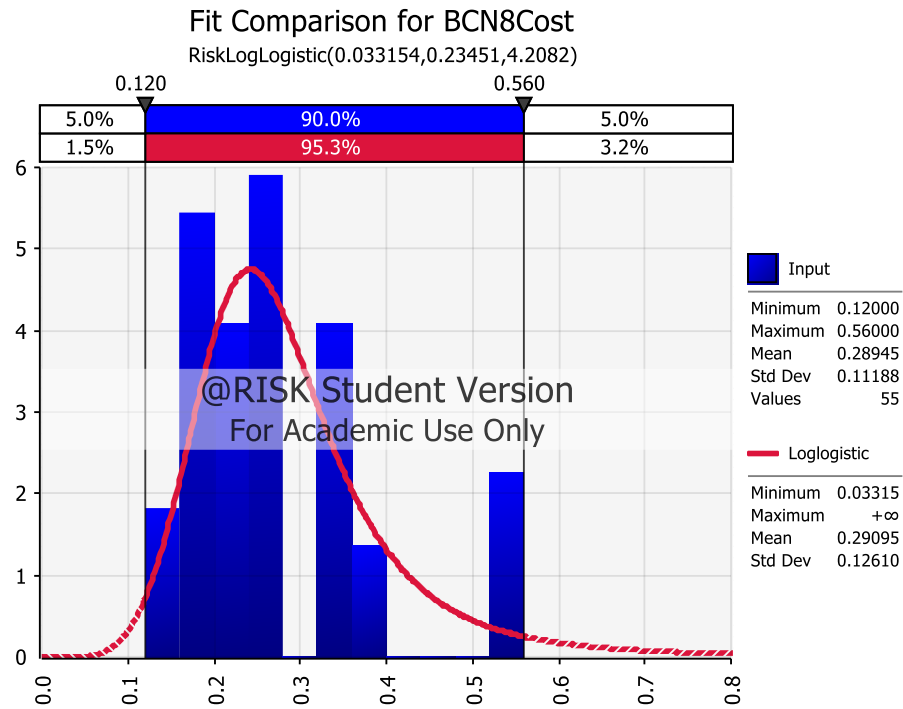


Figure 8-32: Fit comparison for BCN8Cost

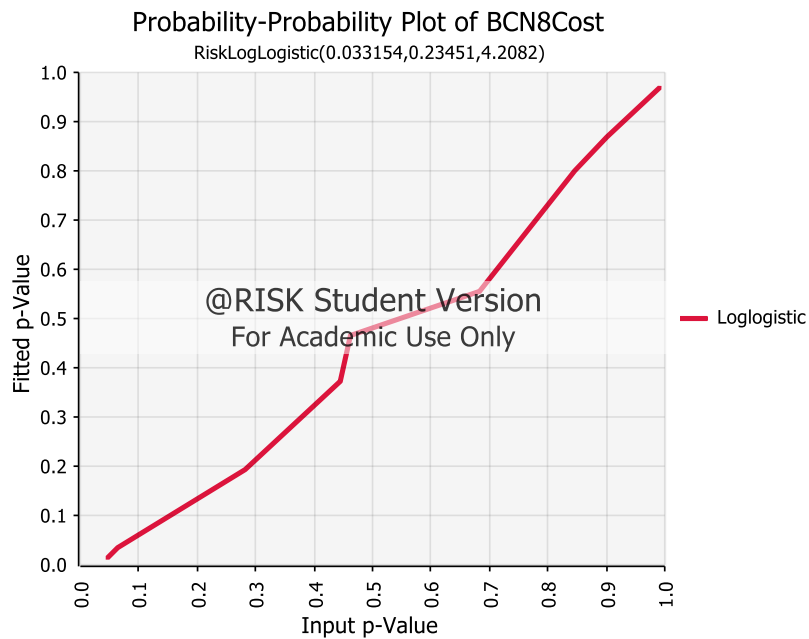


Figure 8-33: Probability-to-Probability plot for BCN8Cost

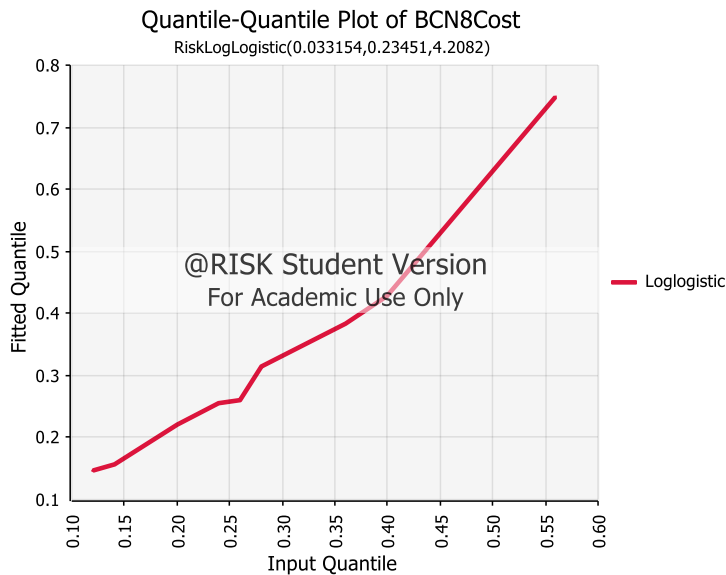


Figure 8-34: Quantile-to-Quantile plot for BCN8Cost

8.9.2.7 BCN10Cost

Figure 8-35 demonstrates the fit comparison for BCN10Cost, while figure 8-36 and figure 8-37, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Exponential distribution best fits the data. This distribution is widely employed in the analysis of Poisson point in processes where events occur continuously and independently at a constant average rate. Furthermore, figure 8-35 shows that the 90.0% and 92.8% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-36 and 8-37, respectively where the fitted and input parameters (p-value and

quartiles) exhibit significant match. For the Exponential distribution of BCN10Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.0911	0.4727

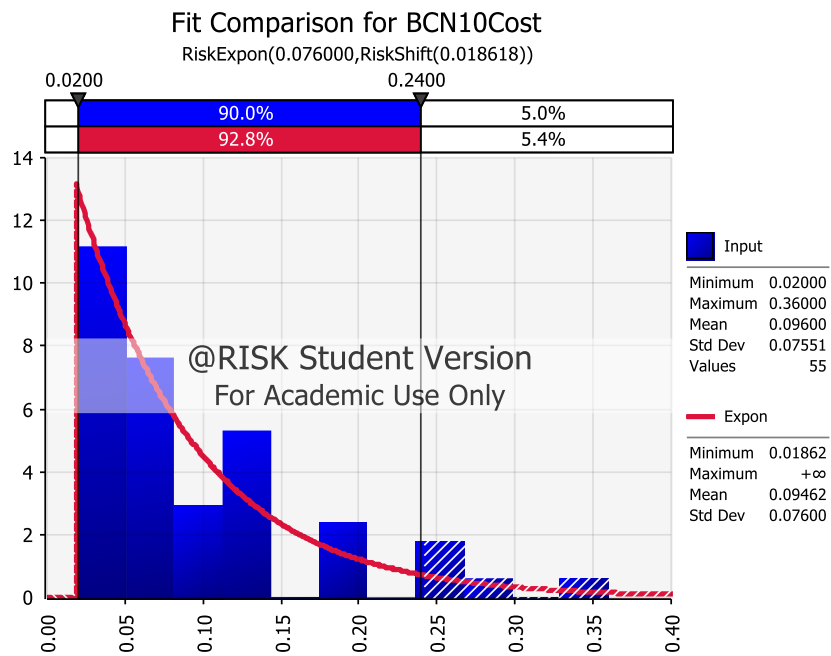


Figure 8-35: Fit comparison for BCN10Cost

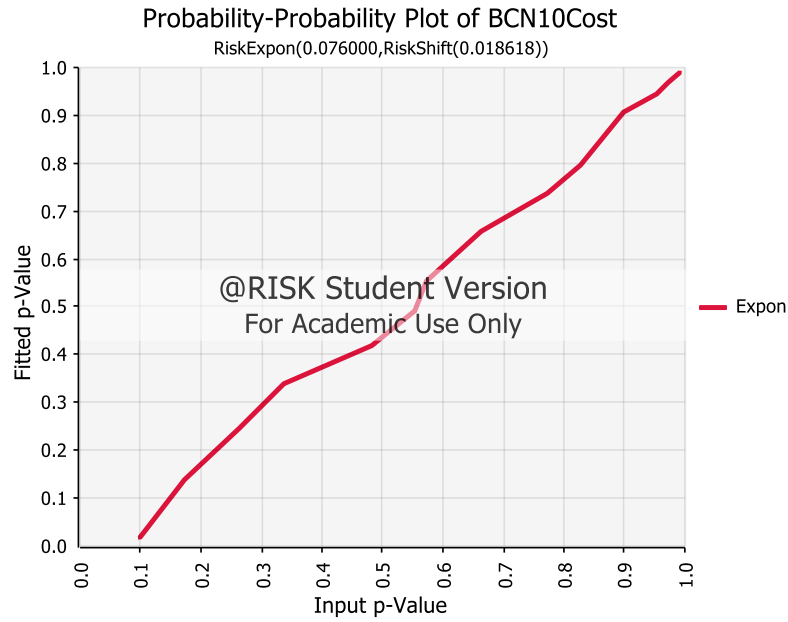


Figure 8-36: Probability-to-probability plot for BCN10Cost

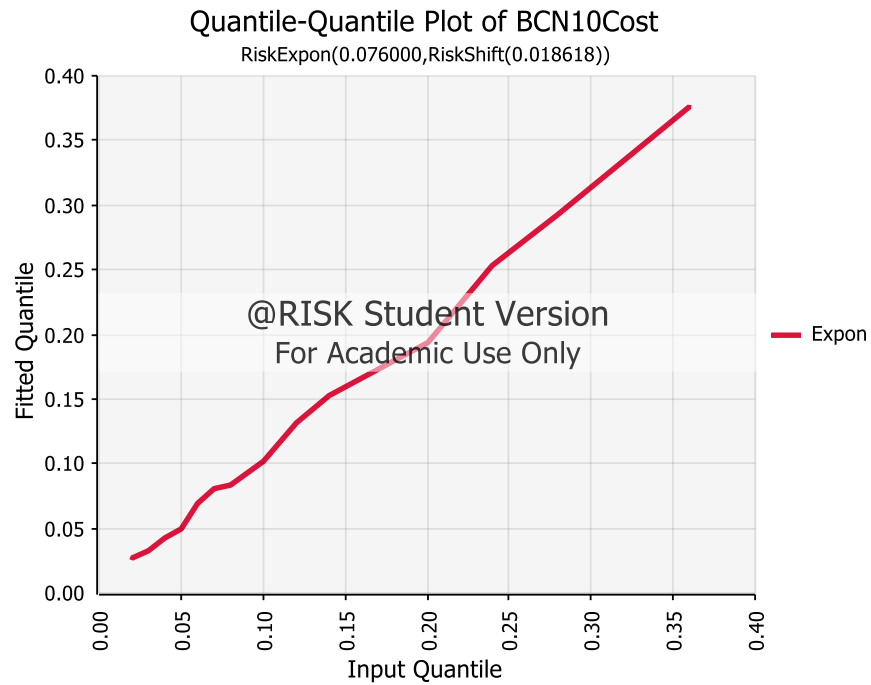


Figure 8-37: Quantile-to-quantile plot for BCN10Cost

8.9.2.8 BPO6Cost

Figure 8-38 demonstrates the fit comparison for BPO6Cost, while figure 8-39 and figure 8-40, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Log logistic distribution best fits the data. This distribution is widely employed in survival assessment of events whose rate increases initially and decreases later. Furthermore, figure 8-38 shows that the 90.0% and 88.0% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-39 and 8-40, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Log logistic distribution of BPO6Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1526	N/A

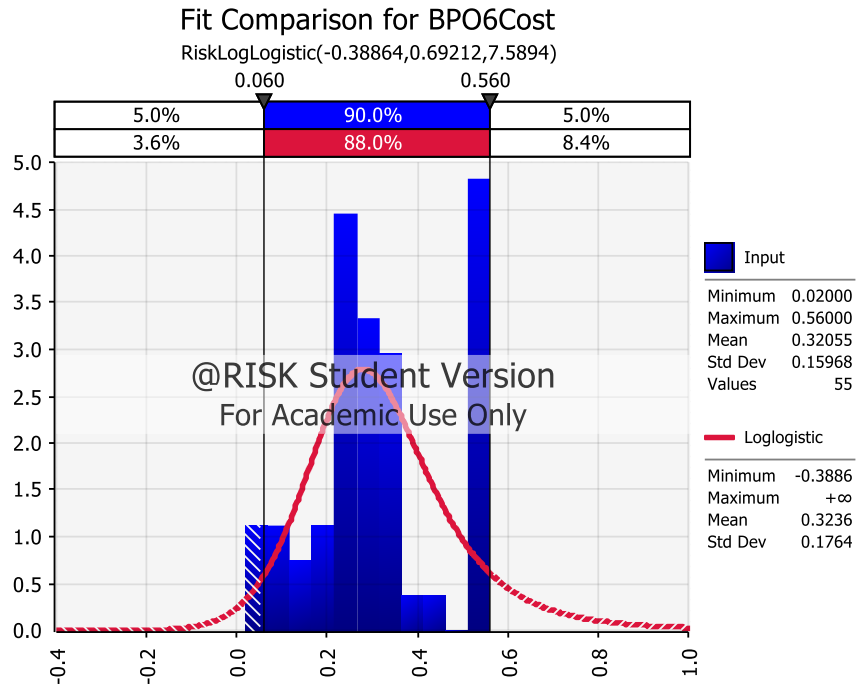


Figure 8-38: Fit comparison for BPO6Cost

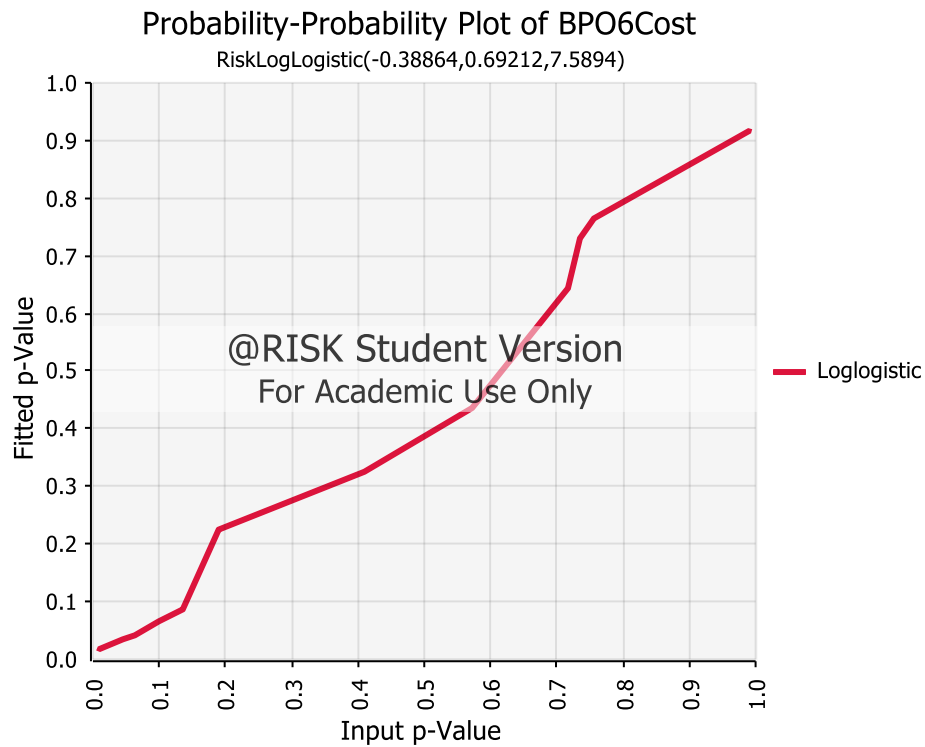


Figure 8-39: Probability-to-Probability plot for BPO6Cost

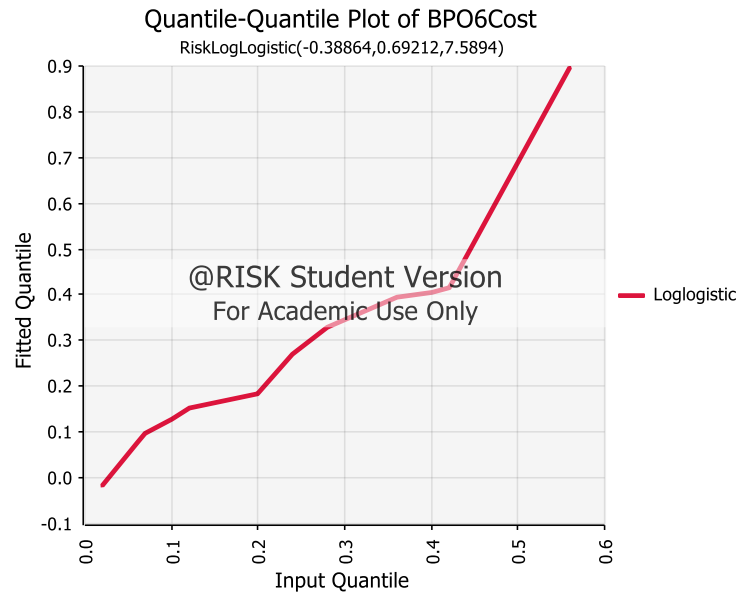


Figure 8-40: Quantile-to-Quantile plot for BPO6Cost

8.9.2.9 BPO7Cost

Figure 8-41 demonstrates the fit comparison for BPO7Cost, while figure 8-42 and figure 43, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Pearson type 5 distribution best fits the data. This distribution is widely employed in modelling time delays when some minimum delays are known with a very high degree of certainty, whereas, the maximum delay is unbounded. Furthermore, figure 8-41 shows that the 90.0% and 88.9% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-42 and 8-43, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Pearson type 5 distribution of BPO7Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value

K-S	0.0793	0.2000
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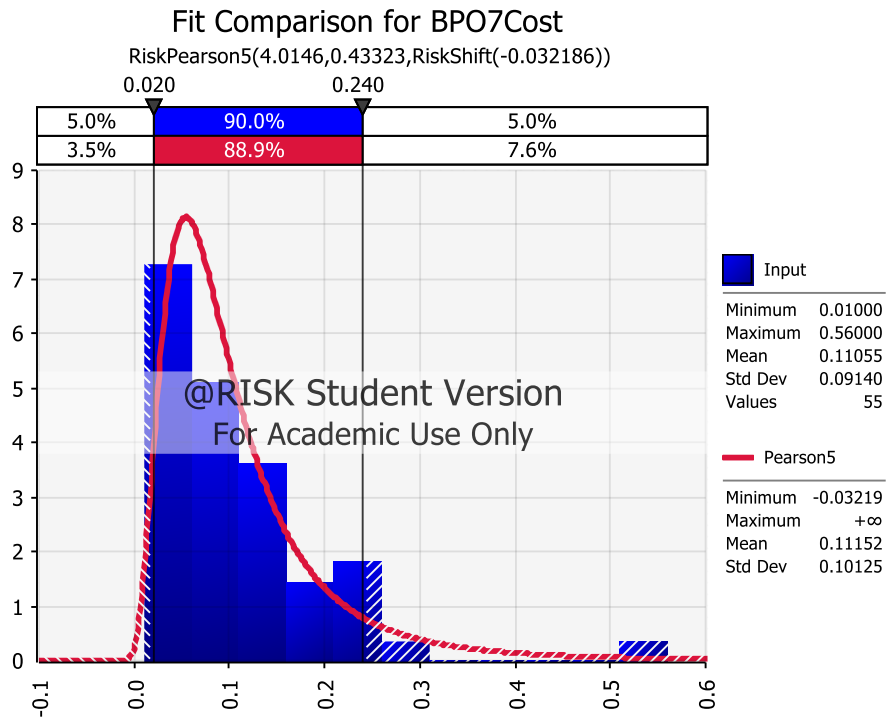


Figure 8-41: Fit comparison for BPO7Cost

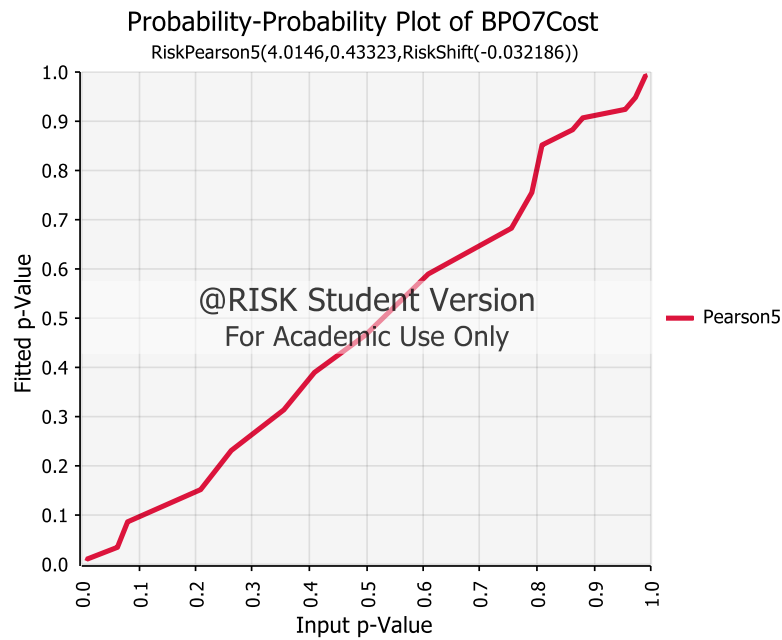


Figure 8-42: Probability-to-Probability plot for BPO7Cost

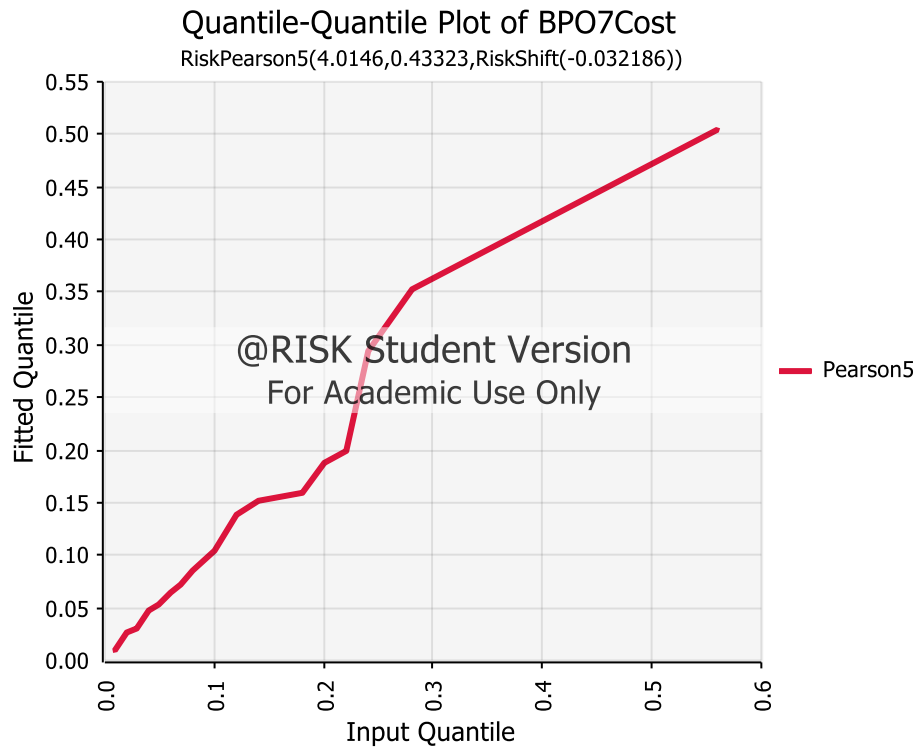


Figure 8-43: Quantile-to-quantile plot for BPO7Cost

8.9.2.10 BPO12Cost

Figure 8-44 demonstrates the fit comparison for BPO12Cost, while figure 8-45 and figure 8-46, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analysed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Exponential distribution best fits the data. This distribution is widely employed in the analysis of Poisson point in processes where events occur continuously and independently at a constant average rate. Furthermore, figure 8-44 shows that the 90.0% and 88.9% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-45 and 8-46, respectively where the fitted and input parameters (p-value and

quartiles) exhibit significant match. For the Exponential distribution of BPO12Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1262	0.0000

