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<https://doi.org/10.15760/etd.7473>

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A Scoring Model to Evaluate Offshore Oil Projects: Case of Eni and Mellitah Oil & Gas

by

Abdulahkim Giadedi

A dissertation submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy
in
Technology Management

Dissertation Committee:
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Portland State University
2020

ABSTRACT

Offshore oil projects have many different and unique characteristics, such as larger project size, higher number of scopes, and higher complexity. In fact, offshore oil projects described as mega projects are ones that require significant assessment and acquisition methods in order to reduce risks and failures. Traditionally, cash flow analysis and return on investment are the most known factors to evaluate offshore oil projects. However, there are several other internal and external factors that affect the overall performance of offshore oil projects. A comprehensive approach and advanced tools are required to evaluate these factors that can have a significant impact before any investment decisions are made.

This study emphasizes some critical and challenging factors that affect the successful implementation of offshore oil projects and scores these factors to highlight their weight of impact on offshore oil projects using a hierarchical decision model (HDM). A comprehensive literature review was conducted to recognize the complexities of these factors. Four perspectives were identified in order to assess the attributes that are necessary for successful offshore projects. These perspectives are economical, technical, political, and safety and environmental. Under each perspective, there are multiple criteria that are linked to each other with complex processes and unique challenges. A hierarchical decision model, along with desirability curves, was implemented to evaluate offshore oil projects in order to improve investment decisions and reduce failure.

DEDICATION

I dedicate my dissertation work to my family for their endless love, support and encouragement.

To my beloved parents, Abdussalam and Sabria

To my lovely wife, Rowida Milad

To my kids, Abdulssalam, Aisha and Atika

ACKNOWLEDGMENTS

I would like to thank the following people, without whom I would not have been able to complete this research, and without whom I would not have made it through my doctoral degree!

First of all, I would like to express my sincere gratitude to my adviser and committee chair Dr. Tugrul U. Daim for the continuous support of my Ph.D study and research, for his patience, motivation, enthusiasm, and immense knowledge. Without his guidance and persistent help this research would not be possible.

I would also like to express my deepest appreciation to my committee members, Dr. Ramin Neshati, Dr. Richard Sperry, and Dr. Birol Yesilada, for their encouragement and insightful comments. I am grateful for all the time, effort and advice they have offered me during this research.

This research would not have been achievable without the active participation, input, and feedback from dozens of subject matter experts, who took time from their busy schedules to understand the research and to help in the validation, quantification, and application of the research model. My sincere thanks also goes to all of them.

Last but not the least, I would also like to acknowledge the support and dedication of Mohamed Swesi, Kosha Amin and Shalah Ghumiem as well as all of ETM department faculty members, staff, and friends who have been a great source of support.

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LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
ANP	Analytical Network Process
BWM	Best Worst Method
CO	Carbon Monoxide
DEMATEL	Decision Making Trial and Evaluation Laboratory
DTA	Decision Trees Analysis
DCF	Discounted Cash Flow
EEZs	Exclusive Economic Zones
ELECTRE	Elimination and Choice Expressing Reality
FPSO	Floating Production, Storage, and Offloaders
HAC	Hierarchical Agglomerative Clustering
HSE	Health, Safety and Environmental
HDM	Hierarchical Decision Model
ICC	Intraclass Correlation Coefficient
IEA	International Energy Agency
mb/d	Million Barrels Per Day
MCDM	Criteria Decision-Making
NPV	Net Present Value
NO _x	Nitrogen Oxides
O&G	Oil and Gas
OOGPs	Offshore Oil and Gas Platforms
PAHs	Polycyclic Aromatic Hydrocarbons
RSV	Root Sum of the Variance
TLPs	Tension-Leg Platform
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UNCLOS	United Nation Convention on the Law of the Sea
VOC	Volatile Organic Compounds
HSE	Health Safety Environmental

CHAPTER 1: INTRODUCTION

With the global energy demand rising every single day, offshore oil production remains a key source of energy for meeting the worldwide energy demand. A recent report by the National Petroleum Council in the United States indicates that this sector has seen great levels of growth in the late 20th century to today, with offshore oil growing from 1% of total production in 1954 to up to 25% in 2008, and offshore natural gas observing a more steady growth, with a less dramatic rise from 1% to 11% in the same time frame [1][2]. In these days, offshore hydrocarbon projects have produced about 30% of the world's oil production and 27% of the world gas production since 2000 [3][4]. There are now over 7000 oil and gas installations and platforms on continental shelves in over 53 countries around the world [5][6]. Among the 30% of the world's oil production that is coming from developing offshore fields, there is around 9% that is coming from deep-water reserves projects contributions [7][8][9].

Compared to capital projects in other industries, offshore oil projects have many different and unique characteristics that can be challenging, such as a larger project size, higher number of scopes, and higher complexity. In general, offshore oil projects tend to be significant in terms of their capital size. So called “multibillion dollar offshore oil megaprojects” are common in industry today. Typical offshore projects also usually have a larger number of individual sub-scopes. These individual project sub-scopes are also quite large themselves with costs in the hundreds of millions of dollars. As such, these individual project sub-scopes are usually implemented or managed by multiple

contractors. To develop offshore oil projects, a large project team is formed that comprises various functional groups. Furthermore, regulatory requirements and the political climate can significantly influence the performance of oil projects [4]. Because most new hydrocarbon reservoirs are discovered in ultra-deep remote waters, companies are faced with unprecedented physical, environmental, technical and project management challenges. Moreover, companies lose billions of dollars in revenues each year due to oil spills resulting from tanker leaks, drilling well blowouts and oil spills [10]. All of these factors combined affect offshore oil projects and lead to higher project complexity. However, as long as oil remains the lifeblood of the economy, investment in offshore exploration and production will continue, but better evaluation methods are needed to overcome all of these challenges and improve the offshore hydrocarbon projects performance.

1.1 Problem Statement

Offshore oil projects are very large in size and complexity, and they require financial investments, hence they are often referred to as multibillion-dollar offshore oil megaprojects. The nature and size of megaprojects mean that participating companies must commit enormous amounts of resources and take on significant risk. Therefore, missing targets in one or more of these multibillion-dollar projects can have major implications for any company's financial performance, either through increased demand on capital (potentially leading to lost opportunities and increased cost of borrowing) or loss of revenue through missed production dates [11]. It has been observed that global

offshore projects have not performed well. More than 60% of the projects have experienced a cost overrun of 33% or more, schedule delays of 30% or longer, and lower than expected hydrocarbon production [12][4]. Traditionally, cash flow analysis and return on investment are the most known methods to evaluate offshore oil projects. However, there are several other internal and external factors that affect the overall performance of offshore oil projects. Evaluation and selection of the right project in the offshore oil sector is characterized by a high volatile price setting market, increasing pressure to minimize cost structures, political concerns, and safety and environmental risks. The combinations of these characteristics provide a motivation for development of new tools to allocate capital and improve the quality of overall decision making in the exploration and production decisions. A comprehensive approach and advanced tools are required to evaluate these factors that can have a significant impact before any investment decisions are made.

CHAPTER 2: LITERATURE REVIEW

The focus of this chapter is to understand the numerous complex characteristics of offshore oil projects. The literature review started with an overview of the oil and gas industry and then navigated to highlighting the classification of oil projects. Next, offshore oil project's performance was discussed along with the root causes of project failures. Finally, this chapter introduced the methodology of offshore oil portfolio management and project selection.

2.1 Oil and Gas Industry

Average annual global oil & gas (O&G) projected capital investment is about US\$1 trillion per year between 2011 and 2035 [13][14]. Based on the CIA World Factbook, the top 20 nations' oil productions are listed in the figure below. Based on this information, Saudi Arabia produces the most at 11.6% of the world's oil production. Moreover, United States consumes the most at 19,650,000.00 bbl per day, a full 25% of the world's oil consumption [15].

Figure 1: Oil production & Consumption % of Global 20 Nations Production

The oil and gas industry is witnessing an unprecedented wave of capital spending, driven by the need to build capacity to meet growing energy demand from emerging markets and to replace depleting supply sources. This capital expenditure has, to date, been underpinned by consistently higher oil prices, globally and gas prices outside North America. This trend is expected to continue. In its World Energy Investment Outlook 2014, the International Energy Agency (IEA) estimates a cumulative investment of US\$22.4t in the global oil and gas sector between 2014 and 2035 [16]. Average annual global investment in oil project capital is about US\$1 trillion per year (IEA, 2011). However, the performances of the oil projects did not get any attention until the recent oil price crashes [14]. The figure below shows the oil investment and spending that will be dominated by North America around 5.8 US \$ trillion between 2014 and 2035 [16].

Figure 2: Regional Cumulative Oil Investment Between 2014 and 2035 (US\$)

However, the total oil capital investment is mainly affected by many factors such as the global price of the oil and its operational cost. Based on data that was collected from more than 15,000 oil fields across 20 countries, Kuwait had the lowest production costs per barrel of oil, at a total cost of 8.5 U.S. dollars per barrel of oil followed by Saudi Arabia of 9.9 dollars total cost per barrel of oil. The production costs were calculated by including a mix of capital expenditures and operational expenditures [17][18]. Capital expenditures included the costs involved with building oil facilities, pipelines and new wells. Operational expenditures included the costs of lifting oil out of the ground, paying employee salaries and general administrative duties.

Figure 3: Average Cost to Produce One Barrel of Oil in Top Oil Producing Countries in 2015 (U.S dollars per barrel)

The figure below illustrates the top 20 nations by oil reserves. Saudi Arabia has almost 25% oil reserves of the world followed by Iraq more than 10%. The total

estimated amount of oil in an oil reservoir, including both producible and non-producible oil, is called oil in place. However, because of reservoir characteristics and limitations in petroleum extraction technologies, only a fraction of this oil can be brought to the surface, and it is only this producible fraction that is considered to be reserves [15].

Figure 4: Top 20 Nations By Oil Reserves (% of global)

2.2 Offshore Oil Projects

Offshore fields are considered as an important source of oil reserves. There are over 7270 offshore oil installations and platforms distributed in more than fifty-three countries [19]. Offshore oil resources also serve as a major source for meeting the global energy demand. According to Maribus (2014), offshore projects have produced about 30 percent of the world's oil production and 27 percent of world gas production since the start of the new millennium [20]. According to the International Energy Administration (IEA), global offshore oil and gas fields would account for about a third of the anticipated one

hundred and twenty million barrels per day consumption rate by 2030 [13][21]. Offshore oil and gas sector is unarguable one of the world's most viable sectors since revenue from its investment have prospects of generating huge revenue annually [21]. In 2016 the contribution of offshore oil production to global oil and gas sector was around 26-27 million barrels per day (mb/d) and offshore gas production has grown by almost 30% to more than 1 000 billion cubic (bcm) per year over the same period. Figures 5 and 6 illustrate the global offshore oil and gas production over the period 2000 -2016. Offshore oil production are in many parts of the world, with the top producing areas being the Middle East, the North Sea, Brazil, the Gulf of Mexico and the Caspian Sea [22].

Figure 5: Global Offshore Oil Production By Water Depth (Million barrel per day)

Figure 6: Global Offshore Gas Production By Water Depth (bcm)

Although the record of discoveries over the last ten years has been impressive, offshore exploration activity has fallen sharply since 2014. The number of exploration and appraisal wells drilled globally (both onshore and offshore) peaked in 2008 at more than 2000 wells by 2014, this was down by some 20% (with most of the decline exhibited onshore). With the fall in prices since 2014, activity levels have plummeted across the board; there were only around 700 exploration and appraisal wells drilled globally in 2016. The count of active offshore rigs declined from an average of 320 in 2013 and 2014 to around 220 at the end of 2016 [22].

Figure 7: Annual Average Offshore Oil Investment By Water Depth and Scenario

2.3 Offshore Oil Projects Performance

Offshore oil projects tend to have a large number of project sub-scopes and sub-scope components. A general hierarchical structure for an offshore oil project is shown in figure 8. This hierarchical structure is based on a typical offshore oil project scope based on an industry standard. The first level typically contains well, subsea system, fixed or floating platform, and pipeline system. First level mainly called the project level and under each system of the first level there are sub-scope and sub-scope components on the second and third levels. Offshore oil projects often involve various sub-scopes and sub-scope components. A typical oil project includes well, subsea system, fixed or floating platform, and pipeline scopes. In addition, they often involve major types of floating platforms, including tension-leg platform (TLPs); spars and semi-submersibles; floating storage and offloading systems (FPSs); and floating production, storage, and offloaders (FPSO). Each sub-scope of an offshore oil project is also very large in terms of its size

and often costs hundreds of millions or even billions of dollars to build. Furthermore, sub-scopes have their own key components. For example, a platform has two major parts: the topsides and substructure [23].

Figure 8: Hierarchical Structure Offshore Oil Projects

Though, historical records on the performances of global offshore oil and gas oil projects show that most did not meet industry expectations [23]. The majority of these projects are facing cost overruns and schedule delay. Based on a 2014 report generated by EY's Global Oil & Gas Center, the majority of oil projects are facing schedule delays and/or cost escalations and these overruns are prevalent in all of the segments and geographies. 64% oil and gas projects are facing cost overruns and 73% of the projects are reporting schedule delays [16]. Figure 9 shows the global distribution of the offshore

oil performance. As the data showed, the Middle East has the worst project performance in term of cost and schedule among other regions. 89% of the projects in Middle East had cost overruns and 87% of them faced schedule delay. Even though North America had the best oil projects' performance compared to other places, 58% of its proportion projects faced cost overruns and 55% of them faced schedule delay. In the aftermath of the oil price fall in 2014, proposed new deep-water projects were generally among the first to be delayed or cancelled as the industry moved towards shorter cycle investments [22].

Figure 9: Global Distribution of the Offshore Oil Performance

2.4 Root Causes of Offshore oil Project Failures

Industry performance data suggests that the factors that result in budget overruns or schedule delays are common across oil and gas projects; however, due to their scale, complexity and cost, the impact is more profound on megaprojects. Industry research suggests that non-technical issues are responsible for the majority of the overruns. According to data provided in Offshore Technology Conference 2013, 65% of project failures were due to softer aspects such as people, organization and governance. 21% were caused by management processes and contracting and procurement strategies, with the remaining 14% of the failures due to external factors such as government intervention and environment-related mandates [24][16].

Figure 10: Root Causes of Offshore O&G Project Failures

To elaborate, often there are internal and external factors that can lead offshore O&G projects to fail. Internal factors including portfolio and project commercial context,

project development and project delivery. The figure 11 shows the most common internal factors that affect the offshore O&G projects as well as the key challenges associated with each factor.

Figure 11: Internal Factors Responsible for Offshore Oil Projects Failures

Moreover, the external factors such as regulatory geopolitical challenges play a significant role in the offshore O&G project's overall performance. The figure 12 illustrates some of the external factors that affect the offshore O&G projects as well as key challenges associated with each factor.

Figure 12: External Factors Responsible for Offshore Oil Projects Failures

2.5 Offshore Oil Portfolio Management and Project Selection

Selecting the right project that fits within the company's strategy is critical in the oil sector. The life cycle of offshore oil project has different phases where at the end of each project phase a review of its performance evaluation is held [23]. The figure 13 shows the whole project life cycle that includes the six significant phases: assess, select, define, execute, operate, and decommission, although these may have different names across various organizations.

Figure 13: General Project Phases of Offshore Oil Projects

However, selection phase is a process to assess each project idea and select the project with the highest priority. Frequently a lack of clear strategic direction and project selection criteria means that over time, organizations develop overly diverse and poorly aligned project portfolios, which often unnecessarily stretch resources, increase portfolio risk and dilute the potential value of inter-project linkages. It is therefore critical to select and subsequently approve appropriate projects that align to company capability, experience and strategy [16]. Most of the decision-making in the selection phase in oil sector can be resumed as a balance between the costs and profits. Nevertheless, oil industry has a large set of risks, uncertainties and also opportunities, which make the decision-making processes difficult. Today, there are several available methodologies which can be used to support the decision making process in oil and gas industries [25]. In particular, net present value (NPV) calculations, discounted cash-flow analysis, Monte Carlo simulation, portfolio theory, decision-tree analysis and preference theory can be used [25][26][27][28]. However, historical records on the performances of global offshore oil projects show that most of these projects did not meet industry expectations [23].

CHAPTER 3: FACTORS AFFECTING OFFSHORE OIL PROJECTS

Through the literature review, seventeen challenge factors have been highlighted. These factors play an important role in identifying an offshore hydrocarbon project's overall performance. The seventeen factors have been captured under five perspectives including economical, technical, political, environmental, and safety perspectives.

3.1 Economical Perspective

The economic evaluation underlying the investment decision is based on the entity's reasonable forecast of future conditions, including capital cost, operational cost and oil prices, which will exist before and during the life of the project.

3.1.1 Oil Price Behavior

The price of a barrel of oil is one of the most important variables in determining an oil company's capital investment strategy, and oil prices have gone through many major swings since its discovery in the latter half of the nineteenth century [10]. In the history of the oil prices, there are various factors that affect the overall oil price and the industry's performance such as wars, increased production, decrease in demand and the discovery of oil shale. The history of oil price shows that the price movement is hard to predict. The oil price dropped more than 30% in a seven-month time frame in the last three decades for five times (1985– 1986, 1990–1991, 1997–1998, 2001, 2008) [29]. In the period between June 2014 and January 2015 the oil price fell by 60%, which is considered as one of the quickest and largest declines in oil history [29]. Since the

offshore hydrocarbon projects cost billions of dollars, oil price remains the most important factor that affects the overall performance and yields of these projects.

3.1.2 Initial Cost

Oil exploration is an expensive, high-risk operation. Since, offshore projects cost a huge amount of money and deep-water wells can even cost hundreds of millions dollars, only very large corporations or national governments are capable to invest and undertake offshore and remote area exploration [30]. The capital investment for individual O&G projects has increased considerably due to the development of more challenging oil fields. The Gorgon project in Australia, which was one of the largest completed offshore projects, was estimated to cost more than \$57 billion, which was almost more than double the initially estimated cost [4]. The major cost categories include engineering and project management, equipment, bulk materials, fabrication, installation, construction, startup and commissioning costs as well as the estimated cost contingency. Gaining an understanding of each cost category will help to understand the project's overall cost performance. Investments in O&G offshore projects require large monetary investments and tremendous amount of resources; hence a failure in any of its various categories can lead to a disaster. A complete and thorough analysis of all factors must be completed before pursuing a project of this sort to ensure success.

3.1.3 Operational Cost

Traditionally, companies have responded to low oil prices, high costs and weak margins by cancelling or postponing projects, laying off staff and freezing spending.

Once the capital investments have been made, the wells have been drilled, platforms are installed, facilities commissioned and pipelines placed in service, much more remains to be done. It needs to be assured that adequate returns are being generated to match the operating expenses as this is the key to maintain production and stay in business [31]. Operational cost include staff expenditure, subsea, pollution control, water injection, maintenance, insurance, transport charges, miscellaneous etc. Operation costs are primarily comprised of the lease operating expenses, which can be highly variable depending on product mix, water depth, distance from the shore, facility size and configuration [32]. When market conditions change, such as in the case of the 2014/15 downshift in crude oil prices, the challenge for operators and service companies is to realign their cost structures, while making the minimum negative impact on the other components of operational excellence. Success in achieving this is usually the main factor if new resource development can continue or if it should be deferred. The challenge for the upstream sector is to take a more strategic view of cost structures so the necessity for tactical and reactive cost reduction measures as oil prices drop is minimized [33]. In O&G offshore projects operational expenses cost the companies hundreds of millions of dollars. Evaluating these operational costs in early stages and managing them effectively can significantly reduce chances of failure.

3.2 Technical Perspective

Technical implications are one of the other challenging factors that are faced by project managers and decision makers in offshore hydrocarbon projects such as,

operational difficulties, large size & multiple scopes, production and reservoir performance.

3.2.1 Size and Complexity

Offshore oil projects tend to be significant in terms of their capital size. So called “multibillion dollar offshore oil megaprojects” are common in the industry today. Typical offshore projects have a larger number of sub-scopes, such as well, subsea system, production system, transportation system, etc. These individual project sub-scopes are also quite large with costs in the hundreds of millions of dollars. As such, these individual project sub-scopes are usually implemented or managed by multiple contractors [4]. With rising project complexity, pressure to deliver on schedule and within budget simultaneously increase, there is a high chance for things to be missed, done incorrectly or simply not accomplished [10]. Large project size and multiple scopes is one of the more important technical factors that must be assessed and evaluated with the appropriate approach to reduce the risk of the complexity and chance of failure.

3.2.2 Operational Difficulties

Deep-water drilling is one of the high-risk operations in the oil and gas sector due to large uncertainties and extreme operating conditions [34]. Since 1994, 2,500 to 3,700 wells have been drilled each year. The number of deep-water (>400 m) wells has grown over the past 15 years while the number of shallow water (<400 m) wells has fluctuated [35]. In some cases, the operation drilling occurs for extremely deep wells, whose depth is more than 9000 meters which can increase the operation costs and risks [36].

Operational complications force companies to increase their spending on the project that will lead to cost overrun and schedule delays. Offshore petroleum projects face different types of operational difficulties such as, complex working equipment, harsh weather conditions, limited access to safety points, hydrocarbon releases, fire, high degrees of temperature and pressure, fatigue, etc. Therefore, deep-water drilling consists of complex operations in which engineering and commissioning mistakes, along with major work overs, can cost tens of millions of dollars [37][38]. Moreover, The remote geographic locations and complexity of upstream operations in deep water locations has led to great distances for the supply chain partners. This in turn has resulted in large in-transit inventories and inventory carrying costs as the companies need to keep a greater amount of safety stock at the final location [39][40][41]. As a result of the operational difficulty, drilling rigs and oil production platforms in offshore rigging are arguably the most hazardous workstations in the world. An operational difficulty is another significant factor that can cause substantial delays to the overall project and lead to a significant loss of money and investments.

3.2.3 Production Performance

The main objective of offshore oil projects is to extract oil from the subsea underground. If the project fails to produce the planned production, it should be considered a failure because the production volume of the oil and gas is one of the key factors to determine a project's profitability and future [4]. However, production performance is often omitted when evaluating an O&G project's performance. The main

reason is the fact that it usually takes 2-5 years of operations to collect enough production records to generate a production index metric. By that time, the project has been totally completed and the project team dismissed, so there is no one to take responsibility for the low production rate. Based on historical record, on average, an O&G project produces just 75% of the planned production due to various reasons, which means it lost 25% of the revenue due to project production failure [42]. In addition to other factors such as, cost, schedule, and safety, actual O&G production performance is also a measure of project success. The O&G reserve is the total amount of O&G that can be technically and economically produced from subsurface through project development. The high average reserve per well implies that fewer wells will be drilled to produce the given amount of reserves, which will lead to greater well production and higher project profitability [4]. Even though the O&G companies use advanced technology in drilling operation, there is still no clear way to evaluate the production performance before the well has been drilled which can cost the project a fortune if it fails.

3.2.4 Reservoir Uncertainty

Enhanced understanding of the geological environment is needed in order to identify potential geo-hazards and develop technological countermeasures to hazardous precursors [43]. However, in order for the geologists to discover the oil, a process that involves shock waves or seismic waves is used in creating a picture of deep rock structures. Even though, geological and geophysical clues can be reassuring, but drilling is the only way to confirm if an oil or gas field actually exists in that location [30]. The

geologic and seismic uncertainty can cause the company to lose money and waste time and resources. Today, the average wildcat well has only one chance in ten of finding an economic accumulation of hydrocarbons. So even though oil and gas prospectors of today have better tools than their predecessors, luck remains a significant factor in the search for oil and gas [14]. Moreover, because of reservoir characteristics and limitations in petroleum extraction technologies, only a fraction of this oil can be brought to the surface, and it is only this producible fraction that is considered to be reserves. Reservoir quality is a key component in determining the value of an oil and gas asset. Failing to measure the reservoir quality accurately is a major contribution for field development failure [44]. However, as the geology of the subsurface cannot be examined, direct or indirect techniques must be used to estimate the size and recoverability of the resource. While new technologies have increased the accuracy of these techniques, significant uncertainties still remain [14].

3.3.Political Perspective

Politics is a central concern for the O&G sector and can be viewed as a source of both risk and opportunity. It is no coincidence that one of the top risks facing offshore oil project, as identified by most recent risk studies, was geopolitics.

3.3.1 Government Stability

Oil and gas companies tend to prefer countries with stable political systems and a history of granting and enforcing long-term leases [45]. However, in the past companies simply go where the oil and gas is, even if a particular country doesn't quite match their

preferences. The main driving factors of investment decisions were made based on sites that were financially beneficial, leading in oil quality and their availability. Numerous issues may arise from this, including sudden nationalization and/or shifting political winds that change the regulatory environment. Depending on what country the oil is being extracted from, the deal a company starts with it is not always the deal it ends up with, as the government may change its mind after the capital is invested, in order to make more profits [46][47]. An important approach that a company takes in mitigating this risk is careful analysis and building sustainable relationships with its international oil and gas partners, if it hopes to remain in there for the long run.

