

**An enterprise risk management framework for managing
hazardous operational refinery risks: Case Oman**

إطار عمل إدارة مخاطر المؤسسة لإدارة مخاطر المصفاة التشغيلية الخطرة: حالة
عمان

by

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of the requirements for the degree of
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Abstract

The oil and gas industry is the leading economic contributor in the Sultanate of Oman. It is considered a critical sector that drives the country's attention to create a comprehensive, reliable, and sustainable performance to create a long-term impact economically. Due to the complexity of the competitive environment in the oil and gas, companies have highlighted the considerable number of risks facing their activities. The environment, health, and well-being of the workforce of oil companies are the most valuable asset that drives the organization productivity in general. The traditional approach of managing risk is not accurate enough to handle the present situation. Better strategies such as enterprise risk management are correctly adjusted to the new modern complex environments.

Moreover, integrating step by step ERM approach will enable continual improvement throughout organizations in decision making. Therefore, this study aims to glance at the hazardous operational risks that face the downstream sector in oil and gas companies in Oman, to develop an enterprise risk management framework which will create a shared understanding of the critical risks involved in the industry among all parties, as well as how they can be managed, and mitigated efficiently, effectively, and imperatively productive.

The following study will be using both primary and secondary data in the analysis. A questionnaire is designed for the primary method and distributed to 37 workers and management team in Oman's petroleum refineries. The study identified the critical operational hazardous risks that effect the long-term processing of crude oil in Oman's petroleum refineries which include, pressure hazard with 33.33 percent and 50 percent assigned as extreme and high risk respectively. Followed by chemical hazard with 27.78 percent and 61.11 percent assigned as extreme and high risk respectively.

Key words: Hazards, Risk, Enterprise Risk Management, Petroleum Refinery, Oman, Oil and Gas Industry, Crude oil

نبذة مختصرة

صناعة النفط والغاز هي المساهم الاقتصادي الرئيسي في سلطنة عمان. يعتبر قطاعاً حيويًا يحفز انتباه الدولة لخلق أداء شامل وموثوق ومستدام لإحداث تأثير اقتصادي طويل المدى. نظرًا لتعقيد البيئة التنافسية في قطاع النفط والغاز ، فقد أبرزت الشركات العدد الكبير من المخاطر التي تواجه أنشطتها. تعد البيئة والصحة النفسية و الجسدية للقوى العاملة في شركات النفط من أهم الأصول التي تدفع إنتاجية المؤسسة بشكل عام. الطريقة التقليدية لإدارة المخاطر ليست دقيقة بما يكفي للتعامل مع الوضع الحالي. استخدام أفضل الاستراتيجيات مثل إدارة مخاطر المؤسسة بشكل صحيح ستناسب مع البيئات المعقدة الجديدة.

علاوة على ذلك ، فإن دمج نهج إدارة المخاطر المؤسسية خطوة بخطوة يمكن من التحسين المستمر في جميع المنظمات في اتخاذ القرار. لذلك ، تهدف هذه الدراسة إلى إلقاء نظرة على المخاطر التشغيلية الخطرة التي تواجه قطاع التكرير والبتروكيماويات في شركات النفط والغاز في سلطنة عمان ، لتطوير إطار إدارة مخاطر المؤسسة الذي سيخلق فهمًا مشتركًا للمخاطر الحرجة التي تنطوي عليها الصناعة بين جميع الأطراف ، وكذلك كيف يمكن إدارتها والتخفيف من حدتها بكفاءة وفعالية وإنتاجية حتمية.

ستستخدم الدراسة التالية كلاً من البيانات الأولية والثانوية في التحليل. تم تصميم استبيان للطريقة الأولية وتوزيعه على 37 عاملاً وفريق الإدارة في مصافي البترول العمانية. حددت الدراسة المخاطر التشغيلية الخطيرة التي تؤثر على المعالجة طويلة الأجل للنفط الخام في مصافي البترول العمانية والتي تشمل مخاطر الضغط بنسبة 33.33% و 50% مخصصة للمخاطر الشديدة والعالية على التوالي. تليها المخاطر الكيميائية بنسبة 27.78 في المائة و 61.11 في المائة مخصصة للمخاطر الشديدة والعالية على التوالي.

الكلمات المفتاحية: المخاطر ، إدارة مخاطر المؤسسة ، مصفاة البترول ، عمان ، صناعة النفط والغاز ،
النفط الخام

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Abbreviations

API	American Petroleum Institute
LNG	Liquified Natural Gas
PDO	Petroleum Development Oman
ERM	Enterprise Risk Management
BP	British Petroleum
COSO	Committee of Sponsoring Organizations of the Treadway Commission
ISO	The International Organization for Standardization
CRO	The Chief Risk Officer
NGL	Natural Gas Liquid
ORPIC	Oman Oil Refineries and Petroleum Industries Companies
PRM	Plan Risk Management
EOR	Enhanced Oil Recovery
RMP	Risk Management Plan
CDU	Crude Distillation Unit
SBU	Strategic Business Unit
QRA	Qualitative Risk Analysis

Chapter One: Introduction

Introduction

This chapter will represent the background of the dissertation. The interest and motivation behind the research topic. The research aim, objectives and questions along with problem statement, limitations and a brief outline of the structure of the dissertation.

1.1 Background

Oil has made a significant change in our modern world in the past 150 years (Artripe 2019). It contributes to each and every aspect of our day to day lives. Starting from home to transportation, pharmaceutical, and plastic products. The oil industry has shaped most areas of our lives in many important ways (El-Badri 2013). It's the most critical source of energy and contributes effectively into the world's economy. It's therefore important to pay great attention to the development of the oil and gas sector since the world new civilization highly depends on it.

The revolution of oil began in the Fourth century AD (El-Badri 2013). China was the first country to drill oil wells through simple bamboo poles. The heavy liquid they extracted back then was used as a source of fuel. Hundred years later, oil was found in Europe and Asia. The oil was extracted from the natural pools over the earth surface (El-Badri 2013).

In the mid-nineteenth century, the modern oil industry took place. An American businessman named Colonel Drake was the first to discover an underground oil reservoir in 1859 near Pennsylvania in the USA (El-Badri 2013). Drake also produced a new method of Well drilling through pipes for two crucial reasons, prevention from any collapse and to be able to penetrate the ground deeply. The oil flowed successfully after drilling up to 21 meters underground. Drake managed to produce 30 barrels of oil per day (El-Badri, 2013).

Scientists and researchers began to intensify a great effort and interest into the Oil after this revolution. After several studies, it was discovered that oil or crude oil is a key raw material for a variety of products mainly including gasoline, diesel, jet fuel, and many more that is used primarily to power transportation systems . Crude oil is also a raw material in which other synthetic products such as, petrochemical, plastics, and fertilizers are derived from it.

Crude oil or the most technical term used "petroleum" is found thousands of feet underneath the earth's surface in a geological formation called reservoirs (El-Badri 2013). It's the result of natural accumulation of organic materials that are decomposed from dead marine animals and plants sank to the sea bed and been trapped in the pores of sedimentary rock approximately 360 to 286 million years ago. Figure 1.1 below illustrates a sketch representation of sedimentary rock that is found in a reservoir. These rocks have physical properties that allow them to hold hydrocarbons reserves. The organic materials are subjected to an enormous amount of heat and pressure in which they undergo a transformation process and they are converted into crude oil. The most common method of extracting crude oil is through the drilling process. After that, the crude oil is been transported by pipelines, ship or trucks to the petroleum refineries where the hydrocarbons is been distilled and separated into its usable products (El-Badri 2013).

The Oil industries consist of three major sectors; up stream, mid-stream and downstream (Suda *et al.*, 2015). The upstream includes the exploration and extraction processes. The mid-stream involves transportation and storage and the downstream is the refining process of crude oil. This research will mainly focus on the downstream sector in petroleum refineries. However, a brief explanation of each stream will be illustrated and elaborated for further understanding in the coming chapter.

In the history of crude oil development, it is observed that the petroleum industry turned the focus attention worldwide. Although this promising industry was first born in the USA in the mid-nineteenth century. It was soon to be grown very rapidly to many other countries globally including Europe such as Brazil and Russia, Asia such as China and the Middle East such as Iraq, Iran, Saudi

Arabia, Kuwait and Oman, starting the journey of searching and exploitation of crude oil reserves (Al-Attiyah *et al.*, 2006).

A review by Suda *et al.*, (2015) clearly stated that the oil and gas industries work in a highly project-based organisation. This means each operation involves multi small projects, to make sure the operations are running smoothly, less risky and as efficiently as possible. Therefore, the efficiency of the industry depends on the success and completion of these small projects. It can be concluded that the oil and gas industries deal with complex and mega projects within their organization. Suda *et al.*, (2015) also stated that for these projects to be successful it highly depends on the ability of effective management. More importantly, proper risk management strategies are required as part of the project framework. Poor risk management leads to project failure. In addition, Bigliani (2013) illustrated that all the organisations that put huge effort and action in their risk profile in order to minimize the risks associated with their projects are positioned to be more successful in the market. Therefore enterprise risk management needs to be studied extensively as it's the key to a successful, more valuable organization.

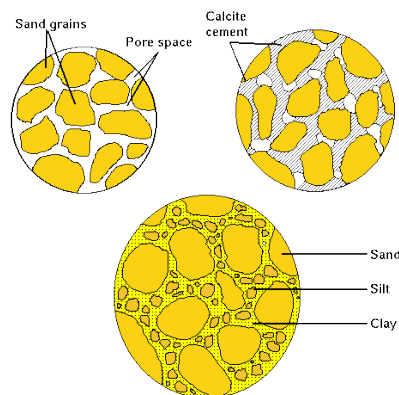


Figure 1.1 Sedimentary rock pores structure

(Adapted from lecture note of Prof. Stephen A. Nelson)

Petroleum industries are generally known to have continuous high potential risks in their projects. Since it deals with complex of chemicals mainly hydrocarbons in their processes of converting

crude oil into its useful products. The petroleum industry has been cited as one of the major source of pollution. The workers in industrial based organization are being exposed to many hazards risks including, health problems, transportation accidents, injuries from heavy tools and equipment, fire, pipeline explosions, and many more (Eyayo, 2014). A review by Kulkarni (2017) stated that accident rate in petroleum industries are 2.5 times more than construction companies and seven times more than other industries and has a long term effect to recover overall. Therefore proper risk management practices are essential to prevent and control the occurrence of these hazards. Regardless the number of years of experience in oil industries, unexpected events will always occur. It is therefore, extremely worth to highlight all the possible hazardous risks associated with the oil and gas industries and glance at the lessons learnt for the future to eliminate global economic losses of billion or millions of USD.

Even though risk management frameworks, policies, and strategies in petroleum industries are already available. Suda *et al.*, (2015) concluded that the need for new extensive theories, frameworks, models, policies, and management strategies should be enhanced every now and then for the oil and gas industries because of its intensive risk factors and business nature. Eventually, having proper risk management strategy in an organisation will generate more efficiency, quality, value, and less time and cost. unlike, failing to manage risk effectively will jeopardize the long-term and affect the reputation of an organisation.

1.2 Problem statement

As a result of this complexity, a number of organizations are being surprised when risks emerge that drive the organization's performance down. One of the major accidents throughout history is the BP gulf oil spill in Mexico on the 20th of April 2010 (CGTN America 2015). A Deepwater horizon oil rig exploded, and a large quantity of crude oil approximately 200 million gallons spews from a well 13,000 feet underwater. Resulted death of eleven workers, wildlife, beaches, and marshes were effected. BP spends almost 1.3 billion dollars and conducted 240 environmental studies (CGTN America 2015). Questions have been raised about the long term effect and impact

of this incident on the population of the species. With the continuous effort and analysed data, BP confirmed that all affected areas are recovering gradually and no long term impact on the species population. This is a strong indication of the importance of being prepared for such emergencies (Bigliani 2003). However, this incident was a lesson learned for BP that made them set global safety standards and become a safer company that derived the organization to be even more successful globally. Therefore, risk management is considered an essential element in today's oil and gas business operations. Since oil became an important factor in our world. The oil and gas sectors are faced with a huge number of risks within their activities ranging from unstable commodity oil prices to health, safety and environmental hazards. Unlike these risks one should pay attention into the most recent ones that organizations are not fully aware about it yet such as cyber threats which are targeting the middle east oil and gas companies in general (Bigliani 2013).

Furthermore, there is an increasing concern that most of the organizations today are having a minimal understanding and confusion on what an enterprise risk management is actually about? Most companies adopt the strategic way of managing risk, in which risks are managed only to meet the overall objectives of the enterprise, or to only meet the necessary and mandatory requirements. This way of managing risks is not accurate enough (Merna and Al-Thani 2008). ERM is managing risk effectively in the enterprise and across all levels of the organization. Therefore, having a solid understanding of what an enterprise risk management (ERM) can change the efficiency, value, and accuracy of managing risks in an organization. It is been observed that most oil and gas organizations in Oman haven't considered ERM as part of their organizational beliefs and culture. However, having an appropriate risk culture creates value, knowledge, attitudes, beliefs, and a strong understanding of risks that are shared and consolidate across the entire organization hence, risks will be mitigated, fewer accidents and safer environment (Schoenfeld 2013).

A video presented by (Stanton 2017) confirmed that the difference between a successful and unsuccessful organization is the flow of information from bottom to top and top to bottom and across the companies levels. Additionally, ERM is the answer to an important question, what are the major risks that can stop the organization achieving their mission. Normally most companies are being distracted by the smaller risks which in fact they should concentrate on the bigger risks

as well. ERM is a powerful management tool that if build in an organizational culture will have a robust capacity to understand and have the bigger picture of all the vulnerabilities and manage it in an effective way.

1.3 Research interest and motivation

Being part of the oil and gas organization, it's one responsibility to work and ensure a safe environment. Risks facing oil and gas sectors are constantly changing and the process of identifying and mitigating risks should be regularly reviewed (Merna and Al-Thani 2008). In fact, most organizations don't plan to fail, all plan to succeed. However, the difference between success and failure is unmanaged risks. Therefore, having a great passion for risks relays on the idea that risk management is the one thing and key element that makes a difference between success and failure and has a strong potential to maximize opportunities and reduce threats in projects, businesses, and life in general.

Oman is leading the region in the development of crude oil. It's an important aspect of Oman's production, its resources, and its future development. The oil and gas sector is within the framework of the government plan to achieve economic diversification, enhance national income sources and providing employment opportunities. An interview with Dr. Ali Al-Ghathiy, petroleum engineering director in PDO illustrated the fact that currently Oman contributes only about (10-12 percent) of crude oil for global production and it aims to contribute up to 25 percent in the next 3-4 years. For this reason, the idea behind this research is aiming at creating a developed enterprise risk management that will spread a great awareness among oil and gas practitioners in Oman to be able to manage risk effectively hence create more employment opportunities, and a solid economic balance.

1.4 Research aim

The research aims to evaluate how the Oman oil and gas sector can manage and mitigate crude oil refining risks. The research will propose an enterprise risk management framework that can be used by oil and gas practitioners in Oman to manage and mitigate potential hazardous risks in petroleum refineries.

1.5 Research objectives

- To review the literature and identify key hazardous risks that can negatively impact the long-term operations of crude oil processing in Oman;
- Examine the long-term effects of economic losses if the operational risks are not managed and mitigated in an efficient way;
- Establish how the operational risks associated with processing of crude oil in petroleum refineries can be managed and mitigated in an efficient way;
- Ascertain how senior project practitioners can create a positive risk management culture within the Oman oil and gas sector;
- Propose an enterprise risk management framework that can be used by oil and gas practitioners in Oman to manage and mitigate potential hazardous risks in petroleum refineries. The framework will comprise of strategies that can be used to manage potential hazardous risks in petroleum refineries.