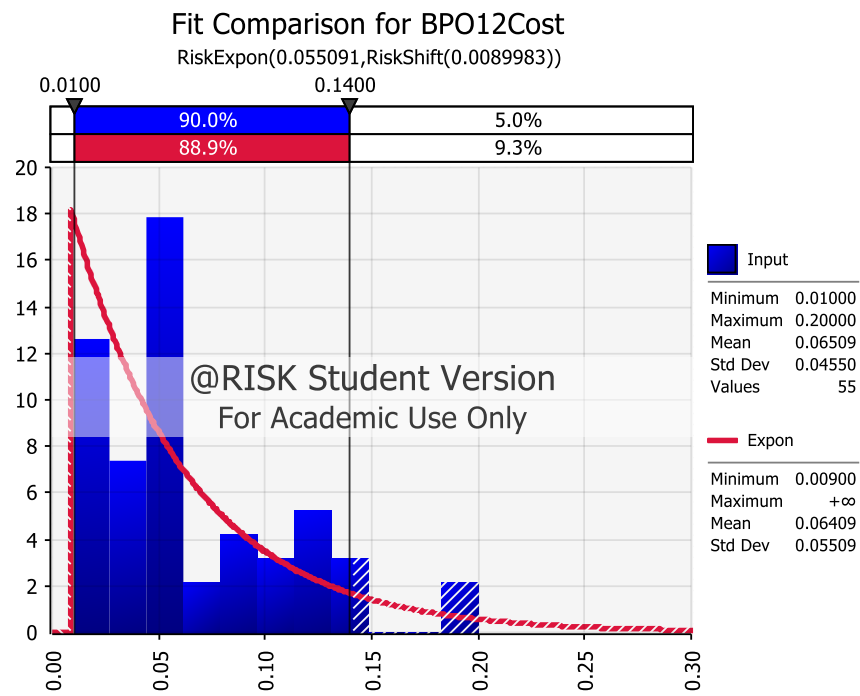


Figure 8-44: Fit comparison for BPO12Cost

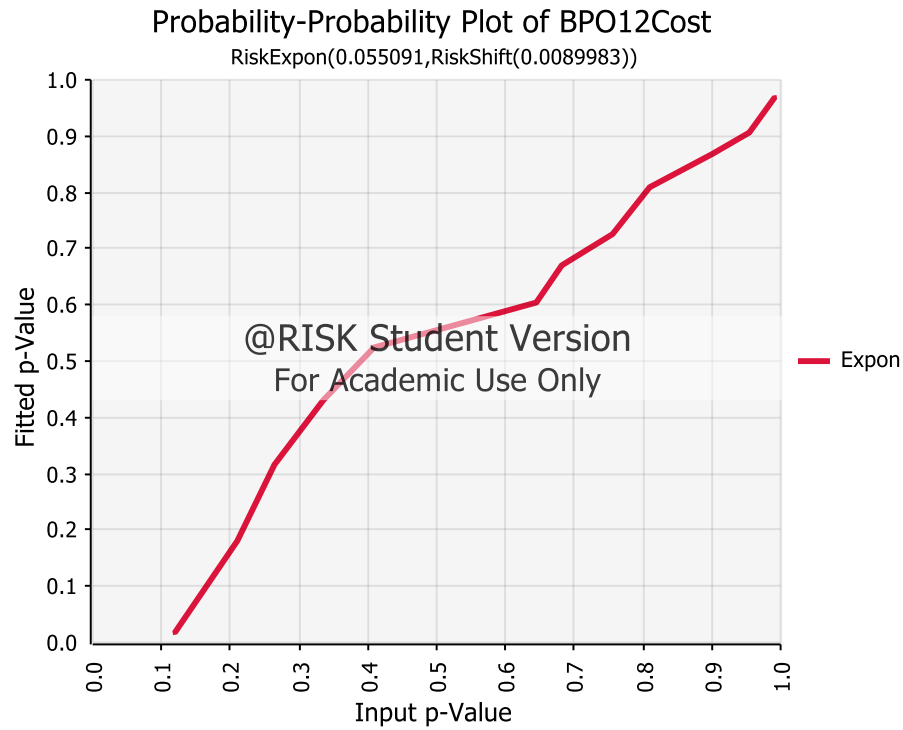


Figure 8-45: Probability-to-Probability plot for BPO12Cost

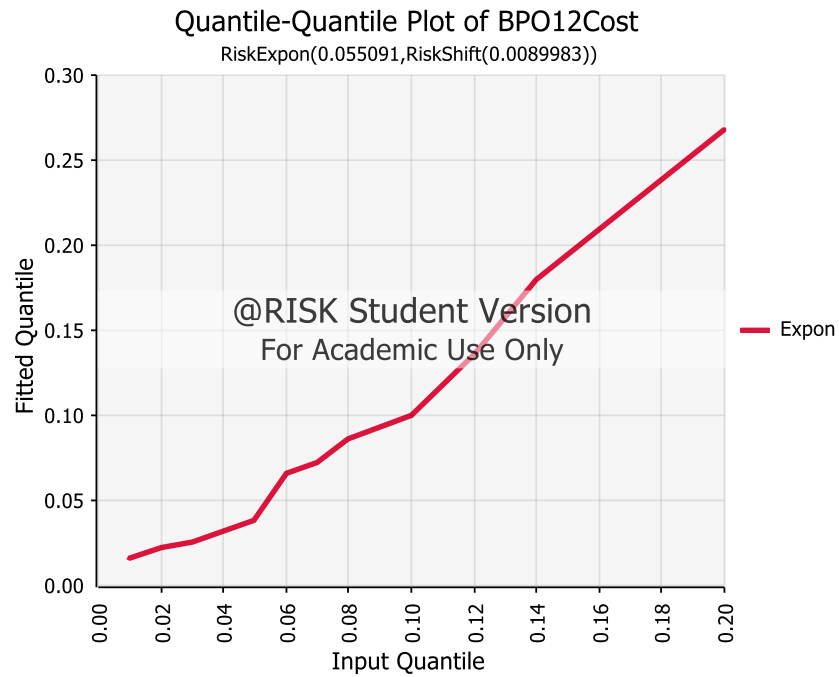


Figure 8-46: Quantile-to-Quantile plot for BPO12Cost

8.9.2.11 BEF2Cost

Figure 8-47 demonstrates the fit comparison for BEF2Cost, while figure 8-48 and figure 8-49, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Weibull distribution best fits the data. This distribution is widely employed in reliability assessment of engineering projects to determine project failure rates. Furthermore, figure 8-47 shows that the 90.0% and 95.2% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-48 and 8-49, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Weibull distribution of BEF2Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1459	0.0000

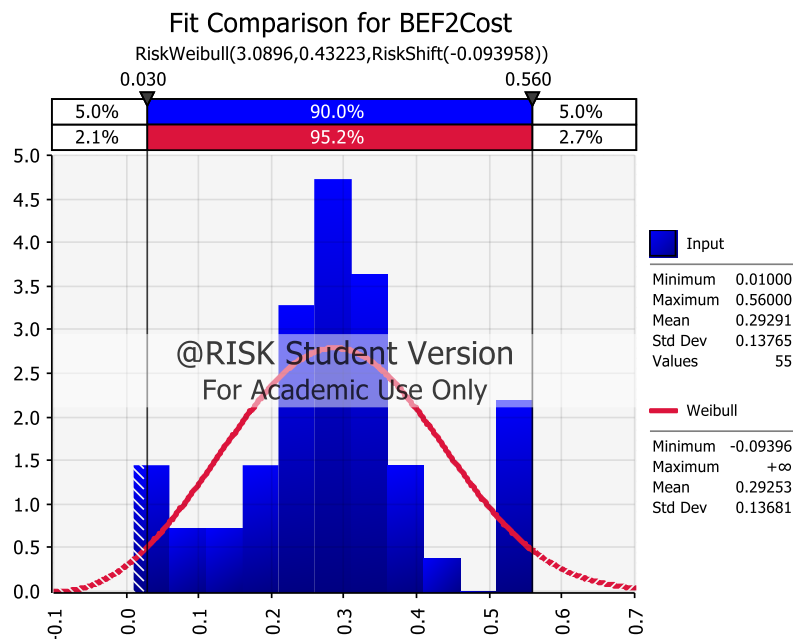


Figure 8-47: Fit comparison for BEF2Cost

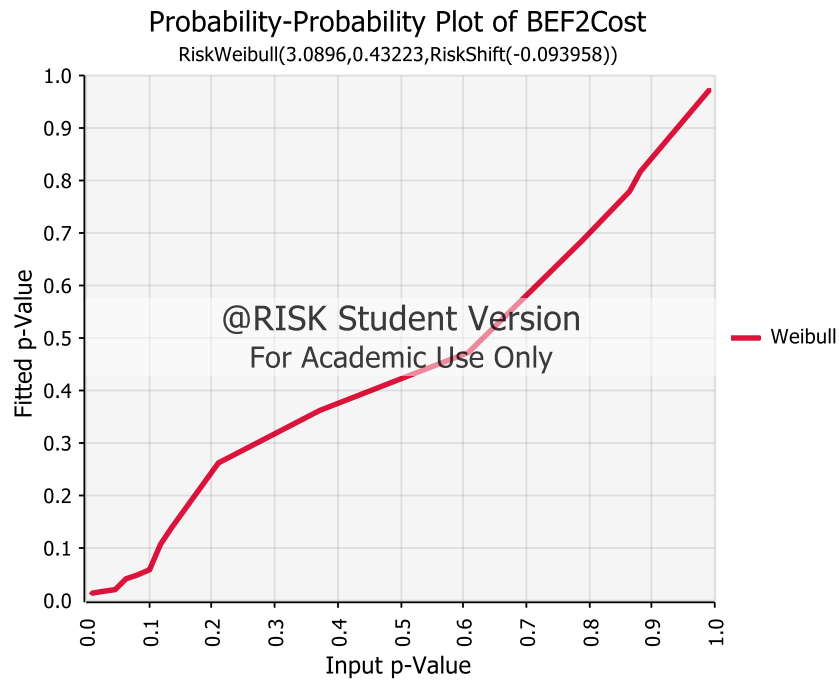


Figure 8-48: Probability-to-Probability plot for BEF2Cost

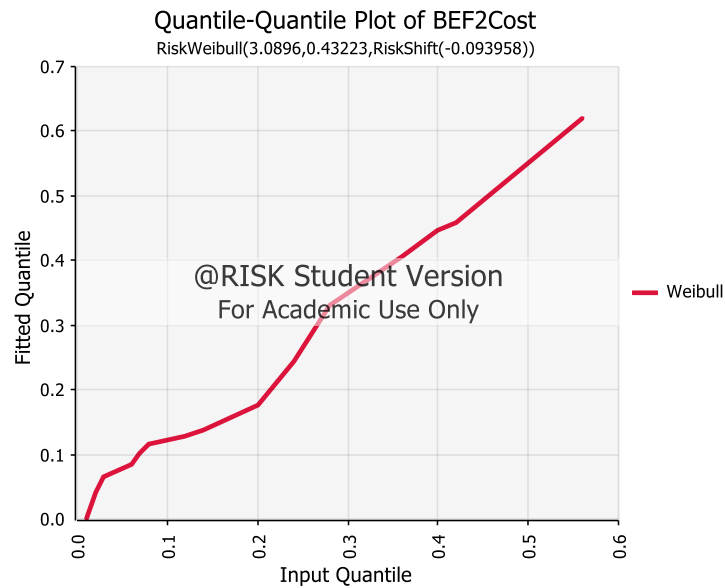


Figure 8-49: Quantile-to-Quantile plot for BEF2Cost

8.9.2.12 BEF7Cost

Figure 8-50 demonstrates the fit comparison for BEF7Cost, while figure 8-51 and figure 8-52, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Extreme value (ExtValue) distribution best fits the data. This distribution is widely employed to determine tail risk in the finance of a project. Furthermore, figure 8-50 shows that the 90.0% and 92.2% match in the input and obtained distribution, respectively. The match is also validated as seen in the P-P and Q-Q plots of figures 8-51 and 8-52, respectively where the fitted and input parameters (p-value and quartiles) exhibit significant match. For the Extreme Value of BEF7Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.0862	0.0364

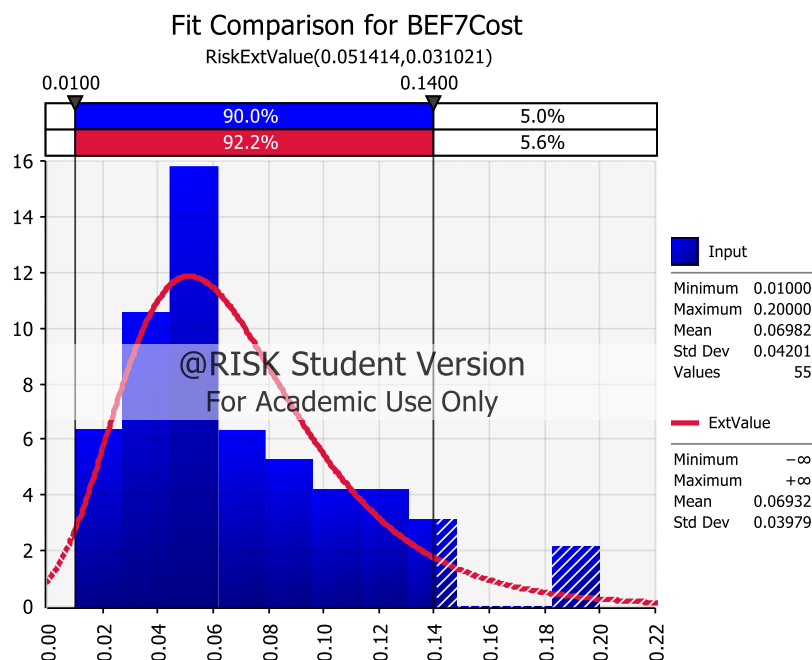


Figure 8-50: Fit comparison for BEF7Cost

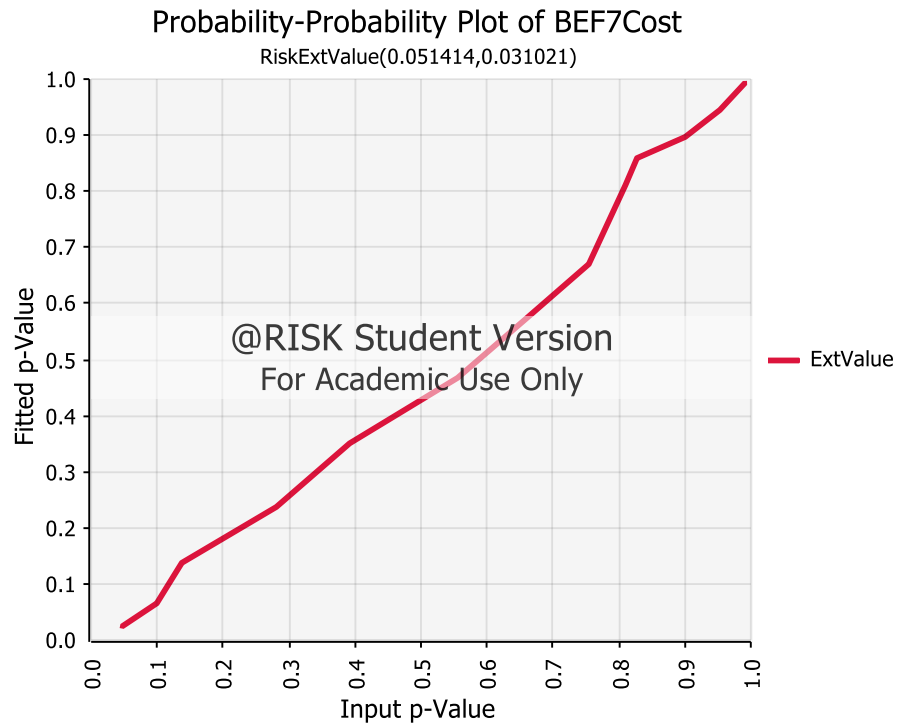


Figure 8-51: Probability-to-Probability plot for BEF7Cost

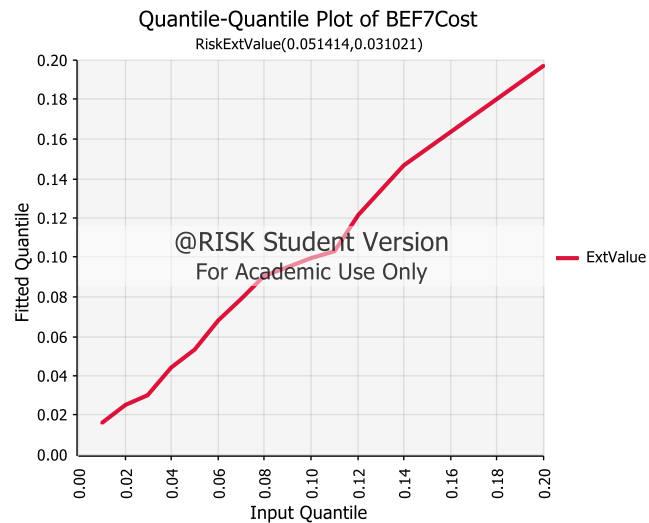


Figure 8-52: Quantile-to-Quantile plot for BEF7Cost

Table 8-16 : Summary of fit comparison for the variables of interests

Variable	Weibull Distribution	Extreme Value Distribution	Log logistic Distribution	Exponential Distribution	Pearson type 5 Distribution	Logistic Distribution
BCT3Cost	✓					
BCT4Cost		✓				
BCT6Cost			✓			
BCT7Cost			✓			
BCT10Cost		✓				
BCT11Cost			✓			
BCN1Cost			✓			
BCN3Cost		✓				
BCN7Cost	✓					
BCN8Cost			✓			
BCN9Cost			✓			
BCN10Cost				✓		
BCN11Cost			✓			
BPO6Cost			✓			
BPO7Cost					✓	
BPO10Cost					✓	
BPO12Cost				✓		

BPO13Cost		✓				
BPO14Cost			✓			
BEF2Cost	✓					
BEF3Cost						✓
BEF7Cost		✓				
Total	3	5	9	2	2	1

From the summary provided in table 8-16, it can be observed that most of the risks associated to the model are mostly associated with Log logistic distribution in which the risk rate increases initially and decreases later on.

8.10 Results of simulation

Figure 8-53 shows the probabilistic representation of the dependent variable (BgtOverrunM2). This distribution was obtained using the input probability distributions for each of the causes of variation in Bgt_OverrunM2 using the association formula generated from the multiple regression analysis. With 5000 iterations employed during the Monte Carlo simulation, the distribution of the simulated BgtOverrunM2 (Simulated_BgtOverrunM2) for the project under assessment was obtained as in figure 8-53. This distribution belongs to the family of logistic distributions – distributions widely employed for modeling growth. The simulated distribution was then tested against the theoretical distributions of the predicted BgtOverrunM2 from the regression model and actual BgtOverrunM2 from the research data using the Chi-Square test, Anderson-Darling test and

Komogorov-Smirnoc test. The test statistics obtained for both the Predicted BgtOverrunM2 and Actual BgtOverrunM2 are presented in Table 8-17 for p-values of 1%, 5% and 10%.

The results in Table 8-17 show that the fit of the actual and predicted BgtOverrunM2 are very similar in all cases of the Anderson-Darling and Komogorov-Smirnoc tests. With the chi-sqaure test, the similarity exists only at a p-value of 5%. Further validation of the fit distribution for both predicted and actual BgtOverrunM2 is carried out by means of fit comparison, P-P and Q-Q plots as in figures 8-54 to 8-59.

For the fit comparison plot figures (8-54 and 8-55), it can be seen that the fit of both the predicted and actual BgtOverrunM2 are similar and follow the logistic distribution. Also, the P-P plots figures (8-56 and 8-57) and the Q-Q plots figures (8-58 and 8-59) show similar pattern for the predicted and actual BgtOverrunM2. The results in the table and the graphs thus provide sufficient evidence that the results of the developed regression model are very similar to those of real cases.

Table 8-17: Test results for predicted and actual BgtOverrunM2

		Predicted BgtOverrunM2			Actual BgtOverrunM2	
P-Value	Chi-Sqaure test	Anderson- Darling test	Komogorov- Smirnoc test	Chi- Sqaure test	Anderson- Darling test	Komogorov- Smirnoc test
0.01	19.2143	0.5302	0.1031	14.5455	0.6141	0.1100
0.05	9.8929	0.4480	0.0844	9.9636	0.4547	0.0864
0.10	9.2500	0.4202	0.0828	7.6727	0.4013	0.0826