3.3.2 Conflict Over Maritime Claims

The United Nation Convention on the Law of the Sea (UNCLOS), established by the United Nations (UN) in 1984, is a quasi-constitutional treaty that grants certain areas of the Arctic seafloor to the five circumpolar nations [48]. The UNCLOS states that exclusive economic zones (EEZs) shall not extend beyond 200 nautical miles (nm) from which the breadth of the territorial sea is measured [49][50]. Based on new research "Offshore oil development and maritime conflict in the 20th century: A statistical analysis of international trends" by Elizabeth Nyman shows that the independent variable is positive and significant at the 95% confidence level, indicating that the threat or use of conflict over maritime claims with offshore oil is indeed more likely to occur in the wake of successful offshore drilling [2]. The conflict over maritime most likely occurs when the high production performance has been achieved which means that a lot of money and

effort have already been put on the project, so any cancellation or delay can lead to a disaster.

3.3.3 Policies, Regulations and Governance Standards

Various policies governing the regulations for offshore hydrocarbon drilling have been radically changing due to fluctuating public and governmental values. Industry regulations aim at stabilizing the conditions for production and efficiency, while the fairly new paths of social regulation deal with external factors of material production, workplace health, safety and environmental security [51]. The success of a petroleum project is also greatly influenced by political uncertainty, such as changing taxes, public service announcement terms, government stability in the developing countries, etc. for example since the 1970s, the offshore oil and gas industry has been subjected to multiple environmental regulations. The biggest regulation impact occurred based on climate change-a new global policy [52][42]. However, since the United States has now decided to walk away from the Paris international agreement for controlling climate change, the offshore petroleum industry may face a regulatory uncertainty, which will in turn affect the whole industry until relevant regulations are established. Offshore petroleum projects have a lifetime of about 40 to 50 years, so any regulation and policy change during this time can increase the cost and cause delays.

3.3.4 Contracts Complexity

O&G companies are required to have a license to explore for hydrocarbons [14]. Finding the right contract that fits within the company's vision is a complicated process

and requires tremendous experience in dealing with offshore O&G contracts in order for the project to be successful. However most governments have their own policies to manage bidding and contracts of O&G offshore projects. Firms have to fulfill the government regulations and policies such as environmental protection, health and safety and public opinion etc. Such processes and others make offshore O&G contracts very complicated and they require the firm to have extended experiences and strong assessment capabilities to go through this long and tedious contract and leasing process. In addition, many of the larger oil and gas companies participate in megaprojects through complex operator or non-operator joint venture agreements to limit risk exposure. This added complexity, combined with the high-risk, high-value nature of the projects, presents a challenge for companies in managing their total portfolio risk [11].

3.4 Environmental Perspective

Environmental impacts of oil and gas operations may influence species, populations, assemblages, or ecosystems by modifying a variety of ecological parameters (e.g., biodiversity, biomass, productivity, etc.). Potential environmental issues associated with offshore oil and gas development projects include the following: Air emissions, Wastewater discharges, Solid and liquid waste management, Noise generation and Spills.

3.4.1 Air Emissions

In recent years, particular attention has been directed towards the impacts caused by the offshore oil and gas industry [53][54][55][56]. Whilst the industry has inevitably yielded substantial economic rewards, it has also been a major cause of marine pollution

and degradation. Activities such as flaring, drilling, construction, transportation and discharge have all played a role in disturbing marine ecosystems [57][58]. Nevertheless, air emissions from hydrocarbon offshore activities considering as a one of the main source of environmental pollution. Gaseous waste released to the air can potentially affect humans, animals, and plant life through inhalation or dermal contact. Indirectly, gaseous waste may alter the comical balance in the atmosphere [59]. The main sources of air emissions continuous or non-continuous resulting from offshore activities include: combustion sources from power and heat generation, and the use of compressors, pumps, and reciprocating engines (boilers, turbines, and other engines) on offshore facilities including support and supply vessels and helicopters; emissions resulting from flaring and venting of hydrocarbons; and fugitive emissions [60]. Principal pollutants from these sources include nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon monoxide (CO), and particulates. Additional pollutants can include: hydrogen sulfide (H₂S); volatile organic compounds (VOC) methane and ethane; benzene, ethyl benzene, toluene, and xylenes (BTEX); glycols; and polycyclic aromatic hydrocarbons (PAHs) [32].

3.4.2 Solid & Liquid Waste Management

The marine environment is host to a diverse set of highly productive and complex ecosystems. In addition to playing a central role in climatic regulation, it also contributes significantly towards biodiversity maintenance, food and energy provision, and the creation of economic and cultural benefits [61][62]. Yet whilst marine systems are highly adaptive they are also vulnerable [63][64]. Typical non-hazardous and hazardous wastes

routinely generated at offshore facilities include general office and packaging wastes, waste oils, oil contaminated rags, hydraulic fluids, used batteries, empty paint cans, waste chemicals and used chemical containers, used filters, fluorescent tubes, scrap metals, and medical waste, among others [60]. These waste materials should be segregated offshore into non-hazardous and hazardous wastes at a minimum, and shipped to shore for re-use, recycling, or disposal. Moreover, oil and gas reservoirs contain water (formation water) that becomes produced water when brought to the surface during hydrocarbon production. Oil reservoirs can contain large volumes of this water whereas gas reservoirs typically produce smaller quantities. In many fields, water is injected into the reservoir to maintain pressure and / or maximize production. The total produced water stream can be one of the largest waste products, by volume, disposed of by the offshore oil and gas industry. Produced water contains a complex mixture of inorganic (dissolved salts, trace metals, suspended particles) and organic (dispersed and dissolved hydrocarbons, organic acids) compounds, and in many cases, residual chemical additives (e.g. scale and corrosion inhibitors) that are added into the hydrocarbon production process. Feasible alternatives for the management and disposal of produced water should be evaluated and integrated into production design. These alternatives may include injection along with seawater for reservoir pressure maintenance, injection into a suitable offshore disposal well, or export to shore with produced hydrocarbons for treatment and disposal [60].

3.4.3 Noise Generation

As the offshore industry expands into the world, the oil and gas exploration activities generate all kinds of waste, varying from contaminated runoff water to material packaging [65][66][67]. Primary concerns relate to marine pollution and toxicity, benthic disturbance, biological depletion, and the loss of archaeological heritage [56][68][25]. Nevertheless, Offshore hydrocarbon activities noise generation has a significant impact on marine environment that get the scientists attention in the last few years. Offshore hydrocarbon activities generating marine noise include seismic operations, drilling and production activities, offshore and near-shore structural installation and construction activities, and marine traffic. Noise from these activities can affect fish and marine mammals [60]. The loudest noises generated by the offshore petroleum industry specially that produced by seismic survey equipment could kill fish at a range of some hundreds of meters [69]. Based the marine impact there are two important potential health problems arising from exposure to noise offshore: noise-induced hearing loss and the potential for sleep disturbance with resultant fatigue and stress that could affect the workers [70].

3.4.4 Oil Spills

Many marine species (e.g., marine mammals, birds and fish) are highly vulnerable to oil spill impacts because they are highly localized and seasonally more abundant near offshore petroleum drilling areas [71][72]. Spills from offshore facilities can occur due to leaks, equipment failure, accidents, or human error. A significant oil spill in marine waters could have extensive and long-term impacts. Abilities to respond to oil spills are

extremely limited, posing significant challenges for implementing pollution prevention techniques [73]. Spills are an important environmental performance indicator for the oil and gas industry since they can have a significant and visible impact on the environment. The degree of environmental impact is highly dependent on the nature of the release, where it occurred and how it was subsequently managed [74]. Based on environmental impacts and climate change, the offshore O&G industry is subjected to new policies and regulations that will increase investment costs and delay production productivity.

3.5 Safety Perspective

Health and safety are important elements of the industry and its working standards. Offshore petroleum projects function in unsafe environments and constantly deal with risky products. Potential safety factors associated with offshore oil and gas development projects including hazard identification and implementing health, safety and environmental (HSE).

3.5.1 Hazard Identification and Risk Management

Safety performances cost companies a huge amount of money and lead to delays to the whole project. A recent example is the Deep-water Horizon accident in 2010. The gas blowout-induced explosion killed 11 workers and injured another 17 of the 126 on board [75]. The Deep-water Horizon accident is the largest blowout catastrophe on record in deep-water oil drilling history and it has already cost about \$62 billion for just British Petroleum (BP) [76][77]. A project's safety performance has become a priority in determining whether an offshore O&G project is successful [4]. Existing data shows that

there were 1183 fatality cases in the U.S. O&G industry between 2003 and 2013. The fatality rate is 29.1 deaths per 100,000 workers, which is eight times higher than the rate for the overall U.S. worker [78]. Hazard identification is an essential step before project implementation and during the project lifecycle phases. Issues potentially impacting safety and environmental stewardship are promptly identified, fully evaluated, and promptly addressed or corrected commensurate with their significance [79]. Accidents on offshore oil and gas platforms (OOGPs) usually cause acute fatalities [80] and financial losses as OOGPs have demanding environment and oil and gas production is a difficult and potentially dangerous operation. The demanding environment includes limited accessibility and danger of encountering hurricanes, massive waves, and storms. Drilling and processing oil and gas turn offshore platforms into a high-pressure, inflammable, and dangerous environment with frequent accidents, including a gas leak, fire, explosion, blow out, structural failure, and adverse weather condition [81][82][83]. By evaluating and identifying such risks and hazards will increase the awareness of safety implementation.

3.5.2 Implementing Health, Safety and Environmental (HSE)

Due to the nature of the work environment and the properties of the products, offshore O&G projects pose more serious safety threats to the workers than their counterparts in other industries. The fatality rate between 2003 and 2013 in the U.S. O&G industry is 29.1 deaths per 100,000 workers, which is eight times higher than the rate for the fatality overall U.S. worker [4]. Early evaluation of implementing health,

safety and environmental (HSE) principles is essential to the success of the project. HSE principles contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technologies at reasonable costs [84]. Proper assessment can prevent negative consequences such as schedule delays and cost increases [85]. Decision makers should take into consideration the project specification factors that could affect HSE implementation such as the complexity of the project, site of the project, number of operations required, depth of the water, size of the project, etc. Such factors that are related to the operation of O&G facilities within harsh environments and situations that pose difficulties in emergency response may represent critical situations and project failure [86].

CHAPTER 4: RESEARCH APPROACH AND METHODOLOGY

This chapter highlights the research approach that was implemented to identify the research gap. Moreover, research objectives, research questions and research methodology sections were presented in this chapter. Though, this study relies on the experts and their willingness to contribute, various challenges associated with expert panels' formation were investigated.

4.1 Research approach

The research starts with a literature review in order to identify and investigate the main factors that affect the performance and success the offshore hydrocarbon projects. The literature review has been conducted with the help of three independent study papers. The first paper provides a broad overview of offshore oil projects and their opportunities and challenges. The purpose of the second paper is to identify and assess key factors impacting the performance of offshore hydrocarbon projects. In the third paper an academic research from an industry point of view has been conducted. Seven experts who have extensive experience not less than 10 years of working in the offshore oil projects were involved in the elaboration of this paper. The main purpose of this paper is to capture the experts' recommendations and feedback in order to assess key factors impacting the performance of offshore oil projects. Figure 14 shows the research processes flow chart.

Figure 14: Research Processes Flow Chart

Figure 15 illustrates the research framework process that would start with evaluating the investment opportunities using a hierarchical decision model. The next step is assigning scores value to each factor and builds the value cures. Last step is to provide index value for each project.

Figure 15: Research Framework Process

4.2 Research Gaps

Numerous researchers have shown that global offshore oil projects have not performed well, including within the three constituents of project management capability: scope, schedule, and budget capabilities [4][12]. Research demonstrates that the majority of offshore oil projects are facing delays, cost escalations, and lower than expected hydrocarbon production [12]. Merrow (2012) shows that 64% of the projects are facing cost overruns. These projects are reporting schedule delays at 73% [87]. EY (2014) reported similar findings with 64% of oil megaprojects experiencing a cost overrun [16]. A new study in 2016 investigated the cost performance of oil projects by analyzing the data of approximately 200 public oil projects in terms of project size, company type and region, showing that the overall average cost overrun of oil projects is 18% with an SD of

29% [88]. Kegang Ling (2017) reported that more than 60% of the offshore oil projects experienced a cost overrun of 33% or more and schedule delays of 30% or longer [4]. Kolltveit and Gronhaug (2004) concluded that Norwegian offshore projects have experienced overruns ranging from 6% to 160% [88][89]. Moreover, Cunningham & Scheck (2016) reported that 68 major projects were scrapped in 2015, which accounts for around 27 billion barrels of oil. All of these studies revealed that the majority of the hydrocarbon offshore projects were delayed and/or faced cost overruns when measured against estimates made during the initial stages of the project life cycle. According to data provided in the Offshore Technology Conference 2013, 65% of project failures were due to softer aspects such as people, organization and governance. Another 21% were caused by management processes as well as contracting and procurement strategies, with the remaining 14% of the failures due to external factors such as government intervention and environment-related mandates [24][16]. However, project portfolio has been highlighted as one of critical factors that leads to project failures [16]. Frequently, a lack of clear strategic direction and project selection criteria means that over time, organizations develop overly diverse and poorly aligned project portfolios, which often unnecessarily stretch resources, increase portfolio risk, and dilute the potential value of inter-project linkages. The capital investment for individual oil projects has, therefore, increased significantly to develop more and more challenging oil fields. The largest completed offshore project, the Gorgon project in Australia, cost more than \$57 billion, which more than doubled the estimated cost [90]. Elsewhere, the Pearl GTL project in Qatar rose nearly 300% from its 2003 budget of \$5 billion [91], while Norway's offshore

oil projects are running roughly 20% above original cost estimates [92]. All findings indicate that the overall cost performance of oil projects is worse than expected, implying that project teams fail to incorporate the risks in the planning phase.

Traditionally, cash flow analysis and return on investment are the most known methods to evaluate offshore oil projects [93]. One of the traditional methods of investment analysis is based on discounted cash flow (DCF). This approach considers an investment as a decision of the now-or-never type. If the net present value (NPV) is positive, the investment must be done without delay, and if the NPV is negative, the investment should be cancelled. However, the DCF method requires detailed assumptions to develop reliable cash flow forecasts. In a typical evaluation, the firm's analysts use sensitivity analysis to identify the key uncertainties, assess probabilities for these key uncertainties, and construct decision trees or simulation models of the project cash flows. They use these models to calculate expected NPVs and distributions on NPVs, which then serve as important inputs into the decision making process. Though management is generally pleased with decision analysis processes, there are typically two concerns. First, there is concern that analyses frequently do not capture some of the flexibilities associated with projects. Decision models typically assume that management makes an initial investment decision, and then the project uncertainties are resolved and cash flows are determined [11]. A second issue that has long concerned many firms is the way cash flows are discounted. Many investments have time horizons as long as 30 or 40 years, and the NPVs for these investments are extremely sensitive to the discount rate used. There is concern, particularly among managers in the exploration and new ventures parts

of a business, that the blanket use of such a risk-adjusted discount rate causes them to undervalue projects with long time horizons [11]. In reality, firms make a series of investment decisions as uncertainties resolve over time. For example, when considering the development of a new oil field, if oil prices, production rates, or reserves exceed their expectations, or if production technology improves, the firm might be able to develop more aggressively or expand to nearby fields. Similarly, if prices, rates, or reserves are below expectations, the firm might be able to scale back planned investments and limit their downside exposure [11]. According to Suslick & Furtado (2001), exploring and producing oil involves risky investments. The authors affirmed that when petroleum executives make investment decisions on petroleum projects, they face several uncertainties including future oil prices, reserves, environmental concerns, the chances of finding petroleum, fiscal terms, current degree of exploration, and operational peculiarities [94]. As the data show, improving offshore oil capital project efficiency is critically needed. Relying on financial assessments alone will not solve the problems that arise later on, and a comprehensive approach is needed to measure project outcomes and identify gaps for future improvements.

	Gap Description	References
1	There is not a specific study, which is aimed to identify the most factors that impact oil offshore projects' investment decision as well as assessing their weights.	[4][12][48][49][50][51][52][53][54][55][56]
2	As the data shows, improving oil offshore capital project efficiency is critically needed. Companies rely only on financial analysis approach and there is a lack of a comprehensive approach to evaluate oil offshore projects before and after the investment decision.	[11][50][57][58][24][16]

Table 1: Summarizes the Research Gaps

4.3 Research Objectives

It has been observed that global offshore projects have not performed well. More than 60% of the projects experienced a cost overrun of 33% or more, schedule delays of 30% or longer, and lower than expected hydrocarbon production [4]. Traditionally, cash flow analysis and return on investment are the most known methods to influence the decision in hydrocarbon offshore projects. However, in current times there are many factors that play a more important role in evaluating oil offshore projects and influencing investment decisions. The main purpose of this research is to identify the key challenging factors that affect oil offshore projects as well as assess their impact on the investment decision. Also, to provide a comprehensive approach to evaluate offshore oil projects before and after the investment decision takes place. Specific objectives of this research include:

1. To identify the major challenging perspectives as well as associated sub-criteria impacting oil offshore projects.
2. To evaluate and score these factors, and highlight their weight of impact on offshore oil projects.
3. To provide a comprehensive framework that can be used for assessing and evaluating offshore oil projects to select the right project.

4.4 Research Questions

1. Which attributes are most important for evaluating offshore oil projects?
2. Is the assessment framework appropriate for evaluating offshore oil projects?

3. To what extent could the developed model results help project managers and decision makers to evaluate offshore oil projects and select the right project?

Figure 16: Gaps Analysis Diagram

4.5 Research Methodology

The main purpose of this research is to emphasize the key challenge factors that affect oil offshore projects as well as to assess their impact on the project. Also, to provide a comprehensive approach evaluating oil offshore projects the investment decision has taken place. The methodology that has been used in this research is the Hierarchical Decision Model (HDM) that was introduced by Cleland and Kocaoglu [95]. The model can be used as a network of relationships among decision hierarchies, where subjective judgments are provided in a comprehensive evaluation [96]. The HDM has adopted by decision makers in various industries [97][98]. The HDM process likes other multi-criteria decision tools such as AHP. Its steps include structuring the decision problem into

levels, followed by pairwise comparison among all variables, calculating the priorities of the objectives, and checking the consistency. The HDM process is more comfortable to the experts related to the relative and absolute preference [99].

In HDM, the subjective judgments expressed in pairwise comparisons are converted to relative weights in ratio scale. This is done by a series of mathematical operations. The methodology can be used for quantifying the judgment of a single decision maker, or multiple decision makers [95]. The basic structure of HDM can vary depending on the needs of each application. Based on Kocaoglu HDM structure contains five levels: Mission, Objectives, Goals, Strategies, and Actions (MOGSA), as shown in Figure 17.

Figure 17: HDM (MOGSA) Structure

However, other structures can be applied under four-level model that will include Mission, Perspectives, Criteria, and Alternatives as it's showing in Figure 18.

Figure 18: HDM Structure

However, during the data collection phase, it is important to consider inconsistency and disagreements among the judgments' of experts. Inconsistency is a disagreement within an individual's evaluation, which in other words shows how an expert could have an inconsistent judgment within his/her comparisons. Disagreements amongst experts can show different quantifications and different perspectives to the same analysis. Nevertheless, HDM has been used in a variety of cases and for several purposes, especially in technology management, to evaluate and understand which technology alternative is the best option in a particular setting, given the criteria established to evaluate the alternatives [101]. Moreover, HDM has been applied in several different settings and fields, proving that it is, indeed, an effective method. The fields and areas that were explored using HDM are, but not limited to, computer selection [102], agriculture [103], university housing [100], transportation options [104], solar

photovoltaic technologies [105], energy [106], health technology assessment [107], selection of graduate school [108], and technology transfer [114], big data projects and smart cities selection [109].

4.6 Experts Selection

HDM relies on the experts and their willingness to contribute. However, selecting experts and formatting panels is the most critical part in these types of research. In this study the experts will be involved in two main steps; (1) validate the model and the desirability metrics. (2) Quantify the model and the desirability metrics. Numerous studies and researches provide a significant amount of information for defining the experts and what characteristics they should have. According to Sternberg (1997), expertise can be seen as a multidimensional prototype that includes seven characteristics [110]:

1. Advanced problem-solving processes.
2. A great amount of knowledge.
3. Advanced knowledge organization.
4. An ability to use knowledge effectively.
5. Creating new knowledge on the basis of knowledge that one already has.
6. Automatized actions.
7. Practical ability, which involves knowing how to get ahead in one's field.

Moreover, other studies have been introduced about the nature and different constituents of expert knowledge. Despite their differences in details, all of these analyses mainly divide expert knowledge into three main components [110]:

1. Formal knowledge.
2. Practical knowledge.
3. Self-regulative knowledge.

According to the Cambridge dictionary, an expert is “a individual who has a high level of knowledge or skill in a particular field” [111]. Based on Cambridge Handbook of Expertise and Expert Performance, Press and edited by K. Anders Ericsson, “Consistently and overwhelmingly, the evidence showed that experts are always made, not born” [112].

In 2005 study represented by Hubert L. Dreyfus and Stuart E. Dreyfus classified the acquisition of expertise into five-stage as following [113]:

Stage 1: Novice: In this stage, an individual is able to recognize and decompose the task without the desired skill.

Stage 2: Advanced Beginner: In this stage, an individual begins to develop an understanding of the relevant context, he or she begins to note, or an instructor points out, perspicuous examples of meaningful additional aspects of the situation or domain.

Stage 3: Competence: In the third stage, the individual gains more experience and the learner is now able to recognize and follow.

Stage 4: Proficiency: In this stage only if the detached, information-consuming stance of the novice, advanced beginner, and distance learner is replaced by involvement, is the student set for further advancement. Then the proficiency will start to develop.

Stage 5: Expertise: In the fifth stage, the individual becomes a proficient expert. He/she is able to recognize how to achieve the goal. Also, the ability to make more subtle and refined discriminations is what distinguishes the expert from the proficient performer.

Based on Hubert L. Dreyfus and Stuart E. Dreyfus definitions, it will be clear that it takes time to become an expert. In addition, research introduced by K. Ericsson, M. Prietula, and E. Cokely, shows that even the most gifted performers need a minimum of ten years (or 10,000 hours) of intense training before they win international competitions. In some fields the apprenticeship is longer: It now takes most elite musicians 15 to 25 years of steady practice, on average, before they succeed at the international level [112].

“It takes time to become an expert. Even the most gifted performers need a minimum of ten years of intense training before they win international competitions” [112].

4.6.1 Challenges Associated with Expert Panels Formation

Expert panels can be defined as a group of experts who agree to provide service, feedback or recommendations on the same task [114]. The expert panel method is a commonly used in foresight to elicit expert knowledge. Expert panels are engaged when highly specialized input and opinion is required for a project [135]. Generally, a variety of experts are engaged based on various fields of expertise to debate and discuss various courses of action and make recommendations. The objective of formatting expert panels

is to allow stakeholders and decision makers to hear a variety of informed (expert) viewpoints from which to decide on recommendations or courses of action in relation to an issue or proposal [116]. It's important to consider primarily technical ability and experience of the expert during the expert panel formatting. Furthermore, ensure that the panels have the broadest possible universal representation in terms of diversity of knowledge, experience and approaches in the fields for which the panels are established.

Meanwhile, numerous studies have identified how many experts required for each panel. Based on “Effective Engagement: building relationships with community and other stakeholders - Book 3 the engagement toolkit” that was published in 2005, number of people required in each panel ranges from 2-12 experts [115]. Successful studies have introduced groups of experts as small as five members [117]. Another study defined the panels as groups of 12-20 individuals who are given specific amount of time to deliberate upon the future of a given topic [118]. However, identifying the size of the panel would be one of the critical issues associated with formatting the expert panel. The number of individuals within the panel is mainly affected by the qualification of these experts and the purpose of formatting this panel. Different successful dissertations and studies show that having 6-12 individual per panel is more reliable and efficient to achieve a significant outcomes [119]. Although, there will always be different considerations and weaknesses associated with formatting expert panels.

- Qualified experts should typically have at least 10 years of experience in the field, which will increase their responsibility and dependability in their work. Due to this, finding the right expert can be challenging and expensive sometimes.

- A long lead-time may be needed to book appropriate experts.
- A highly skilled moderator is required to ensure a positive communication and understanding the panel's objective.

Moreover, it is important to mention some of the characteristics of the group or individual behaviors that are exhibited by panels during their work. These characteristics that may prevent the panel to work effectively include [118]:

1. Expert shares different basic values and goals of the research objective. Sharing a common goal between the expert and the study is an important factor to achieve the expected results.
2. Individuals are unwilling to commit themselves on an issue.
3. Committee members are not necessarily familiar with the needs of the foresight process and may fall into a conventional mode inappropriate to developing a longer-term view of the topics under discussion.

