OPTIMIZATION OF ROUND SHAPE FLOATING LNG SUPPLY CHAIN EFFICIENCY WITH SIMULATION MODELING

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ABSTRACT

Supply chain management plays very pivotal role in business operation of LNG due to increase of gas demand and need of optimization of supply chain process to achieve high profitability and customer satisfaction. Optimum LNG supply chain is obtained through the integration among states in supply chain and high utilization of facilities in every single stage. Integration of those stages should be considered in early stages before actual operation is performed. An effort to integrate LNG supply chain to get optimum performance requires simulation modeling. Critical factors impact the performance metrics were identified by using statistical design of experiment principles, subsequently simulation modeling was used to evaluate various what if (experiments) for determining the interaction among the factors and significance of the factors in LNG supply chain. In the simulation, the critical factors such as storage capacity, offloading rate, transportation capacity and number of LNG carrier were identified. The results of this study indicate that transportation capacity and number of LNG carrier are the most significant factors in achieving optimal amount of LNG in receiving terminal and high performance of LNG carrier. Then, the obtained result was used to design LNG supply chain of Round Shape FLNG using Visual Basic (VB). From the simulation, it is concluded that the optimal balancing of LNG supply chain with 997 tonnage per hour for production capacity requires seven LNG carriers with capacity 93,900 tonnage, storage capacity 288,530 tonnage and offloading rate 7940 tonnage per hour. This combination resulted the amount of received LNG in receiving about 8,013 million tonnage per year and performance of LNG Carrier is about 99,85 %.

ABSTRAK

Pengurusan rantaian bekalan dalam operasi LNG ini memainkan peranan yang sangat penting dengan peningkatan jumlah permintaan gas dan keperluan dalam mengoptimumkan proses ini untuk mencapai keuntungan yang tinggi dan dapat memberi kepuasan kepada pelanggan. Pengoptimuman rantaian bekalan LNG dapat diperolehi melalui integrasi di setiap negara dalam membentuk rantaian bekalan dengan jumlah penggunaan yang tinggi di setiap peringkat. Dalam setiap peringkat tersebut perlu dipertimbangkan pada peringkat awal sebelum pendedahan sebenar dilaksanakan. Satu usaha untuk mengintegrasikan rantaian bekalan LNG untuk mendapatkan prestasi yang optimum dengan memerlukan model simulasi. Kritikal faktor telah dikenal pasti dengan menggunakan reka bentuk statistic dengan menggunakan prinsip percubaan, kemudian model simulasi telah digunakan untuk menilai pelbagai eksperimen bagi menentukan antara faktor dan kepentingan faktor dalam rantaian bekalan LNG. Dalam simulasi, faktor kritikal seperti kapasiti penyimpanan, pemunggahan LNG, pengangkutan kapasiti dan bilangan pengangkut LNG telah dikenal pasti. Keputusan simulasi menunjukkan kapasiti pengangkutan serta nombor pengangkut LNG adalah faktor yang paling penting dalam mencapai jumlah optimum LNG yang diterima dan pengangkut LNG yang tinggi. Kemudian, hasil yang diperolehi telah digunakan untuk mereka bentuk rantaian bekalan LNG dalam bentuk bulat FLNG dengan menggunakan Visual Basic (VB). Dari simulasi yang dilakukan, disimpulkan bahawa keseimbangan optimum dalam rantaian bekalan LNG dengan 997 tan sejam bagi kapasiti pengeluaran memerlukan tujuh pembawa LNG dengan kapasiti muatan 93,900 tan, 288530 tan kapasiti penyimpanan dan kadar pemunggahan 7,940 tan sejam. Gabungan ini diterima dalam menghasilkan jumlah LNG kira-kira 8,013,000 tan setahun dan prestasi pengangkut LNG adalah 99,85%.

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LIST OF ABBREVIATION

EIA	-	Energy Information Administration
CO_2	-	Carbon Dioxides
LNG	-	Liquefied Natural Gas
FLNG	-	Floating Liquid Natural Gas
LPG	-	Liquefied Petroleum Gas
SCM	-	Supply Chain Management
FEED	-	Front End Engineenering Design
DoE	-	Design of Experiment
NGL	-	Natural Gas Liqued
km	-	Kilometer
km^2	-	kilometer square
m	-	Meter
m/s	-	Meter per second
NO	-	Nitric oxide
N_2O_2	-	Dinitrogen dioxide
N_2O_3	-	Dinitrogen trioxide
NO_2	-	Nitrogen Dioxides
NOx	-	Nitric Oxides
O_2	-	Oxygen
PM	-	Particulate matter
SO_2	-	Sulphur Dioxides
SO3	-	Sulphur Trioxides
SOx	-	Sulphur Oxides
NM	-	Nautical Mile