1.6 Research questions

1. What are the key hazardous risks that can negatively impact the long-term operations of crude oil processing in Oman?

2. What are the long-term impact of economic losses if the operational risks are not managed and mitigated in an efficient way?
3. How can the operational risks associated with processing of crude oil in petroleum refineries can be managed and mitigated in an efficient way?
4. How can senior project practitioners create a positive risk management culture?
5. Is there an enterprise risk management framework that can be used by oil and gas practitioners in Oman to manage and mitigate potential hazardous risks in petroleum refineries?

1.7 Dissertation structure

The dissertation is divided into six chapters;

Chapter one:, is an introductory chapter that provides a brief overview on the research. It tells the story of oil, why is it important, how crude oil was discovered and formed, the oil and gas industry main activities and structure and the important of risk management in an organization.

Chapter Two, entails the review of literature. , it is important to offer some basic definitions, concepts, and principles at the beginning. Literature on definition of risk, risk management, enterprise risk management are critically illustrated. Typical hazards affecting petroleum industries are discussed.

Chapter Three: Research Methodology, will represent the methods used in the dissertation.

Chapter Four: Data Analysis & Discussion, it will illustrate the statistical data along with and critical discussion.

Chapter six: Conclusion and Recommendations, the dissertation summary is represented and a list of recommendations, limitation, and further work are addressed.

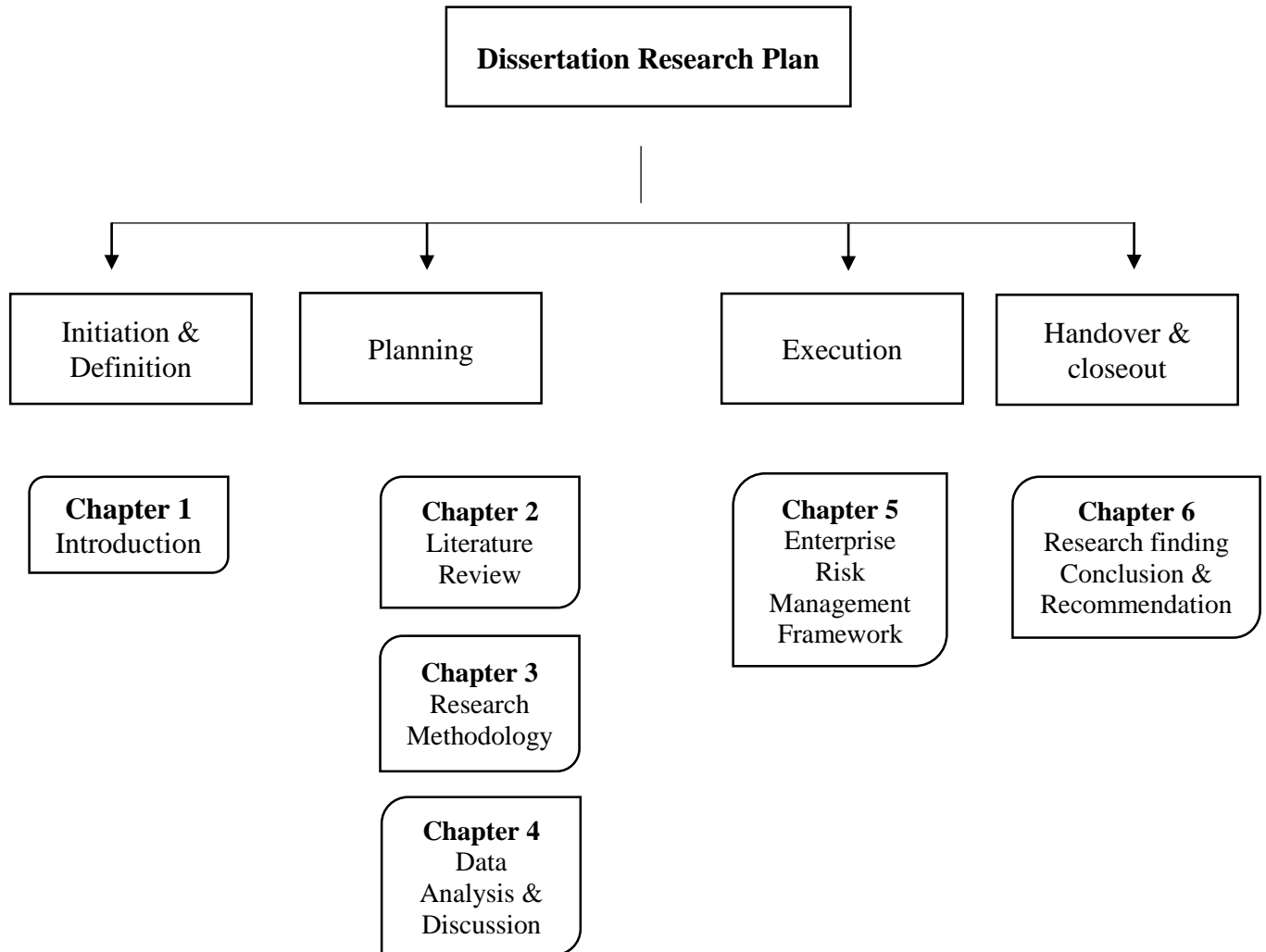


Figure 1.2 Structure of the Dissertation

Chapter Two: Literature Review

Introduction

This chapter introduces the literature review for the current dissertation. It started with an overview of the oil and gas industry in Oman, the main oil and gas activities such as, upstream, midstream and downstream, the process description and definition of crude oil are reviewed and illustrated for a clear understanding of the oil industry. A critique literature on risk, uncertainty, risk management, opportunity management, project risk management, enterprise risk management, chief risk officer, etc.

2.1 The oil and gas industry in Oman

Oman is known for its strategic location. Its located near the Arabian Peninsula, Arabian Sea, and the Persian Gulf, which grants her access to the most critical energy pathways in the world. Moreover, Oman aims to benefit from her strategic location and construct a world-class oil refining and storage complex near Duqm, which is also considered a vital oil transit checkpoint (Oman Country Analysis Brief 2016).

Oman is considered to be one of the largest oil and gas producers in the middle east (Oman Country Analysis Brief 2016). It's ranked among the top 25 of oil producers in the world and the Seventh in the middle east. Similar to many other countries, Oman's oil and natural gas resources are very crucial to its economy. According to statistics, in 2014, the oil and gas sector accounted for almost 84 percent of the government income, which has been used wisely for the growth and development of infrastructure, education, and health care. However, in 2017 and 2018, the oil sector contributed around 72 percent and 70 percent, respectively, on the government income (Figgins et al. 2018). It is clearly shown that the percentage rate decreased in the past two years, as a result of the economic diversification of the country in other sectors such as tourism and logistics. Generally, the country's reliance on the oil and gas sector is potentially high.

According to Figgins *et al.* (2018) Oman encompasses around 4.7 billion barrels of proven oil reserves and approximately 2.5 trillion cubic feet of natural gas reserves. A report published by the

US Geological survey in 2012 reported that an estimated mean of undiscovered energy resources in the south of Oman totaled around 370 million barrels of oil, 40 million barrels of natural gas, and 315 billion cubic feet of natural gas liquids (NGL). However, in the following five years (2014-2018), Oman aimed at producing 120 million cubic meters of gas per day. Also, with rising production levels, growing petrochemical sectors are established, which relies on NGL, and LPG added a potential resource in minimizing the country's dependence on hydrocarbons (Oman Country Analysis Brief 2016). Figgins *et al.* (2018) added that an increase in crude production from low 714,000 barrels per day in 2007 to 1,002,000 barrels per day in 2015 because of the new enhanced oil recovery techniques used, as shown in figure 2.1 below.

The enhanced oil recovery (EOR) technique helped to reverse the production rate after being peaked at approximately 972,000 barrels per day in 2000. Furthermore, the overall increase of petroleum production is a result of other discoveries as well but, EOR techniques such as miscible and steam injection are the critical driver of Oman's growth in oil production.

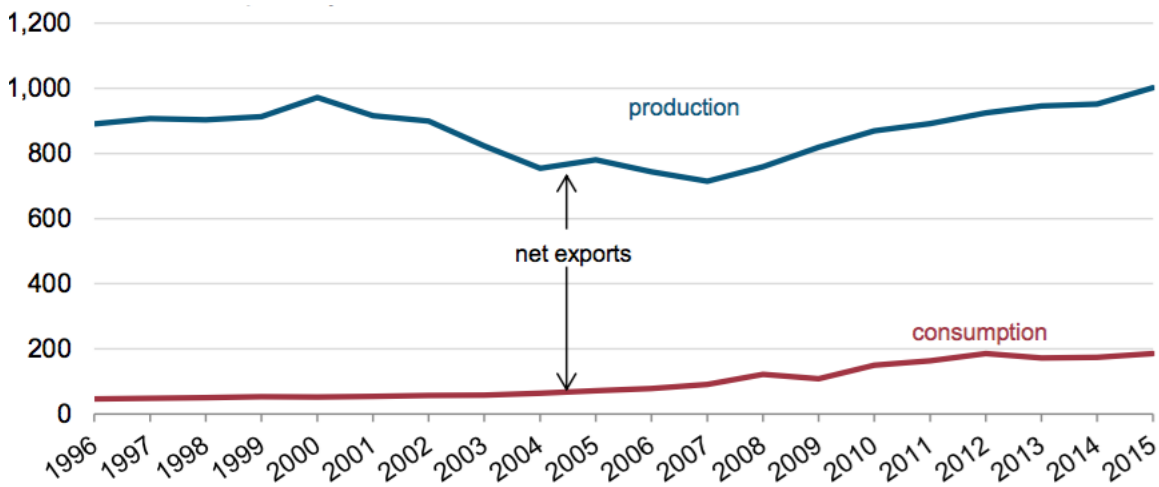


Figure 2.1 Oman petroleum and other liquids production, consumption, and net exports (1996-2015)

(Adapted from Oman Country Analysis Brief 2016).

2.1.1 Oman's oil imports and exports markets

Most of Oman's crude oil is exported to Asia, mainly include China, India, Japan, and South Korea. China is considered the biggest importer of Oman oil, lifting around 77 percent of total exports, following by India with a 10 percent share, Japan 4 percent, and South Korea 3 percent. However, despite the expended production of plastics, Oman doesn't consider a significant exporter of unrefined petroleum products (Figgins *et al.* 2018).

Oman doesn't import any of her oil outside the county, and it doesn't have any international oil pipelines and, the exported oil is shipped to focal countries. However, the country imports some of the unrefined products to domestic markets. Mina Al Fahal is considered the main export terminal since the 1970s, followed by Musandam Gas Plant started crude oil export operations in 2016, and Ras Markaz is the third oil export in Oman (Figgins *et al.* 2018).

Country	Volume (thousand b/d)
China	579
Taiwan	93
Thailand	39
Japan	36
South Korea	17
India	16
Singapore	9
Other	12
Total	801

Figure 2.2 Oman's crude oil exports in 2014
(Adapted from Oman Ministry of Oil and Gas)

2.1.2 Oman's Domestic Markets

The following domestic companies below own the majority of Oman's oil and natural gas production:

- “Petroleum Development Oman” (PDO): PDO is considered the primary producer and operator, and accounts for almost 70 percent of Oman's crude oil. It is 60 percent owned by the government, and 40 percent owned by global oil companies include Shell (34 percent), Total (4 percent), and Partex (2 percent). Additionally, PDO accounts for almost all the natural gas supply in Oman (Figgins *et al.* 2018).
- “Oman Oil Refineries and Petroleum Industries Companies” (ORPIC): ORPIC owns Oman's operating refineries sector in both areas Mina Al-Fahal in Muscat and Sohar (Figgins *et al.* 2018).
- “Oman Gas Company” (OGC): OGC is a leading company for Oman's natural gas distribution and transmission network (Figgins *et al.* 2018).
- “Oman Liquefied Natural Gas” (Oman LNG): is located in Sur, and it's Oman's Operating company of selling and producing liquified natural gas and its by-product. The company owns 51 percent by the government, 30 percent by Shell, 5.54 percent by Total, and other investors (Figgins *et al.* 2018).
- Oman Oil Company: is Oman's leading petroleum investment company for the energy sector in and out of the country. The government fully owns the company and, it invested in an extensive range of upstream oil and gas development and power plant projects (Figgins *et al.* 2018).

2.1.3 Oman and International oil Companies

There are global oil companies that play a significant role in Oman's petroleum industry such as, Occidental Petroleum (OXY), and it's considered the second-largest producer in Oman, British Petroleum (BP), Royal Dutch Shell, Total, and Partex (Figgins *et al.* 2018).

2.2 Crude Oil

Researchers have defined crude oil as a thick sticky black liquid consists of a complex mixture of hydrocarbons, organic compounds, salts, and heavy metals (Bhattacharjee 2013; Burklin *et al.* 1977). Crude oil, which is also known as petroleum or black gold, is a fossil fuel. There are non-renewable resources and highly flammable (El-Badri 2013).

According to American Petroleum Institute (2011) crude oil contains 84% of carbon atoms, 14% of hydrogen atoms, (1-3%) Sulphur content, 1% nitrogen, 1% oxygen, and about 0.1% minerals and salts.

An interesting fact about crude oil is that it is classified into different grades in terms of its color, composition, and consistency (El-Badri 2013). Table 2.1 below summarizes the four main classes of crude oil.

Table 2.1 Crude Oil Classification

GRADES	Characteristics
Light	<ul style="list-style-type: none">• Lighter color.• Thin consistency.• Flows easily.• High API gravity• It contains less amount of Sulphur and metals compound.
Heavy	<ul style="list-style-type: none">• Darker color.• More carbon atoms and very less hydrogen atoms.• Less API gravity• It contains high amount of Sulphur and metals compound.

Sour	<ul style="list-style-type: none"> • It contains higher Sulphur content.
Sweet	<ul style="list-style-type: none"> • It contains law Sulphur content.

Crude oil is categorized as either (light/heavy) depending on its density or the (API) gravity. The API gravity aims to measure whether the crude oil is light or heavy compared to water density. Generally, the crude oil is considered light when the oil API gravity is higher than ten which means its lighter than water and ultimately this will cause the oil to float. In Contrast, If the oil API gravity is less than ten that means its heavier than water as it will gradually sink (El-Badri 2013).

The crude oil is also categorized as either (sour/sweet) depending on the amount of sulphur it contains. When the oil contain more than 0.5% by weight of sulpher content it is considered as sour crude. Similarly, the oil is considered sweet crude when it contain less than 0.5% of Sulphur (El-Badri 2013).

The different physical properties of oil is extremely important to identify the type of treatment required at the refinery. For instance, if the crude contains a great amount of sulpher this indicates its corrosive effect on equipment. On the other hand, the API gravity will indicate whether the crude oil has higher or lower boiling point which is very important for the separation of crude oil into its friction (El-Badri 2013).

2.3 The Process Description of Crude Oil

The downstream sector in the oil and gas industry involves purifying and refining of crude oil into its usable products (El-Badri 2013). This process of converting crude oil into its frictions takes place in petroleum refineries. According to Burklin *et al.* (1977), petroleum refinery can convert crude oil into more than 2500 refined products such as naphtha, gasoline, kerosene, diesel, liquified petroleum gas, lubricating oils, aviation fuel, and feedstocks for the petrochemical industry. It is essential to understand crude oil processing to identify all the possible risks associated with each stage of processing crude oil. Most of Oman’s crude oil is being refined and separated in ORPIC (

Oman Oil Refineries and Petroleum Industries Companies), it is the primary leading refinery sector in Oman, and it locates in Muscat (Mina Al-Fahal) and Sohar. The crude oil is supplied from PDO, petroleum development Oman to the refinery through pipelines, and it's stored in a tank farm. The tank farm aims to ensure the safe storage of crude before processing. Most petroleum refineries perform a wide variety of processes. However, Burklin et al. (1977) stated that the refinery process flow scheme depends on two factors, the composition of crude oil and the slate of chosen petroleum frictions. However, the refinery methods are continually changing (El-Badri 2013). Figure 2.3 below represents a flow scheme of crude oil processing in ORPIC in the crude distillation unit (CDU). Furthermore, the following three main processing functions are illustrated in almost all the refineries worldwide, and it includes; separation, conversion, and treatment.