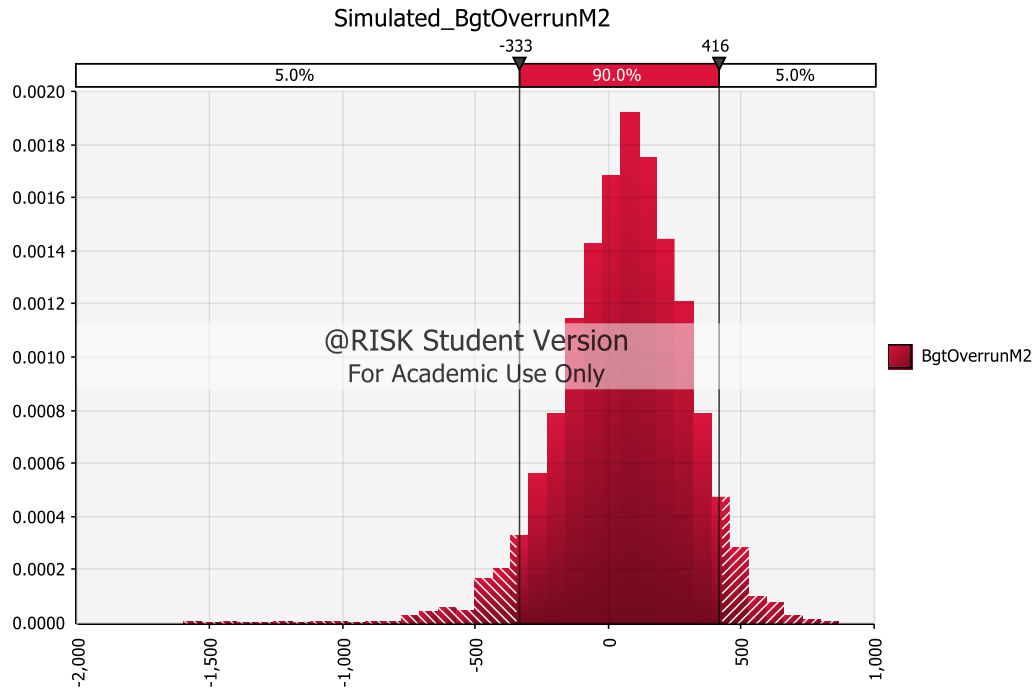


Figure 8-53: Simulated distribution for BgtOverrunM2

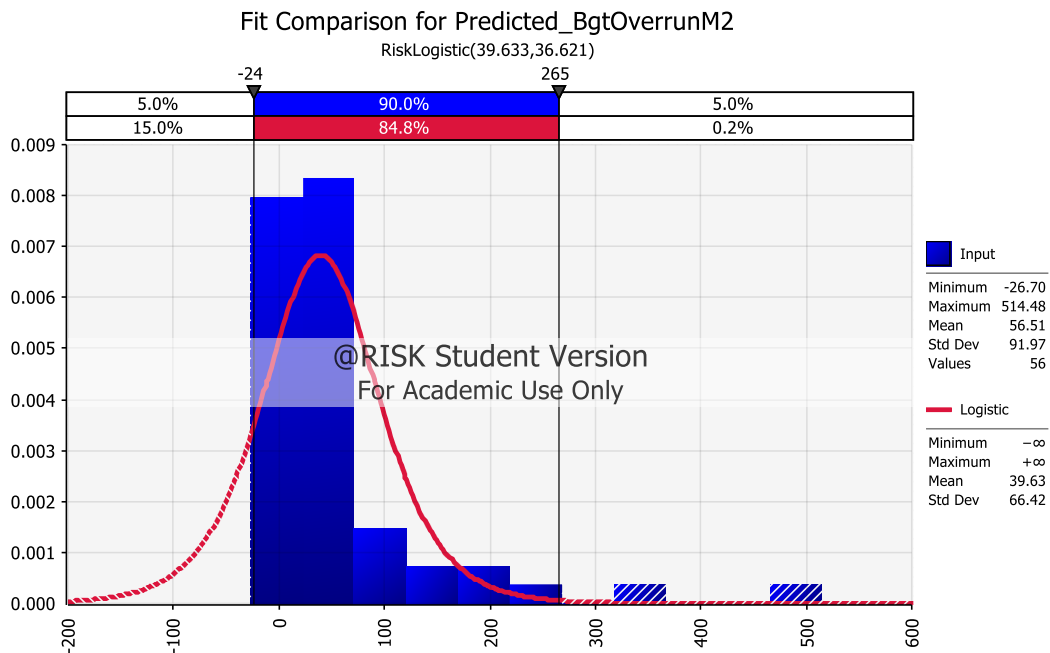


Figure 8-54: Fit comparison for predicted BgtOverrunM2

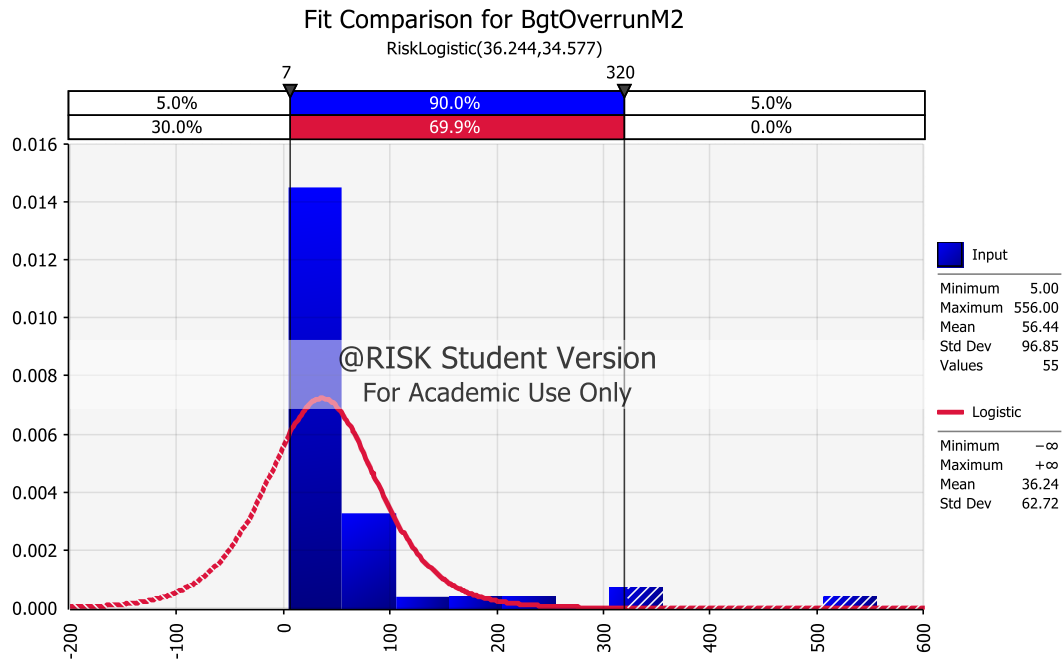


Figure 8-55: Fit comparison for actual BgtOverrunM2

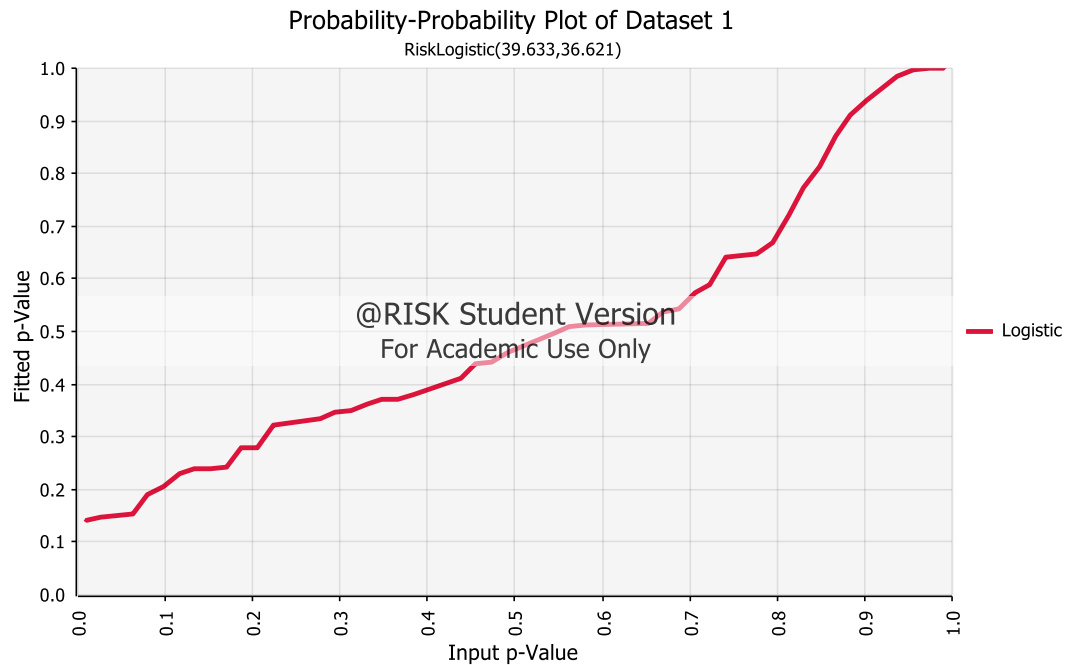


Figure 8-56: P-P plot for predicted BgtOverrunM2

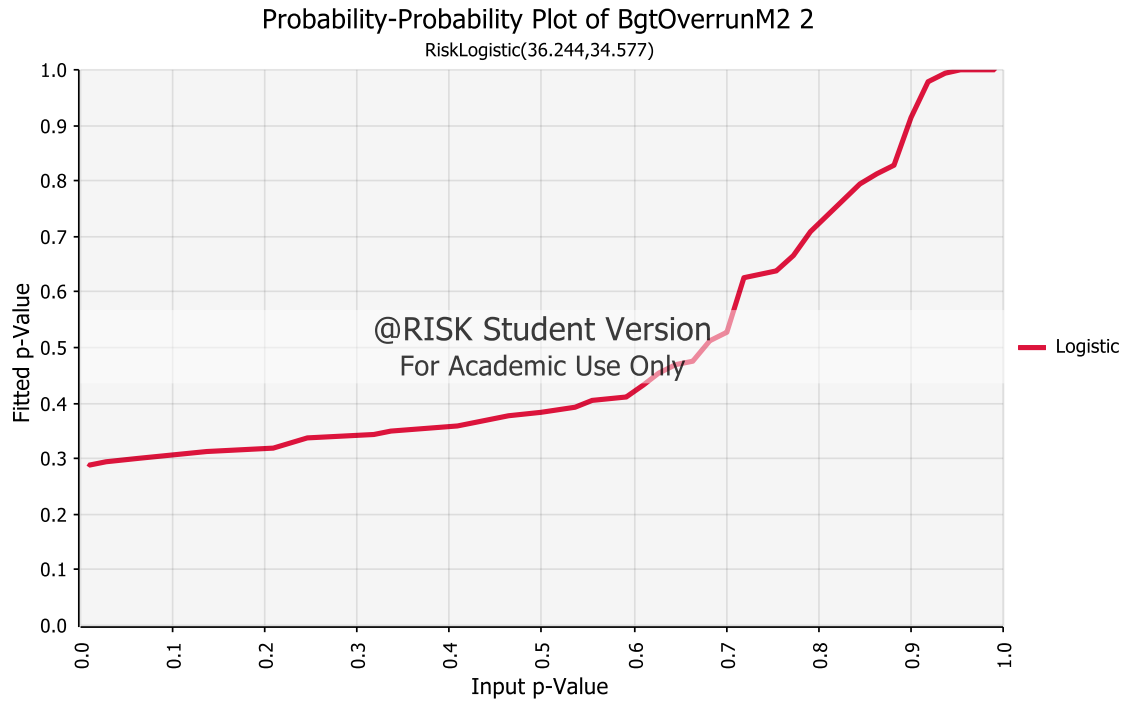


Figure 8-57: P-P plot for actual BgtOverrunM2

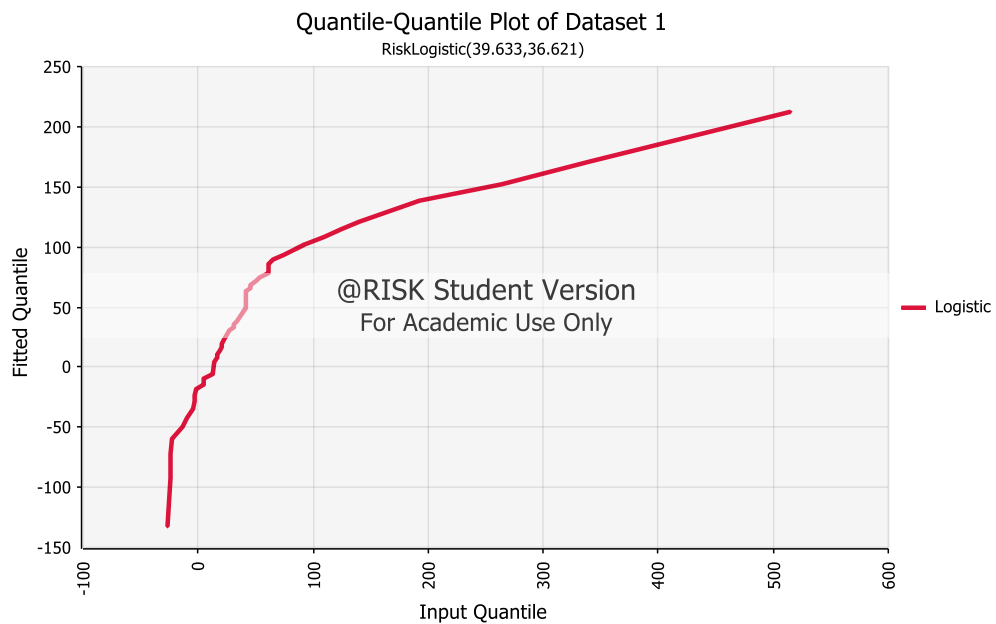


Figure 8-58: Q-Q plot for predicted BgtOverrunM2

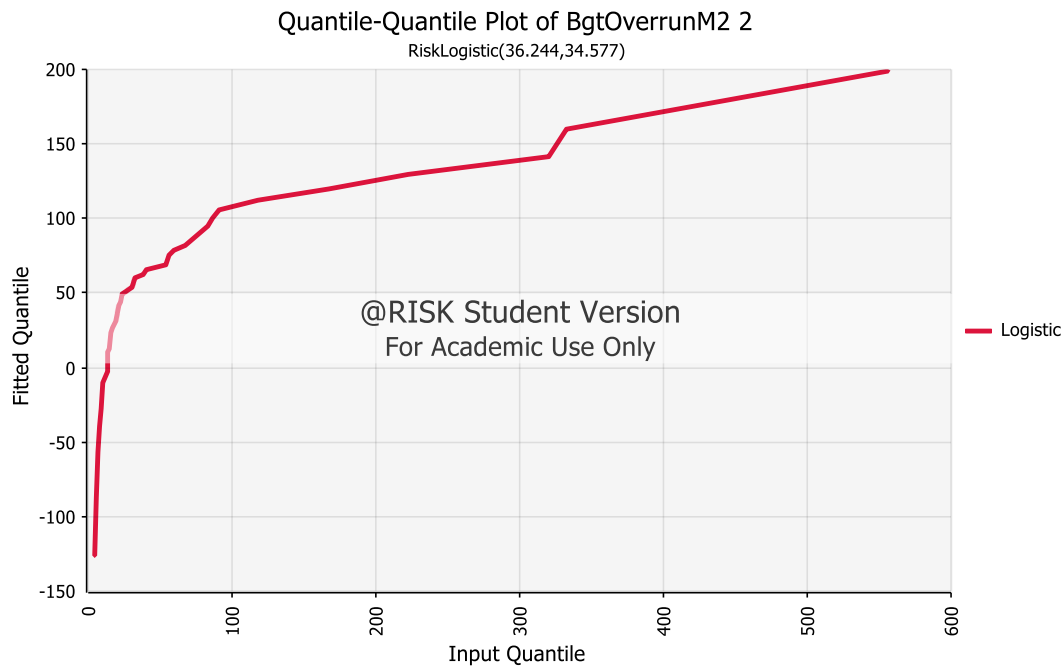


Figure 8-59: Q-Q plot for actual BgtOverrunM2

8.10.1 Trends

Figure 8-60 shows the trend chart with series of layered certainty bands with each band representing a particular certainty level. For example, the ± 1 Std Dev certainty band shows that more than 50% of the forecasted BgtOverrunM2 lies within the band. This can be interpreted as choosing a certainty level of 50% to forecast BgtOverrunM2 due to possible variation in its causes. The highest and lowest variation in certainty of each of the causes is also provided on the graph where it can be seen that BPO6Cost and BPO12Cost experience the highest and lowest variability, respectively, so the first variable BP06Cost contribute more to the cost overrun. Furthermore, the graph of figure 8-61 shows that the variation around the mean of BgtOverrunM2 where it can be seen that the mean of the forecasted BgtOverrunM2 is around 60%. Also, the trend graph for this variable shows that majority of its variability lie within ± 1 Std Dev certainty band.

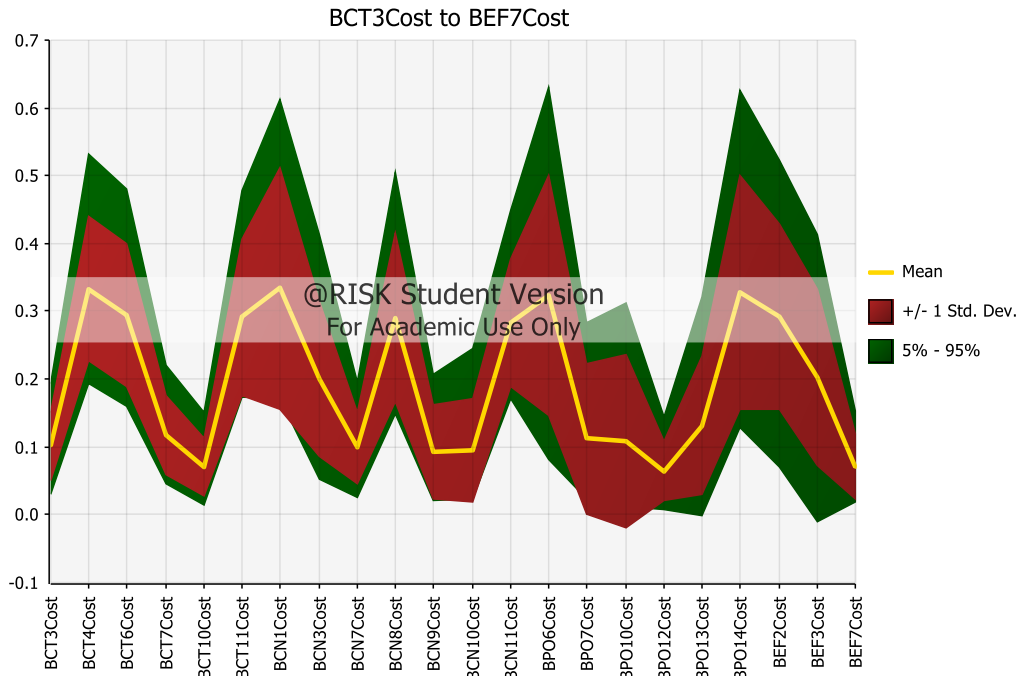


Figure 8-60: Trend line for certainty bands

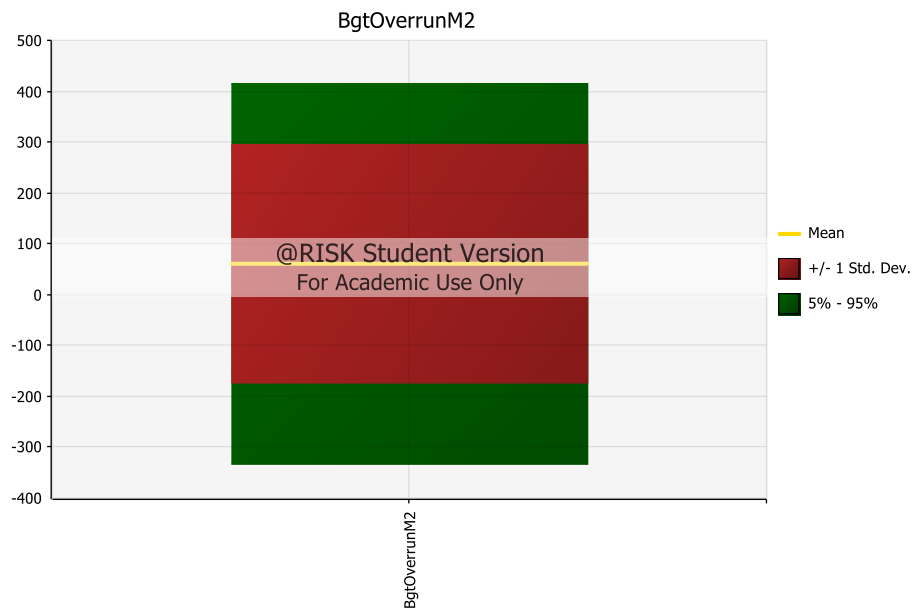


Figure 8-61: Trend line for BgtOverrunM2

8.10.2 Sensitivity analysis

In this section, the importance of each input variable on the forecasted budget overrun per square meter is assessed by conducting sensitivity analysis. The result of this analysis is presented in figure 8-62 for the 10 most influential input variables where it can be seen that each of the input variable exhibits a particular trend with respect to its influence on the forecasted BgtOverrunM2. As per the ranking in Figure 8-66, BPO6Cost is considered to have the highest sensitivity ranking while BCN10Cost has the least sensitivity ranking. Also, it can be seen from the graph that those factors represented by the first 7 legends have a greater impact at lower levels and have low impact at higher levels of the input. Similarly, the last 3 factors represented by the last set of legends have a low impact at lower levels and has high impact at higher levels of the input.

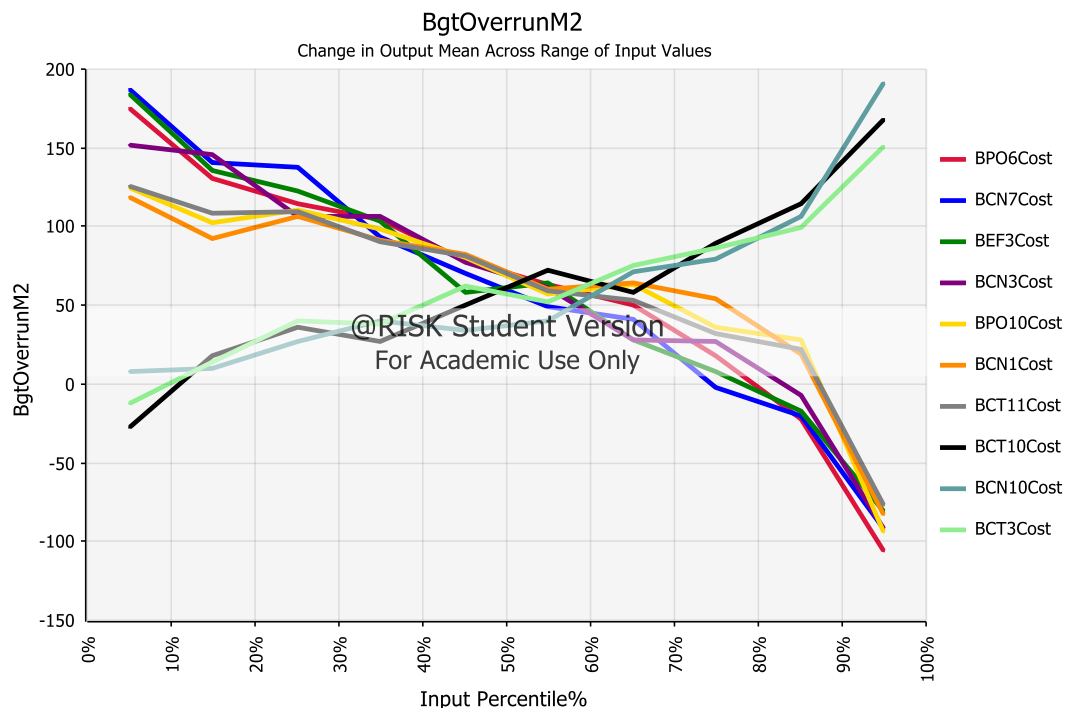


Figure 8-62: Sensitivity analysis of changes in base values of some of the input variables

A further study of the sensitivity analysis is also validated using tornado chart as in figure 8-63. The chart ranks each of the input variables based on the effect they have on the output mean, in this case, mean of the forecasted BgtOverrunM2. This chart also shows the direction in which the variables have significant impact, either in the positive and negative direction. As can be seen from the chart of figure 8-63, most of the significant causes of BgtOverrunM2 have negative impacts. Also, BPO6Cost has the highest impact in the negative direction, while BCN10Cost has the highest impact in the positive direction. It is noteworthy to state that the direction of impact of each of these input variables are similar to those obtained for the coefficient of the variables in the results of the multiple regression analysis. However, the magnitude of weight assigned to each variable in the sensitivity analysis maybe different from those of the multiple regression analysis. For instance, an input variable can have a large weight in the sensitivity analysis but a small weight in the multiple regression analysis, and vice-versa. Finally, in both graphs of figures 8-62 and 8-63, the sensitivity of variables not displayed suggests that their effect on the dependent variable are not as great as that of those displayed per the simulation results.

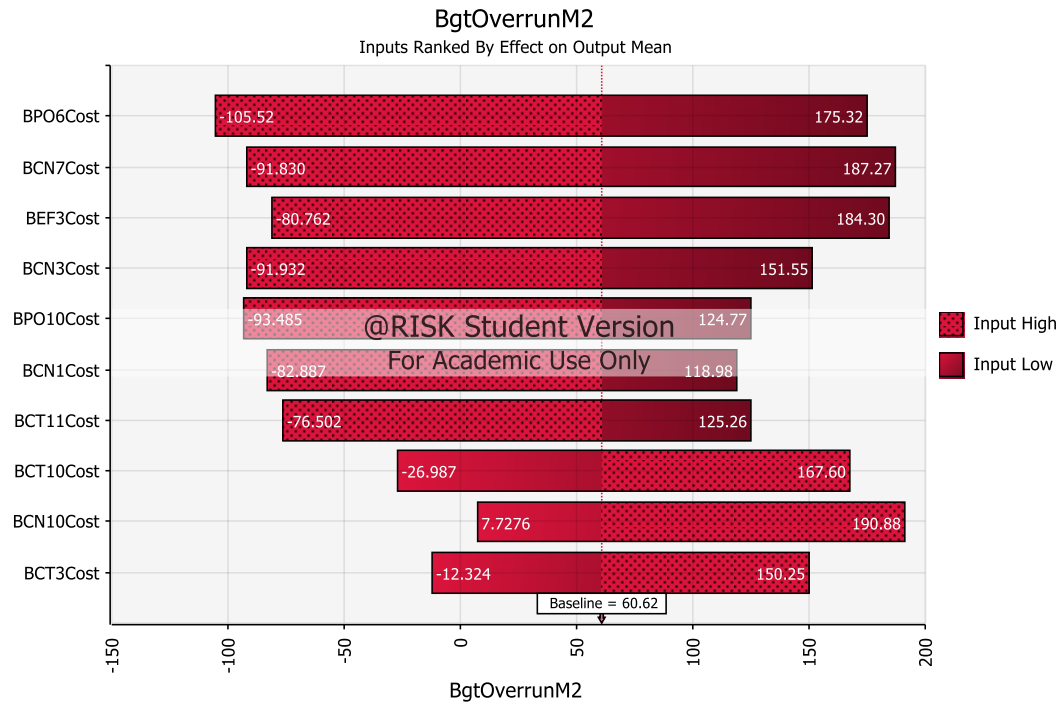


Figure 8-63: Magnitude of the effect of causes of variation on BgtOverrunM2

Contribution to the variation of BgtOverrunM2 by each of the input variable is shown in figure 8-64 where it can be seen that BCN7Cost has the highest absolute contribution to variance. This contribution is negative as seen from the graph. The least variation is experienced with BCN7Cost also with a negative contribution to variance.

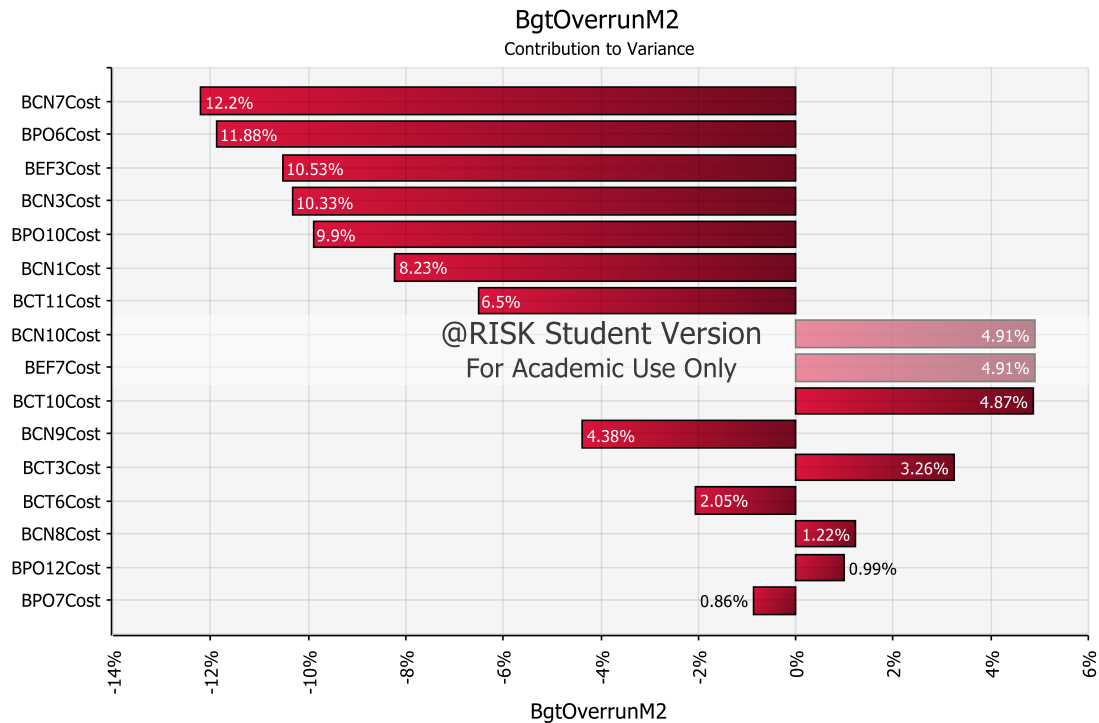


Figure 8-64: Causes of variation input used to measure sensitivity of the output

The graph of figure 8-65 shows the effect of a unit change in the sensitivity of each of the input cause of variation on the forecasted BgtOverrunM2. From the result obtained, it can be seen that 10 of the input sensitivities have a negative coefficient while 6 others have a positive coefficient. The highest negative coefficient is found with BCN7Cost, while BEF7Cost has the highest positive coefficient. For the input variables with positive coefficient, when the value of each of these causes of variation increases, the value of BgtOverrunM2 decreases, and vice-versa.