4.7 Research Validity

The main purpose of the validation phase is to answer these questions:

- Does the model capture the necessary elements needed to satisfy the research goal?
- Does the model valid to apply?

Following previous PhD dissertations [105][120][121][101], the research validity has been guaranteed to answer these questions. However, the validity of the research should

be tested by adopting three measures applied at different phases of the research: construct validity, content validity and criteria-related validity.

- Construct validity refers to the degree to which a research approach complies with its underlying theories. Construct validity of the model will be tested by a group of ETM doctoral students, who have significant amount of research experience in both the energy field and hierarchical decision modeling.
- Content validity refers to the degree to which a measure represents a given domain of interest. Content validity will be tested during the model development phase. After the preliminary model is constructed based on the literature, Subject matter experts who are familiar with decision models will be asked to provide their feedback using the content of the model.
- Criterion-related validity refers to the degree of effectiveness of a model in predicting real-life phenomenon. Criterion-related validity will be implemented after the analysis is completed. The quantified model will be tested against a case study and subject matter experts will determine if the results are acceptable. Also, these experts will be asked to verify if the model could be generalized to other than the case study application.

4.8 Research Quantification

The graph below shows how the Hierarchical Decision Model approach uses the pairwise comparisons technique through each level to determine the weights of each factor.

Figure 19: Pair-Wise Comparisons Technique

The respondent divides 100 points between the pair to reflect his judgment of each element's relative importance in comparison with the other element of the pair [122]. In HDM, the subjective judgments expressed in pairwise comparisons are converted to relative weights in ratio scale. This is done by a series of mathematical processes divided on three different matrices.

The first step is to obtain matrix- A. Starting with define $V_i^{(j)}$ as the perceived value of element when compared with element X_i , the $\frac{n(n-1)}{2}$ pairwise comparisons for n elements results in an n x n matrix.

$$\text{Let } a_{ij} = V_j^{(i)} \quad (1)$$

$$\text{Where } a_{ji} = 100 - a_{ij} \quad (2)$$

As such the matrix-A can be described as following:

i j	x_1	x_2		x_n
x_1	$a_{11} = 50$	$a_{12} = V_2^{(1)}$		$a_{1n} = V_n^{(1)}$
x_2	$a_{21} = V_1^{(2)}$	$a_{22} = 50$		$a_{2n} = V_n^{(2)}$
$\vdots \quad \vdots \quad \vdots$	$\vdots \quad \vdots \quad \vdots$	$\vdots \quad \vdots \quad \vdots$		$\vdots \quad \vdots \quad \vdots$
x_n	$a_{n1} = V_1^{(n)}$	$a_{n2} = V_2^{(n)}$		$a_{nn} = 50$

Table 2: Explanation of Matrix A

Within this we can develop Matrix-B as the following equation:

$$b_{ij} = \frac{a_{ij}}{a_{ji}} = \frac{V_j^{(i)}}{V_i^{(j)}} \quad \text{for all } i,j \text{ except } i=j \quad (3)$$

The next step is to calculate Matrix-C by dividing the elements of each column of Matrix-B by the corresponding elements of the next column.

The following example explains how the weights of the perspective level have been calculated. Let's say expert 1 entered the value of the pairwise comparisons of the perspective level as following:

Economical = E		Technical = T		Political = P		Environmental = N	
E: 60	T: 40	P: 60	N: 40	N: 30	E: 70		
T: 45	P: 55	E: 55	P: 45	T: 55	N: 45		

Matrix A – Symbolic Representation: Based on the information that been collected from expert (1) we can obtain Matrix A as a following:

	E	T	P	N
E	X	40	45	30
T	60	X	55	45
P	55	45	X	40
N	70	55	60	X

Table 3: Obtaining matrix A

The next step is develop Matrix B as showing in equation number (6):

	E	T	P	N
E	1	0.67	0.82	0.43
T	1.5	1	1	0.82
P	1.2	1	1	0.67
N	2.3	1.22	1.5	1

Table 4: Obtaining matrix B

By dividing the elements of each column of Matrix-B by the corresponding elements of the next column we can obtain Matrix-C and calculate the mean for each element of Matrix-C: Orientation for: (E) Economical, (T) Technical, (P) Political and (E) Environmental

	E/T	T/P	P/N
E	1.5	0.8	1.9
T	1.5	1.0	1.2
P	1.2	1.0	1.5
N	1.9	0.8	1.5
MEAN	1.5	0.9	1.5

Table 5: Matrix C

Then, a value of 1 is assigned to N (the element missing from the table 5), and other elements values are calculated based on it, by the ratios indicated as the mean of each column in Matrix C as follow:

$$N = 1$$

$$P = 1 * 1.5 = 1.5,$$

$$T = 1 * 1.5 * 0.9 = 1.4,$$

$$E = 1 * 1.5 * 0.9 * 1.5 = 2$$

Next, we can calculate the sum of Orientation E-T-P-N from the mean of Matrix-C

$$\begin{array}{rcl} N & & 1 \\ P & & 1.5 \end{array}$$

T	1.4
E	2.0
SUM	5.9

Now we are able to find the normalized value of each perspective.

Environmental	0.17
Political	0.25
Technical	0.23
Economical	0.35
Sum	1.00

By following the same steps for each expert we are able to obtain the over all value for each perspective and the contribution value of the four perspectives to the overall research objective of Oil offshore projects evaluation. Moreover, following the same calculation will provide the value of the criteria level.

4.9 Inconsistency Analysis

Inconsistency is one of the critical factors that could affect the result of the model and it should be calculated and controlled in order to achieve reliable outcomes. The definition of inconsistency has been highlighted in many studies that used HDM methodology. According to Abotah, "inconsistency is a measure that explains how reliable and homogeneous the answer of the expert through the whole questionnaire" [120]. Moreover, Estep described inconsistency as disagreement within an individual's evaluation, which in other words shows how an expert could have an inconsistent judgment within his/her comparisons [105]. Based on Abbas study, there are two types of inconsistency that could occur through the individual's judgment within the HDM, these are 1- ordinal, 2- cardinal. Ordinal consistency requires order of preference of the ranked

elements to be maintained. For instance, if the expert preferred A over B, and preferred B over C. It will be violated to the ordinal consistency if he/she preferred C over A [123]. The second type of inconsistency is cardinal that requires preservation of preference proportions. For example, if A is preferred twice over B, and B is preferred thrice over C, then A must be preferred 6 times over C. It will be violated to the cardinal consistency if the expert chooses A to be 5 times preferred over C [123]. According to Gibson, “inconsistency occurs when experts face multiple decisions and have to judge items” [117]. Studies introduce different methods to calculate and control the inconsistency. However, there are two methods that have been used widely in the past few years.

4.9.1 Variance Method

This method of measuring the inconsistency is widely referenced in recent dissertations by Chan, Phan, and Sheik [105][117][124][121][98]. The processes start by calculating the mean.

r_{ij} = relative value of the i th element in the j th orientation for an expert.

$\bar{r}_i$ = mean relative value of the i th element for that expert.

$$\frac{1}{ni} \sum_{j=1}^{ni} r_{ij} \quad (4)$$

After we obtained the mean within the individual data, we measure the standard deviation for the same data.

$$\sqrt{\frac{1}{ni} \sum_{j=1}^{ni} (\bar{r}_i - r_{ij})^2} \quad (5)$$

By calculate the standard deviation, we are able to define the inconsistency as a mean standard deviation of n elements

$$\frac{1}{ni} \sum_{j=1}^n \sqrt{\frac{1}{ni} \sum_{j=1}^{ni} (r_i^- - r_{ij})^2} \quad (6)$$

Kocaoglu recommends 0.10 as the limiting value for the inconsistency for any value of n [122]. The following example shows how to measure inconsistency using the variance method.

Where:

E = Economical

T = Technical

P = Political

N = Environmental

Perspective Level

Number of comparisons = $[n*(n-1)]/2 = 4(4-1)/2 = 6$ pairwise comparisons

Number of perturbations = $4! = 4 * 3 * 2 * 1 = 24$

Constant Sum Matrices:

Matrix A – Symbolic Representation:

	E	T	P	N
E	X	40	45	30
T	60	X	55	45
P	55	45	X	40
N	70	55	60	X

Table 6: Matrix A

Matrix B:

	E	T	P	N
E	1	0.67	0.82	0.43
T	1.5	1	1	0.82
P	1.2	1	1	0.67
N	2.3	1.22	1.5	1

Table 7: Matrix B

Matrix C: Orientation E-T-P-N

Find the Means for Matrix “C” Under Different Orientations:

	E/P	E/N	E/T
	1.2	2.3	1.5
	1.5	1.8	1.5
	1.2	1.8	1.2
	1.5	2.3	1.9
Mean	1.4	2.1	1.5

	T/P	T/E	T/N
	0.8	0.7	1.6
	1	0.7	1.2
	1	0.8	1.5
	0.8	0.5	1.2
Mean	0.9	0.7	1.4

	P/N	P/E	P/T
	1.9	0.8	1.2
	1.2	0.7	1.0
	1.5	0.8	1.0
	1.5	0.7	1.2
Mean	1.5	0.7	1.1

	N/E	N/T	N/P
	0.4	0.6	0.5
	0.5	0.8	0.8
	0.6	0.7	0.7
	0.4	0.8	0.7
Mean	0.5	0.7	0.7

After we determined the means under different orientations, we are able to measuring the value of each perspective under different orientations.

Number of permutation = $4! = 4 * 3 * 2 * 1 = 24$

Measuring the value of each perspective Under Different Orientations:

Orientation					SUM
E T P N	2.03	1.35	1.50	1	5.9
E T N P	1.36	0.91	0.67	1	3.9
E P T N	2.04	1.51	1.36	1	5.9
E P N T	1.51	1.12	0.74	1	4.4
E N T P	1.37	0.67	0.90	1	3.9
E N P T	3.65	1.78	1.11	1	7.5
T E P N	1.35	2.03	1.50	1	5.9
T E N P	0.92	1.37	0.67	1	4.0
T P E N	1.37	1.52	2.05	1	5.9
T P N E	0.66	0.74	0.49	1	2.9
T N P E	0.67	0.50	0.74	1	2.9
T N E P	0.90	0.66	1.35	1	3.9
P E T N	1.51	2.03	1.36	1	5.9
P E N T	1.14	1.53	0.74	1	4.4
P T E N	1.52	1.37	2.05	1	5.9
P T N E	0.74	0.67	0.49	1	2.9
P N E T	1.10	0.74	1.50	1	4.3
P N T E	0.75	0.50	0.67	1	2.9
N E T P	0.66	1.35	0.90	1	3.9
N E P T	0.74	1.50	1.11	1	4.3
N T E P	0.67	0.90	1.35	1	3.9
N T P E	0.50	0.67	0.74	1	2.9

N P E T	0.75	1.12	1.50	1	4.4
N P T E	0.50	0.74	0.67	1	2.9

Table 8: Construction of the Orientation Table Before Normalized

Normalized Value:

Orientation	Economical	Technical	Political	Environmental	SUM
E T P N	0.34	0.23	0.26	0.17	1.00
E T N P	0.35	0.23	0.17	0.25	1.00
E P T N	0.35	0.26	0.23	0.17	1.00
E P N T	0.35	0.26	0.17	0.23	1.00
E N T P	0.35	0.17	0.23	0.25	1.00
E N P T	0.48	0.24	0.15	0.13	1.00
T E P N	0.23	0.34	0.26	0.17	1.00
T E N P	0.23	0.35	0.17	0.25	1.00
T P E N	0.23	0.26	0.34	0.17	1.00
T P N E	0.23	0.25	0.17	0.35	1.00
T N P E	0.23	0.17	0.26	0.34	1.00
T N E P	0.23	0.17	0.35	0.26	1.00
P E T N	0.26	0.34	0.23	0.17	1.00
P E N T	0.26	0.35	0.17	0.23	1.00
P T E N	0.26	0.23	0.34	0.17	1.00
P T N E	0.26	0.23	0.17	0.35	1.00
P N E T	0.25	0.17	0.35	0.23	1.00
P N T E	0.26	0.17	0.23	0.34	1.00
N E T P	0.17	0.35	0.23	0.26	1.00
N E P T	0.17	0.35	0.26	0.23	1.00
N T E P	0.17	0.23	0.34	0.25	1.00
N T P E	0.17	0.23	0.26	0.34	1.00
N P E T	0.17	0.26	0.34	0.23	1.00
N P T E	0.17	0.26	0.23	0.34	1.00
MEAN	0.26	0.25	0.25	0.24	
ST.DV	0.08	0.06	0.07	0.07	

Table 9: Construction of the Orientation Table After Normalized

From the Normalized Value we are able to calculate the inconsistency.

$$\text{Inconsistency} = (1/4) [(0.08) + (0.06) + (0.07) + (0.07)] = 0.069$$

The inconsistency is below the rejection limit 0.1.

4.9.2 Root Sum of the Variance (RSV)

(RSV) method in measuring the inconsistency was introduced by Abbas.

$$\text{Inconsistency (RSV)} = \sqrt{\sum_{i=1}^n \sigma_i^2} \quad (7)$$

Abbas' approach to measure the inconsistency is to apply the root-sum of the variances (RSV) instead of the sum of the standard deviations [117]. According to Kocaoglu, if the variances were higher than threshold value of 0.10, discrepancies are explained to the respondents and new measurements are needed [105]. Nevertheless, the respondents at the end of each measurement session should be given the opportunity to modify their comparisons. Even though they were not given any information concerning the variance value, the respondents typically accepted the results without modification when variance was small, opted for a new measurement when it was high. The following example shows how the inconsistency can be measured within the perspective level, using the same input data that we used in the first example.

Determining inconsistency using the Root Sum of the Variance (RSV) method.

$$\text{Inconsistency (RSV)} = \sqrt{\sum_{i=1}^n \sigma_i^2} \quad (8)$$

MEAN	Economical	Technical	Political	Environmental
MEAN	0.26	0.25	0.25	0.24
Std. Deviation	0.08	0.06	0.07	0.07
Variance	0.006	0.004	0.005	0.005

$$\text{Inconsistency} = \sqrt{(0.006) + (0.004) + (0.005) + (0.005)}$$

$$\text{Inconsistency} = 0.141(\text{RSV})$$

Using table 4.1 provided by Dr. Abbas for $n = 4$, this RSV value corresponds to $\sigma = 0.094$. This value is somewhat high considering $n = 4$. Therefore, it is recommended for the DM to revise the pairwise comparison assignments.

For $n = 4$, the 10% fixed limit corresponds to $\sigma = 0.03$

4.10 Disagreements Analysis

Disagreements amongst experts can show different quantifications and different perspectives to the same analysis. There is group disagreement if the disagreement exceeds a value of 0.10 and a value of 0 would imply complete agreement among the experts [125]. Experts have different backgrounds and experiences that most likely will increase the level of disagreements amongst them. However, Acceptable disagreement has a value of 0.1 or less. According to Kocaoglu disagreement can be measuring by the following equations [126]:

Let m be the number of experts and n be the number of decision variables.

r_{ik} be mean relative value of the i^{th} decision variable for k^{th} expert.

Group relative value of the i^{th} decision variable for m experts is

$$R_i = \sum_k^m r_{ik} \cdot \frac{1}{m} \quad \text{for } i = 1, 2, \dots, n \quad (9)$$

The standard deviation of the relative value of the i^{th} decision variable is:

$$\text{STD}_i = \sqrt{\frac{1}{m} \sum_{k=1}^m (R_i - r_{ik})^2} \quad (10)$$

Disagreement for m experts is calculated as the mean standard deviation of the group n relative values of variables.

$$D = \frac{1}{n} \sum_{i=1}^n STDi \quad (11)$$

Another common approach has been used in several studies to measure the disagreement levels is the intraclass correlation coefficient (ICC) [127][128]. The intraclass correlation coefficient (ICC) is claimed to be suitable method for the assessment of observer agreement [130]. The ICC is supported by the analysis of variance (ANOVA) [131]. Higher ICC values achieved when applied to a more heterogeneous population as compared with a more homogeneous one despite similar levels of agreement [127]. ICC assesses agreement by comparing the variance of different measurements of the same subject made by different observers with the total variance across all measurements and subjects [131]. These variances are derived from ANOVA, and the ANOVA model (one way or two way with random or fixed effects) depends on the agreement study design. The ICC ranges from 0 to 1 and ICC equal 0 means no agreement on the other hand ICC equal 1 means perfect agreement. However, the ICC value can also be negative. The interpretation of negative ICC values remains unclear [129]. Nevertheless, Burdock proposed that ICC values of 0.75 signify good agreement [127]. Based on Terry and Mae study the 95% confident interval of the ICC estimate, values less than 0.5, indicative of poor agreement, ICC value between 0.5 and 0.75, indicative of moderate agreement, ICC value between 0.75 and 0.9, indicative of good agreement and ICC value greater than 0.90 indicative of excellent agreement [128].

According to Shrout and Fleiss (1979) formula that use for calculating ICC as following [129]:

$$ICC = \frac{MS_R - MS_E}{MS_R + (K-1) MS_E + \frac{k}{n} (MS_C - MS_E)} \quad (12)$$

Where:

MSR = mean square for rows.

MSE = mean square for error.

MSC = mean square for columns.

n = number of subjects.

k = number of raters/measurements.

Different studies have used the value of 10% to control the disagreement and according to these researches if the expert panels disagreement acceded the 0.10 value there are several steps that should be taken to treat this disagreement. If the variances were higher than threshold value of 0.10, discrepancies are explained to the respondents and new measurements are needed. However, if second round has been taken and the threshold value still remains higher than 0.10, the respondent who led to higher disagreement should be taken out of the panel [105][120]. In addition, different studies used Hierarchical agglomerative clustering (HAC) method to measure and interpret the disagreement among the experts. The objective is for clustering to discover natural groupings. Hierarchical clustering was defined as, obtains homogeneous clusters of cases based on measured characteristics. In other words, to identify the similarities amongst the experts' evaluation in cluster and gathering new cluster by comparing it with the old one.

Repeat the same process until one cluster will be left out [134]. Moreover, F-test can provide more information if there is significant disagreement among the experts [133]. The Null Hypothesis (H0) for the F-test is that there is a significant disagreement among the expert panel judgment quantification, or H0: $\text{ric} = 0$. The F-value of a pairwise comparison procedure is calculated and compared against the F-critical value of the procedure to determine whether the Null Hypothesis can be rejected or not. If we reject the Null Hypothesis, this means that there is no a significant disagreement in the experts' judgments [105].

4.11 Desirability Curve

Development of a desirability curve is a method to convert either qualitative or quantitative data used for measuring a decision element to a scaled quantitative value [97]. In this research desirability curves will be used to identify how desirable or valuable a metric is for a decision maker. There are several ways to determine the value of a metric. These include standard gamble, constant-sum method, and graphically representing the relative value of the metric [101]. Calculating the importance of each factor through the perspectives with respect to the mission can be done using the following equation:

$$S_{n,jn}^M = \sum_{n=1}^N \sum_{jn=1}^{Jn} (P_{n,jn}^M) (F_{n,jn}^P) \quad (13)$$

Where:

$S_{n,jn}^M$: Relative value of the jn^{th} factor under the n^{th} perspective with respect to the mission (Offshore Oil Project Evaluation).

$P_{n,jn}^M$: Relative value of the jn^{th} success attribute under the n^{th} perspective with respect to the mission. $n = 1, 2, 3, \dots, N$.

$F_{n,jn}^P$: Relative contribution of the jn^{th} factor under the n^{th} perspective. $jn = 1, 2, 3, \dots, N$.

However, after having the importance of each factor relative to the mission using the HDM, the determination of the over all offshore oil project score will be given by multiplying the global importance of each factor by its desirability value and making the total summation that can be computed using the following mathematical representation [99]:

$$\text{Project Score} = \sum_{n=1}^N \sum_{jn=1}^{Jn} (S_{n,jn}^M)(D_{n,jn}) \quad (14)$$

$S_{n,jn}^M$: Relative value of the jn^{th} factor under the n^{th} perspective with respect to the Project score.

$D_{n,jn}$: Desirability value of the performance measure corresponding to the jn^{th} success attribute under the n^{th} perspective.

4.12 Sensitivity Analysis

Sensitivity analysis method will be used to analyze the impacts of potential changes in the values at any level of the model. This method has been used widely in several studies [105][120]. In HDM, the local contributions of decision elements at one level to decision elements on the next higher level, derived from different judgment quantification methods, are supplied as intermediate input to the hierarchical model. Decisions obtained by evaluating the final ranking of alternatives are based on the local contributions. However, values of the local contributions are seldom known at a 100%

confidence level and are subject to variations as the environment changes. Besides, the various pairwise comparison scales and judgment quantification techniques employed in HDM usually yield different local contribution values, and thus different results for the same problem [135] and various group-opinion combining methods may change the current decision [136][137]. Therefore, the solution of a problem is not complete with the mere determination of a rank order of decision alternatives. Sensitivity analysis (SA) will be conducted with the HDM results to develop an overall strategy to meet the various contingencies [138]. The main objective of using the sensitivity analysis is to illustrate how strong the decisions and the results providing form the model [120]. It is performed to test and assure the robustness of both the model and the results [134]. Moreover, using the sensitivity will give a clear picture of how each level of the model and its components relate to each other [121]. In cases where the model's output is the ranking of different alternatives, the sensitivity analysis is specially useful to tell if and how much that original ranking would change due to changes in the priorities of model's components [98].

The preferred information associated with the decision-making on the evaluation components varies from person to person. Meanwhile, different relative criteria weights have a significant effect on the selection of the most appropriate alternatives. The ranking results are very sensitive to the changes in attribute weights. The presence of different attribute weights may result in different ranking orders [139][132]. Often data in multiple criteria decision-making (MCDM) problems are not exact and changeable. Therefore, an important step in many applications of multiple criteria decision-making is to perform

sensitivity analysis according to the input data [140]. In order to implement sensitivity analysis multiple scenarios can be used to test how much the ranking would be altered in a particular setting. According to Chen and Kocaoglu conducting sensitivity analysis in multiple scenarios will calculate the tolerance of the model to changes [101]. This approach has been implemented in several dissertations [98][105][117] [121].

The original ranking of the model will not be changed if:

$$\lambda \geq P_i^c \cdot \lambda^c$$

For the perturbation P_{l*}^c where

$$-C_{l*}^c \leq P_{l*}^c \leq 1 - C_{l*}^c$$

and

$$\lambda = C_r^A - C_{r+n}^A \quad (15)$$

and

$$\lambda^c = C_{r+n,l}^{A-C} - C_{rl*}^A - \sum_{l=1, l \neq l*}^L C_{r+n,l*}^{A-C} \cdot \frac{C_l^c}{\sum_{l=1, l \neq l*}^L C_l^O} + \sum_{l=1, l \neq l*}^L \frac{C_{rl}^{A-O}}{\sum_{l=1, l \neq l*}^L C_l^O} \quad (16)$$

The allowance range of perturbations C_i^c to maintain the original ranking is given by:

$$[\delta_{i-}^c, \delta C_{i+}^O] \quad (17)$$

$$1/|\delta_{i+}^c, \delta_{i-}^c| \quad (18)$$

Nevertheless, scenario method has been used in this research to assess the robustness of the model and its behavior under different and extreme cases. Under different scenario one factor will be boosted to the max score to test the effect of that factor is if it turned out to be the most important factor in reality.

CHAPTER 5: MULTI CRITERIA DECISION MAKING METHODOLOGIES

The multi-criteria decision-making (MCDM) method is a rational mathematical approach that is widely used by the decision makers to help them in evaluating and selecting the appropriate alternative [141][142][143]. The methods generally have been developed in order to facilitate the selection of an alternative with respect to multiple criteria [144]. In general to achieve the expected result using MCDM approaches, decision makers collect and integrate the required data from the sources. MCDM relies on the availability of several components, including databases and other data resources, a data integration component, a decision support tool and a tool for presenting the results. The figure below shows the processes of applying MCDM [145].

Figure 20: Processes of Applying Multi-Criteria Decision-Making

MCDM methods provide mathematical models to weigh criteria, score alternatives and synthesize the final results. The process of decision making with several criteria is characterized by the following phases [146]:

- Objective identification.
- Criteria development.
- Alternative generation, evaluation and selection.
- Implementation and monitoring [147].

Nevertheless, the multi-criteria decision-making approaches have been integrated with many other tools and techniques in the last few decades. The integrations are mainly with the aim of strengthening and empowering MCDM methods to address various decision problems more effectively [144]. There are currently several MCDM approaches in use. The more frequently employed are listed in the table below.