2.3.1 Separation process

The primary phase in the petroleum refinery operations is the separation process in which crude oil is separated into its main fractions that includes, naphtha, kerosene, gas oil, and long residue using three main separation equipment's, a De-salter, pre-flash tower, and a main distillation column. For the separation process, the refinery heats the crude oil into different temperature levels using a heat exchanger and this is accomplished in phases whenever heating is required. Since the type of crude oil extracted in Oman contains high level of salts and impurities such as sulphur, nitrogen, oxygen and metals, the crude oil first enters to the De-salter. The De-salter's primary function is to remove salt, dirt, and impurities from the crude. After that, it goes to the pre-flash tower or its also known as vacuum distillation. In this process, the topped crude is separated into its constituents in a vacuum column with a very low pressure approximately 2.5 bars after being heated to a temperature ranging from (190 – 200 degrees Celsius).The pre-flash column is a multi-tray column, and it consists of sixteen trays. Reboiler is used at the bottom of the column to generate steam, and the crude is separated into different boiling point fractions includes light naphtha, kerosene, and gas oil. The pre-flash column is typically used to reduce the load on the main distillation column. The final stage in the separation process is the distillation column, or it's also known as the crude splitter, where crude oil main products are separated with respect to their different boiling points.

Crude is heated to a very high temperature of approximately 300 degrees Celsius before entering the column. A furnace is used to generate steam at the bottom of the column and, the lightest fractions, which include heavy naphtha (Gasoline) and liquified petroleum gas (LPG), vaporize quickly and rise to the top of the distillation column. The medium-weight fractions, which include jet fuel (kerosene) and diesel oil, distillates from the middle of the column. The most substantial liquids with the highest boiling point, such as long residue (LR), leave at the bottom of the distillation column.

2.3.2 Conversion process

The conversion process is one of the most widely used methods, and it's known as "cracking" or "catalytic cracking" (El-Badri 2013). In this method, high temperature, pressure, and chemical catalyst are used to convert, crack, or split heavy oils into lighter products or large petroleum molecules into smaller ones (Burklin *et al.* 1977). This method takes place in a cracking unit which encompasses of a reactor with a thick wall, large furnaces, dividers, and compartments (El-Badri 2013). The feedstock in this process includes, residual oils and fuel oils with a boiling range of (340 – 540 degrees Celsius) are converted into gasoline and other light fractions (Burklin *et al.* 1977).

2.3.3 Treatment process

Treatment or treating process is the final phase in which petroleum products produced during separation are treated to stabilize and improve their quality by removing unwanted elements such as sulfur, nitrogen, and oxygen (El-Badri 2013; Burklin *et al.* 1977). ORPIC ensures excess sulfur is removed from the crude during refining because Sulphur oxides are considered a significant air pollutant if released to the atmosphere during the combustion of oil. These elements are removed using the hydrodesulfurization unit, hydrotreating unit, chemical sweetening unit, and acid gas removal unit (Burklin *et al.* 1977).

Modern petroleum refineries are equipped with advanced pollution systems that aim to treat wastes such as wastewater and chemicals, as well as, capturing emission of gasses and toxic materials to minimize air and water pollution (El-Badri 2013).

2.3.4 Transportation

Transportation is a critical part of the mid-stream sector, as billions of barrels of crude is transported around the world every day (El-Badri 2013). However, some researchers considers transportation as part of the downstream sector (Suda *et al.* 2015). Transportation process, ensures a safe transfer of crude oil from well to a refinery, service stations, and consuming countries through pipelines, railways, and tankers (El-Badri 2013). Oman doesn't own an international pipeline yet. Table 2.2 below summarizes the three transportation methods.

Table 2.2 Transportation methods
(Adapted from El-Badri 2013)

Pipelines	Roads and Railway	Ocean Tankers
<ul style="list-style-type: none"> • Made from steel. • Around (10-120 cm) inner diameter. • Run for thousands of kilometers. 	<ul style="list-style-type: none"> • Railway are used for highly flammable oil and gas products that needs to be transported carefully. • Railway are long, large, and have special storage unit for accidents prevention 	<ul style="list-style-type: none"> • Specialized tankers build to carry unrefined crude from one location to another. • Oil tankers range from small coastal tankers to ultra large crude carriers (ULCC).



Figure 2.3 Crude oil main products samples (Naphtha, jet fuel, gas oil, & fuel oil)
(Taken from Sohar Refinery Plant)

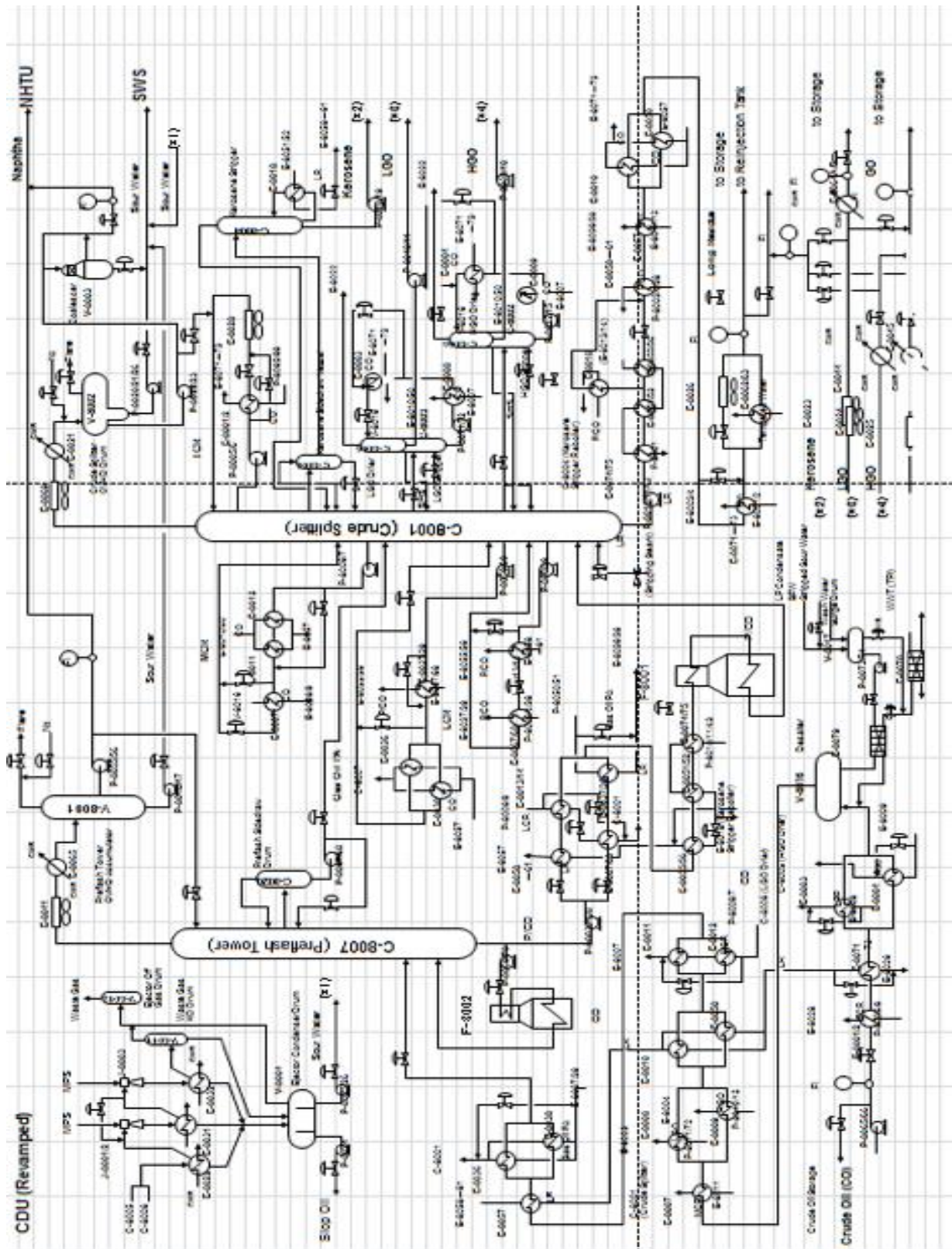


Figure 2.4 Flow scheme representation of crude oil processing (Crude Distillation Unit) – (Adapted from ORPIC)

2.4 Upstream, Mid-stream and Downstream Activities in Oil and gas Industry

Since oil is a critical factor in our lives, it is important to understand how the oil and gas industry is functioning. Most people have less common knowledge on the segments of the industry. The oil and gas industries are organized based on three main activities or functions as illustrated in figure 2.5 below. Historically, most oil industries considered midstream as a small part of upstream and downstream sectors. In the 1980s, US companies started splitting up these sectors into three individual operations.

The upstream sector or it is also known as the exploration and production sector encompasses activities that include exploratory work, which is the process of discovering oil reservoirs underground or (underwater). As well as the extraction process, by which oil is been extracted from the ground (El-Badri 2013; Suda *et al.* 2015). On the other hand, the downstream sector involves activities of purifying and refining of the crude oil . The down-stream sector in the oil and gas industry requires industrial plants that are used to process crude oil and convert it into its useful products that consist of gasoline, jet fuel, diesel, heating oil, asphalt, and petrochemicals. The midstream sector is basically the transportation of oil and gas through pipelines and storage of excess. This function provides a link between producing areas and customer located centers. Table 2.3 below represents the difference between the upstream, midstream, and downstream segments of the oil and gas industry.

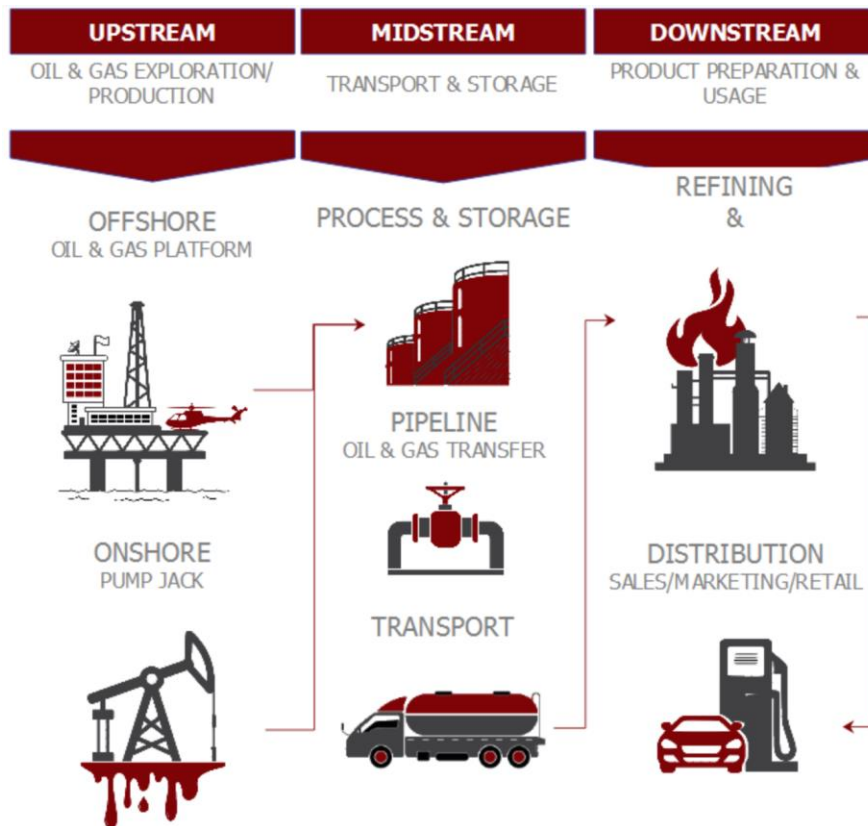


Figure 2.5 Oil and Gas Industry main Sectors (Adapted from ScheduleReader 2019)

Table 2.3 Upstream, mid-stream, & downstream activities
(Adapted from El-Badri 2013; Devold 2013 & Suda *et al.* 2015)

UP STREAM

EXPLORATION	<p>This process involves observation of the ground condition through seismic survey data, analyzing, and determining the best spot for the presence of hydrocarbon and natural gas reserves underground before the drilling process.</p> <p>Special tools are used for this process such as, aerial photography, satellite picture and gravimeter.</p>
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	<p>Oil can be found underwater as well and in this case, the following technical tools for underwater oilfields are used, such as sound waves.</p>
<p>DRILLING</p>	<p>This process involves drilling an exploratory work. The drilling process can be defined as the process of physically creating a borehole deeply underground, which is known as oil wells.</p> <p>There are two types of drilling, onshore and offshore. The onshore drilling is used for drilling under the earth surface. Whereas, offshore drilling is drilling underneath the ocean bed.</p>
<p>PRODUCTION</p>	<p>This process includes the following main functions;</p> <ol style="list-style-type: none"> 1. Estimating budgets 2. Maintenance strategies 3.

MIDSTREAM

<p>FIELD GATHERING</p>	<p>In this process, all extracted oil is been moved through a small diameter pipeline called “spiderweb” to a central location and gathered in large tank volume. After that it is sent to refineries by pipeline, truck, rail, etc.</p> <p>In contrast, natural gas cannot be stored. It is moved through smaller diameter pipelines to central processing to remove impurities and water. The natural gas is been condensed into liquid before it’s moved which is also known as LNG.</p>
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FIELD PROCESSING	Field processing in the midstream sector is extremely essential to temporarily store the oil and natural gas till it's ready to be moved, measure its production rate, remove any dirt or impurities, and separating the oil and natural gas from wastewater.
TRANSMISSION PIPELINE	<p>In this process, the oil and natural gas (LNG) are transported and distributed through the transportation pipeline.</p> <p>Because of the very high-pressure in natural gas, its transported by larger diameter pipelines.</p> <p>Pipelines are considered the safest and efficient method. However, trucks and rail are considered more flexible because of their abilities to ship to multiple destinations.</p>

DOWNSTREAM

PROCESSING/ REFINING	The process of converting crude oil into products through different processing units.
MARKETING & DISTRIBUTION	<p>This includes the business of searching and supplying customers.</p> <p>Major consumers of crude oil products are:</p> <ol style="list-style-type: none"> 1. Petrochemicals and industrial companies. 2. Municipalities 3. Utilities 4. Airlines 5. Trucking fleets

2.5 Risk

Risks, in general, are an unavoidable feature and affects every aspect of our lives. We are exposed to it every single day and we eventually learn how to manage its influence in an unstructured activity based on one's own experience, common sense, instinct, and knowledge.