LIST OF SYMBOL

%	-	Percent
α	-	level of confidence
S	-	Standard deviation
x	-	Mean estimate
n	-	Number of Replication

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CHAPTER I

INTRODUCTION

1. Introduction

Demand of liquid natural gas (LNG) is increased significantly due to demand of natural resources from oil cannot meet the demand requirement. Natural gas as an energy source is increasing importance as the world's demand is expected to increase by 53% between 2008 and 2035 (EIA, 2011). As a consequence of the increasing market for LNG and uncertainty demand, the supply chain management has become more complex and the need for decision support has become even more evident.

Consideration of real supply chain optimization issues for LNG including the production volumes, liquefaction, transportation, storage, regasification and sales volumes plays a very important rule for the decision making before the actual execution. In the world, Natural gas is a vital commodity in the global energy market. It is summarized in Figure 1.1 Clearly; oil is the leading energy source, next in importance, come coal and natural gas contributing almost 50% of the energy sources (Energy Information Administration, 2010).

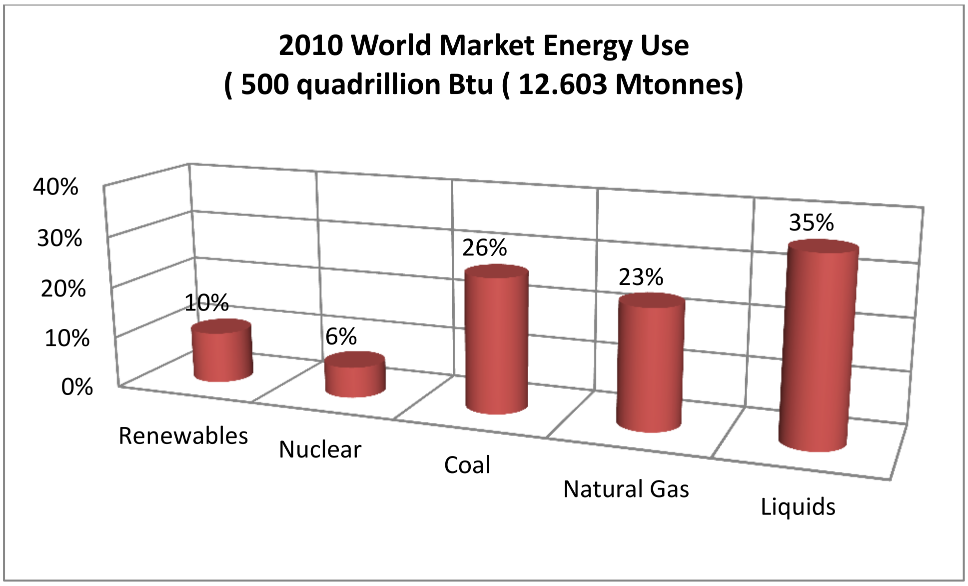

Figure 1.1: World Market Energy Use

Liquid Natural Gas (LNG) is a clean source of energy and its popularity is expected to grow rapidly in the future because it presents many environmental advantages over oil and coal. Carbon dioxide (CO_2), A greenhouse gas related to global warming, is produced from oil and coal at a rate approximately 1.4 to 1.75 times higher than that produced from natural gas. Also, nitrogen oxides (NO_x), Greenhouse gas and a source of acid rain, are formed from burning fuel it causes a wide variety of health and environmental impacts because of various compounds and derivatives in the family of nitrogen oxides, including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide. NO_x is produced from burning natural gas are approximately 20% less than those produced from burning oil and coal. Figure 1.2 shows the projected world total energy consumption by 2030 (Kidnay and Parrish, 2006)