No	MCDM	Definition	References
1	Analytical Hierarchy Process (AHP)	AHP was proposed by Saaty in 1980 as a method that has been used to solve a wide range of socio-economic decision making problems. AHP is a comprehensive framework, which is designed to cope with the intuitive, the rational, and the irrational. In general, AHP has three steps: <ol style="list-style-type: none"> 1. Structuring the hierarchy between criteria and alternatives. 2. Producing pair-wise comparison matrix. 3. Calculating weight values of criteria and scores of alternative performance. 	[147] [148] [150] [149] [151] [152]
2	Analytical Network	The ANP, also introduced by Saaty, is a	[153] [154]

	Process (ANP)	generalization of the AHP. ANP allows for complex interrelationships among decision levels and attributes. The ANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate, direct or indirect. For instance, not only does the importance of the criteria determine the importance of the alternatives in a hierarchy, but also the importance of the alternatives may have an impact on the importance of the criteria.	[155] [156] [157]
3	Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE)	PROMETHEE was introduced by Brans in 1982. The method has been in several applications, such as tourism, management, logistics, and financial applications.	[158] [159]
4	Multi-criteria optimization and compromise solution or (VIKOR)	The VIKOR is one of MCDM methods to solve multi criteria problems. VIKOR aims to determine a compromise solution for ranking and selection considering conflicting criteria. The compromise solution is a feasible solution, which is the closest to the ideal solution.	[160] [161] [162] [163] [164]
5	Elimination and Choice Expressing Reality or (ELECTRE)	The ELECTRE approach was introduced by Benayoun, Roy and Sussman in 1968. There are different methods of using ELECTRE I, II, III, IV, IS and TRI methods. All ELECTRE methods appear to be similar in describing the concepts but each approach can be used to solve a specific type of problem.	[165] [166] [167] [168] [169] [170] [171]
6	Best Worst Method (BWM)	Compared to other MCDM approaches, BWM requires less data, as it does not need a full pairwise comparison matrix.	[172] [173] [174]
7	Technique for Order	The TOPSIS method, which was proposed	[175] [176]

	of Preference by Similarity to Ideal Solution (TOPSIS)	by Hwang and Yoon(1981), is one of the best known classical MCDM. It is based on the concept that the chosen alternative should have the shortest distance from the positive ideal solution (PIS), and the farthest from the negative ideal solution (NIS).	
8	Decision Making Trial and Evaluation Laboratory (DEMATEL)	DEMATEL was introduced by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva in the 1970s to resolve the complicated and intertwined problem group. It has been widely used in many fields such as supply chain and service quality. The DEMATEL is an effective approach for analyzing relationships between factors of concern with respect to the type and severity.	[177] [178] [179] [180] [181] [182] [183]
9	Hierarchical Decision Model (HDM)	HDM was introduced by Cleland and Kocaoglu. The model can be used as a network of relationships among decision hierarchies, where subjective judgments are provided in a comprehensive evaluation. The HDM has been adopted by decision makers in various industries.	[107] [108] [109] [110]

Table 10: Multi-criteria decision-making approaches

5.1 Decision Making Approaches in Oil Industry

Oil sector is characterized by high investment decisions and most of these decisions can be seen as a balance between the costs and profits. However, this industry is closely associated with high uncertainties, risks as well as opportunities, which raises the complexity of the decision-making processes. Oil and Gas companies use different techniques and methods to improve performance and make the right decisions [184] in

particular, net present value (NPV) calculations, discounted cash-flow analysis, Monte Carlo simulation, portfolio theory, decision-tree analysis, and option theory [185][186]. Nevertheless, decision-tree analysis and Monte Carlo simulation are the most appropriate approaches that have been used in O&G industry to support the investment decisions. The following is a brief introduction of these methods as well as their strengths and weaknesses.

5.1.1 Decision Trees Analysis (DTA)

The decision tree methodology is one of the most commonly used data mining methods [187][188][189] and it is widely applied to investment decision-making in Oil and Gas industry [206]. Decision tree provides a clear understanding to the problem and encourages the decision-maker to consider the entire sequential course of action, before the initial decision [189]. The decision tree makes use of conditional probability to determine the best strategy to attain a certain target [191]. It is a method for combining profitability estimates of risk and uncertainty to yield a risk-adjusted decision criterion [189]. Decision tree analysis is able to identify several scenarios within the framework of management ability to improve the project viability and profitability, tied with their probabilities of success. It also helps analysts form a balanced picture of risks, their associated rewards and possible courses of action [191]. In oil industry decision tree focus on managerial decisions such as whether to drill additional wells, or to develop the field or not [192]. The following is a sample example shows how DTA could be used in oil industry.

The initial exploration activities of Offshore Oil Company (A) have led to discover a hydrocarbon field. However, the company has a little information of the size of the reserves and the decision makers should make a decision what size of platform the company should build to start the production. Installing the wrong size platform would be an expensive mistake and will cost the company a huge amount of money.

There are three different scenarios.

- It would be optimal for the company to install a large platform.
- Installing a small platform would be more appropriate decision.
- The company prefers to wait and obtain more information on the reserves before making decision.

The probability of finding large reserve is 60% and that of finding a small reserve would be about 40%. Moreover, installing a large platform when the reserves prove to be large generates an NPV of 170 and 110 for small field. Moreover, installing a small platform when the reserves prove to be small generates an NPV of 130 and 150 for large field. NPV would be 165 for the large field if additional information is obtained and 125 for the small.

Figure 21: DTA Implementation in Oil Industry

In order for the decision maker to make a decision they have to calculate the profit for each scenario.

$$(170 * 0.6) + (110 * 0.4) = 146$$

$$(165 * 0.6) + (125 * 0.4) = 149$$

$$(150 * 0.6) + (130 * 0.4) = 142$$

Based on the calculation, the best decision would require additional reserve's information and implement seismic test before choosing the size of the platform. Furthermore, decision tree analysis can be combined with other decision techniques to analyze many investment projects particularly when uncertainty is incorporated in the decision at discrete points [191]. In reality, each tool has strengths and weaknesses

[193][190] and the following is the highlighting advantage and disadvantage of using decision tree analysis.

5.1.1.1 Strengths of Using Decision Tree Analysis (DTA)

1. Decision tree can state out the problem clearly and it is easy to modify a decision tree as new information becomes available. Set up a decision tree to compare how changing input values affect various decision alternatives. Standard decision tree notation is easy to adopt [194].
2. It can be fit into project management tools. For example, the decision tree method can help evaluate project schedules [195] and decision trees can handle both nominal and numerical attributes and is considered as a nonparametric method [196].
3. Decision trees are capable of handling datasets that may have errors and missing values [194].

5.1.1.2 Limitations of Decision Tree Analysis (DTA)

1. Big and complex decision trees require professional users and experts to solve it. Computing probabilities of different possible branches, determining the best split of each node, and selecting optimal combining weights to prune algorithms contained in the decision tree are complicated tasks that require much expertise and experience.
2. Decision trees, while providing easy to view illustrations, can also be unwieldy. Even data that is perfectly divided into classes and uses only simple threshold

tests may require a large decision tree. Large trees are not intelligible, and pose presentation difficulties.

3. The complexity in creating large decision trees mandates people involved in preparing decision trees having advanced knowledge in quantitative and statistical analysis. This raises the expenditure and cost.
4. Another limitation of the decision tree method is that when evaluating a project with this approach, subjective probabilities and a risk-adjusted discount rate are usually applied. Although it may capture both time and risk preference of the investor, it is not appropriate when many options are present in the investment evaluation [191].
5. Naturally, decision makers prefer less complex decision trees, since they may be considered more comprehensible. Furthermore, according to Breiman (1984) the tree complexity has a crucial effect on its accuracy [194].
6. Irrelevant attributes may affect the construction of a decision tree adversely and a sub-tree can be replicated several times.
7. It is true that decision trees can handle missing values but this also has a disadvantage. Handling the missing data requires a lot of computation which is a drawback by means of computational time.
8. One of the important limitation of using decision tree analysis in O&G industry is that DTA method mainly estimates EV. Its criterion assumes that the decision-maker is only interested in monetary gain [197]. However, when a company is deciding how best to decommission an offshore production facility, for example,

they will want to consider other factors such as corporate image and environmental concerns. All these attributes, like the monetary returns, would have some degree of risk and uncertainty associated with them [190].

5.1.2 Monte Carlo Simulations

Monte Carlo approach was introduced by Metropolis and Ulam in 1949 [198]. It is a numerical experimentation technique to obtain the statistics for the output variables of a system model given the statistics for the input variables. The method is considered as one of the powerful tools in risk analysis, and evaluating all kinds of uncertainties [198][199]. Monte-Carlo simulation method is also called Random simulation or Random sampling technology. In recent decades, with the development of computer technology, this method has been developing rapidly and widely used. At present, Monte-Carlo simulation has been applied to physics, medicine, materials science, agriculture, transportation, management science, social science and many other areas [199]. In the field of the project management Monte Carlo simulation is used primarily in project risk management to estimate the risks associated with the time and the cost of the project [200][201]. The use of Monte Carlo simulation allows not only to find the most likely time or budget of the project, but also to compute their probability of occurrence of any value specified [202]. A summary of the steps used in performing a Monte Carlo simulation are shown in the following pattern [202]:

1. Define an input domain.
2. Generate input variables randomly from the input domain.

- The awareness of using Monte Carlo simulation in O&G industry has increased in the past few years. Decision maker in O&G industry rely on Monte Carlo simulation to generate estimates of prospect reserves as well as the probability of the projects [190]. The equation below shows how the Monte Carlo simulation could calculate the NPV for a simplified oil project with a life of n years, and using a discount rate i [192].

1. Monte Carlo Simulations allows the analyst to describe risk and uncertainty as a range and distribution of possible values for any unknown factor [190].
2. Monte Carlo Simulations allows the analyst to identify factors that have the most significant effect on the resulting values of profit and it can fit with other

approaches such as sensitivity analysis to understand the impact of these factors further [190].

5.1.2.2 Limitation of Using Monte Carlo Simulations

1. One of biggest limitation of using Monte Carlo simulations in oil industry is that a Monte Carlo simulation is not able to assess factors that affect the oil industry such as oil price, political factors and environmental factors and it is mainly used to calculate the NPV and the profitability of the project [190].
2. Applying Monte Carlo simulations to solve decision making problems is quite complicated and requires a large amount of data for analysis and many factors for consideration. Moreover, the decision maker should be familiar with it in order to solve the problem.
3. Applying Monte Carlo simulation requires professional users and experts to solve it and analyze the results.

5.2 Why the HDM Approach is Implemented in this Research

Decision-making could be based on an economic analysis that involves the assessment of revenues and costs, potentially materializing in the future as a result of investments made at the current time. However, decision-making in the oil and gas projects need to be evaluated from extensive points of view since they are influenced by technical, environmental, financial, economical, geopolitical and other perspectives. The investment decision in the oil industry has to be quick and continuous based on the available information [186]. Using the hierarchical decision model (HDM) approach to

make decisions on oil industry has many advantages, and the following is a summary of these benefits.

1. Other methods are mainly focused on economic aspects such as NPV and return on investment. However, the HDM provides a comprehensive evaluation to all factors that impact oil projects such as technical, environmental, financial, economical, and geopolitical.
2. The HDM is a great method to handle different scenarios, and it can be conducted with other tools, such as sensitivity analysis, to provide a clear picture of the problem for decision makers.
3. Decision making in the oil industry is associated with a higher level of complexity and requires large amounts of information and many qualified people who have significant experience to provide their evaluation in the decision making process. Using a HDM in oil industry requires qualified people from all levels that can increase the interaction between top level decision makers with that of technicians and engineers from different departments and divisions.
4. Using the HDM, oil companies can make quick and continuous decisions based on the evaluation results provided by their experts and engineers.
5. In general, the HDM is a great tool to conduct the academic researcher's standpoint of real in-field practices by involving experts in this process. Moreover, the HDM is a great way to translate qualitative data into quantitative information that will make it much easier for decision makers to analyze the problem and define solutions.

CHAPTER 6: MODEL DEVELOPMENT AND PANELS FORMAT

This section introduces the initial model of the research as well as the definition of each component of the model. Moreover, this chapter presents the required experiences, expertise and area of interest for each panel.

6.1 Initial Model

The decision model is based on the comprehensive literature review that was described in the previous sections as well as based on experts' feedbacks and recommendations through the third independent study. Five perspectives have been identified in order to assess and measure the offshore oil projects to improve the investment decision. These perspectives are financial, technical, politics, environmental and safety. Under each perspective there are multiple criteria that are linked to each other with complex processes and unique challenges. An assessment of these challenges associated with offshore oil projects lead to reduced risk and an increased probability of success. Prospects in offshore petroleum projects encounter several challenges such as, safety performance, production performance, geologic and subsurface reservoir uncertainty, government stability, oil spills. Figure 23 illustrates the research model.

Figure 23: Initial Research Model

6.2 Model Levels and Definition

The initial model contents four different levels as following model mission, perspectives level, criteria level and desirability carve.

6.2.1 Level (1) Model Mission

The mission level states the objective of this research, which is evaluating offshore oil projects.

6.2.2 Level (2) Perspectives

		Definition	References
Level (2) Perspectives	Economical	The economic evaluation underlying the investment decision is based on the entity's reasonable forecast of future conditions, including costs and prices, which will exist during the life of the project.	[10][29][30][4][31][32][33]
Level (3) Criteria	Oil Price:	The price of a barrel of oil is one of the most important variables in determining company's capital investment strategy. A change in oil price will affect the whole project. The prices will be different from one project to another based on production starting time, characteristics and quality of the oil. There are about 160 crude oils that are traded internationally. They vary in terms of their characteristics & quality.	[10] [29]
	Initial Cost:	Offshore projects cost a huge amount of money and initial cost is a major challenge to start-up these kinds of projects.	[30][4]
	Operational Cost:	Operating expenses is the key to maintain production and stay in business. Operational cost include staff expenditure, subsea, pollution control, water injection, maintenance, insurance, transport charges, miscellaneous etc.	[31][32] [33]

Table 11: Definition of Economical Perspective and Criteria

Level (2) Perspectives		Definition	References
	Technical	Technical implications are one of challenging factors that are faced by project managers and decision makers in offshore hydrocarbon projects. These include operational difficulties, large size & multiple scopes, production and reservoir performance etc.	[34][35][36][37][38][39][40][41][4][10][42][43][30][14][44]
Level (3) Criteria	Operational Difficulties	Offshore petroleum projects face different types of operational difficulties such as, complex working equipment, harsh weather conditions, limited access to safety points, hydrocarbon releases, fire, high degrees of temperature and pressure, fatigue, etc.	[34][35][36][37][38][39][40][41]
	Size & Complexity	Offshore projects have a larger number of sub-scopes, such as well, subsea system, production system, transportation system, etc. These individual project sub-scopes are also quite large with costs in the hundreds of millions of dollars.	[4][10]
	Production Performance	If a project fails to produce the planned production, it should be considered a failure because the production volume of the oil and gas is one of the key factors to determine a project's profitability.	[4][42]
	Reservoir Uncertainty	Even though, geological and geophysical clues can be reassuring, but drilling is the only way to confirm if an oil or gas field actually exists in that location. The geologic and seismic uncertainty can cause the company to lose money and waste time and resources.	[43][30][14][44]

Table 12: Definition of Technical Perspective and Criteria

		Definition	References
Level (2) Perspectives	Political	Politics is a central concern for the O&G sector and can be viewed as a source of both risk and opportunity. It is no coincidence that one of the top risks facing oil offshore project, as identified by most recent risk studies, was geopolitics.	[45][46] [47][49][50] [2] [51][52][42] [14][11]
Level (3) Criteria	Government Stability	Oil and Gas companies tend to prefer countries with stable political systems and a history of granting and enforcing long-term leases.	[45][47]
	Conflict Over Maritime Claims	The conflict over maritime most likely occurs when the high production performance has been achieved which means that a lot of money and effort have already been put on the project, so any cancellation or delay can lead to a disaster.	[48][49][50] [2]
	Policies, Regulations & Governance Standards	The success of a petroleum project is greatly influenced by political and regulation uncertainty, such as changing taxes, public service announcement terms, workplace health, safety and environmental security, government stability in the developing countries, etc.	[51][52][42]
	Contracts Complexity	O&G companies are required to have a license to explore for hydrocarbons. Also, due to the larger number of sub-scopes, such as well, subsea system, production system, transportation system, etc. O&G companies are required to implement and manage multiple contractors. These kind of individual contractors increase the cost and risk.	[14][11]

Table 13: Definition of Political Perspective and Criteria

		Definition	References
Level (2) Perspectives	Environmental	Environmental impacts of oil and gas operations may influence species, populations, assemblages, or ecosystems by modifying a variety of ecological parameters. Potential environmental issues associated with offshore oil and gas development projects include the following: Air emissions, Wastewater discharges, Solid and liquid waste management, Noise generation and Spills.	[53][54][55][56][57][58][59][60][32][61][62][63][64][65][66][67][68][25][69][70][71][72][73][74]
Level (3) Criteria	Air Emissions	The main sources of air emissions resulting from offshore activities include: combustion sources from power and heat generation, and the use of compressors, pumps, and reciprocating engines on offshore facilities including support and supply vessels and helicopters; emissions resulting from flaring and venting of hydrocarbons; and fugitive emissions.	[53][54][55][56][57][58][59][60][32]
	Solid & Liquid Waste Management	Typical non-hazardous and hazardous wastes routinely generated at offshore facilities include general office and packaging wastes, waste oils, oil contaminated rags, hydraulic fluids, used batteries, empty paint cans, waste chemicals and used chemical containers, used filters, fluorescent tubes, scrap metals, and medical waste.	[61][62][63][64][60]
	Noise Generation	O&G offshore activities generating marine noise include seismic operations, drilling and production activities, offshore and near shore structural installation and construction activities, and marine traffic.	[65][66][67][56][68][25][60][69][70]
	Oil Spills	Spills from offshore facilities can occur due to leaks, equipment failure, accidents, or human error. Abilities to respond to oil spills are extremely limited, posing significant challenges for implementing pollution prevention techniques.	[71][72][73][74]

Table 14: Definition of Environmental Perspective and Criteria

		Definition	References
Level (2) Perspectives	Safety	Offshore petroleum projects function in unsafe environments and constantly deal with risky products. Due to the nature of the work environment and the properties of the products, offshore O&G projects pose more serious safety threats to the workers than their counterparts in other industries.	[75][76][77][4] [78][79][80][81][82][83][9][84][85]
Level (3) Criteria	Hazard Identification & Risk Management	Hazard identification is an essential step before project implementation and during the project lifecycle phases. Issues potentially impacting safety and environmental stewardship are promptly identified, fully evaluated, and promptly addressed or corrected commensurate with their significance.	[75][76][4][77][78][79][80][81][82]
	Implementing Health, Safety and Environmental (HSE)	Early evaluation of implementing health, safety and environmental (HSE) principles is essential to the success of the project. HSE principles contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technologies at reasonable costs.	[83][84][85][86]

Table 15: Definition of Safety Perspective and Criteria

6.3 Experts' Specialized

Finding the right expert is one of the baggiest challenges in this research. It is very important to classify the experts and what their areas of interest are so that they can fit in with the panel requirements before we select them. The basic criteria for choosing and inviting experts to participate in the study were: Expertise in the field, contributions to the field, absence of conflicts of interest, willingness to participate, and availability to

participate. The methods used in selecting the experts were social network analysis and professional connections, both complemented by snowball sampling. In reference to the discussion of the experts' characteristic in section 4.6 this research implements experts metrics identification to ensure that expert biases were under control and not impairing an objective interpretation of the results. The table below shows the required experiences and area of interest for each panel.

Panel No.	Panel Focus	Required Expertise
Panel 1	To validate the literature based hierarchical decision model.	Project Managers Finance Specialists Project Design Policy Managers Environmental Engineers Technical Specialists
Panel 2	To quantify the perspective level and its contribution to the decision level.	Project Managers Project Design
Panel 3	To quantify the economical perspective of the model.	Project Managers Finance Specialists
Panel 4	To quantify the technical perspective of the model.	Project Managers Technical Specialists
Panel 5	To quantify the political perspective of the model.	Project Managers Policy Managers
Panel 6	To quantify the Environmental & Safety perspective of the model.	Project Managers Safety Managers
Panel 7	To validate and quantify the desirability curve.	Project Managers Finance Specialists Project Design Policy Managers Environmental Engineers

		Technical Specialists
Panel (8)	To validate and evaluate the application case and results	Project Managers Finance Specialists Project Design Policy Managers Environmental Engineers Technical Specialists

Table 16: Required Experiences Each Panel

6.4 Expert Panels Format

A total of 43 Experts responded to the invitation and participated in the research expert panels. Appendix A includes a sample of the invitation letter sent to experts. The 43 experts were identified based on their specializations and qualifications that were described in the pervious section. Table 17 illustrates a list of the experts along with their backgrounds, job titles and their countries.

NO.	Current Position	Country	P1	P2	P3	P4	P5	P6	P7	P8
Expert 1	O&G Offshore Project Manager	Ghana	X							
Expert 2	O&G Offshore Project Manager	Italy	X							
Expert 3	O&G Offshore Project Manager	Ghana	X							
Expert 4	O&G Offshore Project Manager	Ghana	X							
Expert 5	O&G Offshore Project Manager	Portugal	X							
Expert 6	O&G Offshore Project Manager	Italy	X							
Expert 7	Senior Manager	Malaysia	X							
Expert 8	O&G Offshore Project Manager	Houston, Texas	X							

Expert 9	O&G Offshore Project Manager	Bahrain	X							
Expert 10	O&G Offshore Project Manager	Libya	X						X	X
Expert 11	Technical Director & Project Manager	Indonesia	X							
Expert 12	O&G Offshore Project Manager	Houston, TX	X							
Expert 13	O&G Offshore Project Manager	Libya	X						X	X
Expert 14	Chief Operating Officer	Saudi Arabia	X							
Expert 15	O&G Offshore Project Manager	Qatar	X							
Expert 16	Vice President, Group Category Management	UAE		X						
Expert 17	Manager of Operations Business Processes & Data Management	Russian		X						
Expert 18	Project Manager	Houston, Texas		X						
Expert 19	Executive Director	United Kingdom		X						
Expert 20	Senior Manager of Deep Water R&D Operation (Subsea & Offshore Operations)	Brazil		X						
Expert 21	Senior Drilling Engineer	Houston, Texas		X						
Expert 22	Project Manager	Russia			X	X				
Expert 23	Upstream Program Manager	Brazil			X					
Expert 24	Offshore Drilling Manager	Pakistan			X					
Expert 25	Strategic Oil and Gas Executive	Dallas, Texas			X					
Expert 26	Project Control & Budget Planning	Argentina			X					

Expert 27	Project Manager	Brazil			X					
Expert 28	Senior Controller/ Accounting Manager	Italy			X					
Expert 29	Drilling Engineer	Russia				X				
Expert 30	Quality Manager, Site Manager	Germany				X				
Expert 31	Senior Project Manager	India				X				
Expert 32	Product Development and Project Manager	Saudi Arabia				X				
Expert 33	Chief Well Engineer	USA					X			
Expert 34	Project Drilling Manager	Spain					X			
Expert 35	Operations Manager	D.R. Congo					X			
Expert 36	Global Markets Manager	Oman					X			
Expert 37	Project Data Engineer	United Kingdom					X			
Expert 38	Senior Staff Process Safety Engineer	Saudi Arabia						X		
Expert 39	Drilling Ops & Rig Manager	Russia						X		
Expert 40	Drilling Manage	UAE						X		
Expert 41	Chef Department Environmental Group	France						X		
Expert 42	QHSE Engineer	Brazil						X		
Expert 43	Production Manager	Libya							X	X

Table 17: Panels Distribution

- Panel (1): was formed to validate the model.

- Panel (2) was formed to quantify the perspective level and its contribution to the decision level.
- Panel (3) was formed to quantify the economical criteria.
- Panel (4) was formed to quantify the technical criteria.
- Panel (5) was formed to quantify the political criteria.
- Panel (6) was formed to quantify the environmental & safety criteria.
- Panel (7) was formed to validate and quantify the desirability curves.
- Panel (8) was formed to validate and evaluate the case application and results.

6.5 Data Collection

Experts were invited using email and linkedin.com. Appendix A includes a sample of the invitation. In addition, email and linkedin.com were used to send the details for participating in the model validation and the model quantification. Appendix B and C include samples of the communications with experts. Qualtrics surveys and one-on-one interviews were used to elicit expert's judgment and feedback for both the validation and quantification steps of the research model. Furthermore, results from quantification were re-entered by the researcher into HDM tool for further analysis.

CHAPTER 7: MODEL VALIDATION, QUANTIFICATION AND DESIRABILITY CURVES DETERMINATION

This chapter introduces the steps that were applied to validate the model. In addition, this chapter presents the results of quantification phase and how the desirability curves were determined.

7.1 Model Validation

As it has been mentioned in chapter three the main purpose of the validation phase is to answer the following questions:

- 1- Does the model capture the necessary elements needed to satisfy the research goal?
- 2- Does the model valid to apply?

The initial model was validated by the experts based on the steps that were described in the validation processes chart below. Two rounds of validation took place using a Qualtrics survey (see Appendix B for the survey format). In the first round, experts evaluated the factors identified by the research as the most critical factors affecting the investment decision in offshore oil project. Experts also were given a chance to suggest other factors based on their experience. In the second round experts validated the factors that were added to the model based on the first round experts' feedback.