Risk can mean differently depending upon different viewpoint, context, and experience (Hillson 2018). In simple terms, risk can be defined as the probability or likelihood of something to be exposed to a threat. However, there is a large volume of published studies describing what is risk?. According to Suda et al. (2015) defined risk “as a problem that might causes loses or might threaten the success of a project.” Hillson (2014) simplified the definition of risk in three words “uncertainty that matters.” However, this definition is not formal enough, but it aims to provide critical insights that can boost a critique understanding of the meaning of risk. The word “matter” includes an adverse effect or positive affect (opportunities or threats) on project objectives. The international standard ISO 301000 defined risk as “the effect of uncertainty on objectives”. Moreover, there are many other international standards in the world of risk management that have the same basic concept as the ISO standard but expanded into different ways. For example, project risk management has its own standard and defines project risk as “uncertain event or condition that if it occurs has a positive or negative effect on project objective”. Similarly, to other standards such as environmental, operational or financial risks all meet at the point that risk has to do with two main ideas, uncertainty and effect of objectives. However, the BS OHSAS 18001 defined “risk as to the likelihood of a hazardous event to occur and the severity that may be caused by the event.” This concept leads to two oriented questions; “what is the probability that a particular hazardous event will occur in the future?” and “How severe the impact on health and safety be if the hazardous event or exposure occurred?”. Therefore, in petroleum refinery risk can be defined as uncertain event or a set of circumstances that if it occurs may affect the people, asset, environment, reputation, production, and the overall objectives of the refinery. One question that needs to be asked among all these definitions of risks, what exactly is the “uncertainties” that “matters.” According to Hillson (2014), risks can have an impact other than project objectives, and it includes the technical performance, customer satisfaction, health, safety, and environmental regulations, corporate

reputation, etc. One criticism of numerous of the literature on the simple definitions of risk is that there is no depth explanation of what exactly are project objectives that matter. Moreover, these definitions lead to an understanding that risk affects the overall purpose of the organization. In contrast, risk affects each level, department, function, project, etc. on the enterprise as a whole. Hillson (2015) stated that for an effective risk management approach, organizations have to deal with; threats that might affect project time and cost, the opportunities, project objectives, and all types of uncertainty not just future events. Table 2.4 below summarizes four different types of uncertainty that might affect a project.

Table 2.4 Types of uncertainties
(Adapted from Hillson 2015)

Type of uncertainty	Definition	Example	How to manage?
Event risk (stochastic)	It is considered the “uncertain future events that may or may not happen.”	A key stakeholder may go out of the business during the project.	Using “ standard risk process ” that is tailored to deal with future events and it includes; Identify, analyze, plan, and implement response.
Variability risk (aleatoric)	It is defined as “certain future events with variable characteristic.”	The cost of raw material that may rise or fall.	Using “ quantitative risk analysis. ” Which includes probability distributions.
Ambiguity risk (Epistemic)	It refers to “certain future events with ambiguous characteristics.”	New regulations are likely to happen, but the scope of change is unknown	Managed through exploring and experimenting which includes, prototyping,

			benchmarking, and seek expert input.
Emergent risk (Ontological)	It is also known as “black swans” and it’s defined as uncertainty that arises from conceptual limitations of beyond the world view.	“Game-changers”	Using “ project continuity management ” which includes resilience and environmental scanning.

2.6 Uncertainty

One of the critical questions among researchers is that how the term uncertainty is different from risk. A considerable amount of literature agreed on the fact that there is an absolute difference between uncertainty and risk that needs to be understood. Merna and Al-Thani (2008) stated that the terms “risk” and “uncertainty” are used interchangeably, but there is a considerable difference among them. They indicated that uncertainty is used to describe a situation where it is possible to attach an event to probability to the likelihood of occurrence. They also added that uncertainty exists in a case where decision-makers lack knowledge, information, and understanding of the possible consequence. Hillson (2012) said that “all risks are uncertain, but not all uncertainties are a risk.” Throughout history, researchers distinguished the difference between risk and uncertainty mathematically, philosophically, and linguistically. A review by Toma *et al.* (2012) illustrated the distinction between risk and uncertainty in terms of probability. He stated that “risk refers to situations in which probabilities targets can be identified for possible results,” while “uncertainty refers to situations or events about which there is insufficient information to identify objective probabilities.” However, there is a continues debate on the terms “risk” and “uncertainty” among researchers. Table 2.5 below summarizes the distinction between risk and uncertainty among different authors.

Table 2.5 The difference between risk and uncertainty among different authors

Authors	Risk	Uncertainty
Merna and Al-Thani (2008)	Known or predictable events	Unknown or un predictable events
Finkel (1990)	Quantifiable	Unquantifiable
Lefebvre (2017)	Controllable events	Uncontrollable events
Holton (2004)	Measurable uncertainty	Unmeasurable risk

2.7 Hazards and Risks

There is a huge confusion among people between risks and hazards. These two words are used interchangeably (Merna & Al-Thani 2008). However, it's important for risk managers or risk assessors to know the difference to plan proper risk management strategy (ThinkAIS 2016). The following table 2.6 below summarizes the common difference between risks and hazards.

Table 2.6 Difference between Hazards vs Risks

	Hazard	Risk
Definition	The possibility of something that has the potential to poses harm or threat to people's life or health, property, and environment.	The probability of that hazard causing harm to people's life or health, property, and environment
Example	Hummer is a hazard	Using the hummer and injuring oneself is a Risk

Generally, industrial plants or refineries are exposed to a tremendous of different hazards present. A study by Eyayo (2014) summarized workplace hazards into different categories illustrated in figure 2.6 below. The hazards are classified into six categories, the first category is chemical hazards, which are considered a type of occupational hazard results from direct exposure to

chemicals in the plant through inhalation, ingestion, and skin contact. These chemicals affect workers' health both short-time as well as a long-term effect. The second category is the physical hazards, which are common source of injuries in the industry. The third category classified as mechanical hazards, which include machinery, vehicles, tools, and equipment's. The fourth, fifth, and sixth category are organizational, environmental, and biological hazards as illustrated in figure 2.6.

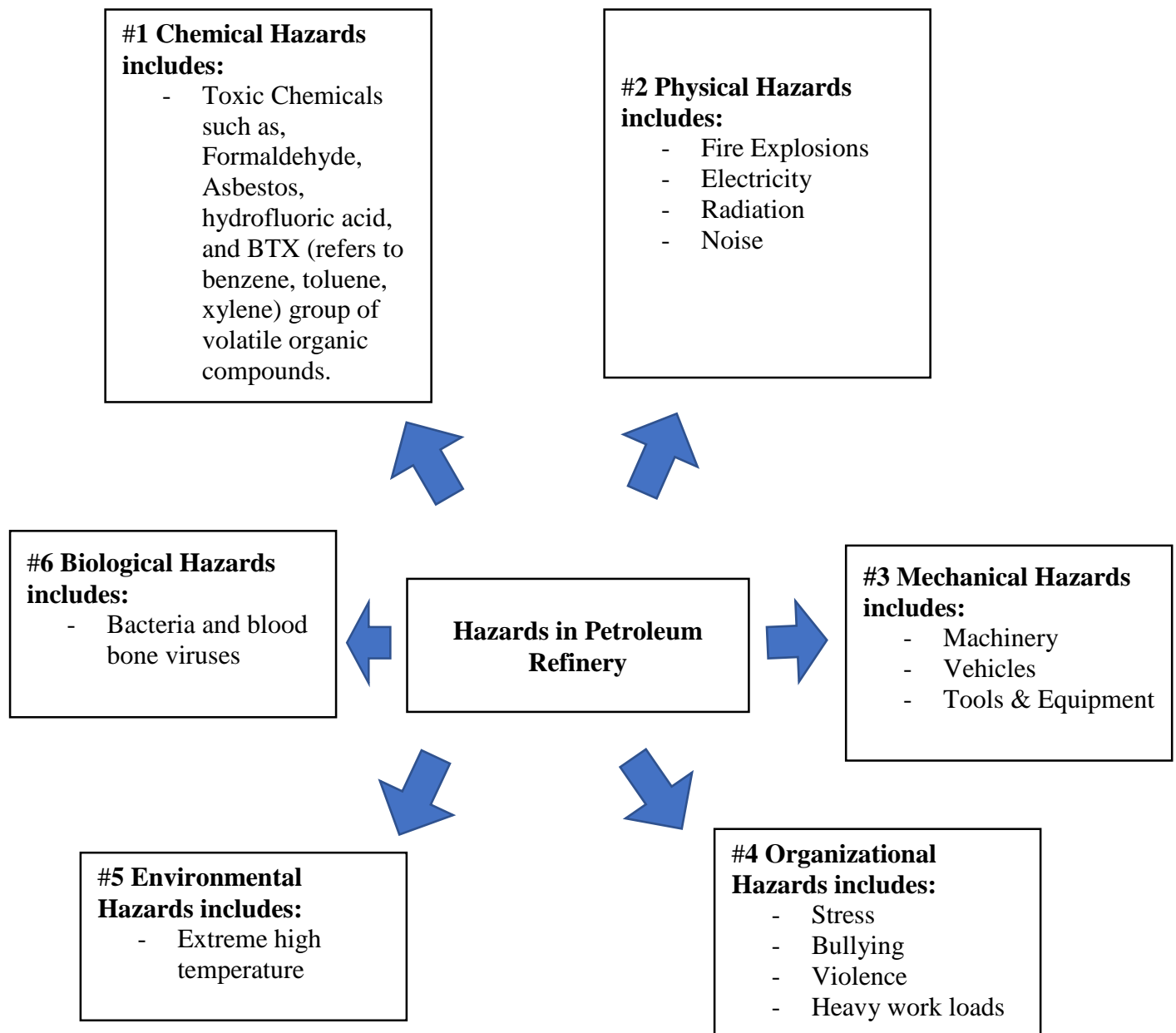


Figure 2.6 Different Hazards in Petroleum Industries (Downstream Sector)

2.8 Risk and Opportunity

There are very few published studies describing opportunity management. Most standards and recent studies include the idea of definite risk or opportunity, along with managing threats (Hillson 2012). Research by Dang (2015) illustrated a review of the concept of the downside and upside risk. He stated that the word “downside risk” is substitutable to the word risk, and usually, people define it concerning an adverse effect or losses. However, recent studies on risk definition proved that risk has a positive outcome as well, which refers to upside risk. Hillson (2012) stated that “Risk are uncertainties that matter” and, as it's explained earlier that the uncertainties that matter could be either threat that if they occur would affect time, cost, and quality. On the other hand, they are future events that, if they happen, would save money, save time, increase value, and enhance reputation. Therefore, enterprises should work hard to look for opportunities and manage them proactively. It can be concluded that the common characteristic of the downside and upside risk is that both are uncertain and effects the overall objectives. The modern understanding of risk includes both threats and opportunities, and both of them consider flavors of risk (Hillson 2012).

2.9 Risk management and organization structure

Most organizations' primary purpose is to achieve and accomplish their desired objectives. The oil and gas companies are dealing with large complex projects; hence, complex goals need to be delivered. These sets of objectives indicate the overall performance of the company. Therefore, oil companies require healthy corporate strategies that include decisions, policies, and frameworks to achieve strategic competitiveness. However, due to the complexity of organizations, these objectives are organized in a hierarchy of goals which, starts at the top level which includes the corporate objectives, these objectives are broken down into several departmental objectives which, are ultimately broken further into the portfolio of objectives. Each portfolio is broken down into projects or operations within which they have detailed purposes (Hillson 2012). However, these objectives are aligned with a set of strategies formulated and require continuous observation and understanding to achieve those goals (Merna and Al-Thani 2008). Eventually, risk management is

considered one the key strategies that needs to be managed at each level of the corporate in both way as an opportunities and threats to achieve organization optimum purposes. Figure 2.3 below represents a typical corporate structure that allows risk management and its function to be focused at each level within an organization

There are very few published literature explaining the exact risks assessed at each level of the organization, who handles risk assessments, and the general functions related to risk management (Merna and Al-Thani 2008). However, a brief explanation on the risks that affect organization at each level and how they should be managed are addressed below.

- Corporate level

The corporate level is considered the top line of the corporate entity, which includes high senior and executives managers, and they are responsible for the overall growth, survival, and stability of the corporate (Merna and Al-Thani 2008). Hillson (2018) illustrated two primary sources of risks that might affect organizations at the corporate level and might alter the ability to manage risk effectively, which are internal and external environmental factors. The internal factors include organizational culture, processes, procedures, policies, strategies, leadership style, and communication. Besides, a good communication flow (up, down), the ability to allow employees to raise concerns without being blamed, the ability to let employees build their ideas without being disciplined, etc. These sorts of actions internally helpful in building a strong foundation for managing risks. External factors may include the market place, the competition, the environment, political, legal, and regulating frameworks. In respect to oil and gas industries, Merna and Al-Thani (2008) stated that oil corporations are subject to new risks that can cause death and severe injury, which can alter the corporates value and perceived failures. Therefore, incorporate sufficient guidelines, policies, and health and safety legislation should be created at the corporate level concerning these events.

In the corporate level risks are managed and assessed in a continuous process which includes risk identification; “analysis of implication”; “response to minimum risk”; and “allocation of

appropriate contingencies”. However, the main purpose of accessing risks at corporate level is to understand the risk that is known with the corporate strategy plan, as a result it will enable a strong communication on risks and risk treatment to flow down to the strategic business unit (Merna and Al-Thani 2008).

- Strategic business unit (SBU)

Merna and Al-Thani (2008) stated that the strategic business unit is a part of the organization in which it focuses on product offerings and market segments. SBU acts as an independent business that is responsible for forming its strategic plan and marketing strategies (Summut-Bonnici and McGee 2014). However, SBU’s are created at the corporate level, and can be subcategorized under it (Merna and Al-Thani 2008). Merna and Al-Thani (2008) address the purpose of SBU relating growth, profitability, and cash flow. They added that effective financial management must balance expected return with command and control of risk. Furthermore, SBU managers are responsible in; identifying strategic business risk and respond to it; environmental and political concerns; business development; the satisfaction of stakeholders; and managing various issues facing strategic business level as well as ensuring coherency concerning corporate strategy implementation and strategic business plan (Merna and Al-Thani 2008).

Strategic business unit level is known to be the critical area that all risks reported from past and present project are addressed. Therefore, one could suggest that all the projects within the organisation should be monitored at SBU. The typical risks associated with SBU are exposures of financial, physical, human assets, and legal liability (Merna and Al-Thani 2008).

- Project level

Most of the companies today are based on several project activities, that are implemented to enhance the growth and long term impact. The project practitioners are managing those projects in the project level. The project are being handled through project life cycle that includes initiation, planning , monitoring and control and closing. The risk management are mitigated in each project

life cycle process. The successful of a project depends on two factors which include a good project management strategy and the right project managers. However, project managers are responsible on three elements. Responsible on the projects as we as the clients, responsible on the project team members and responsible on internal and external stakeholders.

- Arrows: indicates the RISK FLOW or communication through the organization.