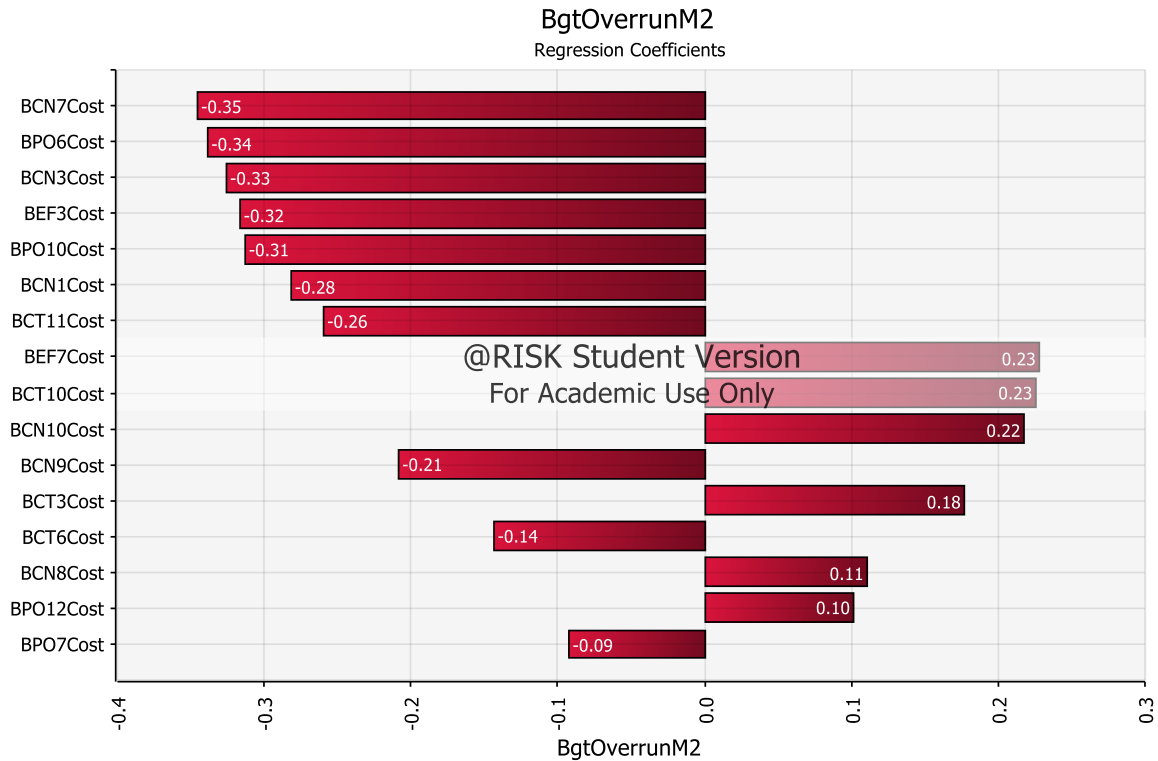


Figure 8-65: Causes of variation input used to measure sensitivity of the output

Finally, in this section, Spearman rank correlation coefficient is utilized in this work to analyze the sensitivity of BgtOverrunM2 to the causes of variation inputs. If a variable exhibits a high correlation coefficient, the correlation between that input and BgtOverrunM2 is considered high and such input has a high determining power in the value of estimated BgtOverrunM2. Results obtained for this analysis are presented in figure 8-66. These results conform with those of the sensitivity-based regression.

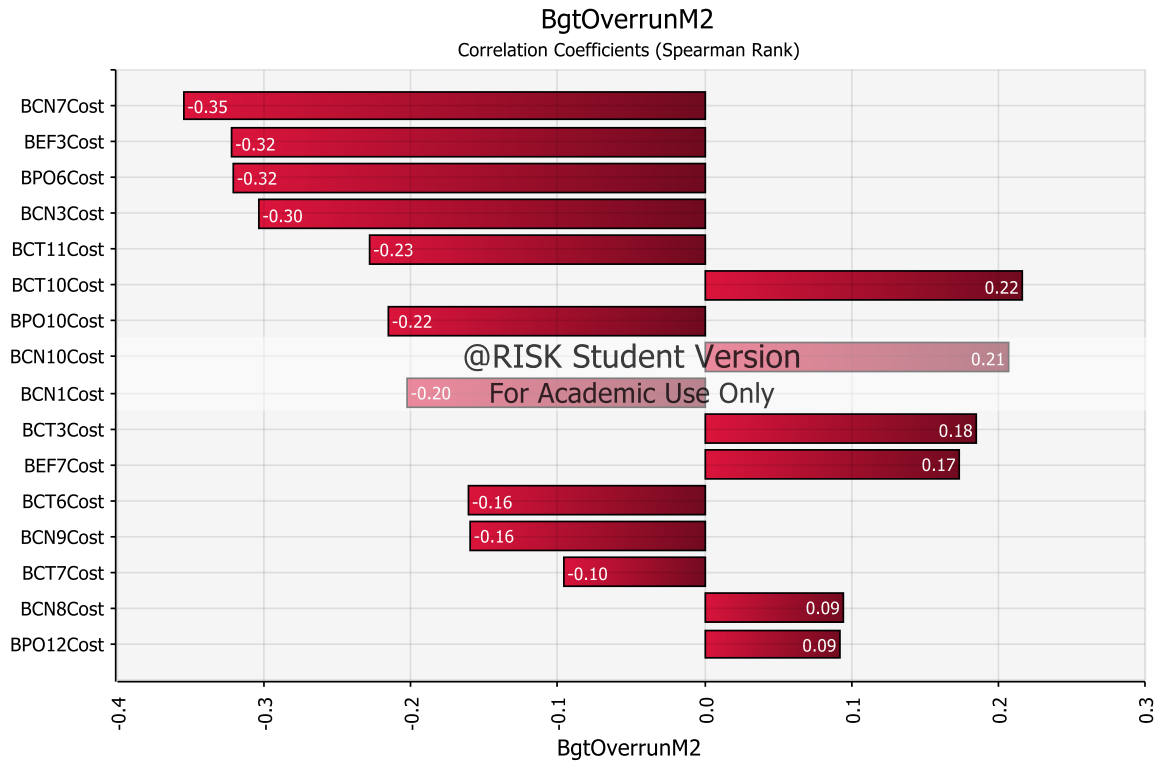


Figure 8-66: Spearman rank correlation coefficient for the analysis of the sensitivity of input variables

8.10.3 Scenario Analysis

Based on conditional median analysis, the influence of a particular input variable on BgtOverrunM2 is tested by means of scenario analysis. This analysis has been utilized to identify the causes of variation that significantly contribute to budget overrun per square meter in projects. The following scenario target values have been employed in the analysis presented in this work:

- ❖ duration overrun > 90th percentile
- ❖ duration overrun > 95th percentile
- ❖ duration overrun > 99th percentile

Results of this analysis are shown in figures 8-67 and 8-69 below.

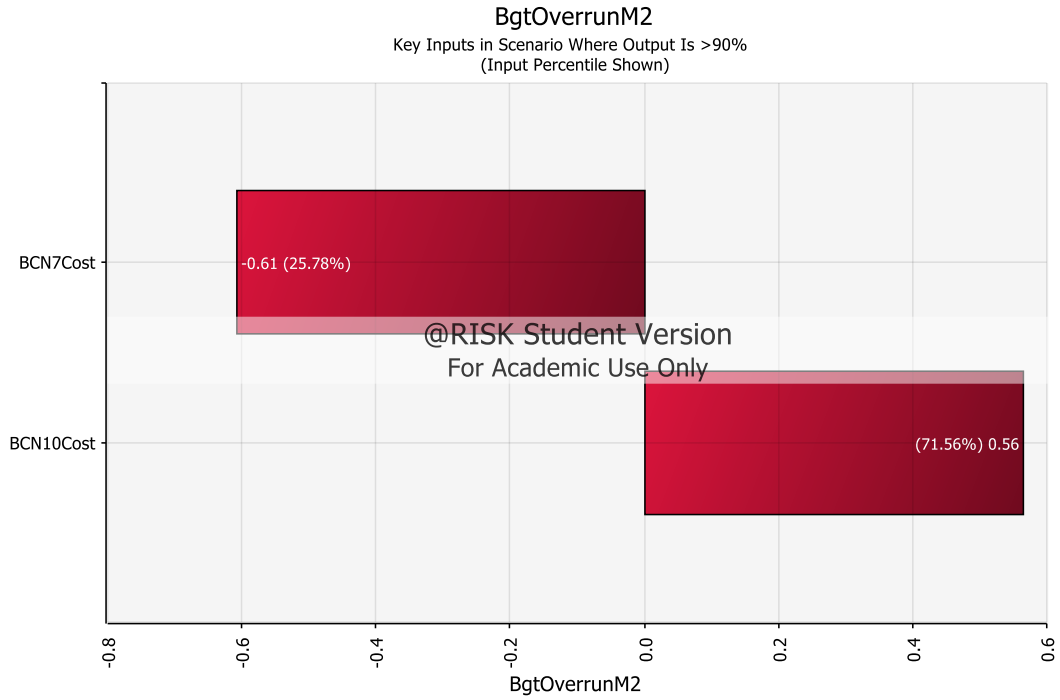


Figure 8-67: Causes of variation in BgtOverrunM2 at 90th percentile

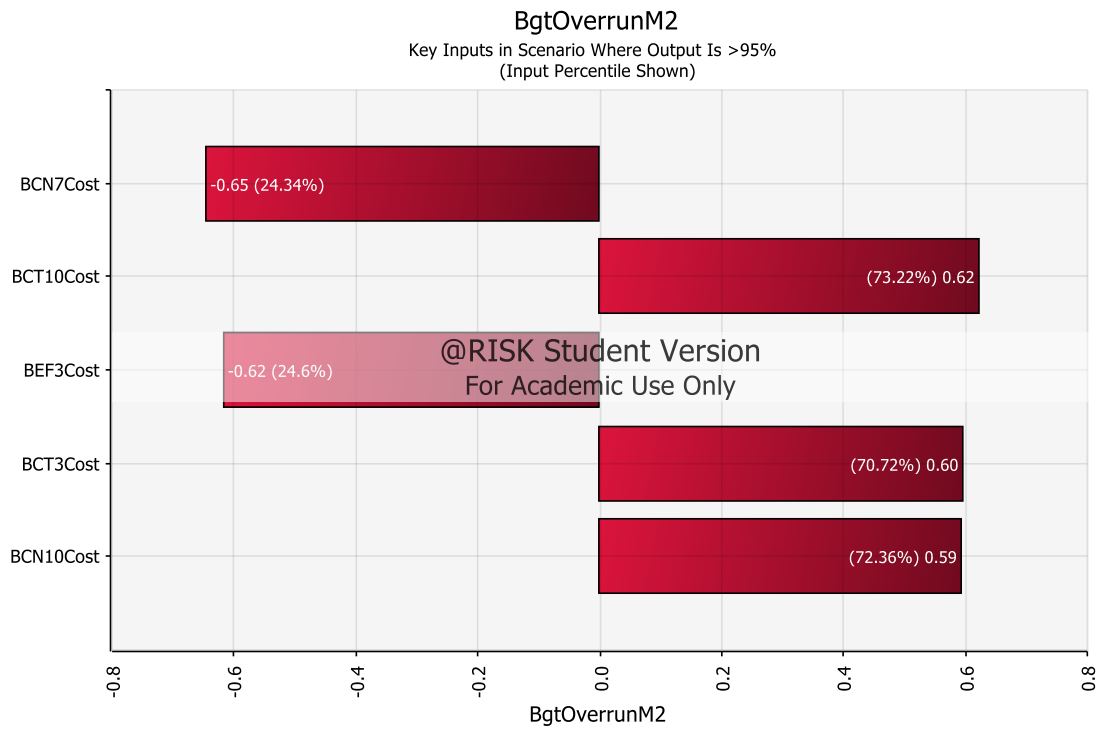


Figure 8-68: Causes of variation in BgtOverrunM2 at 95th percentile

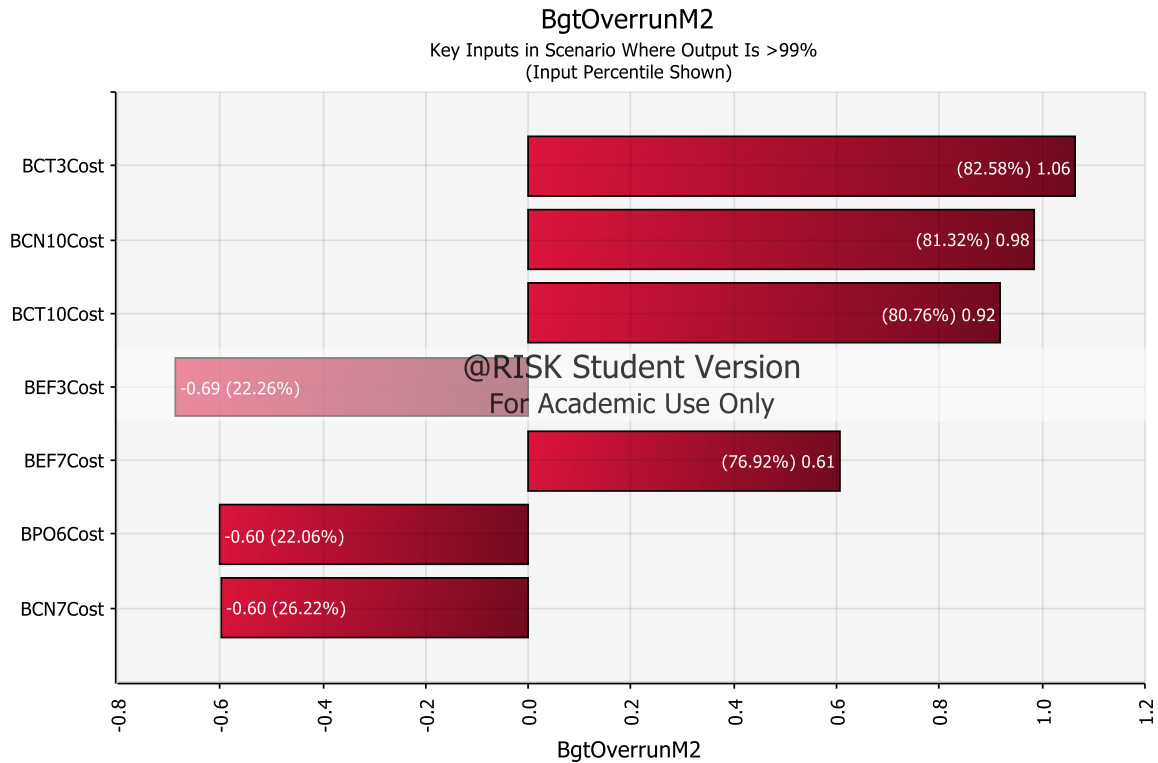


Figure 8-69: Causes of projects delay in BgtOverrunM2 at 99th percentile

Figure 8-67 shows that causes of projects delay for BCN7Cost and BCN10Cost were found to be significant when BgtOverrunM2 is at or above the 90th percentile. Above the 95th percentile, BCN7Cost, BCN10Cost, BEF3Cost, BCT3Cost and BCT10Cost were found to be significant as shown in figure 8-68. Finally, when BgtOverrunM2 above the 99th percentile, BCT3Cost, BCN10Cost, BCT10Cost, BEF3Cost, BEF7cost, BPO6Cost and BCN7Cost were found to be significant figure (8-69).

8.11 Chapter summary

This chapter employed the regression model developed in Chapter 8 to assess the variability of budget overrun per square meter (BgtOverrunM2) in a stochastic manner. The first step in this assessment was to define the input probability distribution of the causes of variation in BgtOverrunM2 by means of fitting them with their best theoretical distribution. Results obtained show that majority of the significant causes of variation in BgtOverrunM2 follow the Log logistic distribution. This distribution is associated with projects where the risk increases at the initial stage of the project and decreases later on. Also, the distribution of all the causes exhibit generally positive skewness. Furthermore, visual representation of these distributions was carried out using P-P and Q-Q plots where the degree of match between the input and fitted parameters is established to be generally high with all the causes of budget overrun

Simulation of BgtOverrunM2 using the input probability distributions was then carried out to assess trend of each of the input variable, sensitivity analysis of BgtOverrunM2 to changes in the causes off variation, scenario analysis. The trends chart revealed that more than 50% of the simulated duration overruns lies within +/- 1 Std Dev certainty band. From the sensitivity analysis, it was discovered that BPO6Cost and BCT3Cost have the highest and lowest highest impact, respectively on the output. The scenario analysis also showed the significant input distributions at various percentile values.

Finally, it is noteworthy that the output probability distribution of the BgtOverrunM2 obtained from the regression model are similar to those of the original data, with both following a log logistic distribution. This affirms the ability of the developed regression model to produce results similar

to those of real cases. Therefore, decision makers can leverage on the findings presented in this work in minimizing causes of budget overrun.

Chapter 9: Discussion of the Findings

9.1 Introduction

The main objectives of this chapter are the findings of this research that are discussed in terms of their implications on budget overrun in the oil field construction industry. Furthermore, the research questions of this thesis are considered to demonstrate how the researcher had met the objectives of the research study. Lastly, the findings of this thesis are evaluated by comparing and contrasting them with findings existing in the literature.

The main aim of the research is to establish a model that could be used to map the causes of delay to the cost overrun of projects delay in oil fields construction projects and to investigate the variables that contribute to budget/cost overrun. There was an observable gap in the body of knowledge on how to model projects delay in petroleum construction industry. The criticality of managing projects delay in oil fields construction projects has been exacerbated by the general complexities associated with the sources of projects delay and how varied the impact may be to various stakeholders such as client/owner, contractor, design/consultant and miscellaneous/external groups within the industry (Abd El-Razek *et al.*2008; Abdul-Rahman *et al.* 2009; Al-Humaidi and Tan 2010; Hossen *et al.*2015; A Elawi *et al.* 2016; Alsharif & Karatas 2016). However, literature indicated that, once the source of a project delay can be identified, it is possible to model the impact the delay may have on other stakeholders (Assaf *et al.*2006; Faridi & El-Sayegh 2006; Hegab *et al.*2007). Similarly, if the source of the project delay is unknown, it is not possible to assess that delay against the impact it may have on all stakeholders of the project in terms of cost.

This chapter therefore presents a discussion of the key research questions and themes analyzed throughout this thesis. The first section presents a discussion on the findings from the literature review. This is followed by a discussion on the findings from the regression simulation modelling exercises. Throughout this chapter, implications of findings are discussed with respect to theory and practice.

9.2 Sources and causes of projects delay

Three sources of information form the core for responding to the research question with regard to the sources of projects delay. The first part of the discussion is based on the findings from the literature review, especially that found in Section 2.7 of the thesis. For example, Alzara *et al.* (2016) argued that major sources for projects delay are project life cycle-related; and they include how project variables such as cost and time are managed; and that these can be triggered by the way that the project scope has been agreed amongst the stakeholders (Nkado 1995; Assaf *et al.* 2006; Faridi and El-Sayegh 2006; Hegab *et al.* 2007; Abd El-Razek *et al.* 2008; Abdul-Rahman *et al.* 2009; Al-Humaidi and Tan 2010; Hossen *et al.* 2015; A Elawi *et al.* 2016; Alsharif and Karatas 2016). Accordingly, the causes of projects delay can be classified based on the origin agent that initiates the delay (Abdul-Rahman *et al.* (2006); Alaghbari *et al.* (2007); El-Razek *et al.* (2008); Omran *et al.* (2010).

There are many stakeholders on projects within the oil fields constructions industry; however, the categorization of stakeholders into owners, consultants, contractors and external factors has been seen to be prudent because literature supports the reasoning that these four categories cover nearly all the sources of projects delay (Oladapo 2007; Ndiokubwayo and Haupt 2009; Keane *et al.* 2010; Aziz 2013; and Eigbe 2016).

From the literature review, it was found that there was no clear classification for the main sources of projects delay in the oil fields constructions industry, which was a critical indication of the need for the research. In addition, it was observed that the body of knowledge on sources of projects delay in the oil fields constructions did not explore how stakeholders have been dealing with the influence of delay on project outcomes. The only clear indication for the oil fields construction has been that the industry experiences delay in the form of cost and time in contract conditions, like

many other industries around the world (Yau and Yang 2012; A Elawi et al.2016; Alzara et al.2016).

This study indicates that poor contractors work, conflicts between business partners related to major tasks achievement, improper safety strategy, delayed and slow supervision in making decisions by owner and delay at line services maintenance (water and electricity) are among the top 5 causes of delay that impact cost overrun in oil fields constructions projects which is consistent with the findings of Alnuaimi and Al Mohsin 2013; Kumaraswamy and Chan 1998; Hamzah et al. 2011;Alzara et al.2016;Alzara et al.2016; Alsharif and Karatas 2016; Abdul Rahman et al.2009; Assaf and Al_Hejji 2006; A Elaw et al.2016; El-Razek et al.2008; Faridi and El-Sayegh 2007;Ibironke et al.2013; Marzouk and El-Rasas 2014;Odeh and Battaineh 2002; Samarghandi et al.2016). More details are illustrated at section 9.3.1.

Therefore, according to the literature review above, the author of the current study has classified the causes of projects delay in oil fields construction projects based on these four categories of its sources: the owner, the consultant, the contractor and the external factors.

9.3 Modelling causes of projects delay in oil fields construction projects

To achieve this objective, the research used several integrated research techniques. Causes of projects delay were considered to be stochastic in nature. This is due to the fact that estimating their influence is not subjective and context dependent, hence using probabilistic methods is more likely to capture their influence. This required us to find the best-fit probabilistic distribution to represent the most influential causes of projects delay. The results from this exercise revealed that a significant number of best-fitting theoretical distributions for causes of projects delay belong to log logistic and extreme value distributions. The selected distribution is validated by the goodness-of-fit tests and the inspection of respective plots. The P-P plot and Q-Q revealed a relatively good fit for other regions of criticality for most of the causes of projects delay distributions.

A systematic procedure was adopted here to transform these input probabilities into useable assumptions in the simulation model. These are then used in the regression model to simulate the project cost overrun percentage.

The sensitivities of the relative assumptions were assessed and then the results of this iterative process were used to optimise and generate the final cost overrun percentage probability distribution. Sensitivity analysis revealed that BCT3Cost cause of projects delay has a high impact on the output. It is interesting also to point out that both the output probability distribution and the original set of data for the project duration overrun percentage fit Johnson SB theoretical probability distribution. This is further evidence to suggest that the developed regression model produces results that are similar to real cases. The project cost overrun percentage distribution allows decision-makers to not only identify the range and variance of possible project cost/budget,

but also facilitate the quantification of the impact of causes at an early stage of project development. This type of analysis assists in developing realistic project duration and budget.

9.3.1 Regression modelling

This research has investigated the causes that significantly contribute to projects delay in budget overrun per square meter (BgtOverrunM2) for oil fields construction projects. In doing that, a multiple linear regression modeling was performed and the regression model obtained is provided in Equation 9-1.. Thus, this chapter presents a discussion of the research findings for the regression modeling exercise. A summary of the results obtained from the modelling process is presented in Table 9-1.

$$\begin{aligned}
 bgtoverrunM2 = & 839.937 + 814.179 * BCT3Cost - 126.5 * BCT4Cost - 319.476 * \\
 & BCT6Cost - 355.513 * BCT7Cost + 1227.796 * BCT10Cost - 524.564 * BCT11Cost - \\
 & 369.444 * BCN1Cost - 665.592 * BCN3Cost - 1529.319 * BCN7Cost + 208.662 * \\
 & BCN8Cost - 710.055 * BCN9Cost + 667.643 * BCN10Cost - 118.62 * BCN11Cost - \\
 & 448.255 * BPO6Cost - 194.586 * BPO7Cost - 572.602 * BPO10Cost + 546.817 * \\
 & BPO12Cost - 149.108 * BPO13Cost - 84.275 * BPO614ost + 152.071 * BEF2Cost - \\
 & 565.927 * BEF3Cost + 1099.205 * BEF7Cost
 \end{aligned}
 \tag{9.1}$$

Equation 9-1 model equation used to predict bgtoverrunM2

Table 9-1: Summary results from the multiple regression modeling process

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.958	.918	.862	35.93242	.918	16.377	22	32	.000

The coefficient of determination (Adjusted R²) gives an indication of the explanatory power of the developed variable. As per the result in table 9-1, it is seen that the model can explain about 86% of the variations in BgtOverrunM2 considering the causes of delay associated with the project owner, contactors, consultants and external factors. Furthermore, the F-statistic is used to evaluate whether the variations explained by the model are by chance or not. With a p-value of 0.000, it can be concluded that the model's explanatory power is not by chance at significance levels of 10%, 5% and 1%, respectively. With an Adjusted R² of 86.2%, the model is not about to explain about 14% of the variations in BgtOverrunM2. This can be attributed to those variables not included in the modelling process or natural random variations which are difficult to account for.