Figure 24: Validation Processes Chart

To validate the items successfully, at least three-quarters of the panelists [75% acceptance rate] should indicate that the captured factor is essential [101][109]. Fifteen experts participated in validation phase from ten different organizations and eleven countries. Expert panel P1 was formed to validate the literature based hierarchical decision model. The experts were selected based on their expertise in the offshore oil field.

NO.	Current Position	Country
Expert 1	O&G Offshore Project Manager	Ghana
Expert 2	O&G Offshore Project Manager	Italy
Expert 3	O&G Offshore Project Manager	Ghana
Expert 4	O&G Offshore Project Manager	Ghana
Expert 5	O&G Offshore Project Manager	Portugal
Expert 6	O&G Offshore Project Manager	Italy
Expert 7	Senior Manager	Malaysia
Expert 8	O&G Offshore Project Manager	Houston, Texas

Expert 9	O&G Offshore Project Manager	Bahrain
Expert 10	O&G Offshore Project Manager	Libya
Expert 11	Technical Director & Project Manager	Indonesia
Expert 12	O&G Offshore Project Manager	Houston, TX
Expert 13	O&G Offshore Project Manager	Libya
Expert 14	Chief Operating Officer	Saudi Arabia
Expert 15	O&G Offshore Project Manager	Qatar

Table 18: List of Experts in Validation Panel

7.1.1 Perspectives Validation

Fifteen experts were participated to validate the perspectives level. The panelists indicated that all the perspectives items were essential. However, most of the experts agree that environmental and safety should be captured under one perspective.

Figure 25: Perspectives Validation Results

7.1.2 Economical Criteria Validation

Fifteen experts were participated to validate the economical factors. The panelists indicated that all of the economical items were essential. Moreover, experts were suggested that return on investment should be added to the economical criteria.

Figure 26: Economical Validation Results

7.1.3 Technical Criteria Validation

Fifteen experts were participated to validate the technical factors. The panelists indicated that all of the technical items were essential.

Figure 27: Technical Validation Results

7.1.4 Political Criteria Validation

Fifteen experts were participated to validate the political factors. The panelists indicated that all of the political items were essential.

Figure 28: Political Validation Results

7.1.5 Environmental Criteria Validation

Fifteen experts were participated to validate the environmental factors. The panelists indicated that two of the environmental items were essential and two were rejected. Moreover, experts recommended that environmental factors related to the safety perspective.

Figure 29: Environmental Validation Results

7.1.6 Safety Criteria Validation

Fifteen experts were participated to validate the safety factors. The panelists indicated that all of the safety items were essential. Moreover, experts were suggested that stringent of the local HSE standards and environmental risk management integration should be added to the economical criteria.

Figure 30: Safety Validation Results

7.2 Second Round of the Validation Phase

Based on the experts feedback form the first round three more factors were added to the model and validated return on investment (ROI), stringent of the local HSE standards and environmental risk management Integration. Fifteen experts were participated in the second round to validate the changes and the new factors. The panelists indicated that all of the new items were essential.

Figure 31: Second Round Validation Results

7.2.1 Return on investment (ROI)

A higher ROI number does not always mean a better investment option. For example, two investments have the same ROI of 50%. However, the first investment is completed in three years, while the second investment needs five years to produce the same yield. The same ROI for both investments blurred the bigger picture, but when the factor of time was added, the investor easily sees the better option. The investor needs to compare two instruments under the same time period and same circumstances [204]. In this research annualized ROI was implemented in order to evaluate different offshore oil projects under the same time period and same circumstances. The annualized ROI calculated as following:

$$\text{Annualized ROI} = [(\text{Ending Value} / \text{Beginning Value}) ^ (1 / \text{Number of Years})] - 1 \quad (19)$$

$$\text{Where: Number of years} = (\text{Ending date} - \text{Starting Date}) / 365 \quad (20)$$

7.3 Final Model

The figure below shows the validated hierarchical decision model that will be used to evaluate offshore oil projects.

Figure 32: Final Model

7.4 Research Quantification

Twenty-seven experts were agreed to participate in the quantification phase in order to quantify the research model and score each factors based on its relative importance to the mission level. In this phase five panels have been formatted including perspectives quantification, economical quantification, technical quantification, political quantification and environmental & safety quantification. As it was explained in previse chapter, experts' judgments were captured through pair-wise comparisons utilizing the constant-sum method. Each comparison is made by distributing 100 points between the pair of items being compared. Data is collected through an online survey tool and the analysis is

done using the HDM software, which also calculated the individual logical inconsistencies and the group disagreements (see Appendix E for the HDM software analysis). In order to quantify the decision for each element, HDM uses pairwise comparison technique. The following equation shows the number of pairwise comparisons [96].

$$N = \frac{n(n-1)}{2} \quad \text{for,} \quad n > 0 \quad (21)$$

Where:

N: number of pair-wise comparisons.

n: number of elements.

By applying this equation, we can find the number of pairwise comparisons that have been made by the experts for each panel. The following explanation illustrates how many pairwise comparisons the participants went through for each panel.

- **Perspective Level:** The experts were asked to compare the contribution of the four perspectives to the overall research objective of offshore oil projects evaluation. Based to the equation the experts completed six comparisons to determine the level output.

Number of comparisons = $[(4*3)]/2 = 6$

- **Economical:** The experts were asked to assess the relative contribution of the four success attributes to the Economical perspective. Based to the equation the experts completed six comparisons to determine the level output.

Number of comparisons = $[(4*3)]/2 = 6$

- **Technical Level:** The experts were asked to assess the relative contribution of the four success attributes to the technical perspective. Based to the equation the experts completed six comparisons to determine the level output.

Number of comparisons = $[(4*3)]/2 = 6$

- **Political Level:** The experts were asked to assess the relative contribution of the four success attributes to the political perspective. Based to the equation the experts completed six comparisons to determine the level output.

Number of comparisons = $[(4*3)]/2 = 6$

- **Environmental & Safety:** The experts were asked to assess the relative contribution of the four success attributes to the environmental perspective. Based to the equation the experts completed six comparisons to determine the level output. Number of comparisons = $[(4*3)]/2 = 6$

Panel	Panel Focus
P2	Perspective Level Quantification
P3	Economical Quantification
P4	Technical Quantification
P5	Political Quantification
P6	Environmental & Safety Quantification

Table 19: Quantification Expert Panels Breakdown

7.4.1 Perspectives Quantification

Panel 2 consisted of 6 participants. They were asked to compare the contribution of the four perspectives to the overall research objective of evaluating offshore oil projects.

The experts completed six comparisons to determine the output shown in table 21.

NO.	Current Position	Country
Expert 16	Vice President, Group Category Management	United Arab Emirates
Expert 17	Manager of Operations Business Processes & Data Management	Russia
Expert 18	Project Manager	Houston, Texas
Expert 19	Executive Director	United Kingdom
Expert 20	Senior Manager of Deep Water R&D Operation (Subsea & Offshore Operations)	Brazil
Expert 21	Senior Drilling Engineer	Houston, Texas

Table 20: Expert in Panel 2

	Economical	Technical	Political	Environmental & Safety	Inconsistency
Expert 16	0.36	0.12	0.25	0.27	0.02
Expert 17	0.35	0.11	0.26	0.28	0.04
Expert 18	0.3	0.13	0.31	0.27	0
Expert 19	0.38	0.09	0.17	0.35	0.04
Expert 20	0.28	0.22	0.2	0.31	0.03
Expert 21	0.27	0.18	0.26	0.29	0.07
Mean	0.32	0.14	0.24	0.3	
Minimum	0.27	0.09	0.17	0.27	
Maximum	0.38	0.22	0.31	0.35	
Std. Deviation	0.04	0.04	0.05	0.03	
Disagreement					0.038

Table 21: Perspectives Quantification Results

Figure 33: Perspectives Quantification

The inconsistency within each expert is acceptable (all < 0.10). Based on this panel's results, the economical perspective is assessed as the most important factor with (0.32) score followed by environmental & safety perspective with (0.30) score.

7.4.2 Economical Quantification

Panel P3 consisted of 7 participants. They were asked to assess the relative contribution of the four success attributes to the economics perspective. The experts completed six comparisons to determine the output shown in table 23.

NO.	Current Position	Country
Expert 22	Project Manager	Russia
Expert 23	Upstream Program Manager	Brazil
Expert 24	Offshore Drilling Manager	Pakistan
Expert 25	Strategic Oil and Gas Executive	Dallas, Texas
Expert 26	Project Control & Budget Planning	Argentina
Expert 27	Project Manager	Brazil
Expert 28	Senior Controller/ Accounting Manager	Italy

Table 22: Experts in Panel 3

	Oil Prices	Initial Cost	Operational Cost	Return on Investment	Inconsistency
Expert 22	0.4	0.15	0.16	0.29	0.03
Expert 23	0.41	0.13	0.17	0.28	0.01
Expert 24	0.48	0.14	0.16	0.22	0.01
Expert 25	0.37	0.12	0.07	0.43	0.01
Expert 26	0.25	0.24	0.21	0.31	0.02
Expert 27	0.28	0.17	0.14	0.4	0.08
Expert 28	0.25	0.26	0.18	0.31	0
Mean	0.35	0.17	0.16	0.32	
Minimum	0.25	0.12	0.07	0.22	
Maximum	0.48	0.26	0.21	0.43	
Std. Deviation	0.08	0.05	0.04	0.07	
Disagreement	0.06				

Table 23: Economical Criteria Quantification Results

Figure 34: Economical Quantification

The inconsistency within each expert is acceptable (all < 0.10). Based on this panel, oil price criterion is assessed as the most important factor with a score of (0.35).

7.4.3 Technical Quantification

Panel P4 consisted of 5 participants. They were asked to assess the relative contribution of the four success attributes to the technical perspective. The experts completed six comparisons to determine the output shown in table 25.

NO.	Current Position	Country
Expert 29	Drilling Engineer	Russia
Expert 22*	Project Manager	Russia
Expert 30	Quality Manager, Site Manager	Germany
Expert 31	Senior Project Manager	India
Expert 32	Product Development and Project Manager	Saudi Arabia

Table 24: Experts in Panel 4

Technical	Operational Difficulties	Project Size & Complexity	Production Performance	Reservoir Uncertainty	Inconsistency
Expert 29	0.12	0.24	0.43	0.22	0.04
Expert 22*	0.07	0.11	0.32	0.51	0.08
Expert 30	0.1	0.1	0.36	0.45	0
Expert 31	0.26	0.29	0.27	0.18	0
Expert 32	0.18	0.25	0.31	0.26	0.04
Mean	0.15	0.2	0.34	0.31	
Minimum	0.07	0.1	0.27	0.18	
Maximum	0.26	0.29	0.43	0.51	
Std. Deviation	0.07	0.08	0.05	0.13	
Disagreement					0.084

Table 25: Technical Criteria Quantification Results

Figure 35: Technical Quantification

The inconsistency within each expert is acceptable (all < 0.10). Based on this panel, production performance criteria is assessed as the most important factor with a score of (0.34).

7.4.4 Political Quantification

Panel P5 consisted of 5 participants. They were asked to assess the relative contribution of the four success attributes to the political perspective. The experts completed six comparisons to determine the output shown in table 27.

NO.	Current Position	Country
Expert 33	Chief Well Engineer	USA
Expert 34	Project Drilling Manager	Spain
Expert 35	Operations Manager	Democratic Republic of the Congo
Expert 36	Global Markets Manager	Oman
Expert 37	Project Data Engineer	United Kingdom

Table 26: Experts in Panel 5

	Government Stability	Conflict Over Maritime Claims	Policies, Regulations & Governance Standards	Contracts Complexity	Inconsistency
Expert 33	0.48	0.07	0.31	0.14	0.05
Expert 34	0.4	0.18	0.24	0.18	0.03
Expert 35	0.16	0.07	0.38	0.39	0.07
Expert 36	0.19	0.19	0.22	0.4	0.05
Expert 37	0.35	0.16	0.27	0.22	0
Mean	0.32	0.13	0.28	0.27	
Minimum	0.16	0.07	0.22	0.14	
Maximum	0.48	0.19	0.38	0.4	
Std. Deviation	0.12	0.05	0.06	0.11	
Disagreement	0.085				

Table 27: Political Criteria Quantification Results

Figure 36: Political Quantification

The inconsistency within each expert is acceptable (all < 0.10). Based on this panel, government stability criteria is assessed as the most important factor with a score of (0.32).

7.4.5 Environmental & Safety Quantification

Panel P6 consisted of 5 participants. They were asked to assess the relative contribution of the four success attributes to the environmental & safety perspective. The experts completed six comparisons to determine the output shown in table 29.

NO.	Current Position	Country
Expert 38	Senior Staff Process Safety Engineer	Saudi Arabia
Expert 39	Drilling Ops & Rig Manager	Russia
Expert 40	Drilling Manage	United Arab Emirates
Expert 41	Chef Department Environmental Group	France
Expert 42	QHSE Engineer	Brazil

Table 28: Experts in Panel 6

	Hazard Identification and Risk Management	Implementing Health, Safety and Environmental	Stringent of the Local HSE Standards	Environmental Risk Management Integration	Inconsistency
Expert 38	0.39	0.18	0.27	0.16	0
Expert 39	0.24	0.22	0.35	0.19	0
Expert 40	0.27	0.18	0.33	0.22	0.03
Expert 41	0.46	0.23	0.16	0.15	0.05
Expert 42	0.35	0.22	0.27	0.16	0.04
Mean	0.34	0.21	0.27	0.18	
Minimum	0.24	0.18	0.16	0.15	
Maximum	0.46	0.23	0.35	0.22	
Std. Deviation	0.08	0.02	0.07	0.03	
Disagreement					0.048

Table 29: Environmental & Safety Criteria Quantification Results

Figure 37: Environmental & Safety Quantification

The inconsistency within each expert is acceptable (all < 0.10). Based on this panel, Hazard identification & risk management criteria is assessed as the most important factor with a score of (0.34).

7.5 Final Model Weights

The output of experts' judgment quantification has been summarized in Table 30 and Figure 38. The table includes local and global importance values for each factor. The most important perspective is economic with a score of 0.32 and the corresponding most important success attribute is oil price 0.35. The experts scored environmental and safety as the second most important perspective with a value of 0.3 and indicated that it is affected by the hazard identification and risk management criterion that has a value of 0.34. Nevertheless, return on investment, production performance, and government stability have high impacts on offshore oil project overall evaluation based on experts' judgment quantification.

Perspectives	Value	Criteria	Local Value	Global Value
Economical	0.32	Petroleum Prices	0.35	0.12
		Initial Cost	0.17	0.05
		Operational Cost	0.16	0.05
		Return on Investment (ROI)	0.32	0.10
Technical	0.14	Operational Difficulties	0.15	0.02
		Project Size & Complexity	0.2	0.03
		Production Performance	0.34	0.05
		Reservoir Uncertainty	0.31	0.04
Political	0.24	Government Stability	0.32	0.08
		Conflict Over Maritime Claims	0.13	0.03
		Policies, Regulations & Governance Standards	0.28	0.07
		Contracts Complexity	0.27	0.06
Environmental & Safety	0.3	Hazard Identification and Risk Management	0.34	0.10
		Implementing Health, Safety and Environmental (HSE)	0.21	0.06
		Stringent of the Local HSE Standards	0.27	0.09
		Environmental Risk Management		
		Integration	0.18	0.05

Table 30: Experts' Judgment Quantification Output

The following graph shows the final global weights that represent the contribution of each criterion to the mission through the perspectives.

Figure 38: Final Model Weights

7.6 Model Inconsistency Results

Inconsistency is one of the critical factors that could affect the results of the model and it should be calculated and controlled in order to achieve reliable outcomes. Acceptable inconsistency has a value of 0.1 or less, according to Kocaoglu. Experts' judgment was analyzed mathematically for inconsistency (more details about

inconsistency analysis can be found in Sections 4.9). Based on the HDM results, inconsistency value among the experts is described as the following:

- The highest inconsistency value among the experts in P2 (Perspective Panel) was 0.07. The highest inconsistency value among the experts in P3 (Economical Panel) was 0.08.
- The highest inconsistency value among the experts in P4 (Technical Panel) was 0.08.
- The highest inconsistency value among the experts in P5 (Political Panel) was 0.07.
- The highest inconsistency value among the experts in P6 (Environmental & Safety Panel) was 0.05.

Therefore, the inconsistency within each expert is acceptable (all < 0.10).

7.7 Model Disagreement Results

Disagreements amongst experts can show different quantifications and different perspectives to the same analysis. There is group disagreement if the disagreement exceeds a value of 0.10 and a value of 0 would imply complete agreement among the experts [106]. Experts have different backgrounds and experiences that most likely will increase the level of disagreements amongst them. However, Acceptable disagreement has a value of 0.1 or less, according to Kocaoglu. Experts' judgment was analyzed mathematically for disagreement (more details about disagreement analysis can be found

in Sections 4.10). Based on HDM disagreements value among the experts is described as the following:

- Disagreements value among the experts in P2 (Perspective Panel) was 0.038.
- Disagreements value among the experts in P3 (Economical Panel) was 0.06.
- Disagreements value among the experts in P4 (Technical Panel) was 0.084.
- Disagreements value among the experts in P5 (Political Panel) was 0.085.
- Disagreements value among the experts in P6 (Environmental & Safety Panel) was 0.048.

Therefore, the disagreement among the experts is acceptable (all < 0.10).

7.8 Desirability Curves

Panel 7 was formatted to validate and quantify the desirability curves (see section 6.4). Following previous research [97][98], the average value of experts' judgments was considered as the final value for the curves creation. The following chart shows each expert's judgments along with the mean values and the curves for each factor. The main benefit of using desirability functions is to provide a standard metrics that decision makers can rely on to make quick and constant decisions without having to go back and consult with the experts or replicate the model and apply it again. Additionally, the desirability metric as a powerful tool that can be conducted with the HDM has been implemented widely in several studies [109][95].

7.8.1 Economical Perspective Desirability Value

The results of the desirability metrics quantifications of the economical factors show in tables 31 – 38.

Factors	Desirability Units	Desirability Scores
Oil Prices	Oil Price $\leq$ \$10	From 0 to 100 experts were asked to score and rank oil price desirability unit based on their experiences.
	Oil Price = \$40	
	Oil Price = \$60	
	Oil Price = \$120	
	Oil Price $\geq$ \$150	Notice: In July 2008 crude oil reached a record peak of US\$147.27. In 2015 crude oil price was between \$48.56 - 33.04 at that time 67 US oil and natural gas companies filed for bankruptcy.

Table 31: Oil Price Desirability Units

Oil Price	
Description	Desirability
Oil Price $\leq$ \$10	0
Oil Price = \$40	28
Oil Price = \$60	53
Oil Price = \$120	92
Oil Price $\geq$ \$150	100

Table 32: Oil Price Desirability Value

Figure 39: Oil Price Desirability Value

Factors	Desirability Units	Desirability Scores
Initial Cost	Initial Cost $\leq$ 500 million	From 0 to 100 experts were asked to score and rank initial cost desirability unit based on their experiences.
	Initial Cost = 1 Billion	
	Initial Cost = 10 Billion	
	Initial Cost = 50 Billion	
	Initial Cost $\geq$ 95 Billion	

Table 33: Initial Cost Desirability Units

Initial Cost	
Description	Desirability
Initial Cost $\leq$ 500 million	100
Initial Cost = 1 Billion	70
Initial Cost = 10 Billion	43
Initial Cost = 50 Billion	20
Initial Cost $\geq$ 95 Billion	0

Table 34: Initial Cost Desirability Value

Figure 40: Initial Cost Desirability Value

Factors	Desirability Units	Desirability Scores
Operational Cost	Low estimated cost of operating expenses	From 0 to 100 experts were asked to score and rank operational cost desirability unit based on their experiences.
	Average estimated cost of operating expenses	
	High estimated cost of operating expenses	
	Extremely high estimated cost of operating expenses	

Table 35: Operational Cost Desirability Units

Operational Cost	
Description	Desirability
Low estimated cost of operating expenses	100
Average estimated cost of operating expenses	80
High estimated cost of operating expenses	30
Extremely high estimated cost of operating expenses	0

Table 36: Operational Cost Desirability Value

Figure 41: Operational Cost Desirability Value

Factors	Desirability Units	Desirability Scores
Return on Investment (ROI)	Negative or less than zero	From 0 to 100 experts were asked to score and rank return on investment desirability unit based on their experiences.
	ROI between 10 - 50 percent	
	ROI between 50 - 70 percent	
	ROI between 70 - 90 percent	
	ROI equal or exceed 100 percent	

Table 37: Return on Investment Desirability Units

Return on Investment (ROI)	
Description	Desirability
Negative or less than zero	0
ROI between 10 - 50 percent	50
ROI between 50 - 70 percent	70
ROI between 70 - 90 percent	92
ROI equal or exceed 100 percent	100

Table 38: Return on Investment Desirability Value

Figure 42: Return on Investment Desirability Value

7.8.2 Technical Perspective Desirability Value

The results of the desirability metrics quantifications of the technical factors show in Tables 39 – 46.

Factors	Desirability Units	Desirability Scores
Operational Difficulties	Project expected to face low level of operational difficulties	From 0 to 100 experts were asked to score and rank operational difficulties desirability unit based on their experiences.
	Project expected to face medium level of operational difficulties	
	Project expected to face high level of operational difficulties	
	Project expected to face extremely high level of operational difficulties	

Table 39: Operational Difficulties Desirability Units

Operational Difficulties	
Description	Desirability
Project expected to face low level of operational difficulties	100
Project expected to face medium level of operational difficulties	74
Project expected to face high level of operational difficulties	23
Project expected to face extremely high level of operational difficulties	0

Table 40: Operational Difficulties Desirability Value

Figure 43: Operational Difficulties Desirability Value

Factors	Desirability Units	Desirability Scores
Project Size & Complexity	No complexity	From 0 to 100 experts were asked to score and rank project size & complexity desirability unit based on their experiences.
	Average complexity	
	High complexity	
	Extremely high complexity	

Table 41: Project Size & Complexity Desirability Units

Project Size & Complexity	
Description	Desirability
No complexity	100
Average complexity	67
High complexity	27
Extremely high complexity	0

Table 42: Project Size & Complexity Desirability Value

Figure 44: Project Size & Complexity Desirability Value

Factors	Desirability Units	Desirability Scores
Production Performance	Low Production Performance	From 0 to 100 experts were asked to score and rank production performance desirability unit based on their experiences.
	Average Production Performance	
	High Production Performance	
	Extremely high Production Performance	

Table 43: Production Performance Desirability Units

Production Performance	
Description	Desirability
Low Production Performance	0
Average Production Performance	43
High Production Performance	83
Extremely high Production Performance	100

Table 44: Production Performance Desirability Value

Figure 45: Production Performance Desirability Value

Factors	Desirability Units	Desirability Scores
Subsurface & Reservoir	Project has a high certainty of reservoir volume	From 0 to 100 experts were asked to score and rank subsurface & reservoir desirability unit based on their experiences.
	Project has a low uncertainty of reservoir volume	
	Project has a average uncertainty of reservoir volume	
	Project has a high uncertainty of reservoir volume	

Table 45: Subsurface & Reservoir Desirability Units

Subsurface & Reservoir	
Description	Desirability
Project has a high certainty of reservoir volume	100
Project has a low uncertainty of reservoir volume	77
Project has a average uncertainty of reservoir volume	33
Project has a high uncertainty of reservoir volume	0

Table 46: Subsurface & Reservoir Desirability Value

Figure 46: Subsurface & Reservoir Desirability Value

7.8.3 Political Perspective Desirability Value

The results of the desirability metrics quantifications of the political factors show in Tables 47 – 54.