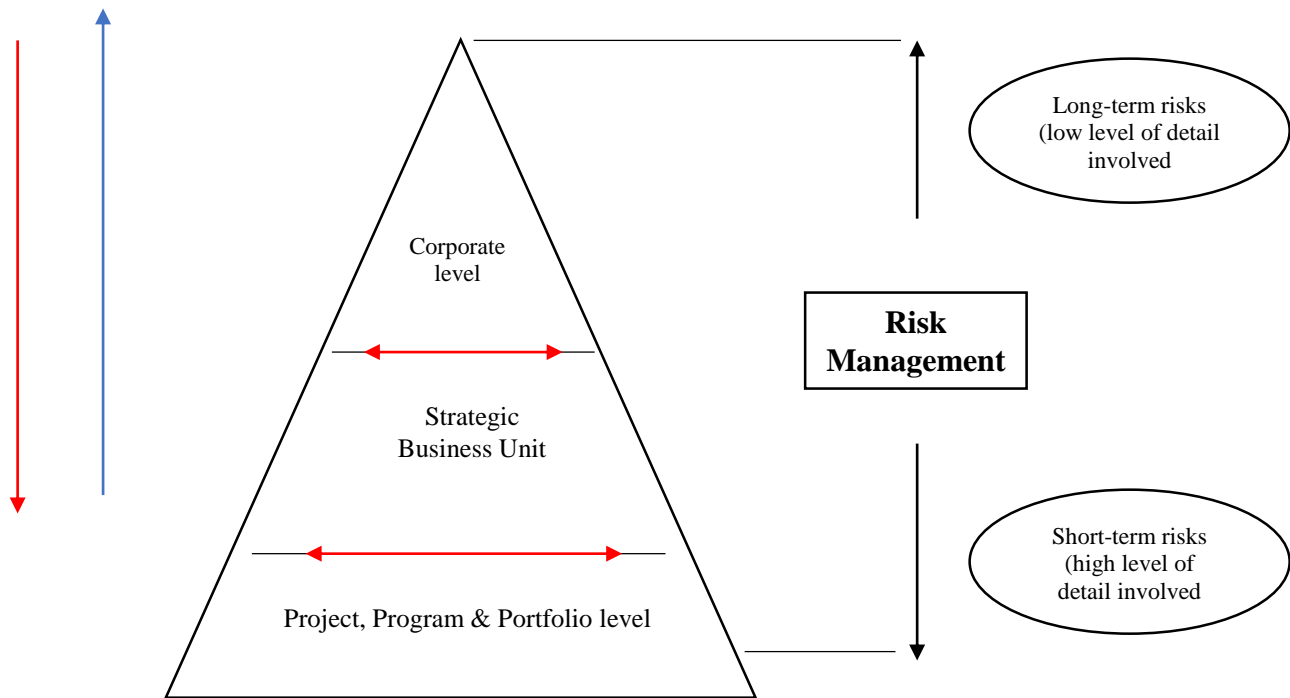


Figure 2.7 Enterprise Organization levels

2.10 Risk Management

“Risk management is not about future decisions, but about the future of decisions that we must take now”

Robert N. Charette

A large and growing body of literature has explained the concept and importance of risk management within the organization and within the project life cycle. According to Merna and Al-Thani (2008, p. 37), one of the main purposes for the establishment of risk management has been because of projects failing to meet organizations' budget, time, quality and overall performance. In addition, the lessons learned from project failure highlight the need for a better risk management strategy. However, Suda et al. (2015) stated that risk management achieves reliability in projects due to its formal procedures and it allows high performance and increases the efficiency of the organization. Kishk and Ukaga (2008) concluded that there are a strong and direct relationship between effective risk management and overall project success and summarized it in the following words “Effective risk management enhances project success. It helps to identify the key risks, assess them and plan a mitigation or contingency for them. Without an effective risk management, the Project Manager would ‘react’ to the risks as they occur against the option of being ‘proactive’ and manage the risks before they occur.”

Hillson (2012), proposed a basic risk management processes whether it's for project process or organizational decision based on asking and answering six important questions. The first question is “what am I trying to achieve?” or “what are we trying to do?”. This question leads to the first step in the risk process which is setting objectives. It requires a deep understanding of organization scope, context, strategy, and the environment within which we have to manage risk. The second question is, “what might affect me?”. This question leads to the second process of managing risk which is risk identification. This process consists of finding and determining all the uncertainties that matter and may affect the future events in both cases positively as an opportunity and will help to achieve goals or negatively as a threat that might prevent from achieving goals. Merna and Al-Thani (2008) point out that risk identification is an important step and it aims to identify all the possible risks (internal and external) that might affect projects, determining their impact on cost, time, and project objectives and documenting the characteristic of each risk. The third question is, “which of those things that might affect me are most important?”. This question leads to the third process which is risk analysis or risk assessment or risk evaluation. In this process risks are prioritized based on two dimensions, how likely is it to happen and if it did happen what effect (positive or negative) could it have in organization objectives. The fourth question is “what should

we do about it?”. This question is critically important and leads to the fourth process of managing risk which is risk response. Risk response is designing some responses to the key risks we have analyzed.

The fifth question is, “did it work?”. Sometimes the necessary actions that we have planned to take in response to risk are not achieving the organization objectives. Therefore, the organization needs to modify their approach.

The sixth question is, “what changed”. In this process organization should make sure to spot all the new risks.

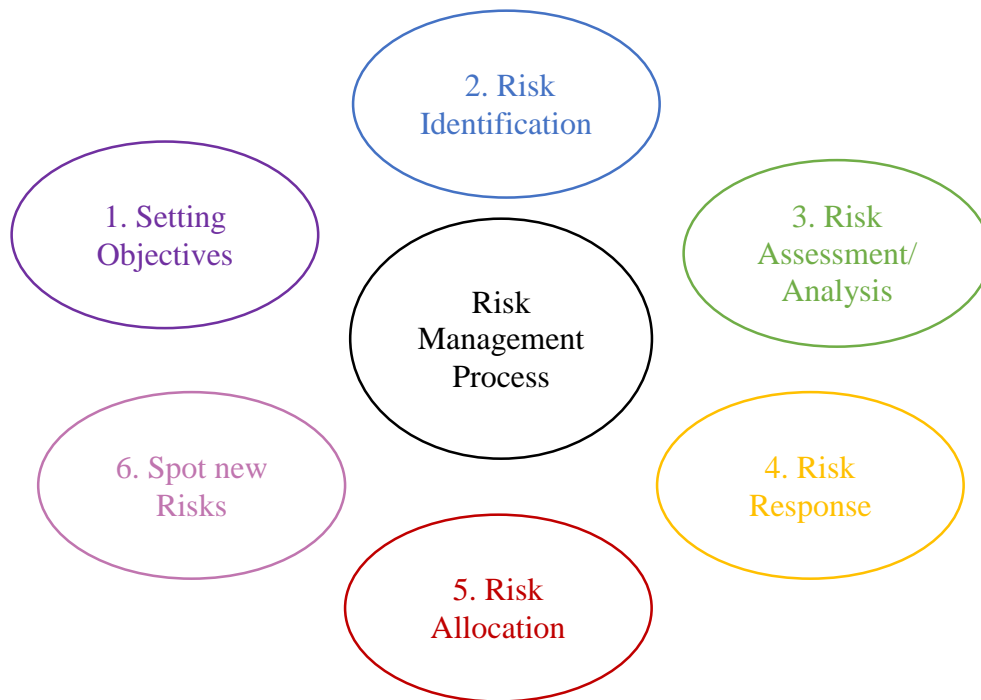


Figure 2.8 Risk Management Process

2.11 Project Risk Management

One of the critical success elements in enterprises that are dealing with a considerable number of projects today, such as oil companies, is to be able to deal with threats and opportunities professionally and strategically (Ronald 2013). However, Osabutey et al. (2013) stressed on the fact that no matter how small and simple a project might seem, anything can go wrong at any time. Therefore, project risk management strategy is vital to the corporate to ensure the mitigation of possible risks from occurring and maximize the potential opportunities. A study conducted by Junior and Carvalho (2013) on the impact of strategic project risk management on project performance. The study was done among 415 different projects and different level of complexity in several industrial sectors in Brazil. The study concludes that by adopting a risk management approach impacted positively on the project success rate. According to the PMBOK Guide (2017) it illustrated that the main reason why an organization should adopt project risk management is to create value while balancing threats and opportunities. Furthermore, PMBOK Guide (2017) introduced seven critical processes of project risk management that should be used in a continuous and intentional manner. Figure 2.8 below represents the project risk management processes.

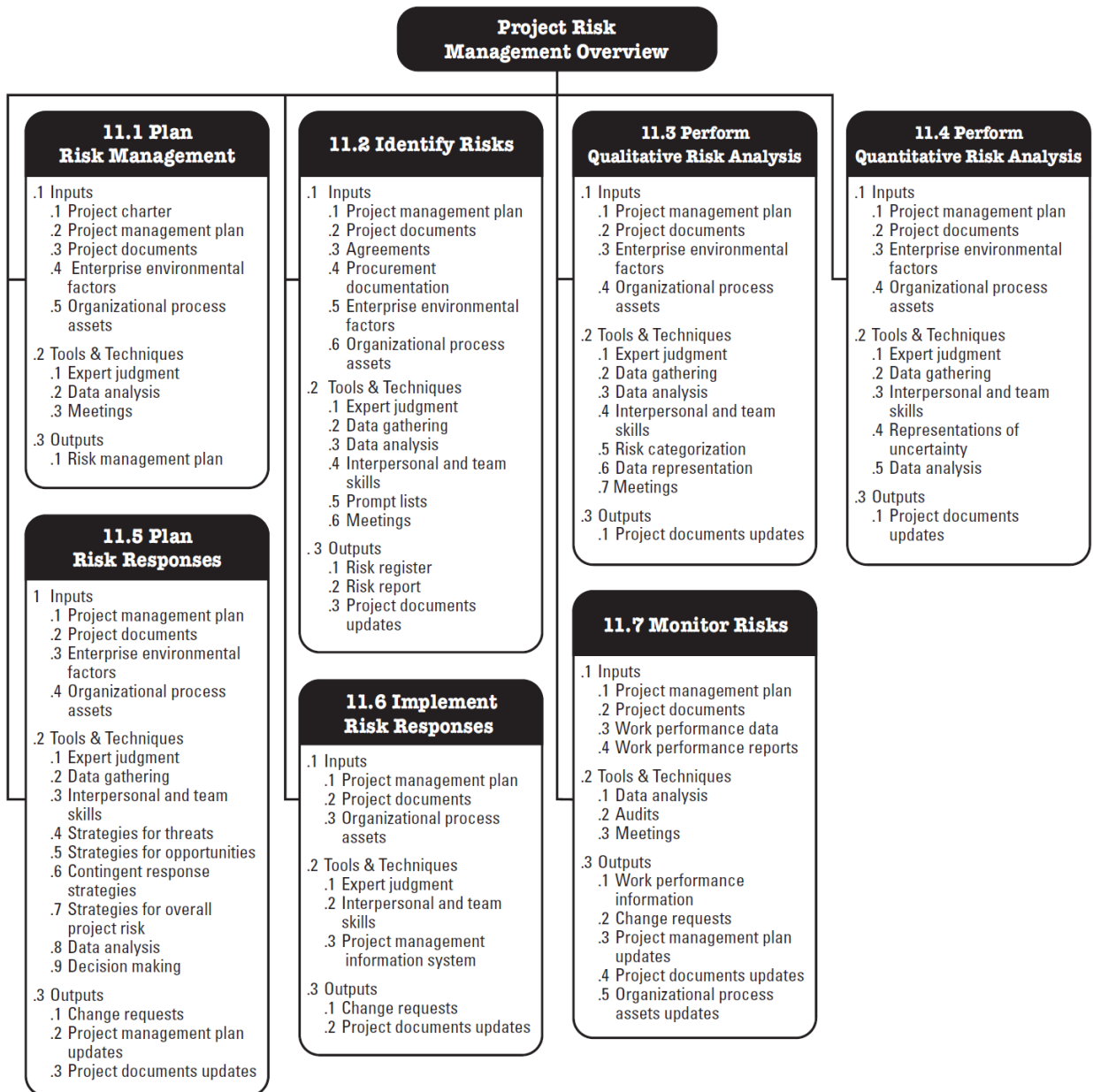


Figure 2.9 Project Risk Management Overview

(Adapted from PMBOK 2017)

2.11.1 Plan Risk Management (PRM)

PRM process aims to define the way of conducting project risk management activities. It consists of undertaking a project charter document that contains a brief description of the project, high-level scope, information requirements, and possible risks (PMBOK Guide 2017). It also includes a project management plan that contains a detailed document of several subsidiary plans of scope, schedule, cost, quality, communication, risks, etc. After that comes the project document, which is considered the key input for this process, and it comprises of stakeholder register in which detail stakeholder roles, responsibility, and attitude toward project risks are illustrated. The enterprise environmental factors also come along the PRM, and it includes a set of overall risk thresholds that the organization or key stakeholders are willing to accept. The final document to be included in the PRM is an organizational process asset, and it comprises of the following vital assets; corporation risk policy; risk breakdown structure; risk concepts and terms standard definitions; risk statement format; risk report, risk register, and risk management plan templates; roles and responsibilities; authority levels; and lessons learned review form previous projects (PMBOK Guide 2017).

2.11.1.1 PRM tools and techniques

There are a wide range of tools and techniques used in each phase of project risk management processes to support and ensure an effective approach (Hayford and Ahmed 2013). In order to accomplish plan risk management process the following tools and techniques are used;

- **Expert Judgment:** expert judgment can be clarified as, an individual or group who has specialized knowledge, experience, skill, or training in the following areas; the organization's strategy to managing risk, this includes ERM framework, types of risk, and to be able to tailor risk management to current project needs (PMBOK Guide 2017).
- **Data Analysis:** The data analysis used for this process is a stakeholder analysis for the purpose of determining the risk appetite of project stakeholder (PMBOK Guide 2017).

- Meetings: a specific planning meeting is held to develop a risk management plan that consists of a community of people inside and outside of the organization. A project manager, individual project team members, and stakeholders are within the organization. Others from outside of the organization include customers, regulators, sellers, and skilled facilitators to help the entire responsible committee to remain focus, reach an agreement of risk approach, and resolve any disagreements that may arise (PMBOK Guide 2017).

2.11.2 Identify Risk

Risk identification is the process that aims to identify and determine individual project risk, the sources of overall project risk, and recording their characteristics. Risk identification is an ongoing process, and it's performed throughout the project since new risks may occur as the project progress. The key individuals who are responsible for risk identification activities include project manager, project team member, customers, stakeholders, project risk specialist, operations manager, and risk management experts, all are brought under one roof to identify risks efficiently and appropriately (PMBOK Guide 2017).

Risk identification includes the following documents (inputs);

- Project management plan: the PMP is a collection of different important plans in one document which includes, requirements, schedule, cost, quality, resource, and risk management plans. As well as, scope, schedule and cost baseline. The entire document aims to provide a good insight of project objectives that are at risk, areas that are subjected to uncertainty will be scheduled, estimated, critical information will be assessed. It also includes a project documents, Agreements, Procurement documentation, Enterprise environmental factors, Organizational process assists.

2.11.2.1 Risk Identification techniques

They are many structured techniques used for risk identification. Hillson (2018) suggested to group them in two ways, those techniques that can be done individually and those that can be done in a group . However, Hillson (2018) also addressed other techniques that are based on time focus of risks that includes, past, present, and future focus techniques. Table 2.7 below represents a view breadth of available techniques.

Table 2.7 Risk identification techniques

Past	Present
<p>1. Past project reviews. This includes the experience of previous projects or previous operations or previous strategic plans that are similar to the risks that could happen now.</p>	<p>Review the contract, technical specification, resource plan, etc. This includes looking at situation as its now and illustrate the current uncertainties.</p>
<p>2. Lessons learned data bases. This includes reviewing at the lessons report, scan through and see what can be learned from the situation.</p>	Future
	<p>Future techniques requires creativity, which include, brain storming, Scenario analysis, and visualization.</p>
<p>3. Checklists A checklists includes capturing previous experience. It lists a whole set of threats and opportunities</p>	

and, address what could happen now in a (yes, no, don't know) basis.	
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2.11.3 Qualitative risk analysis (QRA)

Qualitative risk analysis is a project risk management process in which designated project risks are being assessed for further analysis — using the probability of risk event occurrence and the impact of the risk if it does occur on project objectives (PMBOK Guide 2017). Managing QRA effectively requires identification and management of risk attitude. Furthermore, the key benefits of the following process are to help clarify the importance of individual risk assessment for the project. There are a number of tools and techniques used for this process including; expert judgment; data gathering; data analysis; interpersonal and team skills; meetings, etc.