A summary of the trend and impact of the causes of projects delay in BgtOverrunM2 is provided in Table 9-2 where the causes are grouped in terms of whether the increase or decrease the delay in BgtOverrunM2. Based on the findings of this research work, it was found that most of the causes of delays associated with the projects considered are related with issues arising with the project contractors and consultants, with 7 factors identified in each cases. In both cases, 7 out of the 11 causes studied in this research significantly impact BgtOverrunM2, thereby, representing approximately 64% of causes in each of these categories. The finding is consistent with findings of past studies by Samarghandi *et al.*2016; Sambasivan and soon 2007; Sweis *et al.*2008; Yau &

Yang 2012; Alaghbari *et al.*2007 which indicated that causes of delay related to contractors and consultants were among the top causes impact cost overrun. In the case of causes of delays arising from the project owner's end, 5 out of 13 causes of delay are found to be significant, representing about 39% of causes of delays in this category. Finally, the causes of delay associated with external factors are found to have the least effect on the causes of projects delay in BgtOverrunM2 with 3 out of the 9 factors, representing about 34% of causes in this category.

From the ranking on Table 9-2, the cause of projects delay associated with contractors, BCT4Cost "Poor contractor works" was found to have the most significant positive impact in the delay experienced by the projects considered in this work, which means that the higher the poor contractors work, the more impact will be on cost overrun of the project. This finding is supported by Samarghandi *et al.*2016; Sambasivan and soon 2007; Sweis *et al.*2008;Yau and Yang 2012; Alaghbari *et al.*2007;Toor and Ogunlana 2008; Abdul-Rahman *et al.*2006 . More details on codes/variable names of the causes of delay from case studies on section 7.9.

Table 9-2: Trend and impact rank of the causes of projects delay in BgtOverrunM2

#	Positive Magnitude (Increasing) Described by Code/Variable Name	Description of the Code/Variable Name
1	BCT4Cost	Poor contractors work
2	BPO7Cost	Conflicts between business partners related to major tasks achievement
3	BEF2Cost	Improper safety strategy
4	BPO12Cost	Delayed and slow supervision in making decisions by owner

5	BEF7Cost	Delay at line services maintenance (water and electricity)
6	BCN10Cost	Lack of experience on the part of the consultant's site staff
7	BCN3Cost	Quality assurance requirements by local governments and waiting time for approval of test and inspection
8	BCT6Cost	Rework due to errors during finishing construction tasks
9	BCT10Cost	Contractor's unstable of financial background
10	BPO6Cost	Delay in Progress Payments to Contractors
11	BCN8Cost	Change of sub consultant during project execution
12	BCT3Cost	Delays in sub-contractors work

9.3.2 Stochastic modelling

Monte Carlo simulation – a stochastic modelling approach was used to examine the fitness of the developed regression model. Based on the results obtained, the developed model follows a logistic distribution – a family of distribution used in modeling growth. However, most of the causes of BgtOverrunM2 were found to follow the Log logistic distribution – a family of distribution associated with projects where the risk increases at the initial phase of the project and decreases later on. This finding is supported by A. Hanaf 2017; G. Eke 2017 and P.E. Love, *et. al.* 2013 who noticed that log-logistic distribution best describes the behaviour of factors leading to cost overrun.

Therefore, to minimize BgtOverrunM2, those involved in a project's value chain must ensure a smooth execution of project in its early stage so as to limit the high risk associated with the project during in its initial phase.

Furthermore, discussion on the trend, sensitivity and scenario analysis of the developed model as well as its associated dependent variables are presented.

The trends analysis was also carried out to access the variability of the dependent variables about their mean. While more than 50% of the forecasted BgtOverrunM2 lies within the +/- 1 Std Dev certainty band, the highest and lowest variation in certainty in the causes of BgtOverrunM2 are associated with BPO6Cost (Delay in Progress Payments to Contractors) and BPO12Cost (Delayed and slow supervision in making decisions by owner), respectively.

For the sensitivity analysis, the input variables are ranked based on the effect they have on the output mean (mean of BgtOverrunM2), either input high or input low. Most of the causes of BgtOverrunM2 have input low with BPO6Cost (Delay in Progress Payments to Contractors) exhibiting the highest impact in the input low direction. On the other hand, BCT3Cost (Delays in sub-contractors work) has the highest impact in the input high direction.

Finally, scenario analysis shows the significant dependent variables at a given percentile of BgtOverrunM2. In this work, scenario analysis at 90th, 95th and 99th was carried out and the result shows that both BEF10Cost and BCN3Cost are significant when BgtOverrunM2 is at or above its 90th percentile. For the 95th percentile analysis of BgtOverrunM2, BCN10Cost, BCN3Cost, BCT3Cost and BCT10Cost were found to be significant. Above the 99th percentile, BEF3Cost, BCN10Cost, BCT3Cost, BCN7cost, BEF2Cost, BCT7Cost, BPO6Cost and BCT6Cost were found to be significant.

9.4 Probability distributions associated with most of the causes of projects delay that lead to cost overrun

The findings of this research shows that most causes of cost overrun in the oil field construction follows the log-logistic distribution - a distribution whose rate increases initially and decreases later. Consequently, it can be said that planning and execution efforts must be garnered to aggressively minimize cost-related issues at a project's early life, thereby reducing a project's cost overrun. This finding agrees with that reported by P.E. Love, *et. al.* (2013) where the cost overrun in 49 road construction projects executed in Australia was analyzed. The results obtained shows that log-logistic distribution best describes the behaviour of factors leading to cost overrun. Furthermore, A. Hanaf (2017) carried out a research work on finding the best-fit distribution for causes of cost overrun involving in 33 highway/road constructions projects in Pakistan. A similar work by G. Eke (2017) on the determination of the different probability distributions for causes of cost overrun in construction projects within 120 educational facilities in the UK is reported in the literature. The findings of both works suggest that the lognormal distribution best fits most cause of cost overrun. Resolving the findings of A. Hanaf (2017) and Eke (2017) against that the of this research and P.E. Love, *et. al.* (2013), Ashkar and Mahdi (2006) reported that the log-logistic and log-normal distributions are very similar in shape. The major difference between both are: log-logistic distribution has heavier tail compared to the log-normal distribution, Fisk (1961), and that while the log-logistic distribution is associated with random processes, the log-normal distribution is associated with natural processes. Based on the foregoing, it can be said that the findings of A. Hanaf (2017) and Eke (2017) are consistent with what is found in this research and that of is P.E. Love *et. al.* (2013). A possible source of disparity is the randomness or otherwise of the factor considered in both works. Therefore, the findings presented in this work are consistent with those reported in the literature such as A. Hanaf (2017) , Eke (2017) and P.E. Love, *et. al.* (2013).

9.5 Most likely cost overrun

The finding of this work shows that the most likely cost overrun is associated with the factor BPO6Cost (Delay in Progress Payments to Contractors). This factor possesses the highest variability (figure 8-61), the highest sensitivity (figure 8-66) and highest effect on cause of variation in budget overrun (figure 8-64). The distribution associated with the cause of delay (BPO6Cost) is the Log logistic distribution, whereby risk increases initially and decreases later.

9.6 Mitigation strategies

Numerous studies have attempted to identify the mitigation strategies for project delay and propose suggestions on reducing the impact of delay on time and cost by planning a proper strategy to mitigate delay and reduce the cost by completing projects on time. As per the top 5 causes of delay in oil fields construction projects identified by the current study, in table 9-2 and described in section 9.2, the author suggest the following mitigation strategies selected from the literature review as following:

#	Top 5 Causes of Delay Identified by Current Study	Recommended Mitigation Strategies from literature review	References
1	Poor contractors work	Choose experienced subcontractors with good reputation	Sambasivan & Soon (2006)
2	Conflicts between business partners related to major tasks achievement	Made collaborative decisions instead of making individually.	Assaf & Al-Hejji (2006); Hasan et al. (2014)
3	Improper safety strategy	Develop a new strategy of management in construction	Abdul-Rahman et al. (2006); Arditi et

		projects taking into account the considerations of size, nature, cost, importance of the project and safety and health of the manpower	al., (2017);Fugar2010);(Nguyen et al.(2004); Aibinu & Jagboro (2002)
4	Delayed and slow supervision in making decisions by owner	Minimize change orders during construction to avoid delays. Avoid delay in reviewing and approving of design documents.	Rasas (2013); Sambasivan & Soon (2006);
5	Delay at line services maintenance (water and electricity)	Protect incompleteness of project by insurance. Owners have to study the construction project and services requirements properly.	Kaliba et al.(2008); Koushki et al.(2004); Lo et al., (2006)

9.7 Research implications on practice and research

Several studies have identified causes of project delay. However, limited works have investigated those causes in the context of how they impact cost overrun, specifically in oil field construction projects. By modelling the cost overrun in relation to causes of project delay, the author has been able to identify the causes of delay that translates into cost overrun, thereby filling a gap that exists in the literature. Consequently, the findings of this work can serve as a foundation for future research works.

In the practical realm, the findings of this work shows that main sources of cost overrun are associated with delays that have to do with consultant, contractors and project owners, while external factors play minimal role in cost overrun. Consequently, by mapping out strategies relating to consultant, contractors and project owners, cost overrun can be minimized during

project execution. Also, this work shows that cost overrun in oil field construction is significantly impacted by factors whose risk rate increases initially and decreases later on. Thus, managerial efforts must be channelled to pay particular attention to the early stages of project execution.

9.8 Chapter summary

This chapter has presented a discussion of the key research questions and the implications of the research findings. It began by discussing the literature review findings followed by a discussion of the findings from the regression simulation and modelling process. Then, distribution associated with most of the causes of projects delay in the context of cost overrun had been discussed.

It was found that there is match between the findings from the literature and the research findings for the main sources of projects delay as they originate from four main groups: owner, consultant, contractor and external factors. Each one of these four groups was behind the instigation of unknown numbers of delay causes.

Moreover, the development of a model for analyzing the cost of projects delay in oil fields construction projects was discussed. Finally, the author discussed the results which shows the log-logistic distribution that best describes the behavior of factors leading to cost overrun

Chapter 10: Conclusion

10.1 Introduction

This chapter will introduce the conclusions drawn out of this research in five sections. First, the author illustrated and examined the robustness of the adopted methodology. Second, the objectives of the investigation are revisited with a view to compare expected results with the achievement accomplished. Third, the limitations of this research are summarized and listed. Fourth, the contribution to knowledge is presented. Fifth, areas for further research are discussed and noted.

10.2 Robustness of the research methodology

The research methodology adopted to accomplish the research aims and objectives was presented in Chapter 5. A mixed research approach was employed to achieve the objectives of this investigation. According to in-depth literature review, which was conducted to synthesize existing knowledge on the causes of projects delay, research gaps were identified in the development and refinement of the research questions and objectives. As a result, a large list of possible causes of projects delay factors were identified. This list was cross-referenced to document its validity. Furthermore, the list was classified and clustered according to the source of the projects delay. The author used 55 projects case studies from oil fields construction projects as secondary research data and their causes of projects delay were listed according to the sources/grouping of projects delay reviewed in literature. Also, the author conducted a risk impact survey with 30 experts worked on those projects to estimate the impact of projects delay on cost overrun, which was used as primary data research data to develop the Monte Carlo simulation equations.

An in-depth literature review was carried out to synthesize existing knowledge on the methods for modelling causes of projects delay. This led to the adoption of multiple regression and Monte Carlo simulation techniques to model the association between the causes of projects delay and their impact. The most important causes of projects delay were selected based on the regression analysis. Several fitting measurements were used to assess the validity and robustness of the developed model. For example, in regression significance, Standard Error, R², residual plots, P-P plot, Q-Q, etc., were used to measure the accuracy of the derived model. The model was also validated on unseen data. Similar standard fitness measures, such as the Anderson-Darling fitting test, were used to assess the probability distribution of both the input cause of projects delay variables and the output from the simulation model. The approaches taken in this study are considered suitable given the unique characteristics of the research framework developed in the course of this investigation.

10.3 Accomplishing the research objectives

a. To identify the main sources and causes of projects delay in oil fields construction projects

This objective was achieved through a systematic literature review. A combination of literature sources identified the causes of projects delay in the oil fields construction industry. These causes were clustered into four homogenous groups. These are owner-based group (these causes are shown in table 2-2 of this thesis; in total 22 causes were extracted), contractors-based group (these causes are shown in table 2-3; in total 29 causes were extracted), consultant-based group (these causes are shown in table 2-4; in total 31 causes were extracted) and external factors (these causes are shown in table 2-5; 20 causes were extracted).

These causes of projects delay were extracted and described in detail in Chapter 2. The completion of this objective was a prerequisite for some of the next research objectives. These causes of projects delay extracted from literature review were compared to similar causes from research cases studies and used as secondary data research to

c. To develop a model for analyzing the impact of causes of projects delay on project outcomes (cost overrun) in oil fields construction projects

This research objective was carried out on the assumption that the development of a new framework for assessing the causes of projects delay in oil fields construction projects signifies that the existing methods are inappropriate and need to be rejected. One of the main advancements in knowledge provided by this research is the development of an integrated stochastic model for the assessment of the impact of the causes of projects delay during the execution stage of oil fields construction projects. This objective was achieved through the development of an integrated framework based on multiple regression and Monte Carlo simulation. The achievement of this objective is presented in Chapter 8. The development of the model is based on the sound theoretical models that were reported in the literature and reviewed in chapters 2, 5, 6 and 7. It is important to emphasize here that there is no single best model for every situation; every methodology is based on a particular context and underlying assumption. The model developed by this work is driven by the research gaps that were identified in the literature review. The model forges stronger links between causes of projects delay and their impact on a project outcome in terms of cost overrun. In theory, the model assists organizations to simulate project performance and maintain the impact of projects delay at a minimum level that can be financially tolerated. The model serves as a vehicle for assessing the impact of projects on project performance in terms of cost/budget. It also enables projects stakeholders to identify strategies for management, and assists them in

identifying the causes that may lead to undermining project performance. The developed model can be globally used to analyze the causes of projects delay, providing the primary data that are changed to reflect the context of the application.

10.4 Generalizability, applicability and implications of the findings

In this section, the author discusses the generalizability of the research findings. The developed regression, stochastic models and the modelling are more appropriate for analyzing the impact of possible causes of projects delay at the implementation stage of oil fields construction project development. This will allow for the development of contingency budgets. This will also allow the contracting parties to optimize their bids and put in place mitigating strategies for dealing with the possible causes of projects delay. Although the oil fields construction industry was the source of the primary data, commonalities across similar industries in different countries are possible, which may enable this research to be used in other settings. Certainly, the modelling framework developed in this research provides opportunities for this research in many other industrial sectors. In order to do so, it would be necessary to make some adjustments or additions to the causes of projects delay data and probability distributions and associated possible cost overruns. This is necessary so that the probability distributions reflect the modelling context. It is also worth pointing out the possible appropriateness of the developed modelling framework to support decision-making through the computation of probability distribution of the causes of projects delay and their consequences. The use of probability percentile values will increase confidence in the decision-making process for estimating the impact of the causes of projects delay.

10.5 Research limitation

No one can deny that majority of research projects are based on assumptions; thus, no research framework can claim to be complete. As such, the research framework presented in this investigation will have limitations, some of which are as follows:

1. In its present form, the regression model does not include enough causes of projects delay to allow the user to test their impact;
2. The data for the impact of the causes of projects delay are estimated as a proxy of the cost overrun from the case study projects. If one can obtain data records to trace the impact of projects delay on the oil fields construction duration overrun, this will improve the usability of the model;
3. Only one performance criterion was used to assess the causes of projects delay.

Further research is needed to overcome such limitations. The next section details the study's contribution to knowledge, whilst the final section explores some possible areas for future development and research.

10.6 Contribution to knowledge of the research

This research provides an increased understanding of the events that lead to causes of projects delay. The focus of the research was directed towards projects delay causes' identification and classification, and to modelling the link between these causes of projects delay and their impact (cost overrun was used as a proxy variable to measure the impact). Additionally, an approach to capture the dynamism between the causes of projects delay and their impact was carried out through Monte Carlo simulation. To summarise, the research has contributed towards formalising the estimation of the impact of the causes of projects delay in oil fields construction projects using a combination of regression and Monte Carlo simulation techniques. According to the formulated research questions, the key research contributions of this investigation are summarised in the following areas:

1. The researcher developed and validated probability distribution for the most important causes of projects delay (those that correlate with the proxy variable).
2. The researcher also conducted a multiple-regression analysis to quantify the association between causes of variation and their impact based on real 55 case studies. The model was used to stochastically estimate the impact of causes of projects delay. The objective of the research was to develop a generic model to assist in developing budget contingencies for managing the impact of causes of projects delay in oil fields construction projects.
3. The major contribution then is that the research framework can be used by businesses to model their own factors and help in their decision-making, as opposed to using anecdotal evidence.

10.7 Recommendations for further research

This investigation has identified a number of areas that would benefit from further research. However, the research framework developed in this research could be enhanced in many ways, including the following:

1. Investigation of the other categories – scope, quality, performance and time – is needed in the same way as cost/budget has been investigated in this research.
2. Investigate the impact of projects delay for other petroleum construction projects such as oil fields drilling; oil fields exploration and oil fields artificial islands because this research was only developed based on general oil fields construction projects. Thus, there is a need to test if it can be used for other project types within the same industry.
3. Increase the number of causes of projects delay in the regression model.
4. Map the causes of projects delay to their impact, such as cost and time overrun success criteria.
5. Profile the cost consequences of each of the projects delay causes.

11 References and Appendix

11.1 References

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11.2 Appendixes

11.2.1 Appendix A: List of Case Studies Projects

#	Description	Project Type
1	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning of island surface facilities expansion Artificial Island	Oil Field Construction/Artificial Island
2	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning of island surface facilities expansion Artificial Island	Oil Field Construction/Artificial Island
3	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning of island surface facilities expansion Artificial Island	Oil Field Construction/Artificial Island
4	engineering, procurement, modules and buildings fabrication, transportation, construction and	Oil Field Construction/Artificial Island

	commissioning of island surface facilities expansion Artificial Island	
5	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning of island surface facilities expansion Artificial Island	Oil Field Construction/Artificial Island
6	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning of island surface facilities expansion Artificial Island	Oil Field Construction/Artificial Island
7	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning.	Oil Field Construction/New
8	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning	Oil Field Construction/Development

9	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning	Oil Field Construction/Development
10	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning	Oil Field Construction/Development
11	engineering, procurement, modules and buildings fabrication, transportation, construction and commissioning	Oil Field Construction/Development
12	to engineer, procure, and construct the hull and living quarters bound and The contract includes fabrication and integration of various topside modules	Oil Field Construction/Development
13	the design, procurement, construction and installation of the subsea system oil field development which will also be designed to accommodate production from the later subsea tieback of the oil field; the subsea pipeline system; and the onshore	Oil Field Construction/Development

	pipeline and valve station at the receiving station	
14	4 subsea wells tied back through a manifold with a dual 12" rigid production pipeline/riser	Oil Field Construction/Development
15	Engineering, procurement, construction, installation and pre-commissioning of 7,500 ST [7,000 ST] jacket with installation aids	Oil Field Construction/Development
16	Engineering, procurement, construction, installation and pre-commissioning of 9000 ST [8500 ST] jacket with installation aids	Oil Field Construction/Development
17	McDermott will provide a turnkey solution utilizing advanced float-over technology to install the 7,657-ton production deck in oil field including Engineering, procurement, construction, transportation, installation commissioning and start-up Total weight approximately 12,955 ST	Oil Field Construction/Development
18	Engineering, procurement, construction and installation of Subsea infrastructure, wells,	Oil Field Construction/Development

	manifold, umbilicals, jumpers, flowlines, risers, pump station, pump modules, transformer and topsides support equipment oil field 232 (30,000 ST)	
19	Fabrication and installation of Umbilicals, jumpers, flying leads, pump modules and stations requirements for oil field 235 (14500 ST)	Oil Field Construction/Development
20	Fabrication and installation of Umbilicals, jumpers, flying leads, pump modules and stations requirements for oil field 236 (12,000 ST)	Oil Field Construction/Development
21	Construction, load out, pre-commissioning, transportation, float-over installation and hook-up, 20,300 ST integrated topsides and 6700 ST, 7.6 feet diameter, eight-leg jacket and associated infrastructure	Oil Field Construction/Development
22	Engineering, procurement, construction, installation and commissioning of 84 pre-assembled racks and units (PARs/PAUs) weighing 35000 ST for and associated station requirements	Oil Field Construction/Development

23	Construction engineering, procurement and construction of 24 pre-assembled units, 51 pre-assembled racks and 7 pre-assembled structures with a total weight of 21000 ST oil field	Oil Field Construction/Development
24	Construction of 17400 ST subsea structures and spools, includes fabrication and assembly of 17400 ST of structures, comprising 83 manifolds, control distribution unit (CDU), PLETS and pipeline termination structure (PTS) and respective foundations, with the heaviest unit weighing more than 1800 ST. The work scope also includes 77 jumpers and spools weighing a total of 3500 ST	Oil Field Construction/Development
25	Engineering, Procurement and Construction (EPC) contract to build an oil network compressor station oil field	Oil Field Construction/Development
26	Engineering, procurement and construction (EPC) contract for development of oil field to increase production by 30,000 barrels a day (b/d) of oil.	Oil Field Construction/ Production Development

27	Engineering, procurement, construction, installation and pre-commissioning of the 15750 ST Riser Support Structure , representing 45% of the 35,000 ST of subsea structures PT Total E & P is fabricating for the project oil field	Oil Field Construction/Development
28	Engineering, procurement and construction (EPC) contract for the development of offshore field with capacity to increase production by 25,000 barrels a day (b/d) of oil.	Oil Field Construction/ Production Development
29	Construction of Propane Truck Loading Gantry, including pumps, compressors, meter skid, loading arms, sprinkler system and modification of existing facility for (15,000 ST)	Oil Field Construction/Development
30	Engineering, Procurement and Construction (EPC) contract for the development of an offshore oil field to increase production by 30,000 oil barrels per day by drilling to 5000 extra feet	Oil Field Construction/ Production Development

31	Engineering, Procurement and Construction (EPC) contract for the development of an offshore oil field to increase production by 30,000 oil barrels per day by drilling to 5000 extra feet	Oil Field Construction/ Production Development
32	Engineering, Procurement and Construction (EPC) contract for the installation of Tie-ins at onshore oil field as per the approved design and requirements (12,000 ST)	Oil Field Construction/Development
33	Engineering, Procurement and Construction (EPC) contract for the development onshore oil field by expanding the field up to 25000 SQM	Oil Field Construction/Development
34	Engineering, procurement and construction (EPC) contract to build a carbon black and delayer coke plant with capacity of 25,000 barrels of crude oil per day and produce 30,000 tonnes of carbon black per year and (expanding of land by 180000 SQM extra)	Oil Field Construction/A Carbon Black and Delayer Coke Plant
35	Engineering, Procurement and Construction (EPC) contract for upgrading the internal facilities at two	Oil Field Construction/Development

	onshore oil fields (Perapong 90 and Junad 55) adding 85000 SQM of spaces.	
36	Engineering, Procurement and Construction (EPC) contract for the expansion of an onshore oil field to produce 30,000 o/b per day by drilling to 6500 extra feet.	Oil Field Construction/ Production Development
37	Engineering, Procurement and Construction (EPC) contract for the development onshore oil field by adding extra 250,000 SQM.	Oil Field Construction/Development
38	Engineering, Procurement and Construction (EPC) contract for the development onshore oil field by adding extra 300,000 SQM.	Oil Field Construction/Development
39	Development of an onshore oil block field (200,000 SQM).	Oil Field Construction/Development
40	Development and construction (240,000 SQM).	Oil Field Construction/Development
41	Development and construction field (220,000 SQM).	Oil Field Construction/Development
42	Engineering, Procurement and Construction (EPC) contract for (25) Oil	Oil Field Construction/Development

	Jackets and development (150,000 SQM).	
43	Engineering, procurement and construction (EPC) contract for the development offshore field with capacity to produce 35,000 barrels a day (b/d) of oil . (drilling up to 8000 feet extra)	Oil Field Construction/ Production Development
44	Construction, load out, pre-commissioning, transportation, float-over installation and hook-up, 29,349 ST integrated topsides and 6256 ST, 7.5 feet diameter, eight-leg jacket and associated infrastructure	Oil Field Construction/Development
45	Engineering, procurement, construction, installation and commissioning of 72 pre-assembled racks and units (PARs/PAUs) weighing 34,899 ST	Oil Field Construction/Development
46	Construction engineering, procurement and construction of 13 pre-assembled units, 56 pre-assembled racks and 6 pre-assembled structures with a total weight of 19,290 ST	Oil Field Construction/Development
47	Construction of 15,432 ST subsea structures and spools, includes	Oil Field Construction/Development

	fabrication and assembly of 15,432 ST of structures, comprising 79 manifolds, control distribution unit (CDU), PLETS and pipeline termination structure (PTS) and respective foundations, with the heaviest unit weighing more than 1670 ST. The work scope also includes 63 jumpers and spools weighing a total of 2360 ST.	
48	Engineering, Procurement and Construction (EPC) contract to build an oil network compressor station (350,000 SQM).	Oil Field Construction/Oil Network Compressor Station
49	Engineering, procurement and construction (EPC) contract for development of the offshore field to produce 45,000 barrels a day (b/d) of oil (drilling up to 10,000 feet extra).	Oil Field Construction/ Production Development
50	Engineering, procurement, construction, installation and pre-commissioning of the 8600 ST Riser Support Structure , representing 25% of the 26,000 ST of subsea structures	Oil Field Construction/Development

51	Engineering, procurement and construction (EPC) contract for the development of offshore field with capacity to produce 55,000 barrels a day (b/d) of oil (drilling up to 11,000 feet extra).	Oil Field Construction/ Production Development
52	Construction of Propane Truck Loading Gantry, including 15 pumps, 20 compressors, meter skid, 16 loading arms, sprinkler system and modification/development of existing facility (500,000 SQM).	Oil Field Construction/Development
53	Engineering, Procurement and Construction (EPC) contract to build an oil network compressor station (on 150,000 SQM)	Oil Field Construction/Oil Network Compressor Station
54	Engineering, procurement and construction (EPC) contract for development of the offshore field to produce 100,000 barrels a day (b/d) of oil (by drilling up to 10,000 feet extra).	Oil Field Construction/ Production Development
55	Engineering, procurement, construction, installation and pre-commissioning of the 10,400 ST Riser Support Structure ,	Oil Field Construction/Development

11.2.2 Appendix B: Sample of questionnaire survey

Projects Risks Survey

Dear Participant,

The oil fields industry is one of the important industries. It employs millions of people throughout the world. The sector has experience a number of improvements to ensure the safety and excellent project management in the industry, but still, it is highly risky occupation where delay of projects if even common as compared to other industries of the world.