Factors	Desirability Units	Desirability Scores
Government Stability	Unstable country	From 0 to 100 experts were asked to score and rank government stability desirability unit based on their experiences.
	High risk of instability	
	Some risk of instability	
	Stable country	

Table 47: Government Stability Desirability Units

Government Stability	
Description	Desirability
Unstable country	0
High risk of instability	15
Some risk of instability	47
Stable country	100

Table 48: Government Stability Desirability Value

Figure 47: Government Stability Desirability Value

Factors	Desirability Units	Desirability Scores
Conflict Over Maritime Claims	No conflict over maritime	From 0 to 100 experts were asked to score and rank conflict over maritime claims desirability unit based on their experiences.
	Low probability of conflict over maritime	
	High probability of conflict over maritime	
	Conflicted Area	

Table 49: Conflict Over Maritime Claims Desirability Units

Conflict Over Maritime Claims	
Description	Desirability
No conflict over maritime	100
Low probability of conflict over maritime	70
High probability of conflict over maritime	23
Conflicted Area	0

Table 50: Conflict Over Maritime Claims Desirability Value

Figure 48: Conflict Over Maritime Claims Desirability Value

Factors	Desirability Units	Desirability Scores
Policies, Regulations & Governance Standards	Low level of policies, regulations and governance standards	From 0 to 100 experts were asked to score and rank policies, regulations & governance standards desirability unit based on their experiences.
	Average level of policies, regulations and governance standards	
	High level of policies, regulations and governance standards	
	Extremely high level of policies, regulations and governance standards	

Table 51: Policies, Regulations & Governance Standards Desirability Units

Policies, Regulations & Governance Standards	
Description	Desirability
Low level of policies, regulations and governance standards	100
Average level of policies, regulations and governance standards	73
High level of policies, regulations and governance standards	30
Extremely high level of policies, regulations and governance standards	0

Table 52: Policies, Regulations & Governance Standards Desirability Value

Figure 49: Policies, Regulations & Governance Standards Desirability Value

Factors	Desirability Units	Desirability Scores
Contracts Complexity	Simple	From 0 to 100 experts were asked to score and rank contracts complexity desirability unit based on their experiences.
	Reasonable	
	Complex	
	Very Complex	

Table 53: Contracts Complexity Standards Desirability Units

Contracts Complexity	
Description	Desirability
Simple	100
Reasonable	73
Complex	27
Very Complex	0

Table 54: Contracts Complexity Standards Desirability Value

Figure 50: Contracts Complexity Standards Desirability Value

7.8.4 Environmental & Safety Perspective Desirability Value

The results of the desirability metrics quantifications of the environmental & safety factors show in Tables 55 – 62.

Factors	Desirability Units	Desirability Scores
Hazard Identification & Risk Management	Low-level of safety risk	From 0 to 100 experts were asked to score and rank hazard identification & risk management desirability unit based on their experiences.
	Average level of safety risk	
	High-level of safety risk	
	Extremely high-level of safety risk	

Table 55: Hazard Identification & Risk Management Desirability Units

Hazard Identification & Risk Management	
Description	Desirability
Low-level of safety risk	100
Average level of safety risk	63
High-level of safety risk	17
Extremely high-level of safety risk	0

Table 56: Hazard Identification & Risk Management Desirability Value

Figure 51: Hazard Identification & Risk Management Desirability Value

Factors	Desirability Units	Desirability Scores
Implementing Health, Safety and Environmental (HSE)	HSE easy to implement	From 0 to 100 experts were asked to score and rank Implementing Health, Safety and Environmental (HSE) desirability unit based on their experiences.
	HSE reasonable to implement	
	HSE complex to implement	
	HSE very complex to implement	

Table 57: Implementing HSE Desirability Units

Implementing Health, Safety and Environmental (HSE)	
Description	Desirability
HSE easy to implement	100
HSE reasonable to implement	73
HSE complex to implement	30
HSE very complex to implement	0

Table 58: Implementing HSE Desirability Value

Figure 52: Implementing HSE Desirability Value

Factors	Desirability Units	Desirability Scores
Stringent of the Local Health and Safety Standards	Low stringent of local Health and Safety Standards	From 0 to 100 experts were asked to score and rank stringent of local Health and Safety Standards desirability unit based on their experiences.
	Average stringent of local Health and Safety Standards	
	High stringent of local Health and Safety Standards	
	Extremely high stringent of local Health and Safety Standards	

Table 59: Stringent of the Local HSS Desirability Units

Stringent of the Local Health, Safety and Environmental (HSE) Standards	
Description	Desirability
Low stringent of local Health and Safety Standards	100
Average stringent of local Health and Safety Standards	70
High stringent of local Health and Safety Standards	23
Extremely high stringent of local Health and Safety Standards	0

Table 60: Stringent of the Local HSS Desirability Value

Figure 53: Stringent of the Local HSS Desirability Value

Factors	Desirability Units	Desirability Scores
Environmental Risk Management Integration	Low level of regulation on environmental threats is required	From 0 to 100 experts were asked to score and rank environmental risk management integration desirability unit based on their experiences.
	Average level of regulation on environmental threats is required	
	High level of regulation on environmental threats is required	
	Extremely high level of regulation on environmental threats is required	

Table 61: Environmental Risk Management Integration Desirability Units

Environmental Risk Management Integration	
Description	Desirability
Low level of regulation on environmental threats is required	100
Average level of regulation on environmental threats is required	73
High level of regulation on environmental threats is required	20
Extremely high level of regulation on environmental threats is required	0

Table 62: Environmental Risk Management Integration Desirability Value

Figure 54: Environmental Risk Management Integration Desirability Value

The table below summarizes unit of measurements that helps decision makers to assign value to each of the factors on the value curve.

Perspective	Factors	Unit of Measurements
Economical	Oil Prices	What is the expected level of oil price when project will start to produce oil?
	Initial Cost	What is the required amount of money to start up the project?
	Operational Cost	What is the estimated cost of operating expenses?
	Return on Investment (ROI)	What is the expected percentage of the project return on investment?
Technical	Operational Difficulties	What is the expected level of operational difficulties that the project will face?
	Project Size & Complexity	What is the degree of project complexity?
	Production Performance	What is the production performance level in terms of amount and quality that the project is expected to produce?
	Subsurface & Reservoir Uncertainty	What is the uncertainty level of finding an expected reservoir volume?
Political	Government Stability	What is the stability level of the government that owns the project site?
	Conflict Over Maritime Claims	What is the conflict degree over maritime claims that will face the project site?
	Policies, Regulations & Governance Standards	What is the expected level of the policies, regulations and governance standards the project might face?
	Contracts Complexity	What is the complexity level of implementing the project contracts?
Safety & Environmental	Hazard Identification & Risk Management	What is the level of hazard and risks the project is expected to face?
	Implementing Health, Safety and Environmental (HSE)	What is the required level of implementing effective Health, Safety and Environmental (HSE)?
	Stringent of the Local	How stringent are the local Health, Safety

	Health, Safety and Environmental (HSE) Standards	and Environmental (HSE) Standards? More strict equal higher cost.
	Environmental Risk Management Integration	What is the required level of the environmental rules the company has to incorporate on the project activities?

Table 63: Unit of Measurements Value On Desirability Curve

CHAPTER 8: RESEARCH APPLICATION

Applying a case application can be considered a robust research method that allows the exploration and understanding of complex issues particularly when a holistic, in-depth investigation is required [205]. Through case application methods, a researcher is able to go beyond the quantitative statistical results and understand the behavioral conditions through the actor's perspective. By including both quantitative and qualitative data, a case application helps explain both the process and outcome of a phenomenon through complete observation, reconstruction and analysis of the cases under investigation [206] [207]. The table below explains the advantages of implementing the case application.

No .	Advantages of Case Application	References
1. 2. 3. 4. 5. 6.	Potential to achieve high conceptual validity. Strong procedures for fostering new hypotheses. Case studies allow for both quantitative and qualitative analyses of the data. Usefulness for closely examining the hypothesized role of causal mechanisms in the context of individual cases. The detailed qualitative accounts often produced in case studies not only help to explore or describe the data in real-life environment, but also help to explain the complexities of real-life situations, which may not be captured through experimental or survey research. Capacity for addressing causal complexity.	[208][209][210][211]

Table 64: Advantages and Disadvantages of Case Studies Method

Eni and Mellitah Oil & Gas is considered as a case application subject for this research and the main objective of implementing this case application is to test the model

and demonstrate the idea of this research. Specifically, three offshore oil projects that are located in North Africa and operated by Eni and Mellitah Oil & Gas are implemented as a case application. Baraka offshore oil project is located in Tunisia and the project operated by Eni Oil & Gas. DP3 and DP4 offshore projects are located in Libya and both projects operated by Eni and Mellitah Oil & Gas. Nevertheless, North Africa is considered as one of the essential players in the global oil and gas industry. Applying such a case study to one of the biggest O&G companies in that area will enhance and supplement the results of this research.

8.1 Tunisian Oil industry

Tunisia's oil and gas resources are very small by international standards and especially as compared with those of its neighbors. Its proven oil reserves of 0.42 billion barrels (bnbls) and gas reserves of 0.06 trillion cubic meters. Oil production in Tunisia has been steadily declining after reaching a peak of 120,000 barrels per day (bls/d) in the early 1980s. In 2017, it reached 42,000 bls/d, according to the international energy statistics of the U.S. Energy Information Administration (EIA). Despite the small resource base, the oil and gas sector plays an important role in the economy. Over the last twenty years, it has represented between 3 percent and 7 percent of GDP, and between 8 percent and 18 percent of exports [212].

8.2 Libyan Oil Industry

According to official energy statistics from the US government (EIA), Libya holds the largest oil reserves in Africa, about 41.5 billion barrels as of January 2007; and the

8th largest in the world. However, Libya still remains highly unexplored, as current agreements with oil companies only cover 25 percent of Libya. About 90 percent of Libya's oil is sold to Western Europe. Libya has more oil than its aging equipment can process, and after the recent lifting of the sanctions, the country has resumed the purchase of parts and equipment to upgrade its refining and producing capacities.

Figure 55: Top African Nation Oil Reserves (Billion Barrels)

The country's economy is almost dependent on hydrocarbon production, with crude oil and natural gas representing about 96 percent of all government revenue [213]. The oil and gas facilities are scattered all over the country, on-shore and off-shore, in which water demands for quality and quantity are very high. These facilities include oil and gas fields, pipelines and terminal ports of oil and gas shipping, refineries, gas processing plants and chemical complexes [217]. Libyan oil classified as a "sweet" crude, which means that it has a low percentage of impurities a very desirable attribute [213].

Nevertheless, Libyan oil industry is driven by its foreign policy and interaction with the international community. According to Mills' reports in 2008, Libyan oil production dropped from a peak of 3.4 million barrels per day in 1970 to 1.0 million barrels per day in 1987 due to sanctions and political turmoil. In 2002 and 2006 the oil production reached to 1.4 and 1.8 million barrels per day respectively [214].

8.3 Eni and Mellitah Oil & Gas

The company was established on 21/04/2008 in accordance to an agreement concluded between the National Oil Corp. and Eni North Africa on 16/10/2007. Mellitah Oil & Gas B.V Libyan Branch owned a set of large Gas/Oil processing plants that were worth more than 6 billion U.S. dollars in total investment. The Company manages several onshore and offshore fields spread across the country. Mellitah Oil & Gas ranks as the biggest oil Company in Libya by producing 600,000 equivalent oil barrel/day Crude Oil, Natural Gas, Condensed Gas: Propane, Butane and Nafta in addition to a daily production of 450 tons of Sulphur [215]. Early on 2018 the company has begun production from the second phase of the Bahr Essalam offshore gas field, which is the largest gas field in Libya. Two further wells will begin production within a week under the Eni-NOC joint venture and further seven wells will come on-stream by the end of 2018. The second phase of the Bahr Essalam project will increase the company production potential by 400 million cubic feet of standard gas per day (MMSCFD) to a total output from the field of 1,100 MMSCFD [216]. Moreover, the company made a new discovery of gas and condensates offshore. According to the company, the discovery is closely located to

previously developed fields, 15 km southwest of the Bouri field and 5 km north of the Bahr Essalam field. The discovered well has the capacity to produce in excess of 7,000 barrels of oil equivalent per day (Boepd) and represents Eni's further discoveries in Libyan offshore Area D, following earlier discoveries in 2015 [217].

8.4 Offshore Oil Projects

Baraka Project: Baraka is an offshore oil platform located in Tunisia at the Gulf of Hammamet side. The project operates at depth of 90m. The field operated by ENI Oil Company with \$650 million of total estimate cost to produce 34,000 bpd. [218].

DP3 Project: DP3 platform is apart of the Bouri offshore field. The Bouri Offshore Field is part of Block NC-41, which is located 120 kilometers (75 mi) north of the Libyan coast in the Mediterranean Sea. Consisting of 38 wells, the field was developed using two platforms, a central processing platform (DP4) and a satellite platform (DP3) to produce 150,000bopd of crude oil for export [219].

DP4 Project: DP4 platform is apart of the Bouri offshore field as well. The Bouri oil reservoir is considered to be the biggest of its kind in the Mediterranean region. The DP4 platform is permanently moored at a single point to a Floating Storage and Offloading (FSO) tanker with a storage capacity of approximately 1.5 million barrels (240,000 m³) [220][221].

CHAPTER 9: ANALYSIS OF CASE AND SENSITIVITY ANALYSIS

The model developed in this research was applied to identify overall evaluation scores of the each project that was described in the previous section. A discussion with the experts in panel 8 has been conducted in order to assign a value curve score for each project. The discussion with the experts took place by means of phone interviews and emails. The computation of the final evaluation score is done by the application of the equation 14 that was presented in chapter 4. The following tables show final evaluation scores for each project.

9.1 Project (1): Baraka

Project 1: Baraka					
Perspectives	Criteria	Global Value	Value Curve	Final Score	Perspectives Sum
Economical	Oil Price	0.12	50	6	23.4
	Initial Cost	0.05	88	4.4	
	Operational Cost	0.05	80	4	
	Return on Investment (ROI)	0.1	90	9	
Technical	Operational Difficulties	0.02	75	1.5	6.4
	Project Size & Complexity	0.03	65	1.95	
	Production Performance	0.05	35	1.75	
	Subsurface & Reservoir Uncertainty	0.04	30	1.2	
Political	Government Stability	0.08	47	3.76	16.93
	Conflict Over Maritime Claims	0.03	100	3	
	Policies, Regulations & Governance Standards	0.07	75	5.25	
	Contracts Complexity	0.06	82	4.92	
Safety & Environmental	Hazard Identification & Risk Management	0.1	50	5	17.55
	Implementing Health, Safety and Environmental (HSE)	0.06	55	3.3	
	Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.09	75	6.75	

	Environmental Risk Management Integration	0.05	50	2.5	
Project Total Score					64.28

Table 65: Evaluation Scores for Project 1

9.2 Project (2): Bouri – DP3

Project 2: Bouri - DP3					
Perspectives	Criteria	Global Value	Value Curve	Final Score	Perspectives Sum
Economical	Oil Price	0.12	53	6.36	23.11
	Initial Cost	0.05	70	3.5	
	Operational Cost	0.05	65	3.25	
	Return on Investment (ROI)	0.1	100	10	
Technical	Operational Difficulties	0.02	80	1.6	11.5
	Project Size & Complexity	0.03	35	1.05	
	Production Performance	0.05	97	4.85	
	Subsurface & Reservoir Uncertainty	0.04	100	4	
Political	Government Stability	0.08	15	1.2	14.88
	Conflict Over Maritime Claims	0.03	100	3	
	Policies, Regulations & Governance Standards	0.07	90	6.3	
	Contracts Complexity	0.06	73	4.38	
Safety & Environmental	Hazard Identification & Risk Management	0.1	40	4	18.35
	Implementing Health, Safety and Environmental (HSE)	0.06	30	1.8	
	Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.09	95	8.55	
	Environmental Risk Management Integration	0.05	80	4	
Project Total Score					67.84

Table 66: Evaluation Scores for Project 2

9.3 Project (2): Bouri – DP4

Project 3: Bouri - DP4					
Perspectives	Criteria	Global Value	Value Curve	Final Score	Perspectives Sum
Economical	Oil Price	0.12	58	6.96	24.71
	Initial Cost	0.05	75	3.75	
	Operational Cost	0.05	80	4	
	Return on Investment (ROI)	0.1	100	10	
Technical	Operational Difficulties	0.02	85	1.7	11.75
	Project Size & Complexity	0.03	35	1.05	
	Production Performance	0.05	100	5	
	Subsurface & Reservoir Uncertainty	0.04	100	4	
Political	Government Stability	0.08	15	1.2	15.3
	Conflict Over Maritime Claims	0.03	100	3	
	Policies, Regulations & Governance Standards	0.07	90	6.3	
	Contracts Complexity	0.06	80	4.8	
Safety & Environmental	Hazard Identification & Risk Management	0.1	45	4.5	19.1
	Implementing Health, Safety and Environmental (HSE)	0.06	30	1.8	
	Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.09	95	8.55	
	Environmental Risk Management Integration	0.05	85	4.25	
Project Total Score					70.86

Table 67: Evaluation Scores for Project 3

9.4 Discussion of Case Application

The importance weights of the sixteen factors were obtained from the model, then experts in panel 7 assigned values for each factor using the desirability curves. In order to get the weighted score for each attribute, each value was obtained by the desirability curves multiplied by its important weight. Lastly, the weighted scores were added to get an overall project score. The analysis results show that the DP4 project has higher evaluation scores than other projects. The total evaluation score of the DP4 project is

(70.86) out of 100 while the total evaluation score of projects Baraka and DP3 are (64.28) and (67.84) respectively. See graph number 56. However, if we compare the total score of each perspective, we can notice that the political perspective of the Baraka project is (16.93) which is a better score than the DP3 and DP4 projects. Graph 57 illustrates the evaluation value of each perspective for the three projects.

Figure 56: Projects Evaluation Results

Figure 57: Perspectives Evaluation Results

By taking a closer look at the results, we can notice that the comparison score of the technical perspective of the three projects was expected since projects 2 and 3 have more production and contain higher reservoir volume. In the political side, it is not a surprise that project 1 gained more scores than other projects. Projects 2 and 3 were mainly affected by the Libyan government stability; however, the Tunisian government was considered more stable. Alternately, the economical perspective shows unexpected results. Even though project 1 has less oil production, it has higher economic sectors than project 2. The project 1 higher economical scores mainly were driven by low operational cost and initial cost.

9.5 Strengths and Weaknesses

In order to get a clear evaluation, strengths and weaknesses of each project have been emphasized. On one hand, the political perspective ranked high in Project 1 as it was affected by the stability of the country that hosted the site. On the other hand, production performance and subsurface and reservoir uncertainty attributes were weaknesses of Project 1. Unlike Project 1, Project 2 and 3 showed strengths and high scores in both factors, including production performance and reservoir. However, the two projects express the same weaknesses, which is government stability. The following tables summarize strengths and weaknesses of each project.

Project 1:

Project 1	Perspectives	Criteria	Global Value	Value Curve	Final Score
Strengths	Political	Government Stability	0.08	47	3.76
Weaknesses	Technical	Production Performance	0.05	35	1.75
		Subsurface & Reservoir Uncertainty	0.04	30	1.2

Table 68: Strengths and Weaknesses of Project 1**Project 2:**

Project 2	Perspectives	Criteria	Global Value	Value Curve	Final Score
Strengths	Technical	Production Performance	0.05	97	4.85
		Subsurface & Reservoir Uncertainty	0.04	100	4
Weaknesses	Political	Government Stability	0.08	15	1.2

Table 69: Strengths and Weaknesses of Project 2**Project 3:**

Project 3	Perspectives	Criteria	Global Value	Value Curve	Final Score
Strengths	Technical	Production Performance	0.05	100	5
		Subsurface & Reservoir Uncertainty	0.04	100	4
Weaknesses	Political	Government Stability	0.08	15	1.2

Table 70: Strengths and Weaknesses of Project 3**9.6 Scenario Analysis**

Scenario analysis is conducted to test the robustness of the model. In order to analyze the impacts of potential changes in the values at any level of the model, scenario analysis approach has been used to test the robustness of the model. This analysis aims to measure

how the model's final output will react to changes in the relevance of criteria. Multiple scenarios were created to capture the result of the analyses. Each scenario alters the relevance of perspectives by boosting one of the perspectives and the same process will be repeated for the four perspectives. For instance, economical perspective boosted to be 0.97, while the remaining perspective's values will be 0.01 for each as it shows in table 71.

Perspectives	Economical	Technical	Political	Safety & Environmental
First Scenario	0.97	0.01	0.01	0.01
Second Scenario	0.01	0.97	0.01	0.01
Third Scenario	0.01	0.01	0.97	0.01
Fourth Scenario	0.01	0.01	0.01	0.97

Table 71: Sensitivity Analysis Scenarios

In the first scenario economical perspective was boosted to the maximum value and it has been considering the most important factor. The result shows that the overall Project 1 score was increased from 64.28 to 73.58. Table 72 demonstrates the changes in the overall score for Project 1 and the changes in perspective scores.

First Scenario Economical Perspective Boosted to 0.97						
Perspectives		Criteria	Local Value	Global Value	Project1	
Name	Score				Value Curve	Final Score
Economical	0.97	Oil Price	0.35	0.3395	50	16.98
		Initial Cost	0.17	0.1649	88	14.51
		Operational Cost	0.16	0.1552	80	12.42
		Return on Investment (ROI)	0.32	0.3104	90	27.94
Technical	0.01	Operational Difficulties	0.15	0.0015	75	0.11
		Project Size & Complexity	0.2	0.0020	65	0.13

		Production Performance	0.34	0.0034	35	0.12
		Subsurface & Reservoir Uncertainty	0.31	0.0031	30	0.09
Political	0.01	Government Stability	0.32	0.0032	47	0.15
		Conflict Over Maritime Claims	0.13	0.0013	100	0.13
		Policies, Regulations & Governance Standards	0.28	0.0028	75	0.21
		Contracts Complexity	0.27	0.0027	82	0.22
Safety & Environmental	0.01	Hazard Identification & Risk Management	0.34	0.0034	50	0.17
		Implementing Health, Safety and Environmental (HSE)	0.21	0.0021	55	0.12
		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.0027	75	0.20
		Environmental Risk Management Integration	0.18	0.0018	50	0.09
Project Total Score					73.58	

Table 72: First Scenario Result Project 1

Overall score of Project 2 increased favorably from 67.84 to 72.72. Table 73 demonstrates changes in the overall score for Project 2 and the changes in perspectives scores as well.

First Scenario Economical Perspective Boosted to 0.97						
Perspectives		Criteria	Local Value	Global Value	Project 2	
Name	Score				Value Curve	Final Score
Economical	0.97	Oil Price	0.35	0.3395	53	17.99
		Initial Cost	0.17	0.1649	70	11.54
		Operational Cost	0.16	0.1552	65	10.09
		Return on Investment (ROI)	0.32	0.3104	100	31.04
Technical	0.01	Operational Difficulties	0.15	0.0015	80	0.12
		Project Size & Complexity	0.2	0.0020	35	0.07
		Production Performance	0.34	0.0034	97	0.33
		Subsurface & Reservoir Uncertainty	0.31	0.0031	100	0.31

Political	0.01	Government Stability	0.32	0.0032	15	0.05
		Conflict Over Maritime Claims	0.13	0.0013	100	0.13
		Policies, Regulations & Governance Standards	0.28	0.0028	90	0.25
		Contracts Complexity	0.27	0.0027	73	0.20
Safety & Environmental	0.01	Hazard Identification & Risk Management	0.34	0.0034	40	0.14
		Implementing Health, Safety and Environmental (HSE)	0.21	0.0021	30	0.06
		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.0027	95	0.26
		Environmental Risk Management Integration	0.18	0.0018	80	0.14
Project Total Score					72.72	

Table 73: First Scenario Result Project 2

Overall score of Project 3 increased favorably from 70.86 to 77.63. Table 74 demonstrates changes in the overall score for Project 3 and the changes in perspectives scores as well.

First Scenario Economical Perspective Boosted to 0.97						
Perspectives		Criteria	Local Value	Global Value	Project 3	
Name	Score				Value Curve	Final Score
Economical	0.97	Oil Price	0.35	0.3395	58	19.69
		Initial Cost	0.17	0.1649	75	12.37
		Operational Cost	0.16	0.1552	80	12.42
		Return on Investment (ROI)	0.32	0.3104	100	31.04
Technical	0.01	Operational Difficulties	0.15	0.0015	85	0.13
		Project Size & Complexity	0.2	0.0020	35	0.07
		Production Performance	0.34	0.0034	100	0.34
		Subsurface & Reservoir Uncertainty	0.31	0.0031	100	0.31
Political	0.01	Government Stability	0.32	0.0032	15	0.05
		Conflict Over Maritime Claims	0.13	0.0013	100	0.13

		Policies, Regulations & Governance Standards	0.28	0.0028	90	0.25
		Contracts Complexity	0.27	0.0027	80	0.22
Safety & Environmental	0.01	Hazard Identification & Risk Management	0.34	0.0034	45	0.15
		Implementing Health, Safety and Environmental (HSE)	0.21	0.0021	30	0.06
		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.0027	95	0.26
		Environmental Risk Management Integration	0.18	0.0018	85	0.15
Project Total Score					77.63	

Table 74: First Scenario Result Project 3

The increase in economic value positively impacted the overall scores on all three projects. Table 75 summarizes the changes of projects scores and the changes in ranks of each project. The results showed that there was a rank change in first scenarios. However, those are extreme scenarios, and in practice most likely any change would be much less extreme, thus the model is reliable enough.

First Scenario Economical Perspective Boosted to 0.97			
Project Name	Project 1: Baraka	Project 2: Bouri - DP3	Project 3: Bouri - DP4
Original Scores	64.28	67.84	70.86
Scenario Scores	73.58	72.72	77.63
Value Changes	9.30	4.88	6.77
Original Ranks	3	2	1
Scenario Ranks	2	3	1

Table 75: Summarizes First Scenario Changes of Scores

In the second scenario, technical perspective was boosted to the maximum value and it is considered as the most significant factor. The result shows that the overall Project 1 score was impacted negatively and decreased from 64.28 to 46.12 since a technical

perspective was the critical area in Project 1 evaluation. Table 76 demonstrates changing of Project 1 overall score and changing in perspective scores.