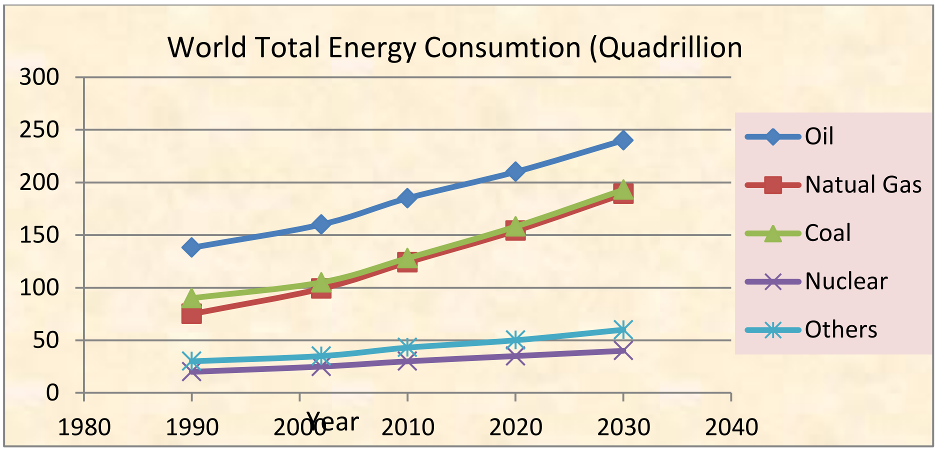

Figure 1.2: World Energy Consumption by Fuel. (EIA, 2007).

1.1 Overview of Liquefied Natural Gas (LNG) Market and Processing

The production of LNG has been practiced since the 1960's. The core concept in producing LNG is the condensation of natural gas. Other processing steps involve the elimination of undesirable impurities and separation of byproducts. A typical composition of natural gas is given in Table 1.1

Table 1.1: Typical Gas Compositions (Sources: Oil and Gas Journal)

TYPICAL NATURAL GAS COMPOSITIONS, MOLE %			
Names of Condensates	No associated gas		
	Dry Gas	Gas condensate	Associated Gas
Carbon Dioxide(CO_2)	**0.5**	**2.5**	**1.0**
Nitrogen (N_2)	**1.1**	**1.0**	**1.0**
Methane (CH_4)	**94.4**	**86.5**	**68.0**
Ethane (C_2H_6)	**3.1**	**5.5**	**15.0**
Propane (C_3H_8)	**0.5**	**3.0**	**9.0**
Iso Butane (C_4H_{10})	**0.1**	**0.3**	**2.0**
Normal Butane ($C2H402$)	**0.1**	**0.7**	**3.0**
Pentanes Plus ($C6H4O2$)	**0.2**	**0.5**	**1.0**
Total	**100.0**	**100.0**	**100.0**

1.1.1 LNG Exported by Countries

By the end of 2010, 18 countries were exporting their natural gas as LNG with the total exporter was 223.8 MMtpa. In addition, four countries – Belgium, Mexico, Spain and the US – were re-exporting LNG imported from another source. Qatar is by far the largest LNG exporter. In 2010, the country supplied 57.5 MMtpa of LNG to the market – more than one quarter (26%) of global supply. Pacific Basin countries, namely Indonesia, Malaysia and Australia are the next largest exporters and together accounted for 29% of the world's LNG supply in 2010.

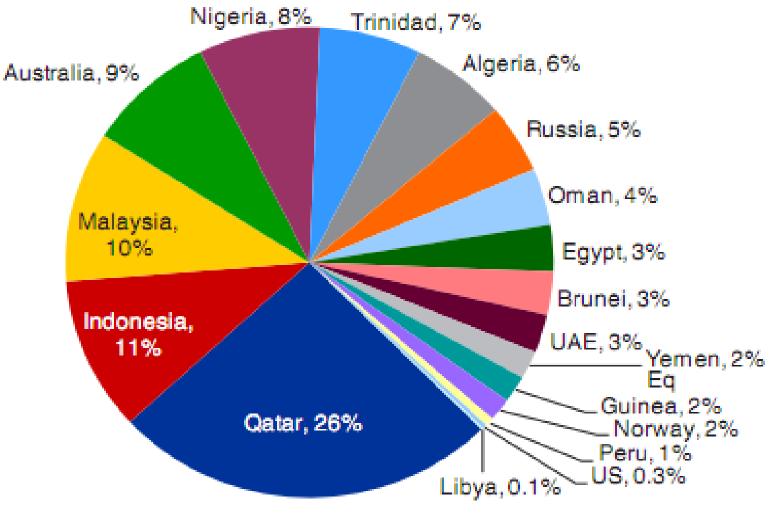

Figure 1.3: LNG Exporters by Country (International Gas Union, 2010)

1.1.2 LNG Importer by Country 2010

Japan has traditionally been the largest consumer of LNG and remains with an annual consumption of 71 MMtpa of LNG in 2010, followed by South Korea at 34 MMtpa. Together, these two countries account for just less than half (47%) of the world's LNG consumption.