The objective of this research is to evaluate the causes/risks of delay of the previous projects you worked with Mubadala Petroleum and related to oil fields for the last 20 years. Your input will help us to find the relationships between causes of delay and projects to improve the industry. We have estimated that it will take you approximately 40-45 minutes to complete the survey.

All individual responses will remain confidential and study data will be integrated and analyzed as a whole. The research outcome will be reported in a summary form to protect confidentiality.

However, if you have any concerns or questions about the questionnaire or about participating in this research, you may contact me on [khouri492@gmail.com](mailto:khour492@gmail.com)

Alternatively, you may communicate my director of studies, Professor H. Boussabaine on 009714 279 1437 (halim@buid.ac.ae).

Thank you for your time and support and I look forward to sharing the results of this survey with all of the participants.

Yours faithfully,

Khalid Al Khoori

PhD Candidate
British university in Dubai
Mobile: +971554923338

The research directed by:
Professor H. Boussabaine
British University in Dubai
Tel: 04 279 1437

A- GENERAL INFORMATION

▪ **Respondent's Current Employment Condition:**

☐ Retired ☐ Employed

▪ **Respondent's position if Employed:**

☐ Public Sector ☐ Private Sector

▪ **Job title:**

- | | |
|---------------------------------------|---|
| ☐ Estimator | ☐ Project Engineer |
| ☐ Project Manager | ☐ Assistant Project Manager |
| ☐ General Manager | ☐ Project Auditor |
| | ☐ Other |

▪ **Experience in the organization/Projects:**

- | | |
|-----------------------------------|--|
| ☐ 5-10 | ☐ 15-20 years |
| ☐ 10-15 years | ☐ More than 20 years |

B(1)-This section includes cost overrun related questions to group B projects which consists of (55) oil fields' projects attached to this email that had been normalized-selected/grouped by its unit of measurement which is square meter (M2).

B 1.1 By using the below probability/impact matrix, please estimate the influence/impact of the following causes of delay related to contractors on the cost overrun of group B projects.

Causes of Delay (related to contractors)		Degree of Risk impact on cost overrun (1 %-72%)	Risk Matrix																																																					
1	Contractors handles multiple projects at the same time		<table><tr><td>Probability</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>VH (90%)</td><td>5%</td><td>9%</td><td>18%</td><td>36%</td><td>72%</td></tr><tr><td>H (70%)</td><td>4%</td><td>7%</td><td>14%</td><td>28%</td><td>56%</td></tr><tr><td>M (50%)</td><td>3%</td><td>5%</td><td>10%</td><td>20%</td><td>40%</td></tr><tr><td>L (30%)</td><td>2%</td><td>3%</td><td>6%</td><td>12%</td><td>24%</td></tr><tr><td>VL (10%)</td><td>1%</td><td>1%</td><td>2%</td><td>4%</td><td>8%</td></tr><tr><td></td><td>VL (5%)</td><td>L (10%)</td><td>M (20 %)</td><td>H (40%)</td><td>VH (80%)</td></tr><tr><td colspan="6">IMPACT</td></tr></table>						Probability						VH (90%)	5%	9%	18%	36%	72%	H (70%)	4%	7%	14%	28%	56%	M (50%)	3%	5%	10%	20%	40%	L (30%)	2%	3%	6%	12%	24%	VL (10%)	1%	1%	2%	4%	8%		VL (5%)	L (10%)	M (20 %)	H (40%)	VH (80%)	IMPACT					
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	VL (5%)	L (10%)	M (20 %)	H (40%)	VH (80%)																																																			
IMPACT																																																								
2	Poor communication and coordination by sub-contractors with other project parties																																																							
3	Delays in sub-contractors work																																																							
4	Poor contractors work																																																							
5	Frequent change of sub-contractors because of their inefficient work																																																							

6	Rework due to errors during finishing construction tasks							
7	Conflicts in sub-contractors schedule in execution of project							
8	Conflicts between contractors and other parties (consultant and owner)							
9	Shortage of experts resources during hazards or emergencies							
10	Contractor's unstable of financial background							
11	Poor site management and supervision by contractor							

Probability					
VH (90%)	5%	9%	18%	36%	72%
H (70%)	4%	7%	14%	28%	56%
M (50%)	3%	5%	10%	20%	40%
L (30%)	2%	3%	6%	12%	24%
VL (10%)	1%	1%	2%	4%	8%
	VL (5%)	L (10%)	M (20 %)	H (40%)	VH (80%)
IMPACT					

B 1.2 By using the below probability/impact matrix, please estimate the influence/impact of the following causes of delay related to consultants on the cost overrun of group B projects.

Causes of Delay (related to consultants)		Degree of Risk impact on cost overrun (1 %-72%)	Risk Matrix																																																																	
12	Poor site management and supervision by consultant		<table><tr><td>Probability</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>VH (90%)</td><td>5%</td><td>9%</td><td>18%</td><td>36%</td><td>72%</td></tr><tr><td>H (70%)</td><td>4%</td><td>7%</td><td>14%</td><td>28%</td><td>56%</td></tr><tr><td>M (50%)</td><td>3%</td><td>5%</td><td>10%</td><td>20%</td><td>40%</td></tr><tr><td>L (30%)</td><td>2%</td><td>3%</td><td>6%</td><td>12%</td><td>24%</td></tr><tr><td>VL (10%)</td><td>1%</td><td>1%</td><td>2%</td><td>4%</td><td>8%</td></tr><tr><td></td><td>VL (5%)</td><td>L (10%)</td><td>M (20 %)</td><td>H (40%)</td><td>VH (80%)</td></tr><tr><td colspan="6">IMPACT</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>						Probability						VH (90%)	5%	9%	18%	36%	72%	H (70%)	4%	7%	14%	28%	56%	M (50%)	3%	5%	10%	20%	40%	L (30%)	2%	3%	6%	12%	24%	VL (10%)	1%	1%	2%	4%	8%		VL (5%)	L (10%)	M (20 %)	H (40%)	VH (80%)	IMPACT																	
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M (50%)	3%	5%							10%	20%	40%																																																									
L (30%)	2%	3%							6%	12%	24%																																																									
VL (10%)	1%	1%							2%	4%	8%																																																									
	VL (5%)	L (10%)							M (20 %)	H (40%)	VH (80%)																																																									
IMPACT																																																																				
13	Poor coordination by the consultant engineer with the parties of the project specially with local authorities																																																																			
14	Quality assurance requirements by local governments and waiting time for approval of test and inspection																																																																			
15	Inaccuracies in technical drawings such as infrastructure services and power load on electric power station																																																																			
16	Unclear first drafts of pipeline connections between both fields																																																																			

	that cause confusion between contractors and sub-contractors							
17	Delay obtaining permits from local authorities							
18	Delay in preparing change orders by sub tasks consultant							
19	Change of sub consultant during project execution							
20	Slow response by the consultant engineer regarding testing and inspection							
21	Lack of experience on the part of the consultant's site staff							
22	Delay in the approval of contractor submissions by the engineer							

Probability					
VH (90%)	5%	9%	18%	36%	72%
H (70%)	4%	7%	14%	28%	56%
M (50%)	3%	5%	10%	20%	40%
L (30%)	2%	3%	6%	12%	24%
VL (10%)	1%	1%	2%	4%	8%
	VL (5%)	L (10%)	M (20 %)	H (40%)	VH (80%)
IMPACT					

B 1.3 By using the below probability/impact matrix, please estimate the influence/impact of the following causes of delay related to project owners on the cost overrun of group B projects.

Causes of Delay (related to projects owners)		Degree of Risk impact on cost overrun (1 %- 72%)	Risk Matrix					
23	Delay in Reviewing and Approving Design Documents by owner							
24	Delay to furnish and deliver the site to the project manager by the owner							
25	Conflicts between business partners of the project							
26	Some changes in materials types and specifications during construction works not being specified in the detailed site plan							
27	Delay in approving project drawings by owner (local government projects council)							

28	Delay in Progress Payments to Contractors	
29	Conflicts between business partners related to major tasks achievement	
30	Too much bureaucracy in project owner management	
31	Delay in decision making by owner for some change requests	
32	Slow communication and coordination by owner	
33	Contract Modifications	
34	Delayed and slow supervision in making decisions by owner	
35	Uncooperative owner	
36	Delay in preparation and approval of drawings by owner	

Probability					
VH (90%)	5%	9%	18%	36%	72%
H (70%)	4%	7%	14%	28%	56%
M (50%)	3%	5%	10%	20%	40%
L (30%)	2%	3%	6%	12%	24%
VL (10%)	1%	1%	2%	4%	8%
	VL (5%)	L (10%)	M (20 %)	H (40%)	VH (80%)
	IMPACT				

B 1.4 By using the below probability/impact matrix, please estimate the influence/impact of the following causes of delay related to external factors on the cost overrun of group B projects.

Causes of Delay (related to external factors)		Degree of Risk impact on cost overrun (1 %-72%)	Risk Matrix																																																																	
37	Accidents during construction		<table><tr><td>Probability</td><td colspan="5"></td></tr><tr><td>VH (90%)</td><td>5%</td><td>9%</td><td>18%</td><td>36%</td><td>72%</td></tr><tr><td>H (70%)</td><td>4%</td><td>7%</td><td>14%</td><td>28%</td><td>56%</td></tr><tr><td>M (50%)</td><td>3%</td><td>5%</td><td>10%</td><td>20%</td><td>40%</td></tr><tr><td>L (30%)</td><td>2%</td><td>3%</td><td>6%</td><td>12%</td><td>24%</td></tr><tr><td>VL (10%)</td><td>1%</td><td>1%</td><td>2%</td><td>4%</td><td>8%</td></tr><tr><td></td><td>VL (5%)</td><td>L (10%)</td><td>M (20 %)</td><td>H (40%)</td><td>VH (80%)</td></tr><tr><td colspan="6">IMPACT</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>						Probability						VH (90%)	5%	9%	18%	36%	72%	H (70%)	4%	7%	14%	28%	56%	M (50%)	3%	5%	10%	20%	40%	L (30%)	2%	3%	6%	12%	24%	VL (10%)	1%	1%	2%	4%	8%		VL (5%)	L (10%)	M (20 %)	H (40%)	VH (80%)	IMPACT																	
Probability																																																																				
VH (90%)	5%	9%							18%	36%	72%																																																									
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L (30%)	2%	3%							6%	12%	24%																																																									
VL (10%)	1%	1%							2%	4%	8%																																																									
	VL (5%)	L (10%)							M (20 %)	H (40%)	VH (80%)																																																									
IMPACT																																																																				
38	Unproper safety strategy																																																																			
39	Traffic control and restriction at job site																																																																			
40	lack of some materials, equipment and tools on the market during economic crises																																																																			
41	Late delivery of some core materials																																																																			
42	Issues related to environmental concerns by local authorities																																																																			
43	Delay at line services maintenance (water and electricity)																																																																			
44	Extra work related to solve public services such as roads, utilities																																																																			
45	Bad weather and unexpected natural events during the mid of construction tasks																																																																			

===== END of Questions =====

11.2.3 Appendix C: Defining the Probability Distribution of the Input (negative) Variables

11.2.3.1 BEF3Cost

Figure 11-1 demonstrates the fit comparison for BEF3Cost, while Figure 11-2 and Figure 11-3, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Logistic distribution best fits the data. This distribution is widely employed for modeling growth and also in logistic regression. For the Logistic distribution of BEF3Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.0988	0.0182

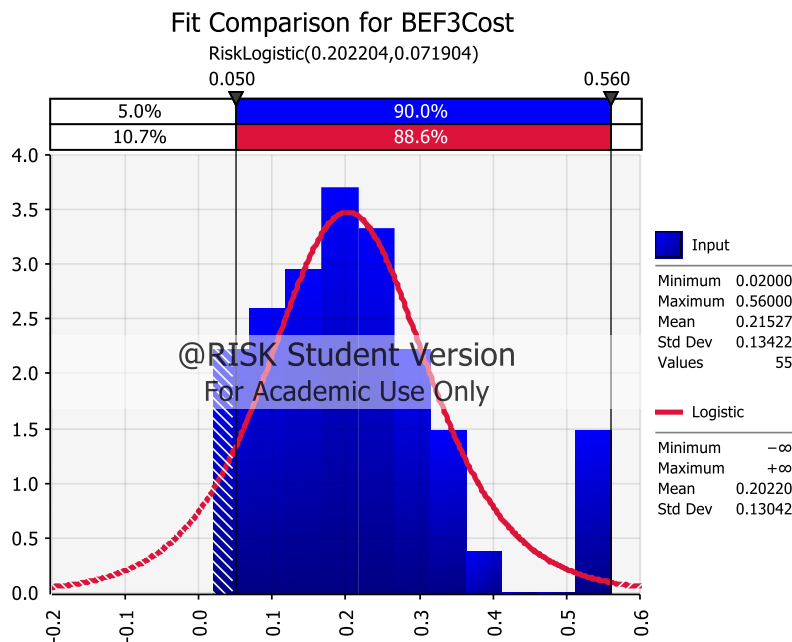


Figure 11-1: Fit comparison for BEF3Cost

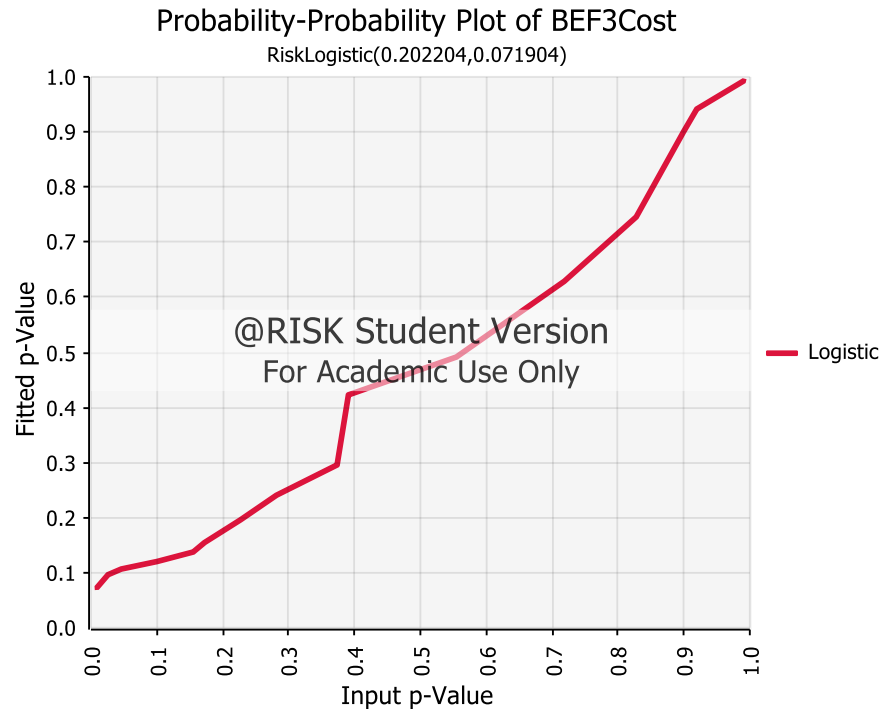


Figure 11-2: Probability-to-Probability plot for BEF3Cost

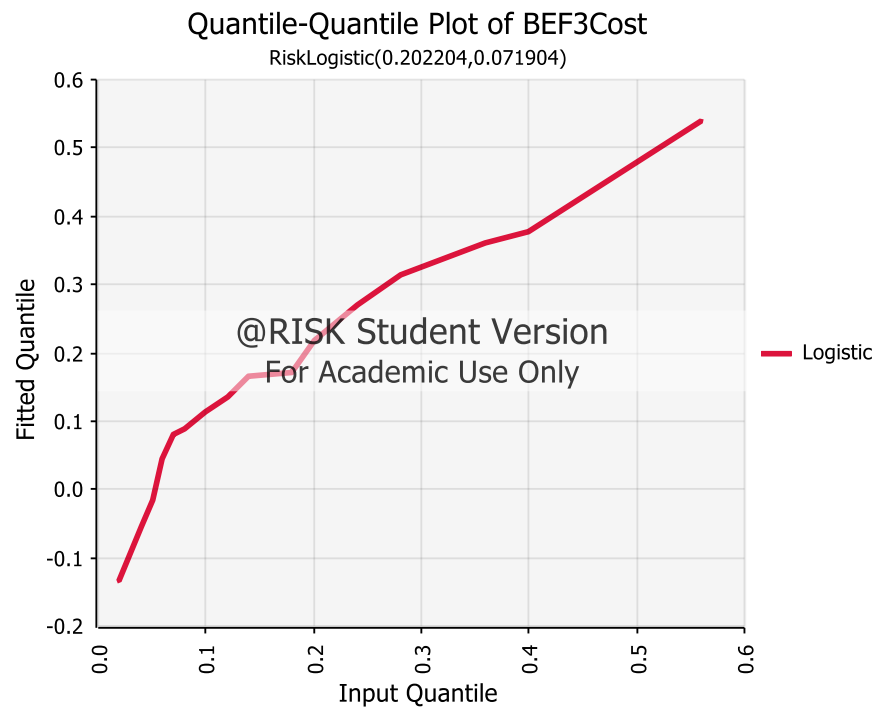


Figure 11-3: Quantile-to-Quantile plot for BEF3Cost

11.2.3.2 BPO13Cost

Figure 11-4 demonstrates the fit comparison for BPO13Cost, while Figure 11-5 and Figure 11-6, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Extreme value (ExtValue) distribution best fits the data. This distribution is widely employed to determine tail risk in the finance of a project. For the Extreme Value of BPO13Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1161	0.0000

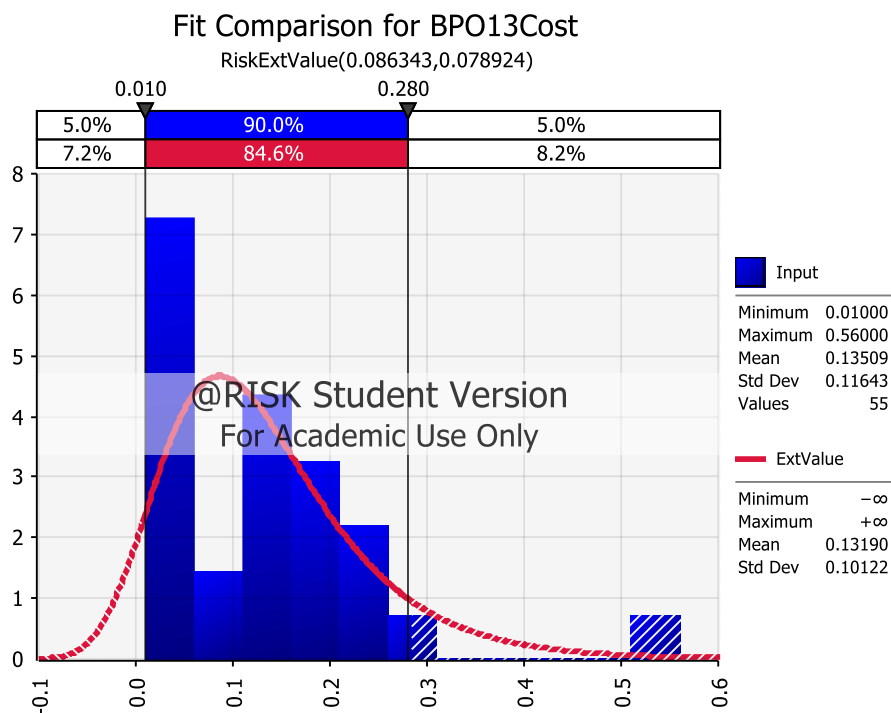


Figure 11-4: Fit comparison for BPO13Cost

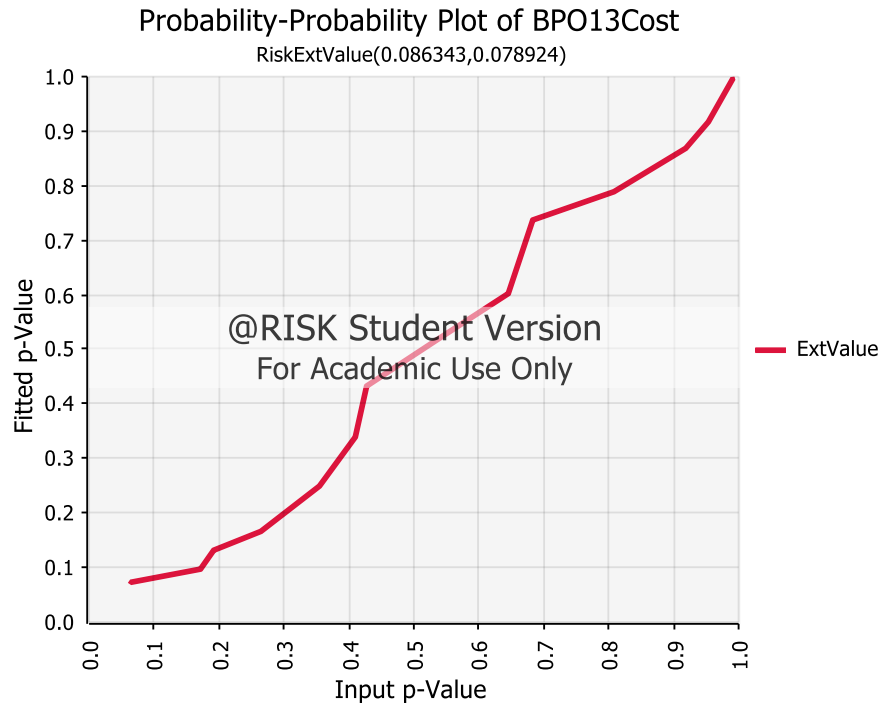


Figure 11-5: Probability-to-Probability plot for BPO13Cost

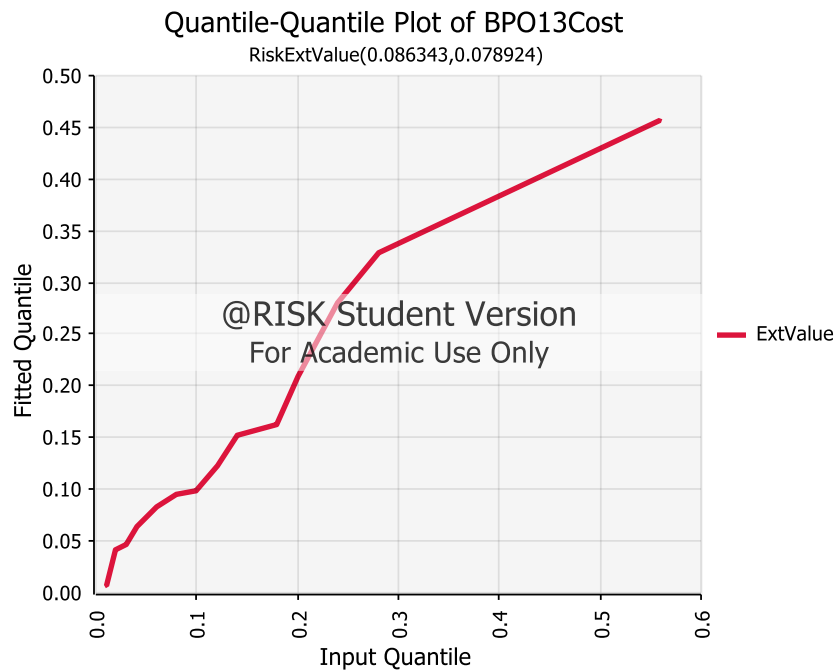


Figure 11-6: Quantile-to-Quantile plot for BPO13Cost

11.2.3.3 BPO14Cost

Figure 11-7 demonstrates the fit comparison for BPO14Cost, while Figure 11-8 and Figure 11-9, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Log logistic distribution best fits the data. This distribution is widely employed in survival assessment of events whose rate increases initially and decreases later. For the Log logistic distribution of BPO14Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1723	0.0000