Second Scenario Technical Perspective Boosted to 0.97						
Perspectives		Criteria	Local Value	Global Value	Project 1	
Name	Score				Value Curve	Final Score
Economical	0.01	Oil Price	0.35	0.0035	50	0.18
		Initial Cost	0.17	0.0017	88	0.15
		Operational Cost	0.16	0.0016	80	0.13
		Return on Investment (ROI)	0.32	0.0032	90	0.29
Technical	0.97	Operational Difficulties	0.15	0.1455	75	10.91
		Project Size & Complexity	0.2	0.1940	65	12.61
		Production Performance	0.34	0.3298	35	11.54
		Subsurface & Reservoir Uncertainty	0.31	0.3007	30	9.02
Political	0.01	Government Stability	0.32	0.0032	47	0.15
		Conflict Over Maritime Claims	0.13	0.0013	100	0.13
		Policies, Regulations & Governance Standards	0.28	0.0028	75	0.21
		Contracts Complexity	0.27	0.0027	82	0.22
Safety & Environmental	0.01	Hazard Identification & Risk Management	0.34	0.0034	50	0.17
		Implementing Health, Safety and Environmental (HSE)	0.21	0.0021	55	0.12
		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.0027	75	0.20
		Environmental Risk Management Integration	0.18	0.0018	50	0.09
Project Total Score					46.12	

Table 76: Second Scenario Result Project 1

When the technical perspective was boosted to the maximum value, the overall score of Project 2 was increased favorably by 14.61 points. Table 77 demonstrates changing of Project 2 overall score and changes in perspective scores as well.

Second Scenario Technical Perspective Boosted to 0.97						
Perspectives		Criteria	Local Value	Global Value	Project 2	
Name	Score				Value Curve	Final Score
Economical	0.01	Oil Price	0.35	0.0035	53	0.19
		Initial Cost	0.17	0.0017	70	0.12
		Operational Cost	0.16	0.0016	65	0.10
		Return on Investment (ROI)	0.32	0.0032	100	0.32
Technical	0.97	Operational Difficulties	0.15	0.1455	80	11.64
		Project Size & Complexity	0.2	0.1940	35	6.79
		Production Performance	0.34	0.3298	97	31.99
		Subsurface & Reservoir Uncertainty	0.31	0.3007	100	30.07
Political	0.01	Government Stability	0.32	0.0032	15	0.05
		Conflict Over Maritime Claims	0.13	0.0013	100	0.13
		Policies, Regulations & Governance Standards	0.28	0.0028	90	0.25
		Contracts Complexity	0.27	0.0027	73	0.20
Safety & Environmental	0.01	Hazard Identification & Risk Management	0.34	0.0034	40	0.14
		Implementing Health, Safety and Environmental (HSE)	0.21	0.0021	30	0.06
		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.0027	95	0.26
		Environmental Risk Management Integration	0.18	0.0018	80	0.14
Project Total Score					82.45	

Table 77: Second Scenario Result Project 2

Overall score of Project 3 was increased positively by 13.40 points. Table 78 demonstrates changes of Project 3 overall score and changes in perspectives scores as well.

Second Scenario Technical Perspective Boosted to 0.97						
Perspectives		Criteria	Local Value	Global Value	Project 3	
Name	Score				Value Curve	Final Score
Economical	0.01	Oil Price	0.35	0.0035	58	0.20
		Initial Cost	0.17	0.0017	75	0.13
		Operational Cost	0.16	0.0016	80	0.13
		Return on Investment (ROI)	0.32	0.0032	100	0.32
Technical	0.97	Operational Difficulties	0.15	0.1455	85	12.37
		Project Size & Complexity	0.2	0.1940	35	6.79
		Production Performance	0.34	0.3298	100	32.98
		Subsurface & Reservoir Uncertainty	0.31	0.3007	100	30.07
Political	0.01	Government Stability	0.32	0.0032	15	0.05
		Conflict Over Maritime Claims	0.13	0.0013	100	0.13
		Policies, Regulations & Governance Standards	0.28	0.0028	90	0.25
		Contracts Complexity	0.27	0.0027	80	0.22
Safety & Environmental	0.01	Hazard Identification & Risk Management	0.34	0.0034	45	0.15
		Implementing Health, Safety and Environmental (HSE)	0.21	0.0021	30	0.06
		Stringent of the Local Health, Safety and Environmental Standards	0.27	0.0027	95	0.26
		Environmental Risk Management Integration	0.18	0.0018	85	0.15
Project Total Score					84.26	

Table 78: Second Scenario Result Project 3

The positive changes on the technical value impacted each project differently. Table 79 summarizes the changes on project scores due to this boost. The results showed that there wasn't a rank change in second scenarios, thus the model is reliable enough.

Second Scenario Technical Perspective Boosted to 0.97			
Project Name	Project 1: Baraka	Project 2: Bouri - DP3	Project 3: Bouri - DP4
Original Scores	64.28	67.84	70.86
Scenario Scores	46.12	82.45	84.26
Value Changes	-18.16	14.61	13.40
Original Ranks	3	2	1
Scenario Ranks	3	2	1

Table 79: Summarizes Second Scenario Changes of Scores

In the third scenario, the political perspective was boosted to the maximum value and it is considered as the most important factor. The result shows that the overall Project 1 scores have been affected positively and increased by 6.54 points. Table 80 demonstrates changes to Project 1 overall scores and changes in perspective scores as well.

Third Scenario Political Perspective Boosted to 0.97						
Perspectives		Criteria	Local Values	Global Values	Project 1	
Name	Score				Value Curve	Final Score
Economical	0.01	Oil Price	0.35	0.0035	50	0.18
		Initial Cost	0.17	0.0017	88	0.15
		Operational Cost	0.16	0.0016	80	0.13
		Return on Investment (ROI)	0.32	0.0032	90	0.29
Technical	0.01	Operational Difficulties	0.15	0.0015	75	0.11
		Project Size & Complexity	0.2	0.0020	65	0.13
		Production Performance	0.34	0.0034	35	0.12
		Subsurface & Reservoir Uncertainty	0.31	0.0031	30	0.09
Political	0.97	Government Stability	0.32	0.3104	47	14.59
		Conflict Over Maritime Claims	0.13	0.1261	100	12.61
		Policies, Regulations & Governance Standards	0.28	0.2716	75	20.37
		Contracts Complexity	0.27	0.2619	82	21.48
Safety & Environmental	0.01	Hazard Identification & Risk Management	0.34	0.0034	50	0.17
		Implementing Health, Safety and Environmental (HSE)	0.21	0.0021	55	0.12

		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.0027	75	0.20
		Environmental Risk Management Integration	0.18	0.0018	50	0.09
Project Total Score					70.82	

Table 80: Third Scenario Result Project 1

Moreover, the third scenario's results show that the overall Project 2 and Project 3 scores were affected negatively. Both projects are considering the political perspective as critical a part. Table 81 demonstrates changes of the overall score and the perspective score of Project 2.

Third Scenario Political Perspective Boosted to 0.97						
Perspectives		Criteria	Local Values	Global Values	Project 2	
Name	Score				Value Curve	Final Score
Economical	0.01	Oil Price	0.35	0.0035	53	0.19
		Initial Cost	0.17	0.0017	70	0.12
		Operational Cost	0.16	0.0016	65	0.10
		Return on Investment (ROI)	0.32	0.0032	100	0.32
Technical	0.01	Operational Difficulties	0.15	0.0015	80	0.12
		Project Size & Complexity	0.2	0.0020	35	0.07
		Production Performance	0.34	0.0034	97	0.33
		Subsurface & Reservoir Uncertainty	0.31	0.0031	100	0.31
Political	0.97	Government Stability	0.32	0.3104	15	4.66
		Conflict Over Maritime Claims	0.13	0.1261	100	12.61
		Policies, Regulations & Governance Standards	0.28	0.2716	90	24.44
		Contracts Complexity	0.27	0.2619	73	19.12
Safety & Environmental	0.01	Hazard Identification & Risk Management	0.34	0.0034	40	0.14
		Implementing Health, Safety and Environmental (HSE)	0.21	0.0021	30	0.06
		Stringent of the Local Health,	0.27	0.0027	95	0.26

		Safety and Environmental (HSE) Standards				
		Environmental Risk Management Integration	0.18	0.0018	80	0.14
Project Total Score					62.99	

Table 81: Third Scenario Result Project 2

Project 3 scores been dropped by almost 6 point as summarized in table 82.

Third Scenario Political Perspective Boosted to 0.97						
Perspectives		Criteria	Local Values	Global Values	Project 3	
Name	Score				Value Curve	Final Score
Economical	0.01	Oil Price	0.35	0.0035	58	0.20
		Initial Cost	0.17	0.0017	75	0.13
		Operational Cost	0.16	0.0016	80	0.13
		Return on Investment (ROI)	0.32	0.0032	100	0.32
Technical	0.01	Operational Difficulties	0.15	0.0015	85	0.13
		Project Size & Complexity	0.2	0.0020	35	0.07
		Production Performance	0.34	0.0034	100	0.34
		Subsurface & Reservoir Uncertainty	0.31	0.0031	100	0.31
Political	0.97	Government Stability	0.32	0.3104	15	4.66
		Conflict Over Maritime Claims	0.13	0.1261	100	12.61
		Policies, Regulations & Governance Standards	0.28	0.2716	90	24.44
		Contracts Complexity	0.27	0.2619	80	20.95
Safety & Environmental	0.01	Hazard Identification & Risk Management	0.34	0.0034	45	0.15
		Implementing Health, Safety and Environmental (HSE)	0.21	0.0021	30	0.06
		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.0027	95	0.26
		Environmental Risk Management Integration	0.18	0.0018	85	0.15
Project Total Score					64.91	

Table 82: Third Scenario Result Project 3

An increase in the political value affected each project differently. Table 83 summarizes the changes on project scores and their rankings. The results showed that there was a rank change in third scenarios. However, those are extreme scenarios, and in practice most likely any change would be much less extreme, thus the model is reliable enough.

Third Scenario Political Perspective Boosted to 0.97			
Project Name	Project 1: Baraka	Project 2: Bouri - DP3	Project 3: Bouri - DP4
Original Scores	64.28	67.84	70.86
Scenario Scores	70.82	62.99	64.91
Value Changes	6.54	-4.85	-5.95
Original Ranks	3	2	1
Scenario Ranks	1	3	2

Table 83: Summarizes Third Scenario Changes of Scores

In the forth scenario, safety & environmental perspective was boosted to the maximum value and it has been considered as the key factor. The result shows that the overall Project 1 scores have been affected negatively and dropped by 6.31 points. Table 84 demonstrates changes to Project 1 overall scores and changes in perspective scores.

Forth Scenario Safety & Environmental Perspective Boosted to 0.97						
Perspectives		Criteria	Local Value	Global Value	Project 1	
Name	Score				Value Curve	Final Score
Economical	0.01	Oil Price	0.35	0.0035	50	0.18
		Initial Cost	0.17	0.0017	88	0.15
		Operational Cost	0.16	0.0016	80	0.13
		Return on Investment (ROI)	0.32	0.0032	90	0.29
Technical	0.01	Operational Difficulties	0.15	0.0015	75	0.11
		Project Size & Complexity	0.2	0.0020	65	0.13
		Production Performance	0.34	0.0034	35	0.12
		Subsurface & Reservoir Uncertainty	0.31	0.0031	30	0.09

Political	0.01	Government Stability	0.32	0.0032	47	0.15
		Conflict Over Maritime Claims	0.13	0.0013	100	0.13
		Policies, Regulations & Governance Standards	0.28	0.0028	75	0.21
		Contracts Complexity	0.27	0.0027	82	0.22
Safety & Environmental	0.97	Hazard Identification & Risk Management	0.34	0.3298	50	16.49
		Implementing Health, Safety and Environmental (HSE)	0.21	0.2037	55	11.20
		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.2619	75	19.64
		Environmental Risk Management Integration	0.18	0.1746	50	8.73
Project Total Score					57.97	

Table 84: Forth Scenario Result Project 1

When the safety & environmental perspective was boosted to the maximum value, the overall scores of Project 2 been dropped by 7.50 points. Table 85 demonstrates changes to Project 2 overall score and changes in perspectives scores as well.

Forth Scenario Safety & Environmental Perspective Boosted to 0.97						
Perspectives		Criteria	Local Value	Global Value	Project 2	
Name	Score				Value Curve	Final Score
Economical	0.01	Oil Price	0.35	0.0035	53	0.19
		Initial Cost	0.17	0.0017	70	0.12
		Operational Cost	0.16	0.0016	65	0.10
		Return on Investment (ROI)	0.32	0.0032	100	0.32
Technical	0.01	Operational Difficulties	0.15	0.0015	80	0.12
		Project Size & Complexity	0.2	0.0020	35	0.07
		Production Performance	0.34	0.0034	97	0.33
		Subsurface & Reservoir Uncertainty	0.31	0.0031	100	0.31
Political	0.01	Government Stability	0.32	0.0032	15	0.05
		Conflict Over Maritime Claims	0.13	0.0013	100	0.13
		Policies, Regulations &	0.28	0.0028	90	0.25

		Governance Standards				
		Contracts Complexity	0.27	0.0027	73	0.20
Safety & Environmental	0.97	Hazard Identification & Risk Management	0.34	0.3298	40	13.19
		Implementing Health, Safety and Environmental (HSE)	0.21	0.2037	30	6.11
		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.2619	95	24.88
		Environmental Risk Management Integration	0.18	0.1746	80	13.97
Project Total Score					60.34	

Table 85: Forth Scenario Result Project 2

The overall scores of Project 3 dropped by 7.91 points. Table 86 demonstrates changes to Project 3 overall score and changes in perspectives scores as well.

Forth Scenario Safety & Environmental Perspective Boosted to 0.97						
Perspectives		Criteria	Local Value	Global Value	Project 3	
Name	Score				Value Curve	Final Score
Economical	0.01	Oil Price	0.35	0.0035	58	0.20
		Initial Cost	0.17	0.0017	75	0.13
		Operational Cost	0.16	0.0016	80	0.13
		Return on Investment (ROI)	0.32	0.0032	100	0.32
Technical	0.01	Operational Difficulties	0.15	0.0015	85	0.13
		Project Size & Complexity	0.2	0.0020	35	0.07
		Production Performance	0.34	0.0034	100	0.34
		Subsurface & Reservoir Uncertainty	0.31	0.0031	100	0.31
Political	0.01	Government Stability	0.32	0.0032	15	0.05
		Conflict Over Maritime Claims	0.13	0.0013	100	0.13
		Policies, Regulations & Governance Standards	0.28	0.0028	90	0.25
		Contracts Complexity	0.27	0.0027	80	0.22
Safety & Environmental	0.97	Hazard Identification & Risk Management	0.34	0.3298	45	14.84
		Implementing Health, Safety	0.21	0.2037	30	6.11

		and Environmental (HSE)				
		Stringent of the Local Health, Safety and Environmental (HSE) Standards	0.27	0.2619	95	24.88
		Environmental Risk Management Integration	0.18	0.1746	85	14.84
Project Total Score					62.95	

Table 86: Forth Scenario Result Project 3

Increasing the safety & environmental value influenced each project differently. Table 87 summarizes the change on projects scores. The results showed that there wasn't a rank change in forth scenarios, thus the model is reliable enough.

Forth Scenario Safety & Environmental Perspective Boosted to 0.97			
Project Name	Project 1: Baraka	Project 2: Bouri - DP3	Project 3: Bouri - DP4
Original Scores	64.28	67.84	70.86
Scenario Scores	57.97	60.34	62.95
Value Changes	-6.31	-7.50	-7.91
Original Ranks	3	2	1
Scenario Ranks	3	2	1

Table 87: Summarizes Forth Scenario Changes of Scores

CHAPTER 10: RESEARCH VALIDITY

As it has been mentioned in the previous chapter, the main purpose of the validation phase is to answer the following questions:

- Does the model capture the necessary elements needed to satisfy the research goal?
- Does the model valid to apply?

Following previous PhD dissertations [105][117][120][121], the research validity has been guaranteed to answer these questions. However, the validity of the research should be tested by adopting three measures applied at different phases of the research: construct validity, content validity and criteria-related validity.

10.1 Construct validity

Construct validity refers to the degree to which a research approach complies with its underlying theories and to determine if the preliminary model construct is suitable for measuring the desired outcome. The decision model was developed based on the comprehensive literature review that was described in the previous sections as well as based on experts' feedbacks and recommendations through the third independent study. Construct validity of the initial model was tested by faculty and a group of ETM doctoral students, who have significant amount of research experience in both the energy field and hierarchical decision modeling.

10.2 Content validity

Content validity refers to the degree to which a measure represents a given domain of interest. Content validity has been tested during the model development phase. After the preliminary model was constructed based on the literature, Subject matter experts who are familiar with decision models were asked to provide their feedback using the content of the model. Expert panel P1 was formed to validate the literature based hierarchical decision model. The experts were selected based on their expertise in the offshore oil field. Two rounds of validation took place using a Qualtrics survey. In the first round, experts evaluated the factors identified by the research as the most critical factors affecting the investment decision in offshore oil project. Experts also were given a chance to suggest other factors based on their experience. In the second round, experts validated the factors that were added to the model based on the first round expert's feedback.

Moreover, five panels have been formatted including perspectives quantification, economical quantification, technical quantification, political quantification and environmental & safety quantification in order to quantify the research model and score each factor based on its relative importance to the mission level. As it was explained in fourth chapter, expert's judgments were captured through pair-wise comparisons utilizing the constant-sum method. Each comparison is made by distributing 100 points between the pair of items being compared. Data is collected through an online survey tool and the analysis is done using the HDM software, which also calculated the individual logical inconsistencies and the group disagreements.

10. 3 Criterion-related validity

Criterion-related validity refers to the degree of effectiveness of a model in predicting real-life phenomenon. Criterion-related validity is implemented after the analysis is completed. The quantified model has been tested against a case study and subject matter experts determined if the results were acceptable. Also, these experts were asked to verify if the model could be generalized to other areas than the case study application. Three different offshore oil projects were conducted through the model as a case study. Expert panel P8 was formed to allocate scores to each project against the value curve. In addition, the model results were presented to these experts and they were asked if the assessment framework was appropriate enough for evaluating offshore oil projects. The experts confirmed that the model could be a helpful method to aid and even possible enhance the investment decision. This model also indicated the potential to be applied to various offshore oil projects.

CHAPTER 11: DISCUSSION

This chapter brings forward a discussion of the research results that includes model validation and qualification, and an implemented case study.

11.1 Practical Application: General

The gap analysis in chapter 4 illustrated that a comprehensive approach and advanced tools are required to evaluate offshore oil projects that can have a significant impact before any investment decisions are made. The research model has been validated by expert panels that have a broad understanding and experience of managing offshore oil projects. The expert panels confirmed that the structure and model content were appropriate for evaluating offshore oil projects. Moreover, the research quantification that includes assigning weights for the perspective level and success attributes were assessed by expert panels that hold a breadth of management experience in oil projects. Thus, the research model is considered quite versatile and can be readily applied to any offshore oil project.

Based on the experts' judgments, the quantification phase of the model generated outstanding results. The economical perspective was assessed as the most important factor with 32% of relative weight followed by the environmental and safety perspective with 30% of relative weight. The political perspective was evaluated as the third factor with 24% of relative weight, followed by the technical perspective with 14% of relative weight.

11.2 Practical Application: Economical Perspective

Under the economical perspective, there are multiple criteria that are linked to each other with complex processes and unique challenges that include oil price, initial cost, operational cost and return on investment (ROI). An assessment of these challenges associated with oil offshore projects leads to reduced risk and an increased probability of success. Based on experts' judgments, oil price criterion was assessed as the most important factor with 35% relative weight. Oil prices change from one project to another depending on the type and quality of the oil that the project will produce. Another factor that affected the economical perspective is the return on investment. The experts assigned 32% of relative weight to the return on investment factor. In addition, the initial cost factor was assigned as the third most important factor with 17% of relative weight. However, operational cost was assigned as the least important economical factor with 16% of relative weight. Decision makers, before they make their investment decision, should get a clear picture of project economical factors such as oil prices, initial cost, operational cost, and ROI.

11.3 Practical Application: Technical Perspective

Under the technical perspective, experts validated four factors: operational difficulties, project size and complexity, production performance, and reservoir uncertainty. The experts assigned production performance as the most important technical factor with 34% of relative weight. The second ranked technical factor was reservoir uncertainty with 31% of relative weight. In addition, project size and

complexity was ranked as the third most vital technical factor with 20% of relative weight. The least important technical factor was reasoned to be operational difficulties with 15% of relative weight. The opinions of the experts aligned with the results of the study where the production performance factor has a significantly higher impact on project profitability and success.

11.4 Practical Application: Political Perspective

Under the political perspective, experts endorsed four factors that play essential roles in offshore oil evaluation. These included government stability, conflict over maritime claims, contracts complexity, and policies, regulations, and governance standards. The experts indicated that government stability was the most significant political factor with a contribution weight of 32% among other political factors. Offshore oil projects have long life cycle time and government stability can play a vital role in the success of these types of projects. The second main political factor was policies, regulations, and governance standards, with 28% of relative weight. On the other hand, the contracts complexity factor was considered the third most important factor with 27% of relative weight. Finally, all the experts agreed that even though conflict over maritime claims is a key factor that should be evaluated before the investment decision takes place, conflict over maritime claims is not a critical factor to all offshore oil projects. The experts indicated that conflict over maritime claims ranked as a fourth political factor with only 13% of relative weight.

11.5 Practical Application: Environmental & Safety Perspective

Under the environmental and safety perspective, experts validated four factors: hazard identification and risk management, implementing health, safety and environmental (HSE), stringent local HSE standards, and environmental risk management integration. The experts indicated that hazard identification and risk management was the most important environmental and safety factor with a contribution weight of 34% among other environmental & safety factors. The second most important environmental and safety factor was stringent local HSE standards with a relative weight of 27%. Based on their opinion, the rise in a project's costs can be directly driven by tougher HSE standards. Ultimately, the implementing health, safety and environmental (HSE) factor was assigned as the third most important factor with 21% of relative weight. The environmental risk management integration ranked fourth with 18% of relative weight.

11.6 Model Generalization

The oil business sector can be classified into two types of projects, onshore and offshore oil projects. As it was mentioned in the previous sections, the research model is generalizable and can be readily applied to any offshore oil project around the world. Theoretically, most of the perspectives and criteria used in this study can be applied to evaluate onshore oil projects. However, changes of factor's weight should be considered in this evaluation since the influence of various criteria on investment decisions will be much different. For example, on the environmental and safety factor, the offshore oil

projects operate in more hazardous environments where the risk factors are much higher compared to onshore oil projects. Therefore, the relative weight of the environmental and safety factor would be different in onshore and offshore projects. Conclusively, indeed the same model can be used to evaluate a wide variety of oil projects, whether it be onshore or offshore, as long as the correct criteria weights are assigned to the study with respect to their corresponding situations.

CHAPTER 12: CONCLUSIONS

The final chapter of this research summarizes the research by documenting the conclusions, demonstrating how the gaps were addressed, and how this research contributes to improve offshore oil project evaluation before and after the investment decision takes place. The analysis of the data identified potential limitations, the various assumptions that were made, and a few particulars that represent constraints or model limitations. A discussion is included to suggest how the present limitations can create opportunities for future research.

12.1 Conclusions and Contributions

Evaluating and selecting the right project in the offshore oil sector is characterized by a high volatile price setting market, increasing pressure to minimize cost structures, political concerns, and safety and environmental risks. The combinations of these characteristics provide a motivation for development of new tools for allocating capital and improving the quality of overall decisions in the exploration and production decisions. Making important decisions in the oil industry requires an incorporation of major uncertainties, long time horizons, multiple alternatives, and complex value issues in the decision model [222]. As it was described in chapters 2 and 3, the academic literature shows that a comprehensive approach to evaluate the offshore oil projects and improve the investment decision is lacking. Improving offshore oil capital project efficiency is critically needed. Relying on financial assessments alone will not solve the rising problems later on. A comprehensive approach is needed to measure project

outcomes and identify gaps for future improvements [94]. Nevertheless, the main contribution of the proposed research is to fulfill the research gap and provide a framework that can be used for assessing and evaluating offshore oil projects to improve the investment decision. This study provides a comprehensive approach including most of the factors impacting the investment decision of offshore oil projects and assessing their weights of impact as well as those associated with desirability matrices and sensitivity analyses to estimate multiple scenarios.