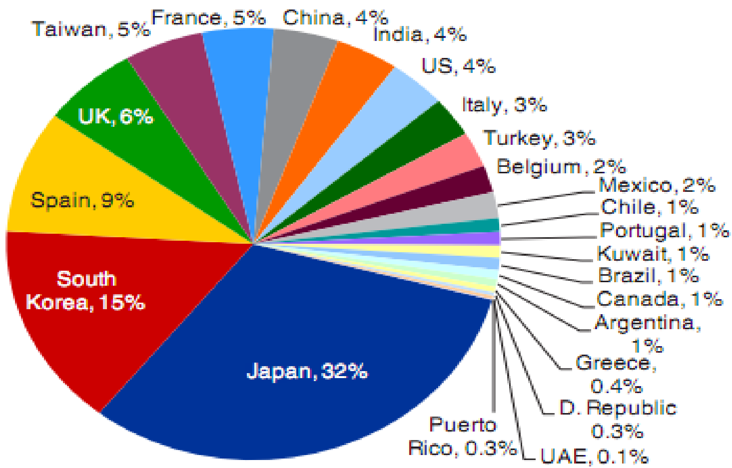

Figure 1.4: LNG Importer by Country (International Gas Union, 2010)

1.1.3 Processing of LNG

The attention is turning to the potential of exploiting stranded offshore gas field using floating production, liquefaction, storage and offloading vessels – floating LNG is increased due to high demand and plenty of new small potential Natural resources available in deep sea. Round shape FLNG represents a fast-track route to obtain remote gas reserves which will help to bridge the expected supply shortfall in worldwide LNG production, it causes the interest in the FLNG sector is growing because of a lack of suitable onshore sites and pipeline infrastructure to offer economic access to the large number of offshore mid-tier stranded gas reserves. FLNG projects also offer reduced cost and schedule risk for operations in remote onshore locations. It is also a mobile asset that can quickly be operated at other locations.

Round shape FLNG concepts have a number of advantages over conventional liquefaction plants for offshore resources, not only the ability to station the vessel directly over distant fields, but also the ability to move the production facility to a new location once the existing field is depleted.

Therefore, In the round shape FLNG concept, planning and operational decision play a vital role in the success or failure of firm in determining the supply chain capacity and design of storage. The challenge to achieving these objectives is complicated because there are inextricably related and often conflicting. Therefore, simulation modeling was used to quantify the true performance of a facility, enabling alternative proposals to be evaluated to ascertain their true worth. This makes decision-makers easy to identify and address unforeseen issues and exploit commercial opportunities. The ability to "run the plant before it is built" through simulation modeling ensures that the world's leading manufacturers "get it right first time."

1.2 Background of Project

Any companies are linked to and interacted with other organizations, whether it is suppliers, customers, third party logistics providers, or intermediaries. The performance of a firm is dependent on the strengths and weaknesses of its partners in the supply chain. The competition has moved from competition between firms at the same level in the production process to competition between supply chains, from raw materials to end customers. A company's ability to create trust-based and long-term business relationships with customers, suppliers, and other strategic partners becomes an important competitive indicators. Therefore, Tendency towards increased integration and cooperation between the enterprises in the supply chain results in greater complexity in the management and control technology, which requires increased coordination of resources and activities (Birgit and Tage, 2005).

Viewed from company's activity, LNG can be considered a single product. The process starts from under water production, liquefaction, storage, transportation and regasification is shown in Figure.1.5 for conventional and Figure 1.6 for Floating LNG supply chain process. A brief overview of each step along the chain is provided below.

1) Extracting the natural gas from the geological strata
2) Transporting the gas via a pipeline(s) to a treatment and liquefaction plant;
3) Conditioning and dehydrating the raw gas to remove impurities such as carbon dioxide and water and the heavier hydrocarbons, which form natural gas liquids such as liquid petroleum gas (LPG)
4) Liquefying the conditioned gas, through cooling, and storing it in cryogenic tanks;
5) Loading the LNG into purpose built carrier vessels and transporting it to international markets;
6) Unloading and storage at LNG receiving terminals;
7) Converting the LNG back to gaseous form by heat exchange; and
8) Distributing the natural gas to the consumer via gas transmission lines.