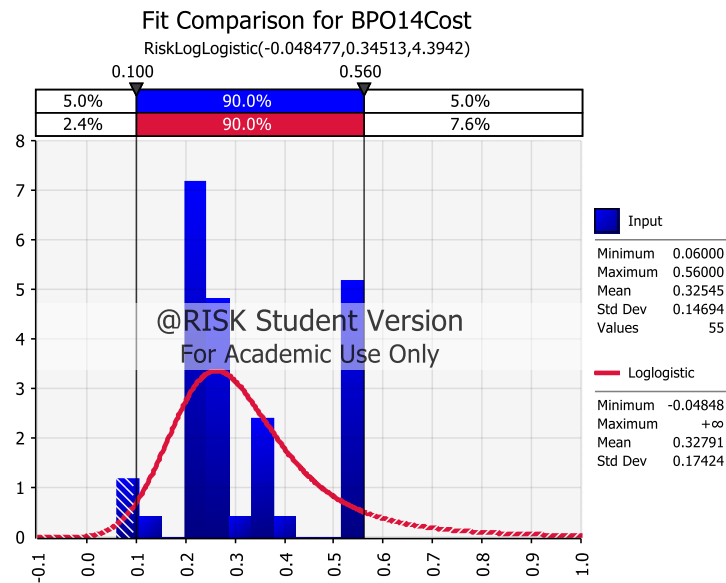


Figure 11-7: Fit comparison for BPO14Cost

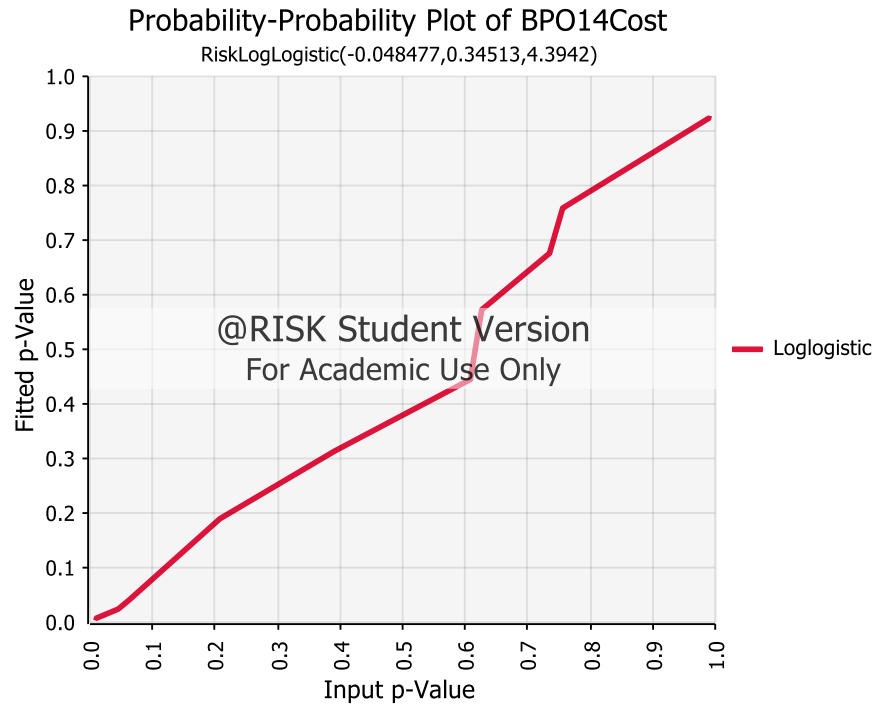


Figure 11-8: Probability-to-Probability plot for BPO14Cost

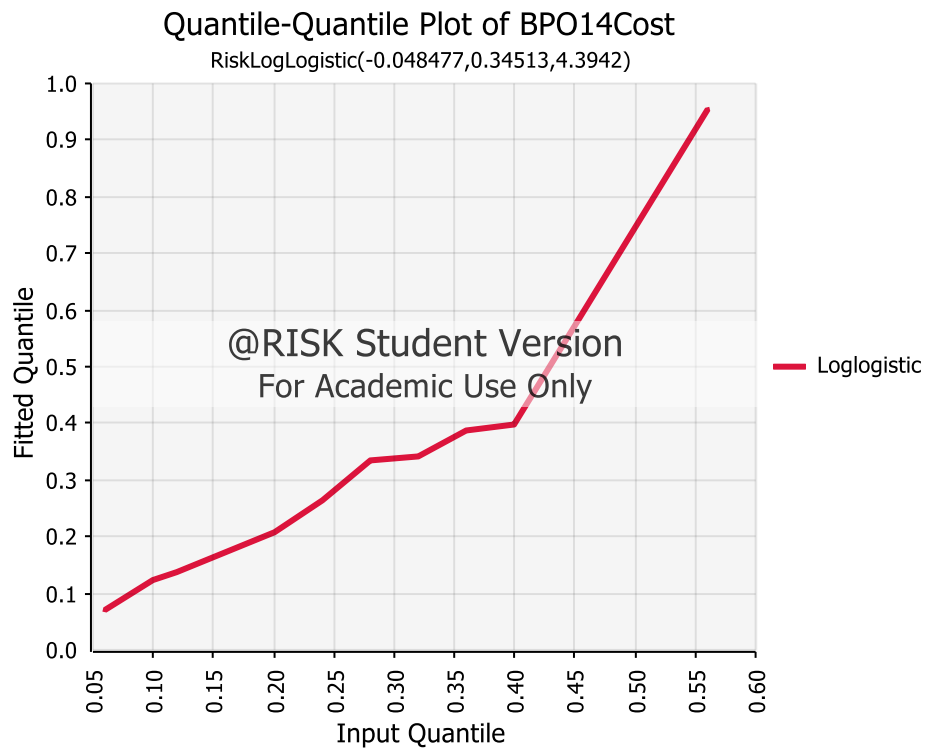


Figure 11-9: Quantile-to-Quantile plot for BPO14Cost

11.2.3.4 BPO10Cost

Figure 11-10 demonstrates the fit comparison for BPO10Cost, while Figure 11-11 and Figure 11-12, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Pearson type 5 distribution best fits the data. This distribution is widely employed in modelling time delays when some minimum delays are known with a very high degree of certainty, whereas, the maximum delay is unbounded. For the Pearson type 5 distribution of BPO10Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1077	0.0182

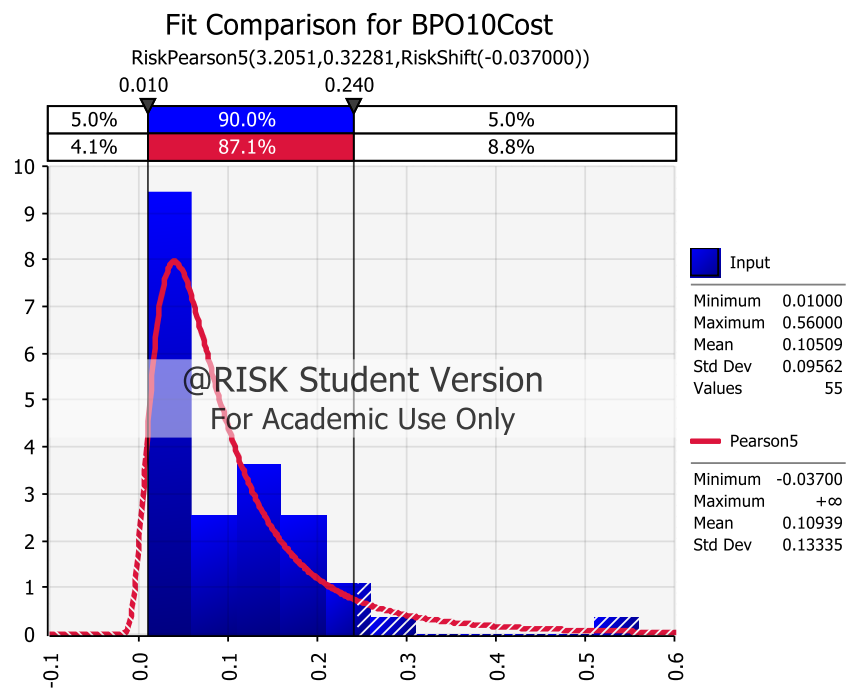


Figure 11-10: Fit comparison for BPO10Cost

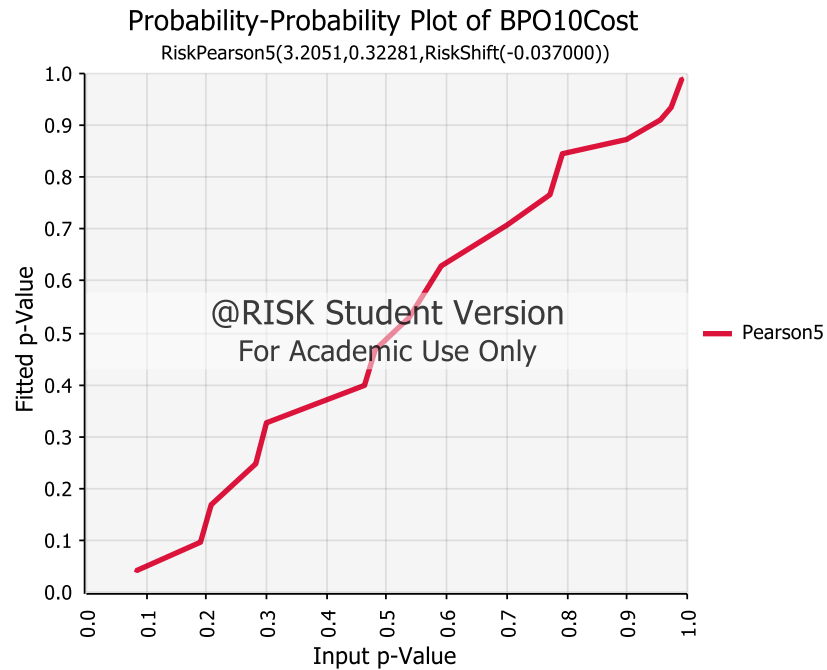


Figure 11-11: Probability-to-probability plot for BPO10Cost

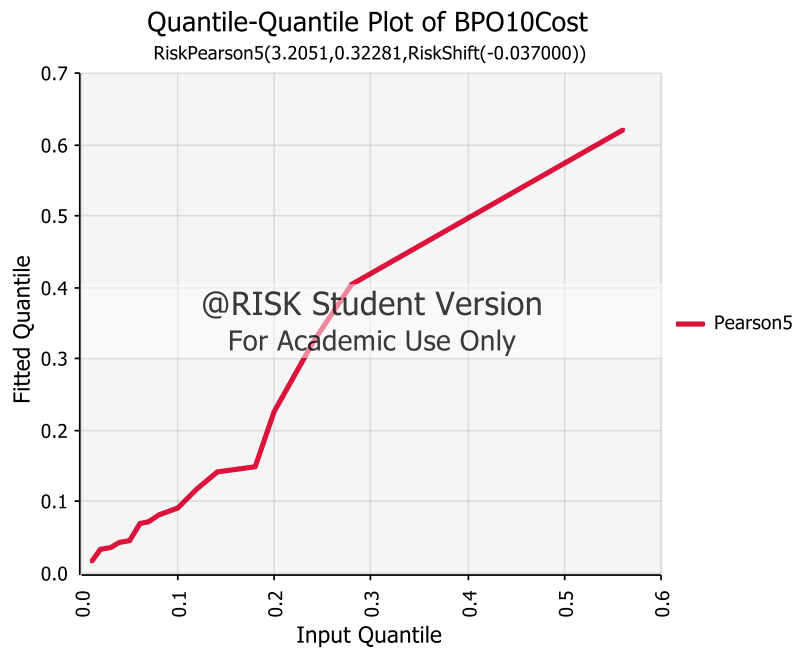


Figure 11-12: Quantile-to-quantile plot for BPO10Cost

11.2.3.5 BCN11Cost

Figure 11-13 demonstrates the fit comparison for BCN11Cost, while Figure 11-14 and Figure 11-15, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Log logistic distribution best fits the data. This distribution is widely employed in survival assessment of events whose rate increases initially and decreases later. For the Log logistic distribution of BCN11Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1921	0.0000

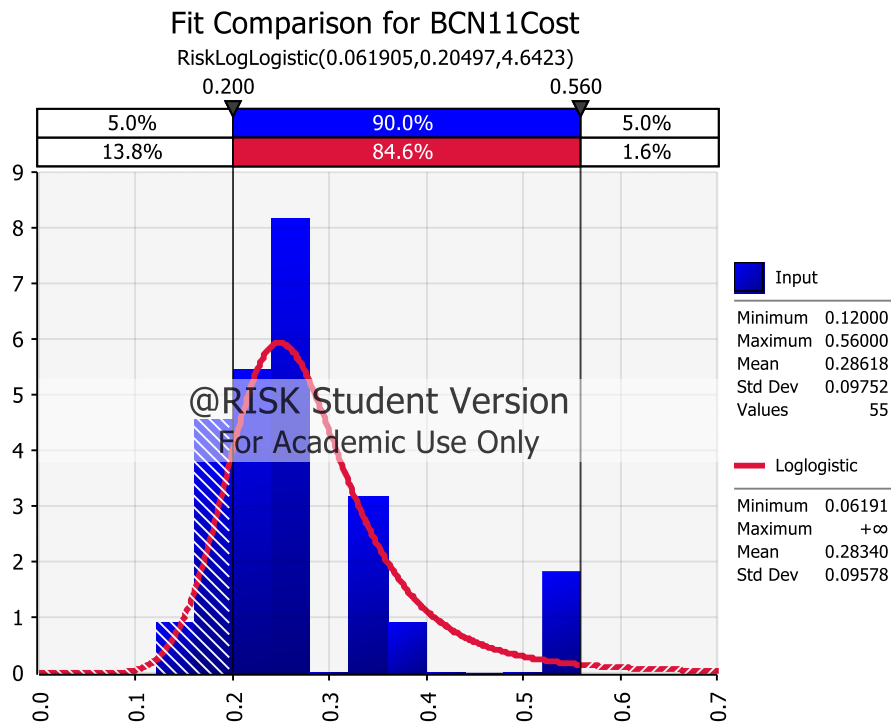


Figure 11-13: Fit comparison for BCN11Cost

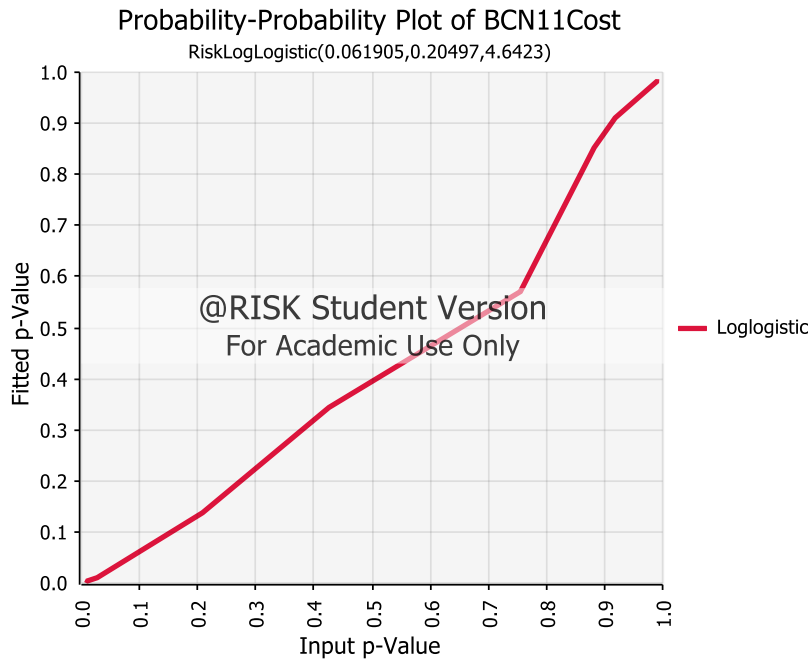


Figure 11-14: Probability-to-Probability plot for BCN11Cost

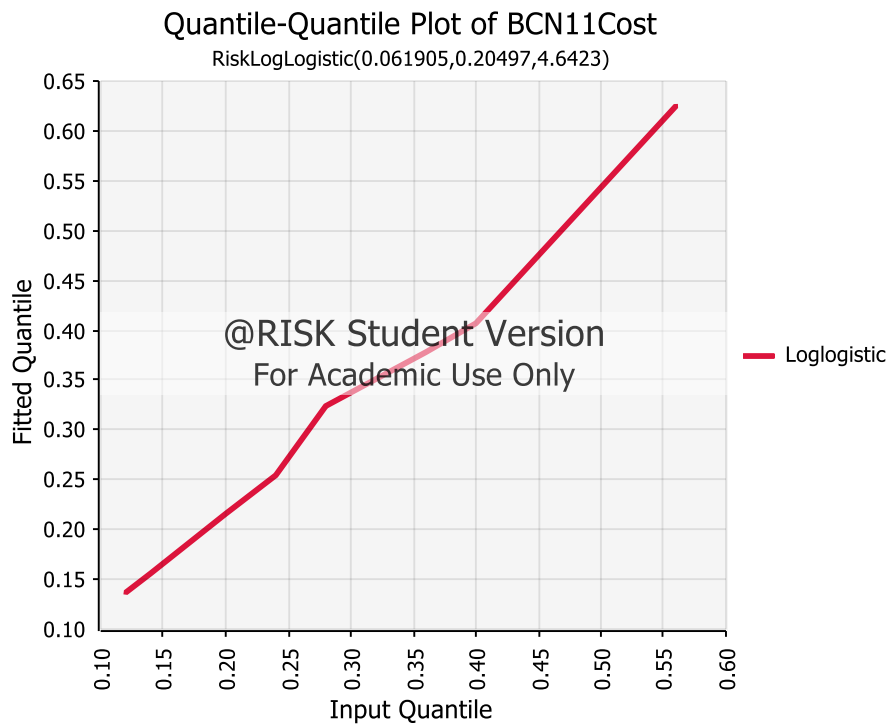


Figure 11-15: Quantile-to-Quantile plot for BCN11Cost

11.2.3.6 BCN9Cost

Figure 11-16 demonstrates the fit comparison for BCN9Cost, while Figure 11-17 and Figure 11-18, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Log logistic distribution best fits the data. This distribution is widely employed in survival assessment of events whose rate increases initially and decreases later. For the Log logistic distribution of BCN9Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1088	0.0182

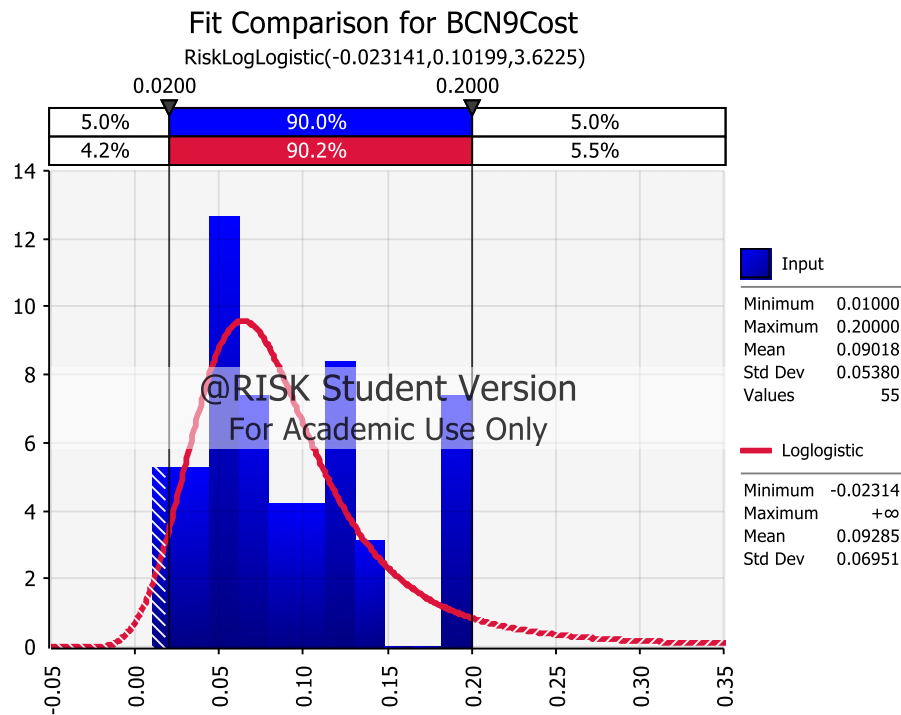


Figure 11-16: Fit comparison for BCN9Cost

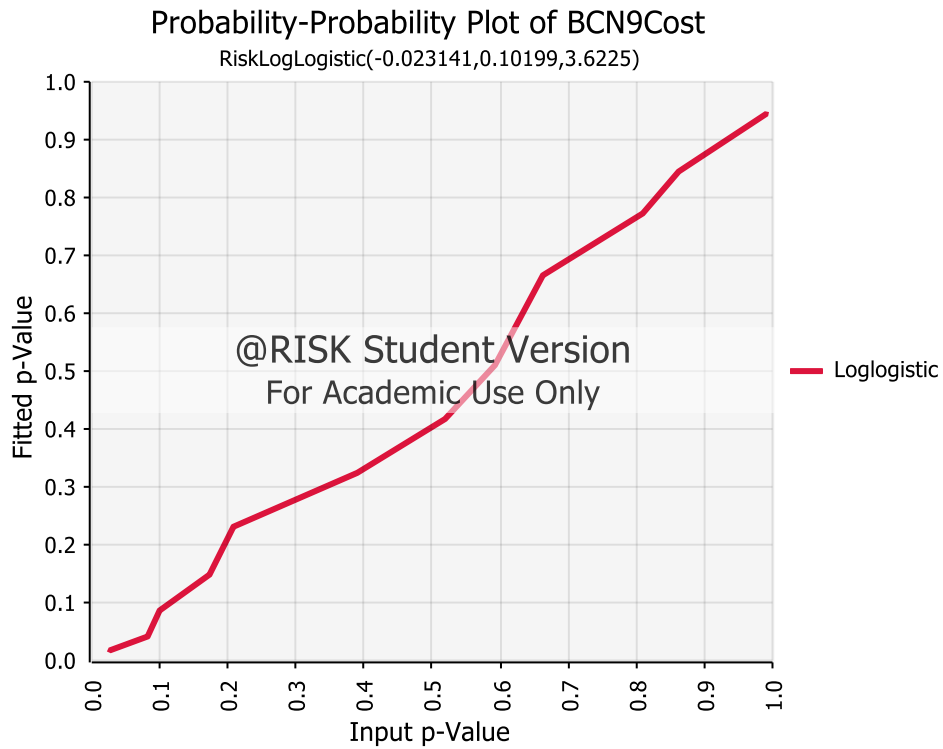


Figure 11-17: Probability-to-Probability plot for BCN9Cost

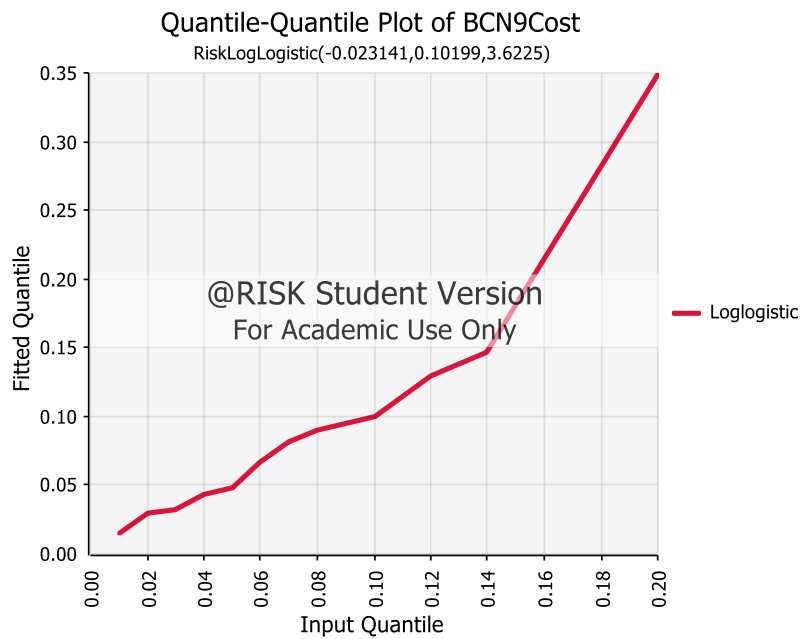


Figure 11-18: Quantile-to-Quantile plot for BCN9Cost

11.2.3.7 BCN7Cost

Figure 11-19 demonstrates the fit comparison for BCN7Cost, while Figure 11-20 and Figure 11-21, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Weibull distribution best fits the data. This distribution is widely employed in reliability assessment of engineering projects to determine project failure rates. For the Weibull distribution of BCN7Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1016	0.0364