2.11.4 Quantitative risk analysis

Quantitative risk analysis is similar to qualitative risk analysis, but with the addition of numerical bandings of consequence and frequency, which are combined to give a risk level. There are several standard techniques for this approach, including layers of protection analysis. This technique uses numerical bands (often orders of magnitude) to describe frequencies and consequences associated with the hazard being considered.

2.11.5 Plan risk responses

According to the PMBOK Guide (2017) plan risk response is a process of creating responses, selecting the right strategies, and actions to maximize opportunities and minimize threat to project objectives. In order to create a healthy plan risk response the following documents are developed;

project management plan, project documents; enterprise environmental factors; and organizational process assets as shown in figure 2.5.

2.11.5.1 Plan risk response tools and techniques

Risk response tools may include;

1. expert judgment where its is explained earlier on plan risk management process
2. Data gathering
3. Interpersonal and team skills
4. Strategies for threats as its summarized in table below;

Strategies for threats	Explanation	Actions (Examples)
Avoid	Risk avoidance is an act where project teams eliminate or protect the project from threats and their impact (PMBOK Guide 2017).	<ul style="list-style-type: none"> • Changing the strategy of a project. • Extending the schedule • Reducing scope • Removing the cause of a threat.
Transfer	Risk transfer is a risk response strategy that involves the project team to shift both ownership and bear the impact of a threat to a third party (PMBOK Guide 2017).	<ul style="list-style-type: none"> • Insurance • Warranties • Performance bonds • Guarantees
Mitigate	Risk mitigation is a process where the project team takes action to minimize the probability of occurrence	<ul style="list-style-type: none"> • adopting simpler processes (less complex) • conducting more tests • Prototype development

	and impact of a threat (PMBOK Guide 2017).	
Accept	Risk acceptance is a strategy where project teams acknowledge the existence of a threat, and no proper action is taken. This strategy is more appropriate for low-priority threats (PMBOK Guide 2017).	<ul style="list-style-type: none"> • Establish a contingency reserve that may include, time, money, and resources to handle risks if it occurs.

5. Strategies for opportunities as shown in table below;

Strategies for opportunities	Explanation	Actions (Examples)
Escalate	Escalate is a risk response strategy where project team agrees that	
Exploit	Exploit is the strategy where organisations ensure that opportunity is realized. This strategy is generally selected for high-priority opportunities (PMBOK Guide 2017).	<ul style="list-style-type: none"> • Using new technologies to reduce, completion time, cost, and duration.
Share	Share is a strategy where ownership of an opportunity is transferred to a third party in order to share some benefit if positive risk occurs (PMBOK Guide 2017).	<ul style="list-style-type: none"> • Forming “risk-sharing” partnerships, joint ventures, and teams.
Enhance	Enhance is the strategy of raising the probability and the impact of positive	<ul style="list-style-type: none"> • Adopting more resources to an

	risks (opportunity) (PMBOK Guide 2017).	activity in order to finish early.
Accept	Accept is a strategy where the project team takes advantage of the opportunities, but without making any proactive action. This strategy is generally used for low-priority opportunities and in situations where it's costly to address an opportunity (PMBOK Guide 2017).	<ul style="list-style-type: none"> • Establishing a contingency reserve that includes, amount of time, money, and resources incase opportunity occurs.

6. Contingent response strategies: is a risk response strategy where it's used if certain events occur. Generally, for specific risks, project teams conduct a response plan that will only be executed under certain predefined conditions. All the risk responses that are identified using the following strategy are known as fallback or contingency plans (PMBOK Guide 2017).
7. Strategies for overall project risk: is a risk response strategy where risk responses are implemented to address the overall project risk, not only individual project risks. However, the same risk response strategies used for individual project risk are applied to overall project risk, which includes the following key elements; Avoid, Exploit, Transfer/share, mitigate/enhance, and Accept (PMBOK Guide 2017).
8. Data analysis
9. Decision making

2.11.6 Implement risk response

According to the PMBOK Guide (2017), implement risk response in the process that comes after an agreed-upon risk response plan, strategies, and actions are chosen. Furthermore, it aims to ensure that these agreed plans are being executed to minimize and maximize project threats and opportunities, as well as overall project risk exposure. Hillson (2018) stated that implement risk

response is a critical process in which if risk owner failed to choose the right risk response strategy, then nothing could change at all concerning risks, or they can make things get worse. However, Hillson (2018) added that there are two essential factors project risk owners or project risk practitioners should keep in mind while choosing the list of strategies, and there are cost and risk effectiveness. Implement risk response is achieved by addressing the following documents, “project management plan”, “project documents”, “and organisational process assets.”

Implement risk response tools and techniques

1. Expert judgment
2. Interpersonal and team skills
3. Project management information

2.11.7 Monitor risk

The last process in project risk management in risk monitoring. The PMBOK Guide (2017) explained monitor risk as the process in which risk owners are constantly monitoring the implemented agreed-upon risk response strategies, and observing identified risk.

2.12 Risk appetite, risk tolerance and risk threshold

These three concepts are fundamental yet misunderstood in the world of risk management (Usmani 2019). There is a large volume of published works of literature describing the meaning of each idea, but there is no one specific definition in which all researchers agree. However, Hillson (2012) described the meaning of each risk concept individually and stated the common relationship between them. The first concept which is risk appetite, the meaning of “appetite” linguistically means “hunger” and this leads to the understating that risk appetite is the level or amount of risk an organization is willing to take in peruse to its objectives. Hillson (2012) added that this definition of risk appetite used by corporate level regulators. Risk appetite is held and set at the corporate level and it flows all the way down to the project, portfolio, and program level. Risk appetite is

important. Because, each project needs to understand how much risk to take and how much risk is too much risk, and if the project is delayed or overbudget what happens to risk thresholds or risk tolerance, and here comes the relationship of these three concepts, there are all considered as constraints within which the organization manage the risk on the project as well as the program, the department and the function. It affects every part of the business. Therefore,

Hillson (2018) argues that the term “risk tolerance” is particularly unhelpful and confusing because it’s ambiguous, and it has two potential meanings. It can mean how much the organization is prepared to bare which is similar to risk appetite, or it can mean something that we can measure with a plus and minus boundary, which in this case we mean risk thresholds. However, according to PMBOK Guide (2017) “risk tolerance is the specified range of acceptable results”. Davis and Brooks (2013) stated that “Risk tolerance is essentially the degree to which someone is prepared to trade the chance of failing to achieve some additional but less-important goals, for the risk of not achieving some more-important ones”.

2.13 Enterprise Risk Management

Enterprise risk management (ERM), became a popular concept in today’s complex organizations. It is considered an ultimate approach for effective risk management. Moreover, ERM is a significant source that aims to boost the ability of the senior board of directors and top management to oversee the entire risk portfolio facing an enterprise as a whole (Daud et al. 2010). According to Hillson (2018), enterprise risk management (ERM) is the process of managing risk consistently and coherently. He added that ERM is a senior management (or chief risk officer) function who is responsible for creating a shared understanding of risk, excellent communication of risk, standard procedures for managing risks, and integrating these procedures with stakeholders. However, a review by Daud et al. (2010) highlighted that there are very few published academic research on the accomplishments or obstacles for further progress of the adoption of ERM within an organization.

A study implemented by Rogers & Ethridge (2013) on 500 oil and gas companies in 2009 and 2010 have examined and analyzed the company's performance in implementing a developed enterprise risk management within their systems to mitigate risks and achieve corporate objectives. After reviewing and collecting information, it was concluded that companies ranking higher fortune numbers are the ones who implement a mature ERM system. However, the study included six companies in their analysis. The company listed with the most elevated fortune rate achieved an estimated gross income of \$75.79 and \$90.92 in 2009 and 2010, respectively.

2.14 Project Manager

Managers have a leading role in setting objectives, motivate people, build strategic plans, control project execution, resolve issues, ensure quality, mitigate risk, and ensures continuity within an organization (Asadi 2015). However, Asadi (2015), stated that one of the challenges facing corporates today is that managers neglect the importance of building strategic risk management within their projects, which leads to a negative outcome. Furthermore, some project managers try to minimize risk and uncertainty within their plan, but eventually, it causes either overestimates or underestimates risks (Suda *et al.*, 2015). Therefore, project managers should have an impressive stock of knowledge, skills, and abilities to manage complex situations such as risk as well as, manage and complete projects effectively and successfully (Iacob 2013). Authors have shaped some skills for project managers to accomplish risks in particularly Iacob (2013) highlighted six competence skills for a project manager includes, "leadership, communication, organization, team-building, adaptability and technical skills".

Suda *et al.*, (2015) added that the success of any project depends on the ability of a project manager to manage risk prone changing environment within the corporate framework.

2.15 Risk culture

Risk culture has recently become a fundamental focus in the world of risk management. It is considered an essential part of excellent enterprise risk management (ERM) practices and achieves the organization's long-term strategic goals (Farrell and Hoon 2009). Hillson (2018) explained the definition of risk culture by first describing the term "culture" as a set of values, beliefs, knowledge, and understanding shared by a group-oriented with a common purpose and interest. Therefore, risk culture can be defined as a set of shared values, beliefs, understanding, and knowledge about risk in pursuing the company's objectives. However, Hillson (2018) stated that a simple (A-B-C) model is used to develop a consistent and supportive understanding of culture across the entire organization, as shown in figure 2.9 below.

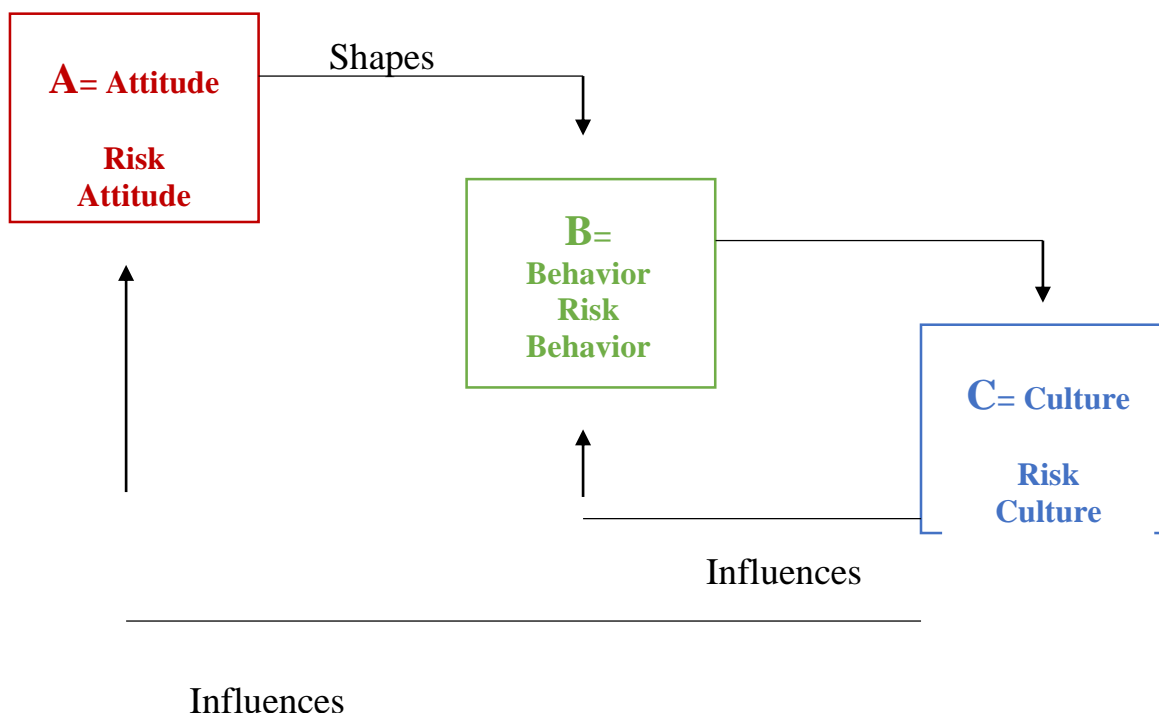


Figure 2.10 The A-B-C model for risk
(Adapted from Hillson 2014)

Hillson (2012) explained the A-B-C model as follows;

- C stands for culture;
- B stands for behavior;
- And A stands for attitude.

Project practitioners can develop a risk culture using gap analysis and this can be addressed using the following questions;

1. “where are we now?”
2. “where do we want to be ?”
3. “what needs to change?”
4. “Design and implement risk culture change program”
5. “where are we now”? (and repeat).

2.16 Potential Risks in petroleum industries

A large amount of published literature reviewed the potential risks associated with the upstream activity in the oil and gas industry. Meanwhile, few published studies addressed the potential risks associated with the downstream sector of crude refining.

One of the potential risks that face the oil and gas industry, in general, is instability in global oil prices. The price of crude oil and its products is determined by the supply and demand factor worldwide. Moreover, the cost of gasoline, for example, is determined by the global demand and supply of crude oil. However, cash flow risk is generally outside the control of the oil organizations but can result in a delay in projects or decreasing output (Merna and Al-Thani 2008).

2.17 Health, Safety and Environment

There is a large volume of written references describing the importance of health and safety in industrial and manufacturing corporates to protect and maintain the overall health of the workers

and the environment (Merna & Al-Thani 2008; Bigliani 2013; Eyayo 2014). Bigliani (2013) clearly emphasized that humans and environmental health and safety should be the number one priority for the oil and gas industries since it's exposed to a huge number of risks in their sectors including downstream activities. Furthermore, Merna & Al-Thani (2008) included that all corporates must have health and safety as a major part of their risk management system.

2.18 Chief risk officer (CRO)

Merna and Al-Thani (2008) stated that the key nominated individual who has the power to enhance the ERM approach successfully is the chief risk officer. The CRO is in charge of the entire process and has the ability at the board level to go through all ideas. However, many enterprises do not have a specified risk officer. Solo (2018) illustrated that there is a potential increase in the number of CRO positions growing from 65 percent in 2002 to 89 percent in 2013 at the global financial institutions. Brown (2010) stated that “if organizations are serious about risk management, they require a dedicated senior role to spearhead the program. It is the only way to ensure that ERM will be fully embraced. This is why the role of the CRO should be here to stay.” Daud et al., (2010) points out, the need for CRO in an organization is debatable among researchers. Some favor the ERM committee or group to be responsible for the ERM function across the entire entity. Unlike, others prefer one responsible individual to manage risks and supervise the whole process. A review by Daud et al. (2010) investigated the influence of chief risk officer (CRO) on ERM approaches among 500 public listed companies in Malaysia. It was concluded that the companies with a good quality CRO's were able to have a strong influence on the level of ERM adoption. However, one of the limitations of this research is that it did not investigate corporate performance after applying ERM.

The key role responsibility for CRO are illustrated below:

1. Courage to direct the company's management towards taking on excessive risk or compliance issues (Sarder 2017).
2. Responsible for the entire ERM program (Brown 2010).

3. Working with other managers for the establishment of effective risk management (Daud et al. 2010).
4. Addressing and responding to the day to day issues such as, risk events, incidents, etc. (Sarder 2017).
5. Monitoring progress
6. An excellent communicator and influencer and being able to report relevant risk information up, down, and across the entire organisation among, employees, stakeholders and, senior board members (Brown 2010; Daud et al. 2010).

CRO's are considered to have a set of critical skills to be able to grasp governance, comprehensive strategy, compliance, and performance systems (Brown 2010). However, the critical skills for the CRO are debatable among researchers. Daud et al. (2010) illustrated two essential qualities, secure communication, and teamwork. Brown (2010) included project management skills, business skills, and having the ability to change organizational attitude and culture. Rosa (2006) suggested the following qualities, a developed risk consciousness, strong knowledge in risk management curriculum, primary business process, communication, and facilitation skills.