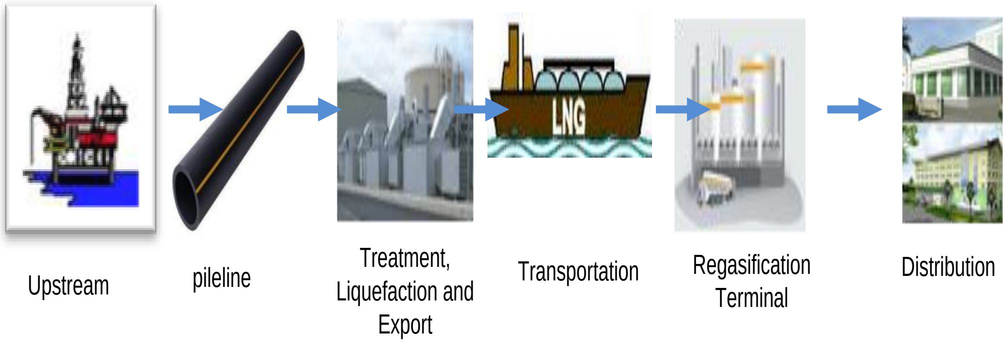

Figure 1.5: Conventional LNG Supply Chain - from Upstream to Distribution

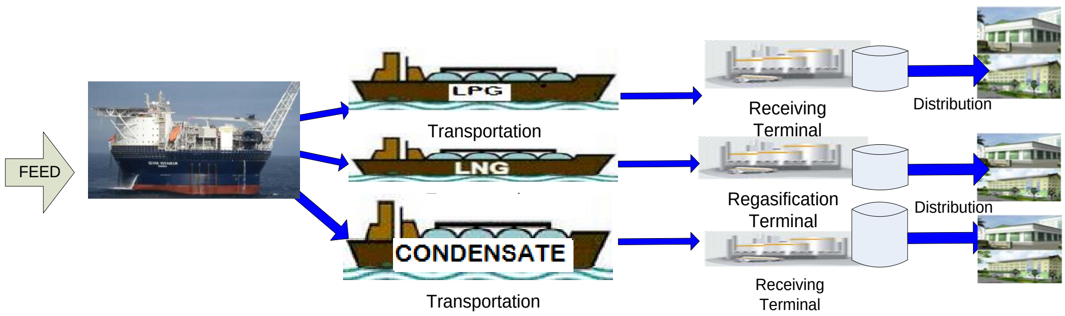

Figure 1.6: Floating LNG supply chain process: from Upstream to Distribution

There are significant differences between conventional supply chain and FLNG supply chain as mentioned above. For round shaped FLNG, The facility is moored directly above the natural gas field. It routes Natural Gas from the field to the facility via riser. When the gas reaches the facility, it is processed to produce LNG, LPG, and condensate. The processed feed gas is treated to remove impurities, and liquefied through freezing, before being stored in the hull. Ocean-going carriers will offload the LNG, as well as the other liquid by-products, for delivery to markets worldwide.

Supply chain management (SCM) is required to coordinate all input or output flows so that products are produced and distributed in the right quantities, to the right locations, and at the right time. The main objective is to achieve acceptable total profits together with the desired customer satisfaction levels by determining the optimal production plans and schedules, capacity of inventory, transportation and number of carriers.

The interaction among factors such as upstream, production process equipments, storage, transportation and receiver are extremely complex and difficult to obtain balancing without using simulation. The advantage of Simulation process provides invaluable insight into where unforeseen constraints and bottlenecks lie. Once potential issues are identified, simulation models allow numerous what-if to be analyzed to evaluate how best to improve the performance of the LNG supply chain of Round Shape FLNG. These aids can help understand how existing facilities can be used effectively resulting in improving the availability and profitability.

Niels Stchedroff (2003), studied modeling a continuous process with discrete simulation techniques and its application to the LNG supply chain. Banu Y. Ekren (2008) on the other hand performed a simulation based experimental design to analysis factors affecting production flow time.

Unlike previous studies, this project used simulation modeling based on an experimental design approach to determine optimal LNG Supply Chain by considering the capacity of production, storage, transportation and receiving terminal 7.8 MTA capacities.

Simulation modeling or computer simulation was chosen for this project work due to its powerful ability in dealing with either simple or complex systems which are more preferable to measure the possible optimal performance of LNG Supply Chain. The process of designing a digitalized model representing a real or a proposed system for the experimentation purpose and understanding of the system's actual behaviors with given factors and scenarios. The selected scenario is simulated using Visual Basic for the proposed strategies by considering the balancing of the LNG supply chain.