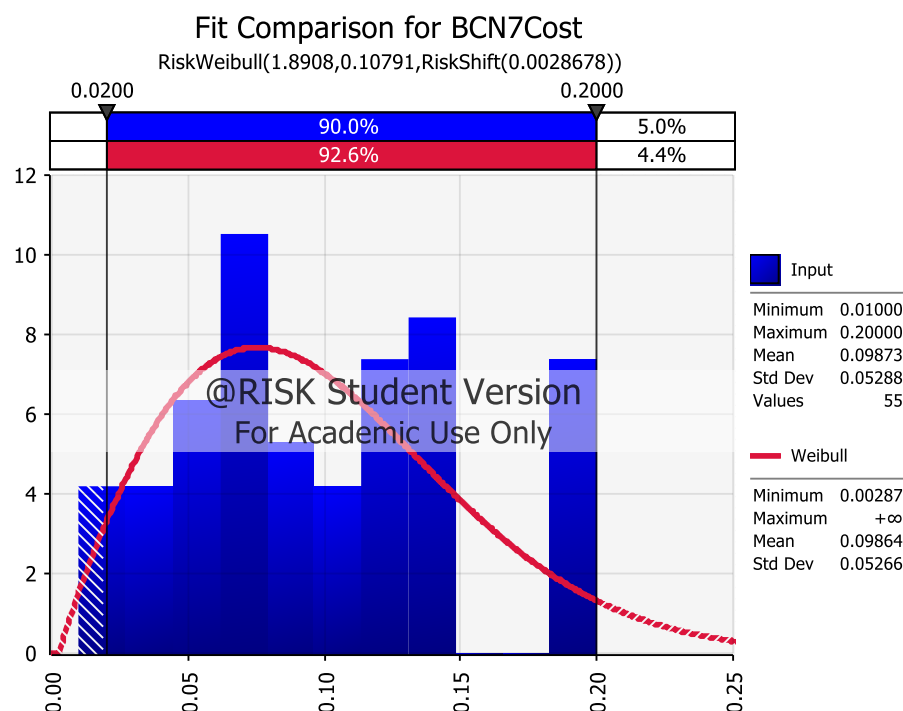


Figure 11-19: Fit comparison for BCN7Cost

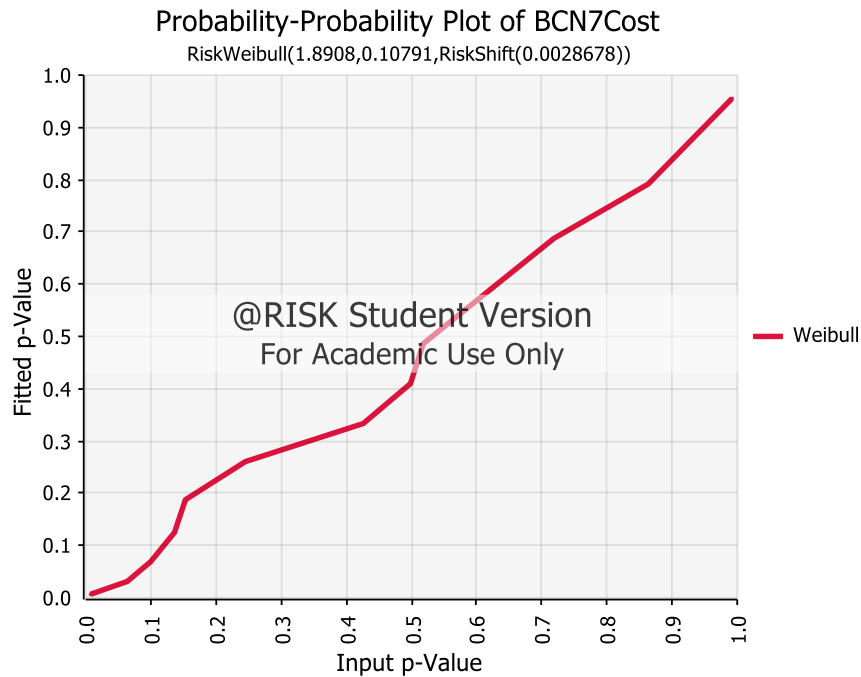


Figure 11-20: Probability-to-Probability plot for BCN7Cost

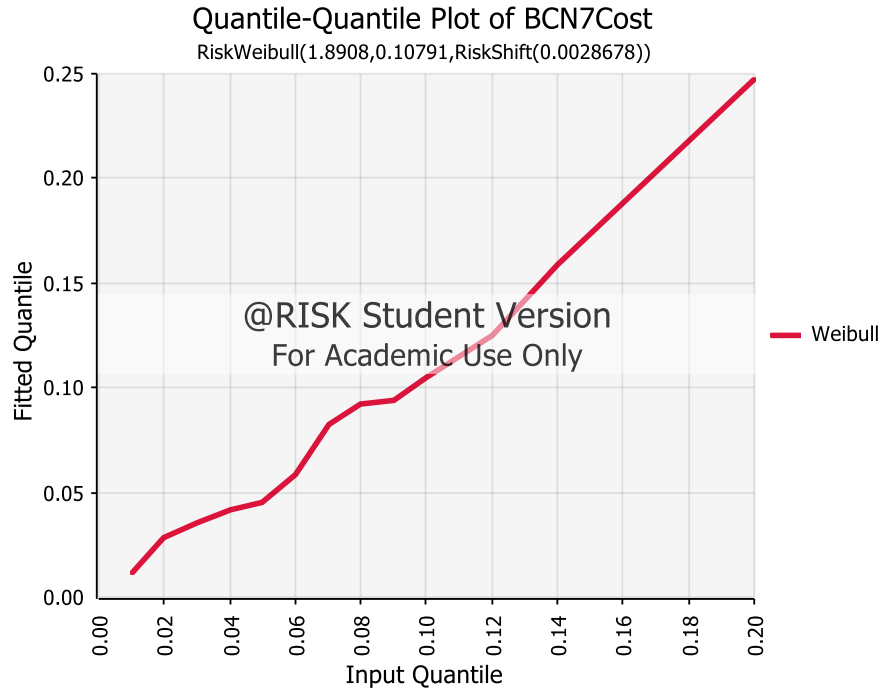


Figure 11-21: Quantile-to-Quantile plot for BCN7Cost

11.2.3.8 BCN1Cost

Figure 11-22 demonstrates the fit comparison for BCN1Cost, while Figure 11-23 and Figure 11-24, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analysed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Log logistic distribution best fits the data. This distribution is widely employed in survival assessment of events whose rate increases initially and decreases later. For the Log logistic distribution of BCN1Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1612	0.0000

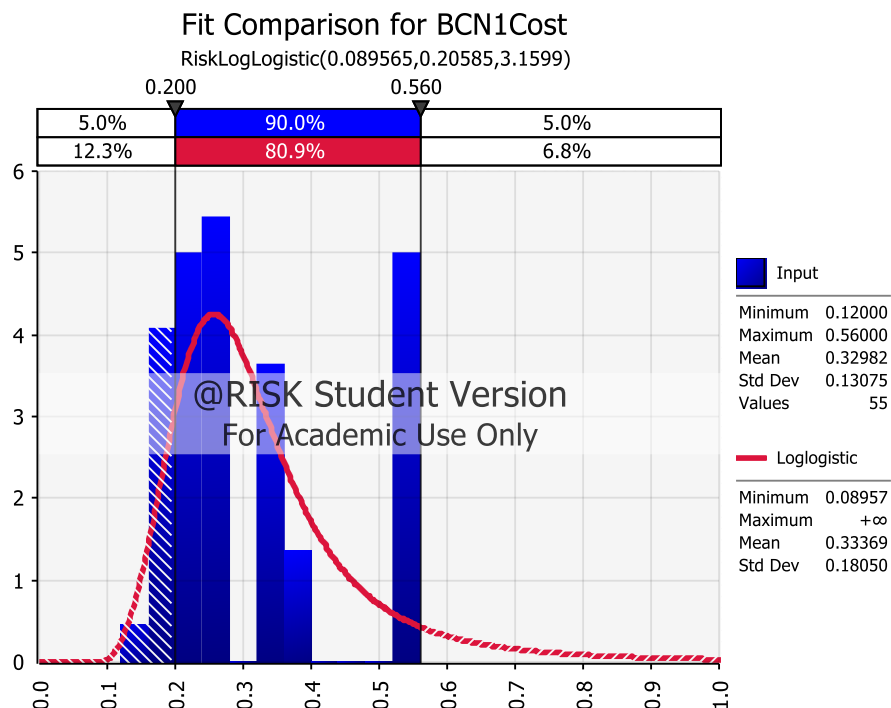


Figure 11-22: Fit comparison for BCN1Cost

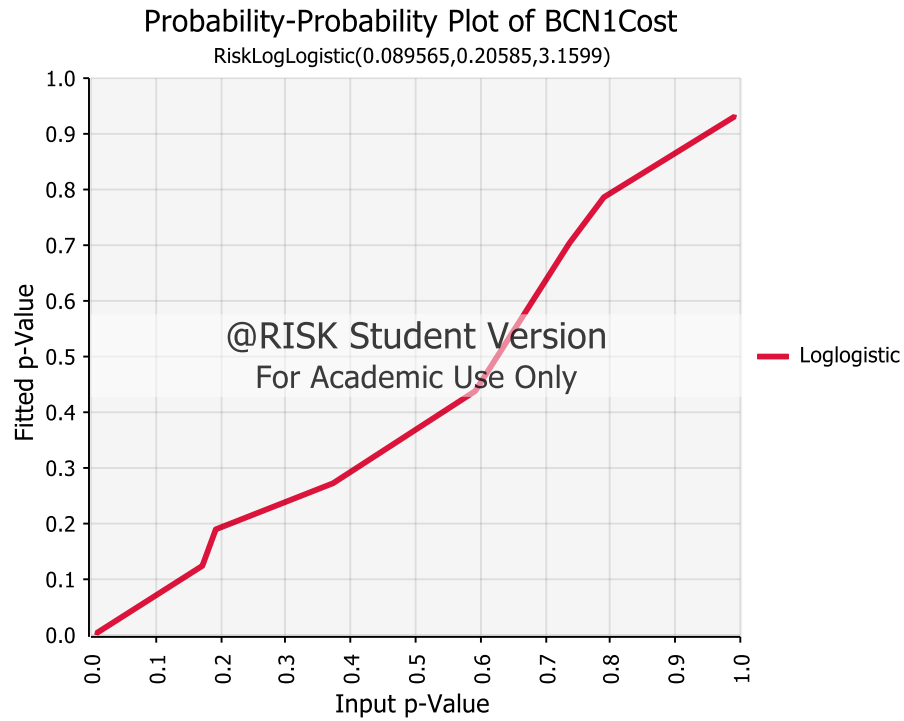


Figure 11-23: Probability-to-probability plot for BCN1Cost

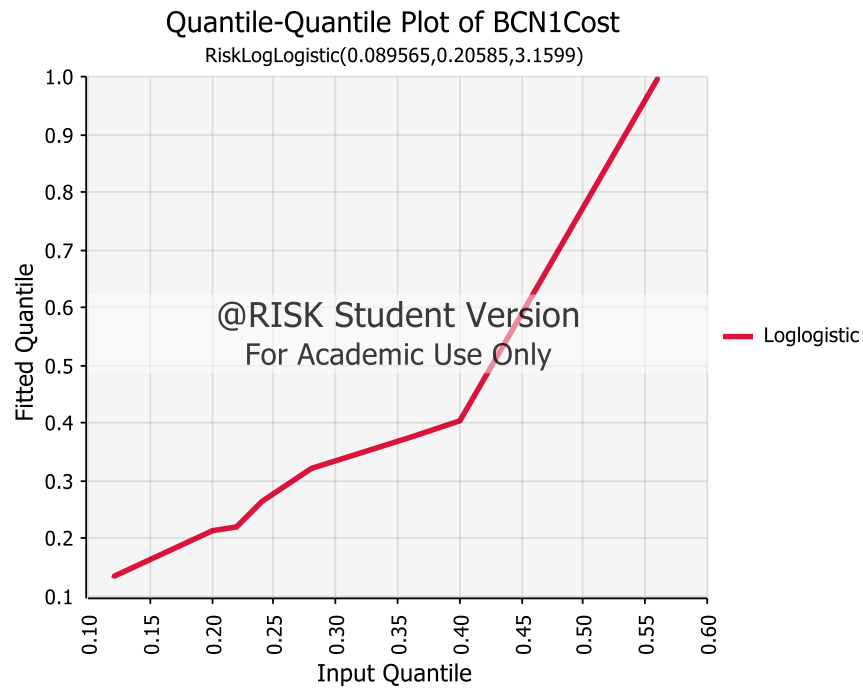


Figure 11-24: Quantile-to-quantile plot for BCN1Cost

11.2.3.9 BCT11Cost

Figure 11-25 demonstrates the fit comparison for BCT11Cost, while Figure 11-26 and Figure 11-27, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Log logistic distribution best fits the data. This distribution is widely employed in survival assessment of events whose rate increases initially and decreases later. For the Log logistic distribution of BCT11Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1950	0.0000

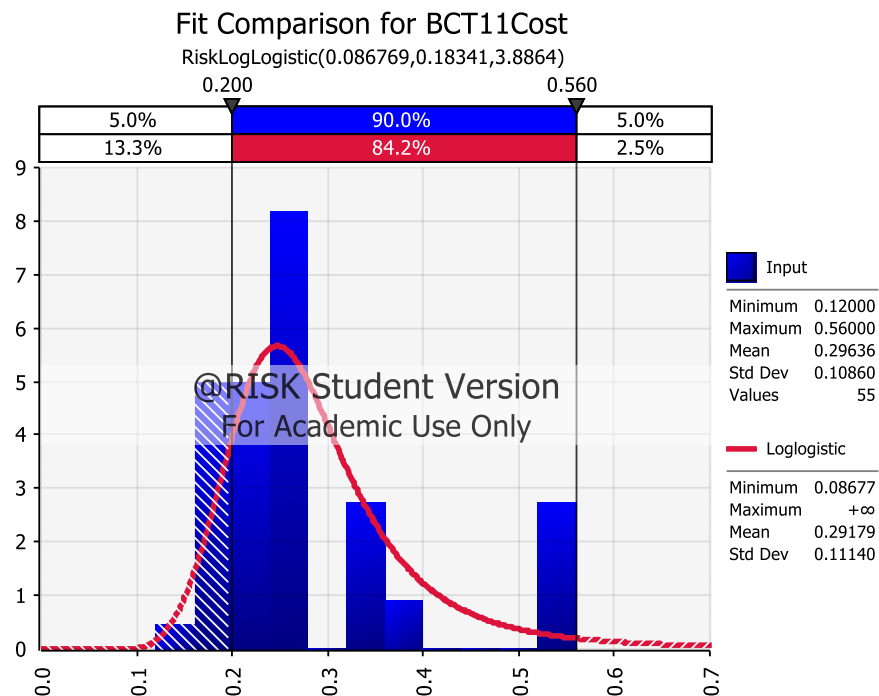


Figure 11-25: Fit comparison for BCT11Cost

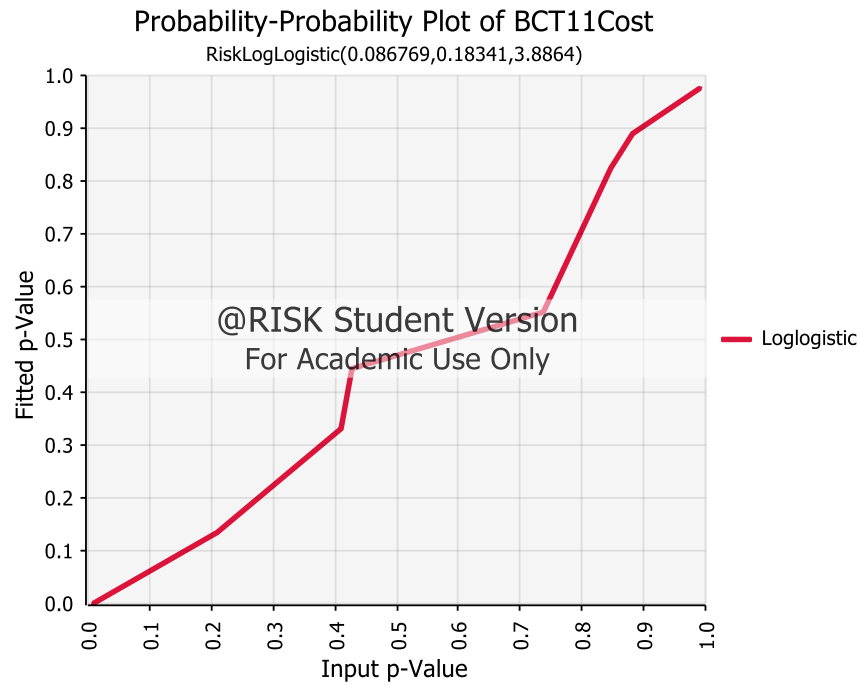


Figure 11-26: Probability-to-probability plot for BCT11Cost

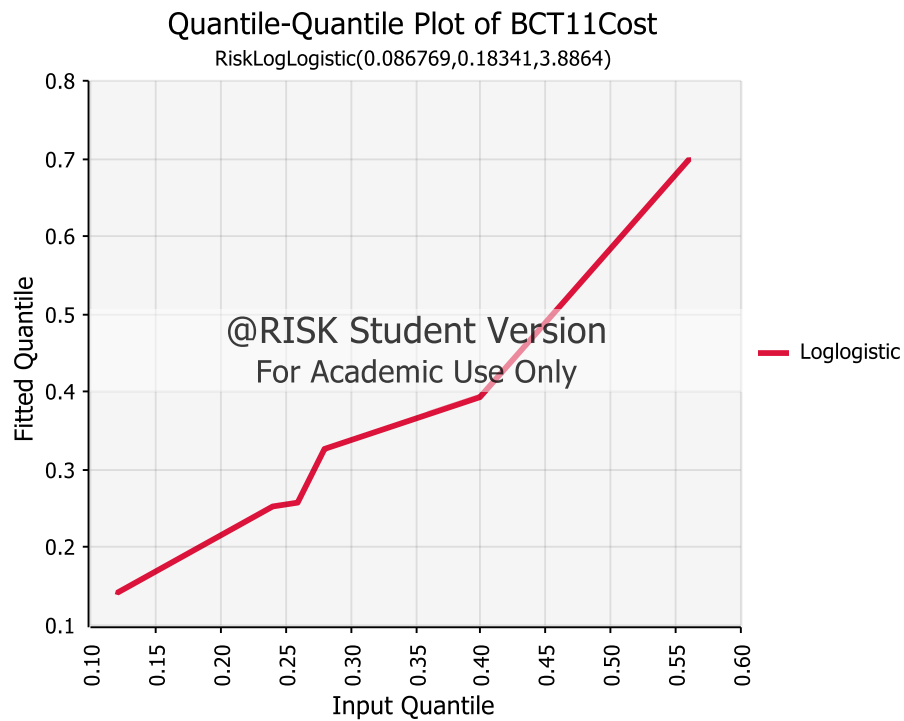


Figure 11-27: Quantile-to-quantile plot for BCT11Cost

11.2.3.10 BCT7Cost

Figure 11-28 demonstrates the fit comparison for BCT7Cost, while Figure 11-29 and Figure 11-30, shows its probability-to-probability plot and quantile-to-quantile plot, respectively. The data sample for this variable was analyzed using probabilistic modelling software and using Kolmogorov-Smirnov goodness-of-fit test, it was found that from the available continuous distributions, Log logistic distribution best fits the data. This distribution is widely employed in survival assessment of events whose rate increases initially and decreases later. For the Log logistic distribution of BCT7Cost, the goodness-of-fit test parameters are:

Test	Fit value	P-value
K-S	0.1259	0.0000

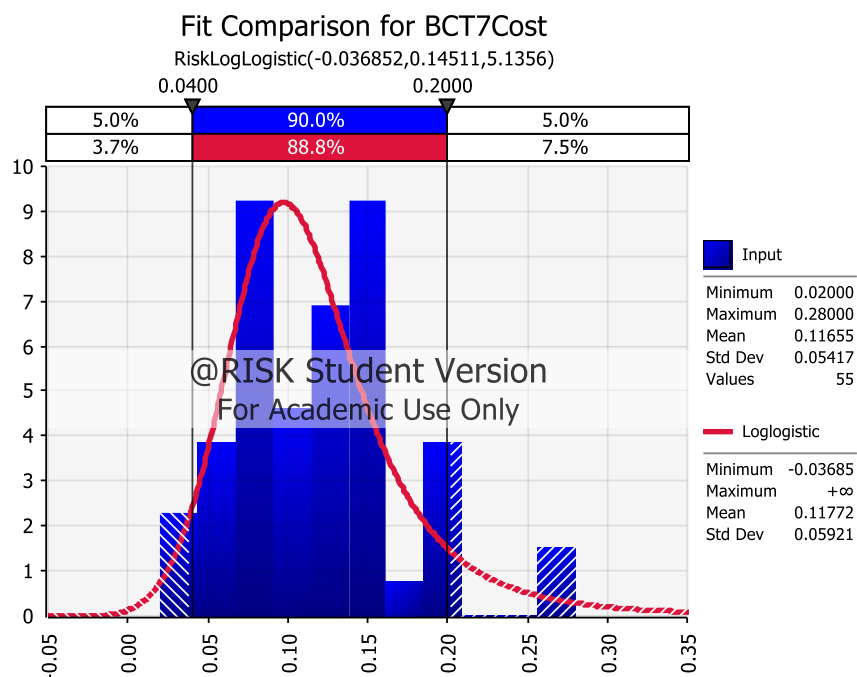


Figure 11-28: Fit comparison for BCT7Cost

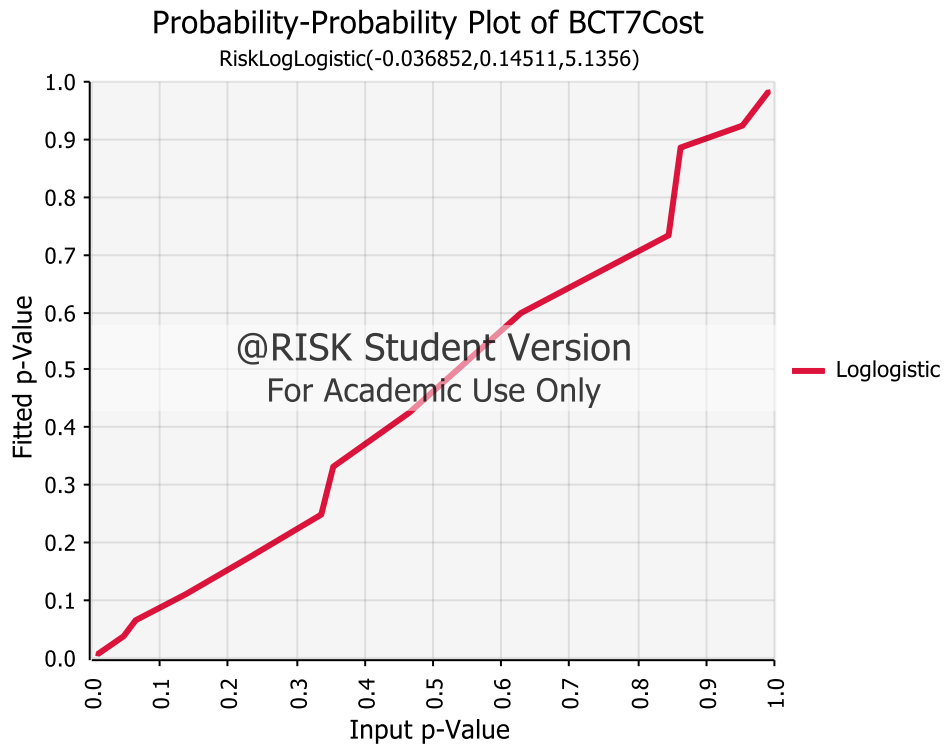


Figure 11-29: Probability-to-Probability plot for BCT7Cost

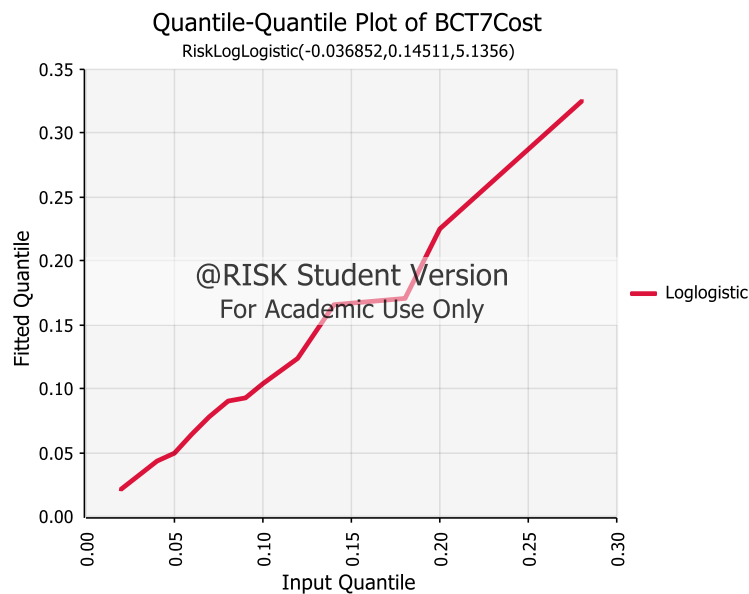


Figure 11-30: Quantile-to-Quantile plot for BCT7Cost