Chapter Three: Methodology

Introduction

The following chapter provides a critical overview of the methods used in the dissertation. Bright and detailed data were gathered using mixed-methods, which includes both qualitative and quantitative methods. The quantitative approach was collected using a questionnaire distributed to around (35 to 37) workers and the management team in Oman's petroleum refineries. Quantitative measure considers a useful supplement and extends the qualitative analysis. Meanwhile, the qualitative method is one of the more practical ways which helped in creating a critical insight from researchers, scientists, and the author's point of view. These approaches allowed to develop, introduce, and evaluate how Oman oil and gas sector can manage and mitigate potential hazardous risks in petroleum refineries.

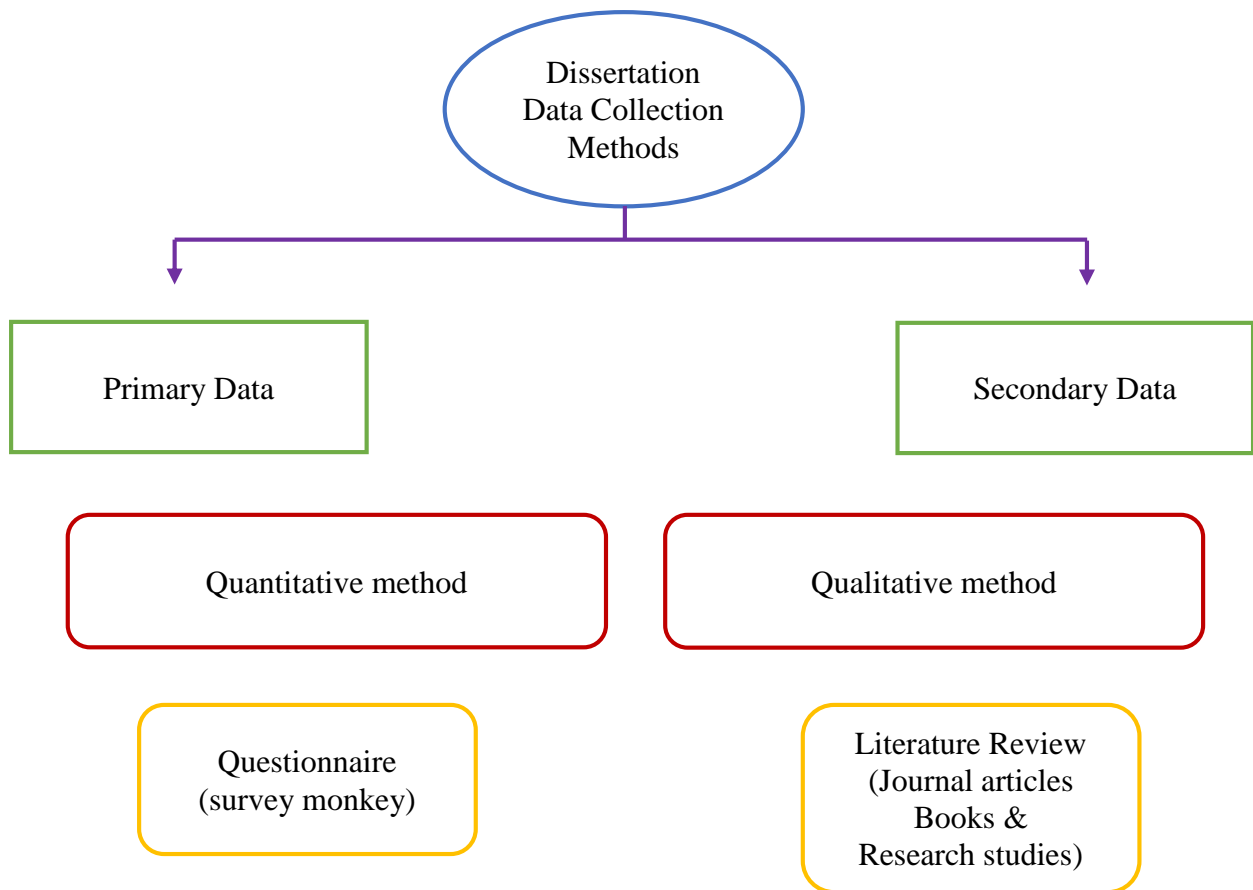


Figure 3.1 Data collection methods structure

3.1 Research questions

This quantitative study sought to build a theory in answer to the following questions:

Q1: What are the key hazardous risks that can negatively impact the long-term operations of crude oil processing in Oman?

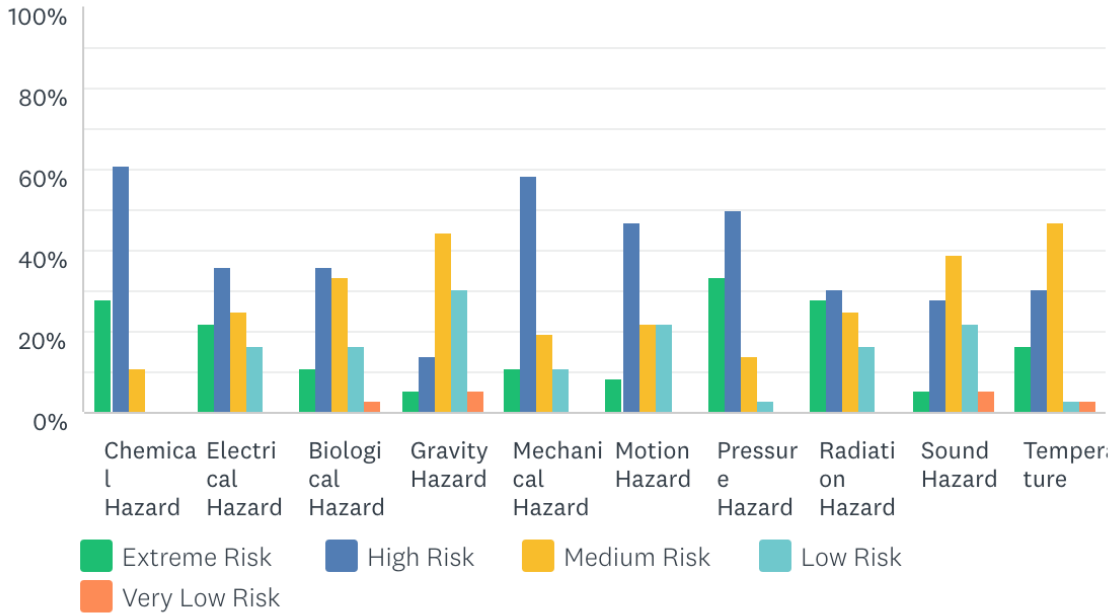
RQ2: How do senior management of petroleum industry in Oman manage the following risks?

3.2 Questionnaire Design

The design of the questionnaires is based on three sets or sections. The first and second sections give statistical data of the respondent. The first question is divided into eight subsections, where multiple-choice are set to identify the level of risks occurring on each type of potential operational hazards in petroleum refineries. The multiple-choice designed based on the following format: a scale rating from 1 to 5 assigned to the options, 1= Extreme Risk, 2= High Risk, 3=Medium Risk 4= low Risk, 5= Very low Risk. The second section is also divided into four subsections in which it examines how satisfied the workers are on the ability of senior management of petroleum refineries in managing risks related to; overall health and safety of employees; environmental pollution; operational risks; and theft in the refinery. A multiple-choice designed based on a scale rating from 1 to 3 assigned to the following options, 1= Excellent, 2= Satisfactory, 3= Unsatisfactory. The third section is based on an open question where employers and senior managers can explore their reasons for the long-term impact of economic losses if operational risks are not managed or mitigated. A sample of the questionnaire is presented in appendix A.

Chapter Four: Data Analysis and Discussion

Section 4.1



The present study was designed to determine the likelihood and the consequence of critical operational hazardous risks that might affect the long-term operations of crude oil in refineries to take the appropriate actions to manage and mitigate those risks effectively. In reviewing the literature, it was clearly emphasized that risk is the probability or likelihood of something to be exposed to a threat. from the following definition risk can be calculated as follows;

$$\text{Risk} = \text{likelihood} \times \text{Consequence}$$

The likelihood is known as how likely someone to be exposed to hazard, the consequence, on the other hand, is how negative the outcome or the impact can be.

Hazard can be defined as any substance, physical effect, or condition which have the potential to cause harm, including illness and injury, damage to property, products, production losses or increased liabilities, the environment, or reputation, including needs and expectations of stakeholders. Furthermore, all the hazards are been classified into ten types as shown in figure 4.1.

Therefore, after determining what the critical operational hazardous risk is from the above bar chart, a risk matrix can be created to have an overall level of risk using the assessment of likelihood and consequence. In contrast, by analyzing and prioritizing the critical operational hazardous risks, these findings further support the senior managers in developing risk assessment or risk analysis while conducting a risk management plan for petroleum refineries in Oman.

Extreme	Black risk are extreme
High	Red risks are high
Medium	Yellow risks are medium or moderate
Low	Green risk are low
Very low	Blue risk are very low

Black	<p>Extreme risk</p> <ul style="list-style-type: none"> • It should be considered as emergency • An immediate action to be taken to reduce the risk or activity caused
Red	<p>High risk</p> <ul style="list-style-type: none"> • Require severe attention of management and fast action plan developed as a priority.
Yellow	<p>Medium risk</p> <ul style="list-style-type: none"> • Require action and mitigation measures to reduce the risk
Green	<p>Low risk</p>

	<ul style="list-style-type: none"> Review possibility to reduce risk further by applying industrial best practices.
Blue	<p>Very low risk</p> <ul style="list-style-type: none"> Can be kept aside for future mitigation.

The bar chart provides the level of each hazardous operational risk occurring rates in Oman’s petroleum refineries between the following assigned level, ranging from extreme risk to very low risk. Overall, from the bar chart, it is shown that the highest percentage rate among extreme risks is pressure hazards, followed by chemical and radiation hazards with the same percentage rate. Moreover, over half of the respondents rated chemical hazards as the highest percentage rate among high risks, followed by mechanical, pressure, and motion hazards, respectively. In respect to medium risk, the temperature hazard rated the highest, followed by gravity, sound, and biological hazards, respectively. A small number of respondents rated the hazards as low risk. However, the highest low risk assessed on gravity hazard. Ultimately, Almost 90% of the respondents did not rate any of the hazards as very low risks.

Turning now to the experimental evidence on each level of risks evaluating the most critical operational hazards that require more attention to be managed and mitigated, taking into consideration the three most dangerous levels of risks, which are extreme, high, and moderate risks. The critical operational hazard rated as the highest extreme risk with a percentage rate of 33.33% is pressure hazard. The pressure hazard in Oman petroleum refineries is caused by a compressed gas cylinder, pressure piping, pressure vessels, tanks, hoses, pneumatic, and hydraulic equipment. However, One individual respondent stated that each pressure equipment should be rated separately. Because, some are extremely dangers and requires immediate action, especially gaseous pressure cylinders, while others are less dangerous such as water-related pressure equipment’s. However, the pressure hazard is rated as a second critical factor as high risk with a percentage rate of 50 %. Therefore, senior managers in Oman’s petroleum refineries need to take strict attention and immediate action on pressure hazards, which can cause fire, explosions, and oxygen-deficient. This results from the release of syngas (carbon monoxide and hydrogen), oxygen, methanol, and refinery gasses. Some of these gasses may affect the eye, lungs, central nerve system,

or sudden cardiac death if accidentally inhaled. Others may cause “jet fires,” vapor cloud explosion, fireball if released in the ignited section, and it depends on the quantity of flammable material around. Gasses such as H₂S, carbon monoxide, methane, and hydrogen are considered highly flammable gasses that can ignite without any source of ignition.

The other critical operational hazardous risk rated as the second-highest extreme risk is chemical hazards with a 27.78% rate. Furthermore, over half of the respondents rated chemical hazards as the optimum highest risk facing petroleum refineries in Oman with a 61.11% rate.

Chemical hazards are considered as, occupational hazard and it’s caused when employees or workers in refineries are exposed to harsh, toxic, and volatile chemicals during plant operations. Some workers are in direct contact with acids, steam, and hot surfaces which can cause long-term detrimental health effect. However, table below summarizes the four types of different causes of chemical hazards;

Table 4.1 Chemical hazard classification in oil industries

(Adapted from Eyayo 2014)

Fumes, particles, fibers, and mist	“Carbon Black”, “Welding Fume”, “Oil Mist”.
Organic, solvents and compounds	“Acetone”, “hydrocarbons”, “Benzene”.
Metals	“Acetone”, “hydrocarbons”, “Benzene”.
Inorganic gasses	“Carbon monoxide”, “Hydrogen sulphide”, “Sulphur dioxide”.

Overall, exposure to those chemicals various widely, short as well as long term health effects ranging from damage in the central nerve system, suffering in the liver, and metal poisoning (due

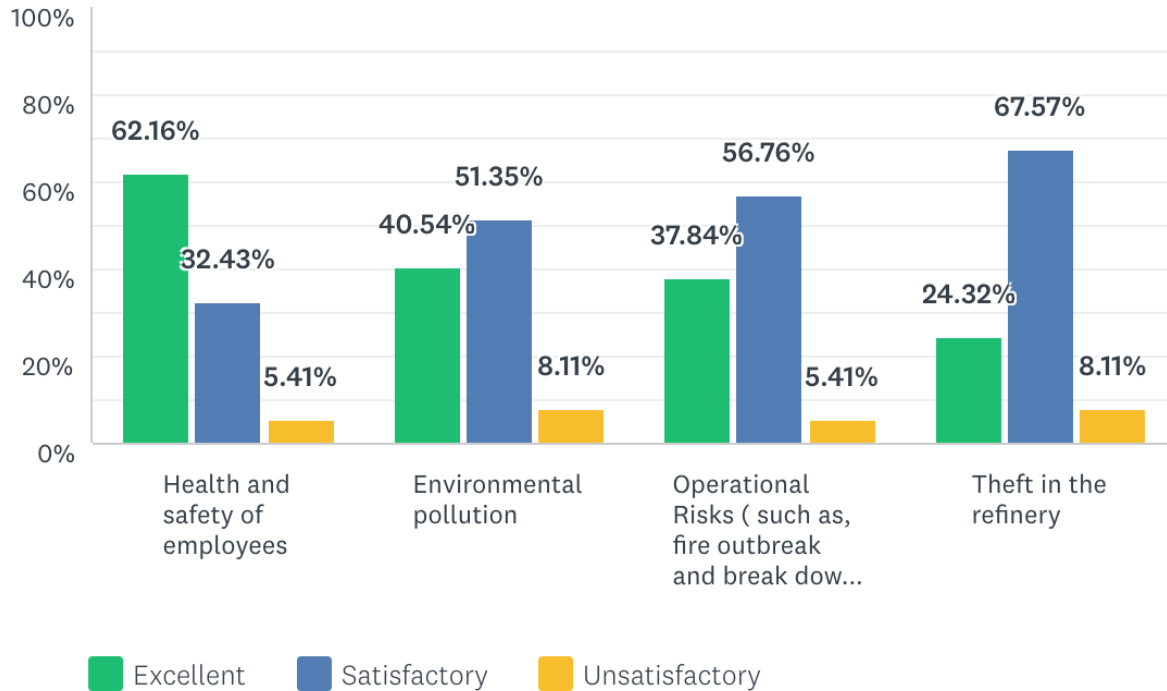
to exposure of solvents), dermal, and respiratory allergies, cancers, reproductive disorders, and many more (Eyayo 2014).

Chemical hazard can also be affected by release of H₂S, carbon monoxide, hydrofluoric acid, and methanol. Some of these toxic gasses are highly flammable when mixed with air such as carbon monoxide, H₂S gas.