By implementing the research model decision makers will not only be able to evaluate the four important perspectives (economical, technical, political, and environmental and safety) that affect the offshore oil projects, but also they will be able to obtain the contribution weights of the sixteen factors under these perspectives to the overall project evaluation. The contribution result of the research model is to provide a specific weighted score for each offshore oil proposals project. First of all, the hierarchical decision model provides a specific important weight to the sixteen factors that affect the offshore project investment decision. Then the research provides a desirability curves standard that decision makers can use to rank and assign scores for each of sixteen attributes in order to evaluate multiple projects. The desirability functions offer a standard metrics that decision makers can rely on to make quick and constant decision without having to go back and consult with the experts or replicate the model and apply it again. After obtaining the importance weights of the sixteen factors from the model and factors scores from the desirability curves, decision makers would be able to get the weighted score for each attribute – each score multiplied by its important weight.

Lastly, the weighted scores would be added to get an overall project score. The investment decision in offshore oil projects is associated with high risk and is directly affected by different factors. The research model helps decision makers to achieve better evaluation of offshore oil projects and improve their investment decision. The model addresses the gaps identified as part of the literature review. The main contribution of this study is summarizing as following:

1. The first multi perspective hierarchical model that highlighted the importance weights of different factors for evaluating offshore oil projects for the industry use.
2. Scores and desirability curves indicate improvement paths and potential solutions.
3. The model can be used to evaluate multiple offshore oil projects in the region.

Table 88 summarizes the gaps and the contributions this research addresses.

Research Gaps	Contributions
There is not a specific study, which is aimed to identify the most internal and external factors that impact the offshore oil project.	This research identifies the major challenging factors and assesses their impact on offshore oil projects.
There is a lack of a comprehensive approach to evaluate offshore oil projects before and after the investment decision takes place.	This study provides a comprehensive approach including the factors that most impact investment decisions in offshore oil projects and assessing their weights of impacts as well as those associated with desirability matrices and sensitivity analyses to estimate multiple scenarios.

Table 88: Summarizes the Gaps and the Contributions

Table 89 summarizes the research questions and how the research addressed these questions.

Research Questions	Addressing the Questions
Which attributes are most important for evaluating offshore oil project?	Model validation and quantification address this question. For more details see chapter 7.
Is the assessment framework appropriate for assessing offshore oil projects?	Research application and the case study analysis address this question. For more details see chapter 8 and chapter 9.
To what extent the developed model results could help project managers and decision makers to evaluate offshore oil projects?	Panel 8 was formed to validate the model and the case study results. In this step the model results were presented to experts and they were asked if the assessment framework is appropriate enough for evaluating oil offshore projects. The experts confirmed that the model would be a helpful method to enhance the investment decision and it could be applied to different offshore oil projects around the world. For more details see chapter 10.

Table 89: Summarizes Research Questions and How Were Addressed

12.2 Limitations

This study provides a comprehensive approach that take account of the factors that impact the decision making process for the establishment of offshore oil projects, assessing their weights of impact as well as those associated with desirability matrices and sensitivity analyses to estimate multiple scenarios. Thus, it's very important to mention that the main goal of this model is to enhance and often aid the decision making process during the early phases of project selection. However, decision makers must

perform the necessary due diligence and engage other tools to assess important factors that are not represented in this research model such as net present value, discount rate, and other factors. Moreover, certain factors that have been demonstrated by the model need further assessment by the decision makers before assigning their scores on a desirability curve. For instance, when assessing the government stability factor, decision makers should take into consideration that the concept of government stability is not only a governing body's ability of granting and enforcing long term leases, but also comes with unfavorable aspects such as their effectiveness in execution, their ability to control corruption, political stability, and maintain regulatory quality.

Great care was taken to identify the best panels in order to provide their judgment quantification. Nevertheless, different users may obtain different results when using the same method. People have different experiences and background. The preferred information associated with experts on the evaluation criteria varies from person to person. Meanwhile, different relative criteria weights have a significant effect on the selection of the most appropriate alternatives. The ranking results are very sensitive to the changes in attribute weights. The presence of different attribute weights may result in different ranking orders. While the scenario analysis attempted to mitigate these biases, there is still the potential for some impact.

The proposed model aimed to assess most factors impacting offshore oil projects to support an investment decision. For this purpose, a case application was conducted with the research to test the robustness of the model. Due to the competitiveness of the oil sector, companies tend to withhold any information related to an investment proposals

project. However, the future proposals investments of offshore oil projects led by this study referenced ongoing offshore oil projects as a case application. This step will not affect the result since the same steps should be completed to evaluate any future investment project.

12.3 Future Work

The limitations described in the previous section offer opportunities to develop the model further. In particular, considering more factors that might impact the success of offshore oil projects, such as natural disasters and economic recessions, as well as refreshing the model periodically, will maintain its relevance. As described in the limitation section, the complexity of certain factors needs further analysis by the decision makers before they assign their scores on a desirability curve that offers opportunities to expand the implementation of these factors. More specifically, the economical and political factors that have highest affected weights on offshore oil projects based on the experts' evaluation needs further analysis. Finding resources that can provide information related to the future proposals investments of offshore oil projects, and using the research model to evaluate these projects, would likely identify additional opportunities. Another opportunity for future work is to extend the application of the model to other oil projects. Conducting the research model with onshore oil projects requires some modifications to relative weights to ensure accurate results.

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APPENDIX A: LETTERS OF INVITATION TO EXPERTS

Invitation Letter/Email

Re: Invitation to be an expert in Abdulhakim Giadedi's PhD research

Dear Mr./Ms.:

My name is Abdulhakim Giadedi, PhD Candidate in Engineering and Technology Management Department (ETM) at Portland State University (PSU). I am conducting my dissertation research entitled "Offshore Oil Projects Evaluation".

As part of my research, I am conducting a survey to help me validate and quantify my research model. I have identified you as an expert in the field. Your knowledge, background, experience, and expertise will be very helpful for my research.

If you agree to participate in this research, I will send you web-based data collection instruments for you to provide your response. The research instruments will take about 5~10 minutes to complete.

I will be honored if you could accept my invitation and join the expert panel. I would also appreciate greatly if you could suggest other experts who have expertise or experiences in Offshore Oil Projects.

I look forward to receiving your reply!

Best Regards,

Consent:

Your participation in this study indicates that you have read the information provided (or the information was read to you) on this link:

https://drive.google.com/file/d/1hKD1k0uwjiYs6rP72vsN_m9yTNmfaWl8/view?usp=sharing

Abdulhakim Giadedi
PhD Candidate
Engineering and Technology Management Department (ETM)
Portland State University (PSU)

APPENDIX B: QUALTRICS SURVEYS TO VALIDATE THE MODEL

Oil and Gas Offshore Projects Evaluation

The purpose of this research is to provide a comprehensive framework that can be used for assessing and evaluating O&G offshore projects to select the right project.

The preliminary Hierarchical Decision Model (HDM) for evaluating O&G offshore projects shown below for your reference:

- Please click **"Yes"** if you think that the specific perspective or the specific criteria contributes to the Oil and Gas offshore projects evaluation.
- Please click **"No"** if you think that the specific perspective or the specific criteria does not contribute to the Oil and Gas offshore projects evaluation.
- If there are other perspectives, please add them in the space provided.
- If you have any comments, please add them in the space provided.

Please identify the perspectives that contribute to the O&G offshore projects evaluation:

	YES	No
Economical	☐	☐
Technical	☐	☐
Political	☐	☐
Environmental	☐	☐
Safety	☐	☐

If you think that there are other additional perspectives needed to be added, please add them below:

Other comments:

Please validate the criteria associated with Economical perspective:

	YES	No
Oil Price:	☐	☐
Initial Cost:	☐	☐
Operational Cost:	☐	☐

If there are other criteria needed to be added, please add them below:

If you have any comments, please add them below:

Please validate the criteria associated with Technical perspective:

	YES	No
Operational Difficulties:	☐	☐
Size & Complexity:	☐	☐
Production Performance:	☐	☐
Reservoir Uncertainty:	☐	☐

If there are other criteria needed to be added, please add them below:

If you have any comments, please add them below:

Please validate the criteria associated with Political perspective:

	YES	No
Government Stability:	☐	☐
Conflict Over Maritime Claims:	☐	☐
Policies, Regulations & Governance Standards:	☐	☐
Contracts Complexity:	☐	☐

If there are other criteria needed to be added, please add them below:

If you have any comments, please add them below:

Please validate the criteria associated with Environmental perspective:

	YES	No
Air Emissions:	☐	☐
Solid & Liquid Waste Management:	☐	☐
Noise Generation:	☐	☐
Oil Spills:	☐	☐

If there are other criteria needed to be added, please add them below:

If you have any comments, please add them below:

Please validate the criteria associated with Safety perspective:

	YES	No
--	-----	----

Hazard Identification & Risk
Management:

☐☐

Implementing Health, Safety and
Environmental (HSE):

☐☐

If there are other criteria needed to be added, please add them below:

If you have any comments, please add them below:

APPENDIX C: QUALTRICS SURVEYS TO QUANTIFY THE MODEL

A Hierarchical Decision Model to Evaluating Oil and Gas Offshore Projects

1. To identify the major challenging perspectives as well as associated sub-criteria impacting O&G offshore projects.
2. To evaluate and score these factors and highlight their weight of impact on offshore O&G projects.
3. To provide a comprehensive framework that can be used for assessing and evaluating O&G offshore projects to select the right project.

Please click on the next button (-->) on the right bottom of the screen to start the survey.

First Name

Last Name

Please click on the next button (-->) on the right bottom of the screen

You will quantify the importance of each perspective through pairwise comparisons. Please read the instructions below:

Items will be compared against each other, in pairs. Assign the points according to your opinion. The assignment of points should reflect the importance of each item. Example: if A is 3x more important than B, A should receive 75 points and B should receive 25 points. Note that for each pairwise comparison, the total of points assigned must be 100. Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for summary about each factor

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.

If you have comments, please provide them here:

Economical Perspectives	
Oil Price:	Oil Price refers to the probability of the oil price when the project starts to produce oil as well as the expected change on the prices during the project life cycle.
Initial Cost:	Offshore projects cost a huge amount of money and initial cost refers to the challenging of finding the funds and how much will cost the company to start-up projects.
Operational Cost:	Operational cost refers to the operating expenses to maintain production and stay in business. Operational cost include staff expenditure, subsea, pollution control, water injection, maintenance, insurance, transport charges, miscellaneous etc.
Return on Investment (ROI):	Return on Investment measures the gain or loss generated on an investment relative to the amount of money invested and compares the profitability as well.

You will quantify the importance of each factor through pairwise comparisons. Please read the instructions below:

Items will be compared against each other, in pairs. Assign the points according to your opinion. The assignment of points should reflect the importance of each item. Example: if A is 3x more important than B, A should receive 75 points and B should receive 25 points. Note that for each pairwise comparison, the total of points assigned must be 100. Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for summary about each factor

Pairwise Comparison											
	0	10	20	30	40	50	60	70	80	90	100
Operational Cost											0
Initial Cost											0
Total:											0

Pairwise Comparison											
	0	10	20	30	40	50	60	70	80	90	100
Return on Investment (ROI)											0
Initial Cost											0
Total:											0

Pairwise Comparison											
	0	10	20	30	40	50	60	70	80	90	100
Return on Investment (ROI)											0
Operational Cost											0
Total:											0

If you have comments, please provide them here:

Technical Perspectives	
Operational Difficulties:	Refers to different types of operational difficulties projects will face that will rise risks and costs such as, complex working equipment, harsh weather conditions, limited access to safety points, hydrocarbon releases, fire, high degrees of temperature and pressure, fatigue, etc.
Size & Complexity:	Refers to size of the project and risk of having a larger number of sub-scopes, such as well, subsea system, production system, transportation system, etc. These individual project sub-scopes are also quite large with costs in the hundreds of millions of dollars.
Production Performance:	Refers to risk of failure to produce the planned production, since the production volume of the oil and gas is one of the key factors to determine a project's profitability.
Reservoir Uncertainty:	Refers to the geologic and seismic uncertainty since drilling is the only way to confirm if an oil or gas field actually exists in that location. The geologic and seismic uncertainty can cause the company to lose money and waste time and resources.

You will quantify the importance of each factor through pairwise comparisons. Please read the instructions below:

Items will be compared against each other, in pairs. Assign the points according to your opinion. The assignment of points should reflect the importance of each item. Example: if A is 3x more important than B, A should receive 75 points and B should receive 25 points. Note that for each pairwise comparison, the total of points assigned must be 100. Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for summary about each factor

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.

If you have comments, please provide them here:

Political Perspectives	
Government Stability:	Refers to stability of the government hosts the site. Oil and Gas companies tend to prefer countries with stable political systems and a history of granting and enforcing long-term leases.
Conflict Over Maritime Claims:	In spite of clearly defined boundaries, maritime disputes are common where countries compete over oil discovery. The conflict over maritime most likely occurs when the high production performance has been achieved.
Policies, Regulations & Governance Standards:	Refers to regulation uncertainty, such as changing taxes, public service announcement terms, workplace health, safety and environmental security, government stability in the developing countries, etc.
Contracts Complexity:	Refers to the complexity and difficulty to implement and manage multiple contractors.

You will quantify the importance of each factor through pairwise comparisons. Please read the instructions below:

Items will be compared against each other, in pairs. Assign the points according to your opinion. The assignment of points should reflect the importance of each item. Example: if A is 3x more important than B, A should receive 75 points and B should receive 25 points. Note that for each pairwise comparison, the total of points assigned must be 100. Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for summary about each factor

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.

If you have comments, please provide them here:

Environmental & Safety Perspectives	
Hazard Identification & Risk Management:	Refers to the identification and evaluation of any issues potentially impacting safety and environmental of the project. Hazard identification is an essential step before project implementation and during the project lifecycle phases.
Implementing Health, Safety and Environmental (HSE):	Refers to the ability to implement the health, safety and environmental (HSE) principles. HSE principles contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technologies at reasonable costs.
Stringent of the Local HSE Standards:	Refers to the stringent policies and regulations of the local government in implementing health, safety and environmental (HSE) principles. More stringent means more money spending on the project.
Environmental Risk Management Integration:	Refers to the environmental enforcement rules that the company has to conduct on the project activities.

You will quantify the importance of each factor through pairwise comparisons. Please read the instructions below:

Items will be compared against each other, in pairs. Assign the points according to your opinion. The assignment of points should reflect the importance of each item. Example: if A is 3x more important than B, A should receive 75 points and B should receive 25 points. Note that for each pairwise comparison, the total of points assigned must be 100. Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for summary about each factor

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.

Pairwise Comparison											
	0	10	20	30	40	50	60	70	80	90	100
Implementing Health, Safety and Environmental (HSE)											0
Hazard Identification and Risk Management											0
Total:											0

Pairwise Comparison											
	0	10	20	30	40	50	60	70	80	90	100
Stringent of the Local HSE Standards											0
Hazard Identification and Risk Management											0
Total:											0

Pairwise Comparison											
	0	10	20	30	40	50	60	70	80	90	100
Environmental Risk Management Integration											0
Hazard Identification and Risk Management											0
Total:											0

APPENDIX D: QUALTRICS SURVEYS TO QUANTIFY THE DESIRABILITY CURVE

Desirability Metrics for Oil Price Criteria:

Please assign a value (from "0" to "100") on each metric.

At least one metric is required to be assigned as "0", meaning the least desirable.

At least one metric is required to be assigned as "100" meaning the most desirable.

Example:

Expert assigned values or scores to the Oil Price based on his/her experience and knowledge as following:

From 0 to 100 Please score and rank the desirability unit of the Oil Price?

Value of Crude Oil Price										
0	10	20	30	40	50	60	70	80	90	100
Oil Price ≤ \$10										
<hr/>										
<hr/>										
Oil Price = \$40										
<hr/>										
<hr/>										
Oil Price = \$60										
<hr/>										
<hr/>										
Oil Price = \$120										
<hr/>										
<hr/>										
Oil Price ≥ \$150										
<hr/>										
<hr/>										

From 0 to 100 Please score and rank the desirability unit of the Initial Cost?

Initial Cost										
0	10	20	30	40	50	60	70	80	90	100
Initial Cost ≤ 500 million										
<hr/>										
<hr/>										
Initial Cost = 1 Billion										
<hr/>										
<hr/>										
Initial Cost = 10 Billion										
<hr/>										
<hr/>										
Initial Cost = 50 Billion										
<hr/>										
<hr/>										
Initial Cost ≥ 95 Billion										
<hr/>										
<hr/>										

From 0 to 100 Please score and rank the desirability unit of the Return on Investment (ROI)?

0 10 20 30 40 50 60 70 80 90 100

Return on Investment (ROI)

Negative or less than zero

ROI between 10 - 50 percent

ROI between 50 - 70 percent

From 0 to 100 Please score and rank the desirability unit of the Operational Cost?

0 10 20 30 40 50 60 70 80 90 100

Operational Cost

Low estimated cost of operating expenses

Average estimated cost of operating expenses

High estimated cost of operating expenses

Extremely high estimated cost of operating expenses

ROI between 70 - 90 percent

ROI equal or exceed 100 percent

From 0 to 100 Please score and rank the desirability unit of the Operational Difficulties?

0 10 20 30 40 Operational Difficulties 60 70 80 90 100

Project expected to face low level of operational difficulties

Project expected to face medium level of operational difficulties

Project expected to face high level of operational difficulties

Project expected to face extremely high level of operational difficulties

From 0 to 100 Please score and rank the desirability unit of the Project Size & Complexity?

0 10 20 30 40 Project Size & Complexity 60 70 80 90 100

No complexity

Average complexity

High complexity

Extremely high complexity

From 0 to 100 Please score and rank the desirability unit of the Production Performance?

0 10 20 30 40 Production Performance 60 70 80 90 100

Average Production Performance

High Production Performance

Extremely high Production Performance

From 0 to 100 Please score and rank the desirability unit of the Subsurface & Reservoir?

0 10 20 30 40 50 60 70 80 90 100

Subsurface & Reservoir

Project has a high certainty of reservoir volume

Project has a low uncertainty of reservoir volume

Project has a average uncertainty of reservoir volume

Project has a high uncertainty of reservoir volume

From 0 to 100 Please score and rank the desirability unit of the Government Stability?

0 10 20 30 40 50 60 70 80 90 100

Government Stability

Unstable country

High risk of instability

Some risk of instability

Stable country

From 0 to 100 Please score and rank the desirability unit of the Contracts Complexity?

0 10 20 30 40 50 60 70 80 90 100

Simple

Reasonable

Complex

From 0 to 100 Please score and rank the desirability unit of the Conflict Over Maritime Claims?

0 10 20 30 40 50 60 70 80 90 100

No conflict over maritime

Low probability of conflict over maritime

High probability of conflict over maritime

Conflicted Area

From 0 to 100 Please score and rank the desirability unit of the Policies, Regulations & Governance Standards?

0 10 20 30 Policies, Regulations & Governance Standards 40 50 60 70 80 90 100

Low level of policies, regulations and governance standards

Average level of policies, regulations and governance standards

High level of policies, regulations and governance standards

Extremely high level of policies, regulations and governance standards

From 0 to 100 Please score and rank the desirability unit of the Hazard Identification & Risk Management?

0 10 20 30 Hazard Identification & Risk Management 40 50 60 70 80 90 100

Low-level of safety risk

Average level of safety risk

High-level of safety risk

Extremely high-level of safety risk

From 0 to 100 Please score and rank the desirability unit of the Implementing Health, Safety and Environmental (HSE)?

0	10	20	30	40	50	60	70	80	90	100
---	----	----	----	----	----	----	----	----	----	-----

HSE easy to implement

HSE reasonable to implement

HSE complex to implement

HSE very complex to implement

From 0 to 100 Please score and rank the desirability unit of the Stringent of the Local Health, Safety and Environmental (HSE) Standards?

0	10	20	30	40	50	60	70	80	90	100
---	----	----	----	----	----	----	----	----	----	-----

Low stringent of local Health, Safety and Environmental (HSE) Standards

Average stringent of local Health, Safety and Environmental (HSE) Standards

High stringent of local Health, Safety and Environmental (HSE) Standards

Extremely high stringent of local Health, Safety and Environmental (HSE) Standards

From 0 to 100 Please score and rank the desirability unit of the Environmental Risk Management Integration?

0	10	20	30	40	50	60	70	80	90	100
---	----	----	----	----	----	----	----	----	----	-----

Low level of regulation on environmental threats is required

Average level of regulation on environmental threats is required

High level of regulation on environmental threats is required

Extremely high level of regulation on environmental threats is required

APPENDIX E: HDM SOFTWARE TOOL

Version: Beta 2.0

Evaluating Oil and Gas Offshore Projects

```
graph TD; Mission((Mission)) --- Economical((Economical)); Mission --- Technical((Technical)); Mission --- Political((Political)); Mission --- Environmental((Environmental));
```

[Show Instructions](#)

Please give your judgment for each pair of nodes below toward Mission:

Technical	50		50	Economical
	1		1	

Political	50		50	Economical
	1		1	

Environmental & Safety	50		50	Economical
	1		1	

Political	50		50	Technical
	1		1	

Environmental & Safety	50		50	Technical
	1		1	

Environmental & Safety	50		50	Political
	1		1	

Version: Beta 2.0

Evaluating Oil and Gas Offshore Projects

```
graph TD; Economical((Economical)) --- OilPrice((Oil Price)); Economical --- InitialCost((Initial Cost)); Economical --- OperationalCost((Operational Cost)); Economical --- Return((Return));
```

[Show Instructions](#)

Please give your judgment for each pair of nodes below toward Economical:

Initial Cost	50		50	Oil Price
	1		1	

Operational Cost	50		50	Oil Price
	1		1	

Return on Investment (ROI)	50		50	Oil Price
	1		1	

Operational Cost	50		50	Initial Cost
	1		1	

Return on Investment (ROI)	50		50	Initial Cost
	1		1	

Return on Investment (ROI)	50		50	Operational Cost
	1		1

[Show Instructions](#)

Please give your judgment for each pair of nodes below toward Technical:

Project Size & Complexity	<input type="text" value="50"/>	<input type="text" value="1"/>	Operational Difficulties	<input type="text" value="50"/>	<input type="text" value="1"/>
Production Performance	<input type="text" value="50"/>	<input type="text" value="1"/>	Reservoir Uncertainty	<input type="text" value="50"/>	<input type="text" value="1"/>
Operational Difficulties	<input type="text" value="50"/>	<input type="text" value="1"/>	Operational Difficulties	<input type="text" value="50"/>	<input type="text" value="1"/>
Production Performance	<input type="text" value="50"/>	<input type="text" value="1"/>	Project Size & Complexity	<input type="text" value="50"/>	<input type="text" value="1"/>
Reservoir Uncertainty	<input type="text" value="50"/>	<input type="text" value="1"/>	Project Size & Complexity	<input type="text" value="50"/>	<input type="text" value="1"/>
Reservoir Uncertainty	<input type="text" value="50"/>	<input type="text" value="1"/>	Reservoir Uncertainty	<input type="text" value="50"/>	<input type="text" value="1"/>
Production Performance	<input type="text" value="50"/>	<input type="text" value="1"/>	Production Performance	<input type="text" value="50"/>	<input type="text" value="1"/>

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Please give your judgment for each pair of nodes below toward Political :

Conflict Over Maritime Claims	<input type="text" value="50"/>	<input type="text" value="1"/>	Government Stability	<input type="text" value="50"/>	<input type="text" value="1"/>
Policies, Regulations & Governance Standards	<input type="text" value="50"/>	<input type="text" value="1"/>	Government Stability	<input type="text" value="50"/>	<input type="text" value="1"/>
Contracts Complexity	<input type="text" value="50"/>	<input type="text" value="1"/>	Government Stability	<input type="text" value="50"/>	<input type="text" value="1"/>
Policies, Regulations & Governance Standards	<input type="text" value="50"/>	<input type="text" value="1"/>	Conflict Over Maritime Claims	<input type="text" value="50"/>	<input type="text" value="1"/>
Contracts Complexity	<input type="text" value="50"/>	<input type="text" value="1"/>	Conflict Over Maritime Claims	<input type="text" value="50"/>	<input type="text" value="1"/>
Contracts Complexity	<input type="text" value="50"/>	<input type="text" value="1"/>	Policies, Regulations & Governance Standards	<input type="text" value="50"/>	<input type="text" value="1"/>

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Please give your judgment for each pair of nodes below toward Environmental & Safety:

Implementing Health, Safety and Environmental (HSE)	<input type="text" value="50"/>	<input type="text" value="1"/>		Hazard Identification and Risk Management	<input type="text" value="50"/>	<input type="text" value="1"/>
Stringent of the Local HSE Standards	<input type="text" value="50"/>	<input type="text" value="1"/>		Environmental Risk Management Integration	<input type="text" value="50"/>	<input type="text" value="1"/>
Implementing Health, Safety and Environmental (HSE)	<input type="text" value="50"/>	<input type="text" value="1"/>		Hazard Identification and Risk Management	<input type="text" value="50"/>	<input type="text" value="1"/>
Stringent of the Local HSE Standards	<input type="text" value="50"/>	<input type="text" value="1"/>		Environmental Risk Management Integration	<input type="text" value="50"/>	<input type="text" value="1"/>