1.3 Problem Statement

In the operation of a large LNG processing plant there are uncertainties related to planning and realization of an optimal operation strategy. Demand of LNG throughout the world has been increased significantly and followed by the increment of LNG exploration to meet the requirement. Operating optimal production process and utilization of equipments to meet the requirement are one of important thing that must be considered before running the project to avoid losing money due to inefficiency of related resources and over production. However, the importance of including the whole production chain (upstream, treatment, liquefaction, storage, transportation and regasification) in the optimization of the LNG supply chain can impact to the profit of the project. The whole value needs to be maximized and balanced to meet optimal utilization of facilities.

There are many possible operational issues will be faced in LNG supply chain using round shape FLNG. Namely, determining the capacity of storage, LNG carrier scheduling and terminal storage capacity. The optimal operation cannot be obtained if one of those variables is not balanced and integrated.

Generally, the problem statement of this Project is how the optimal LNG supply chain of Round-Shape FLNG project is built by integrating the supply chain process started from FEED, production process, storage, transportation and receiving terminal?

1.4 Project Objectives

The main objectives of this project are:

i. To identify the problem of Round-Shape FLNG supply chain.
ii. To develop maximal balancing capacity of the LNG supply chain starting from FEED gas at upstream state, production, rounded-shape FLNG storage, transportation and receiving terminal using simulation to meet optimal production.

1.5 Project Questions

In order to achieve the rproject objectives mentioned above, the following questions should be answered systematically.

- How is Round Shape FLNG supply chain starting from FEED until receiving terminal?
- How to achieve optimal production output, capacity of round-shape FLNG storage, transportation capacity and number of vessels needed by considering Supply chain integration process?
- What are alternative solutions to obtain an optimal capacity of FLNG output, storage and carrier to meet demands?
- What is the recommended solution to achieve optimal FLNG supply chain from FEED to receiving terminal?

1.6 Expected Contributions of Research

This research will give contributions to FLNG companies to do planning, operation and scheduling due to the changes of the LNG operation system.

For planning

- Due to the increase of LNG demand and the global market competition throughout the world, the demand will be fluctuated (uncertainty demand) it can cause the company get difficulties in making decision on business investment. However by using the designed simulation the company will be easier to see various alternatives in decision making by modifying the existing simulation before implementing it.

For operation

- Efficient operation of LNG production is very important to get higher profit in running the LNG business. In order to maximize the utilization of existing facilities and find out the alternative improvements, using simulation is one of the simplest ways, not only can visualize the process, but also show the performances achieved by the facilities. From the information, the decision maker can find as many as optimal alternatives as possible in order to get the targeted profit. .

For Scheduling

- Integration of every activity in the LNG supply chain of Round Shape FLNG is very important. This project can help organizations or companies involved in LNG supply chain operation.

1.7 Scope of Research

1. This project focuses on a LNG supply chain (SC) of Round Shape FLNG starting from FEED, treatment process until receiving terminal that is from Arapura Sea (Indonesia) to Osaka Receiving Terminal (Japan).
2. Only LNG product that was simulated in this project.
3. The receiving terminal was assumed in normal operation where the capacity of the terminal can store all the delivered products.

1.8 Structure of Project

This report consists of six chapters, as summarized below:

Chapter 1 Introduction

Chapter 1 is the introduction of the study. This chapter explains about the research statement, problem statement, objective of study, scope of study and matters that have relate to the introduction of the project.

Chapter 2 Literature Review

Chapter 2 is the literature review of the project and contains on several topics related to this study, describe definition, principle and approach used in conducting this project. Topics reviewed include supply chain management optimization, strategic supply chain optimization, design of supply chain, integration of supply chain, supply chain in oil and gas, Floating LNG, Design of Experiment and Simulation Modeling.

Chapter 3 Research Methodology

Chapter 3 which presents a feasible approach for achieving project’s goals.

Chapter 4 Case Study and Data Collection

This chapter is about the collected information related to the LNG Supply Chain

Chapter 5 Results and Discussion

Chapter 5 displays the result and data analysis using statistical analysis

Chapter 6 Conclusion

Chapter 6 consists of a summary of the whole study. Then, Findings of the research are presented in brief. Finally, some future research is suggested.

1.9 Conclusion

This chapter highlighted a general introduction about the entire study. At the beginning of this chapter, the introductions of supply chain management and supply chain for LNG were briefly discussed. It was followed by the research statement and the problems that this area is faced with. The objectives and scopes of the project were stated to address the boundaries of the study. The significance of the study was discussed. Lastly, the arrangement of the entire report was explained.

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