In terms of mechanical hazards that was rated among the highest risk with a 58.33% rate. Mechanical hazards includes rotating equipment, drive belts, motors, conveyors, and compressed springs. It's considered a very high risk since its related to the operating equipment that drives the oil and gas industry. The mechanical parts are likely to be experienced faults in which it will require spare parts replacements, maintenance, and continue to follow up on the performance for the operation to be smooth.

	EXTREME RISK	HIGH RISK	MEDIUM RISK	LOW RISK	VERY LOW RISK	TOTAL	WEIGHTED AVERAGE
Chemical Hazard	27.78% 10	61.11% 22	11.11% 4	0.00% 0	0.00% 0	36	1.83
Electrical Hazard	22.22% 8	36.11% 13	25.00% 9	16.67% 6	0.00% 0	36	2.36
Biological Hazard	11.11% 4	36.11% 13	33.33% 12	16.67% 6	2.78% 1	36	2.64
Gravity Hazard	5.56% 2	13.89% 5	44.44% 16	30.56% 11	5.56% 2	36	3.17
Mechanical Hazard	11.11% 4	58.33% 21	19.44% 7	11.11% 4	0.00% 0	36	2.31
Motion Hazard	8.33% 3	47.22% 17	22.22% 8	22.22% 8	0.00% 0	36	2.58
Pressure Hazard	33.33% 12	50.00% 18	13.89% 5	2.78% 1	0.00% 0	36	1.86
Radiation Hazard	27.78% 10	30.56% 11	25.00% 9	16.67% 6	0.00% 0	36	2.31
Sound Hazard	5.56% 2	27.78% 10	38.89% 14	22.22% 8	5.56% 2	36	2.94
Temperature	16.67% 6	30.56% 11	47.22% 17	2.78% 1	2.78% 1	36	2.44

Section 4.2



Excellent	High
Satisfactory	Moderate
Unsatisfactory	Low

This study was proposed to investigate how satisfied workers are concerning the ability of senior management of the petroleum industry in Oman in managing the following critical causes of risk; health and safety of employees, environmental pollution; operational risks; and theft in the refinery. However, levels ranging from excellent to unsatisfactory are assigned to measure the performance. The primary purpose of the following model is to figure out the weakest area that needs better development for a productive, more valuable industries in Oman.

Overall, it is clearly shown from the bar chart that the highest most manageable area in Oman is the health and safety of employees, and it decreased gradually concerning environmental, operational, and theft in the refinery, respectively. Besides, the highest area of risk-rated as satisfactory is theft in the refinery, and it decreased gradually concerning operational, environmental, and health and safety, respectively. However, only a small number of respondents rated any of these risk causes as unsatisfied, which is a good indication that shows the amount of effort Oman is offering to mitigate those risks in general.

The health and safety of employees rated the highest with approximately 62.16% as an excellent best-managed area in Oman's downstream-sector. Followed by, environmental pollution with approximately 40.54% rate. Generally, Oman's health, safety, and environment regulations include but are not limited to; providing occupational health and safety awareness programs to the workers across all disciplinary areas to foster a safety-minded culture that keeps health, safety, and environment as number one priority.

Theft in the refinery is rated the highest with a 67.57% rate as a satisfactory, followed by operational risks with approximately 57.57%. It clearly is shown that senior management in Oman's petroleum refineries is still facing some challenges concerning these two areas. Theft in a refinery is considered to be an inappropriate act of stealing crude oil from the pipelines of oil companies. Recently, crude oil theft has been addressed to be one of the most significant challenges facing oil companies. Oil company employees may facilitate theft in the refinery, or local population, or individual unauthorized oil companies. Different techniques are used for this purpose; the most popular technology used is hot-tapping and cold-tapping. However, it might be recommended to senior managers to monitor the flow of crude continuously; refineries could be mapped from the air and controlled; tracking the flow transmitter. Senior managers should also aim at creating a culture based on honesty.

	EXCELLENT	SATISFACTORY	UNSATISFACTORY	TOTAL	WEIGHTED AVERAGE
Health and safety of employees	62.16% 23	32.43% 12	5.41% 2	37	1.43
Environmental pollution	40.54% 15	51.35% 19	8.11% 3	37	1.68
Operational Risks (such as, fire outbreak and break down of equipment)	37.84% 14	56.76% 21	5.41% 2	37	1.68
Theft in the refinery	24.32% 9	67.57% 25	8.11% 3	37	1.84

Chapter five: Enterprise Risk Management Framework

5.1 Introduction

This chapter introduces the ERM framework for Oman's petroleum refineries (Downstream sector) to help mitigate hazardous operational risks. Risk or project practitioners can use this framework as a guideline for the management of these risks.

5.2 Purpose and scope

The fundamental purpose of this guideline is to provide an enterprise framework on the management of risks in petroleum refineries. The following guidance pertains to operational risks that may impact the assets, people, and environment.

The guideline helps to define an approach to implement an integrated plan of risk management across the organization. It supplements the 'Risk Management Process Manual' and provides the basis for the creation of a risk management infrastructure, thus facilitating the implementation of industry best practices across Oman refineries.

5.3 Risk Objectives

This guideline aims to achieve a robust Risk Management Framework in which all operational and HSE risks to be identified proactively, communicated, and efficiently controlled across the organization. The application of this Enterprise Risk Management guidelines provide the basis for a robust Risk Management practice, which comprises of the following objectives:

1. Better identification of opportunities and threats.
2. More confident and rigorous decision-making and planning.
3. Proactive management of opportunities and threats.

4. More effective and efficient allocation and use of resources.
5. Improved incident management and reduction in loss and the cost of risk, e.g. Commercial insurance premiums, penalties etc.
6. Improved stakeholder confidence and trust
7. A clear understanding by all staff of their roles, responsibilities and authorities for managing risk.
8. Improved compliance with all applicable national & international legislation.
9. Better corporate governance.
10. The development of organizational culture with mature risk awareness.

5.4 Description

This framework of managing the potential risk within the petroleum refinery will be achieved via the management of known and potential hazards. Those potential hazards to be managed efficiently and effectively will undergo the five steps of risk management continuous process, as shown in figure 5.1 below.

5.4.1 Risk Identification

Each business unit and support function in the refinery ensures that all types of risks, and sources of risks to which they are exposed, are identified. For the identification process to be achievable appropriate qualitative and quantitative hazard identification techniques, such as HSE/Process Safety audits, Inspections, Job Safety Analysis, HAZID, HAZOP, QRA, SIL-LOPA, SIMOPS, PSSR, What-if Analysis, SWIFT, HSEIAs, PHSERs, FMEAs, Model Reviews, P&ID Reviews, Incident & Nearmiss reporting. The study of past incidents can also identify areas of high risk. Failures of software and hardware systems and events caused by human error also consider in the hazard identification exercises.

1. Decide What will be impacted and How

This step assists in identifying the best approach to managing the risk. At this point, all the people, environment, or assets that may be harmed by the hazard needs to be identified. It includes all stakeholders, including staff/employees, contractors, and sub-contractors, who are working at petroleum facilities and offsite individual and public.

5.4.2 Risk Analysis

In this process, all identified hazards are subjected to an assessment for risk potential. Evaluation of risk means the method of estimating the ‘likelihood of occurrence’ of specific undesirable events (the realization of the hazards), and the ‘severity of the harm or damage’ caused together with level of risk. There are three conventional risk assessment methods widely used;

- Qualitative.
- Semi-quantitative
- Quantitative

5.4.3 Qualitative risk assessment

A qualitative risk assessment is a systematic examination of what in the workplace could impact stakeholders, the environment to make decisions as to whether existing precautions or control measures are sufficient or further work needs to be accomplished to prevent threats.

In carrying out a qualitative risk assessment, it is necessary to complete the following steps;
Identify the hazards;

- Identify the possible consequences (Decide what may be impacted and how);
- Evaluate risk (and decide whether the existing precautions are adequate or whether more should be done);
- Record the findings.

Most petroleum refineries in Oman can use risk assessment Matrix (RAM) as a guide in determining risk potential during the risk assessments. A Risk Matrix may also be used addressing the operational hazardous risk levels. Thus, an understanding of the risk can be reached relatively quickly.

5.4.4 Quantitative risk assessment

Quantitative Risk Assessments are used to help evaluate potential risks when qualitative methods cannot provide an understanding of the risks, and more information is needed for risk management.

- **Hazard identification guide**

A list of all the possible hazards in petroleum refineries are listed below;

Hazard	Control measures
Hydrocarbon release	<ol style="list-style-type: none"> 1. All manual valves to be chain- locked and tagged. 2. All equipment should be depressurized/drained / Nitrogen purged and gas tested. 3. All tools and equipment have to be inspected before use, and defective tools shall be immediately replaced. 4. Drip trays or spill kits to be available on site. 5. Continuous monitoring of gas. 6. Continuous monitoring of loop pressure. 7. Use of tools which are electrically insulated for example; Brass hammer / nylon hammers, wooden hammer, etc.
Biological agent hazard	<ol style="list-style-type: none"> 1. Display a clear, suitable, and sufficient warning signs, including the biohazards sign. 2. Appropriate decontamination and disinfection procedures must be in place. 3. Safe storage and disposal of contaminated waste are needed. 4. Must ensure containers are secure and identified clearly. 5. Procedures must be in place for the use of biological agents/ materials containing them. This will vary with the equipment being used. 6. Where required, effective vaccines to be available for employees not already immune. 7. Access to be restricted to authorized personnel only.

	<ol style="list-style-type: none">8. Any equipment to be used must be suitable for its use, maintained, and in a safe condition for use, especially respiratory protective equipment.9. Only people with adequate instructions and training to be involved with biological agents.10. Any non-disposable PPE must be stored in appropriate facilities, separate from outdoor clothing, checked, kept clean and repaired, or replaced if faulty.11. Emergency plans need to include: potential incidents and emergencies that can occur. Roles, responsibilities, and authority of the individual during an emergency. Procedures that employees must follow. All PPE is required. Methods for cleaning up and disposal of waste.
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Chapter Six: Conclusions & Recommendations

In conclusion, the oil and gas industries share a primary goal in producing hydrocarbons as efficiently, safely, and cost-effectively as possible within their downstream sectors. However, adopting healthy strategies and set of rules plays a vital role in directing the organization to achieve and creating their optimum value, stability, and containment. Risk management is one of the most issues facing modern organizations today due to continues change, customer demands, and market globalization. Furthermore, risk management is continuously developing even after hundred years; risk seniors are still in the process of learning new approaches on how to manage risk, the uncertain world that we are in, and manage uncertainty effectively.

However, having a healthy approach to identify, assess, and manage risks is essential to survive in today's market. Therefore, Enterprise risk management framework is built to have a complete structure in managing risks effectively and across the whole organization.

This dissertation has investigated the key hazardous risks that can negatively impact the long-term operations of Oman's crude oil processing using both ways, reviewing the literature and conducting a statistical approach. The key major hazardous risks highlighted from the literature are chemical, physical, mechanical, organizational, environmental, and biological hazards. The dissertation also has explained the long-term effect of economic losses if these risks and not managed in an efficient way. These affects includes but are not limited to unemployment crises, reduction on people's salaries and revenues, and sharp drop in country's currency. The study also addressed some strategies and procedures that can be followed to mitigate these critical risks, the role of project practitioners in creating a positive risk culture in Oman's oil sector, and proposed an enterprise risk management framework that can be used with oil and gas practitioners in Oman.

6.1 Recommendations

1. Enhance risk intelligence within an organization
2. Evaluate enterprise risk maturity level
3. Senior managers and directors in Oman should link the ERM framework within their strategy execution, strategy setting, and strategy management. Linking ERM will generate the following fundamental principles (Frigo and Anderson 2011);
 - ERM is an approach that will identify, assess, and manage internal and external events, risks, and uncertainties that could prevent achieving the organization's strategic objectives.
 - ERM will create and protect shareholder and stakeholder value.
 - It's a primary element in building a strong foundation of good risk management across the entire enterprise.
4. Senior project practitioners should adopt or develop the A-B-C model for risk culture
5. Adoption of "digital oilfield" or "integrated operations" technology

It is to design and transform the down-stream sector through enabling the creation of a digital environment and replicates the performance of the oilfield on a computer-based technology. In which it will improve the oil and gas sector's desirability by converging the operational technology with information, especially in current low oil price challenges. In addition, it can have more benefit in achieving better productivity through distant monitoring of drilling operations and through logistics and optimization of supply chain.

6. Conducting a continuous workshop, training programs, and relevant courses to employees

Recommended measures related to the critical operational hazardous risks in Oman's petroleum refineries:

Chemical hazards

- Special safety cabinet should be used to store all hazardous chemicals.
- Fume hood should be provided to those places where chemicals are used.
- Chemicals spill kits should be provided to the workers who are dealing with toxic chemicals.
- First aid courses and training should be conducted to all the workers who deal with chemicals and other hazardous materials.
- Use of personal protective equipment (PPE).
- Work permit system

Pressure hazards

- Operating petroleum refineries should be designed and constructed based on international standards that are specially equipped to prevent and control fire and explosions. Also, creating isolation provisions of processes, utilities, storage, and safe areas. Moreover, safety distances are also required that can be accomplished using specific safety analysis, and application of internationally fire safety standards (World Bank Group 2016).
- Provide warning systems, for example, smoke and heat detection, gas and liquid pressure monitoring convenience systems (World Bank 2016).

6.2 Limitations

Finally, several significant limitations need to be considered concerning the following study. First, limited to a very tight deadline that has stopped me from taking time reading and doing more in-depth research, being critique enough in particular literature, and writing enough information related to each literature component. Second, the sample size was relatively small, not enough questionnaire responses, couldn't visit any petroleum refineries to observe the risks, and have a clear understanding. Third, limited to the type of questions addressed on the questionnaire, which should be consulted to risk specialists to draft more focused questions. Fourth, limited to direct citation and acknowledge some authors.

6.3 Future and further work

Some of the amendments and improvements in this study for future work could be;

- Risks could be evaluated in both upstream as well as downstream sectors since the most critical operations and high-risk environment are centered in the upstream activity.
- Apart from the questionnaire, conducting interviews with senior managers in oil industries would generate a clear depth on how risks are managed in Oman.
- New theories, methods, and frameworks should be adopted in the oil industries due to its sophisticated risks and business nature, as this will enhance value and increase the cost.

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Appendix A

- **Questionnaire:**

Risk Management

An enterprise risk management framework for managing hazardous operational refinery risks: Case Oman

The research aims to evaluate how the Oman oil and gas sector can manage and mitigate crude oil refining risks. The research will propose an enterprise risk management framework that can be used by oil and gas practitioners in Oman to manage and mitigate potential hazardous risks in petroleum refineries.

OK

1. Enter Your Full Name

2. Job Title

3. What are the key hazardous risks that can negatively impact the long-term operations of crude oil processing in Oman?

There are eight types of hazards risks listed below, Please indicate the level of occurrence of each hazard using a scale from (1-5), **1= Extreme Risk, 2= High Risk, 3=Medium Risk 4= low Risk, 5= Very low Risk**

	Extreme Risk	High Risk	Medium Risk	Low Risk	Very Low Risk
Chemical Hazard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Electrical Hazard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Biological Hazard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gravity Hazard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mechanical Hazard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Motion Hazard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pressure Hazard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Radiation Hazard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sound Hazard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Temperature	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4. How do senior management of petroleum industry in Oman manage the following risks?

A scale from (1-3) is illustrated below: **1= Excellent, 2= Satisfactory, 3= Unsatisfactory**

	Excellent	Satisfactory	Unsatisfactory
Health and safety of employees	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Environmental pollution	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Operational Risks (such as, fire outbreak and break down of equipment)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Theft in the refinery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>