OPTIMIZATION OF ROUNDED-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. This paper present optimization of the rounded-shape floating LNG using simulation modelling. The optimum FLNG is obtained through the integration among states in supply chain and high utilization of facilities in every single stage. 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 the LNG supply chain. In the simulation, the critical factors such as storage capacity, offloading rate, transportation capacity and number of LNG carrier were identified. Result simulation shows transportation capacity and number of LNG carrier was 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 the LNG supply chain with 997 tonnage per hour for production capacity requires seven LNG carriers with capacity 93900 tonnage, storage capacity 288530 tonnage and offloading rate 7940 tonnage per hour. In total, the amount of LNG in receiving terminal was estimated 8.013 million tonnage per year and performance of LNG Carrier was 99.85 %.

Key-Words: Liquified Natural Gas; Supply Chain; Optimization; Rounded Shape FLNG; Simulation Modelling.

1 Introduction

Demand of liquid natural gas (LNG) increases due to oil natural resources not meet the demand requirement. Natural gas as an energy source is increasing in importance as the world's demand which is expected to increase by 53% between 2008 and 2035 [12]. By the end of 2010, 18 countries have been exporting their natural gas as LNG with the total exporter was 223.8 MMTPA. In 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. Japan has traditionally been the largest consumer of LNG and with an annual consumption of 71 MMTPA of LNG in 2010 and followed by South Korea at 34 MMTPA.

As a consequence of the increasing market for LNG and uncertainty demand, the supply chain management has become more complex and accurate information is required to select the optimum option in business operation. There several important factors when coordinating decisions along the LNG value chain. It is not only deal with the routing of vessels and the fulfillment of the contracts, but also have to look into how to production process of LNG, storage capacity and upstream liquefaction facilities, the re-gasification process and required number of vessels. All the processes have very significant integration each other's during operation. Deal with risks associated with the high cost of constructing of floating plants, storage capacity and transportation, long term contracts with durations of 25-30 years are frequently applied.

In the LNG supply chain process, there is diversity LNG supply chain flow between conventional and floating LNG (FLNG). The difference can be seen from the transferring system from offshore to onshore operation. Conventional supply chain, LNG is transferred from offshore to onshore using pipeline and liquedfaction process is executed onshore, the FLNG however, all the liquefaction processess are done on the floating vessel before transporting to receiving terminal via LNG carrier. Therefore the LNG supply chain of FLNG requires very careful capacity calculation and integration in every stage of the LNG supply chain process from production process capacity to receiving terminal.

Consideration of real tactical supply chain optimization issues for LNG including the production volumes, capacity of liquefaction, transportation, storage, regasification and sales volumes are very important in the decision making for long term business operation. In order to obtain the optimal decision before signing the agreement, simulation modeling is one of the good approach that can be used to predict future plan and make very confident decision for every involved parties.

Generally, a simulation can be defined as the process of designing a mathematical logical model of a real system and experimenting with this model on a computer. Simulation allows the user to monitor the dynamics of a system under various conditions by changing the input and provides its users with an understanding of the system being modeled. The simulation also gives organizations the ability to ask "what-if?" when making strategic and operational decisions to be better. Statistical Design of Experiment is used to analysis the significancy of every controllablevariable in the simulation. It gives users a low cost of doing experiments for complicated issues and safe environment for organizations that produce dangerous products in which to experiment with different strategic scenarios. As a result, decision-makers can be sure and more confident that they have found the solution that is most fit for their organization before running the project. Benefits of supply chain using simulation modeling are numerous including improved throughput, reduced costs and lead-times and better utilization of resources before the actual project is done.

The results of simulation modeling have been applied successfully for over a decade to help organizations meet their long term strategic production goal. Simulation modeling has been used to optimize pipelines, storage, and the export facilities required to accommodate additional production capacity: to plan capital projects in anticipation of demand.

This paper discusses simulation modeling and Design of Experiment (DoE) to measure and analysis the performance of the Rounded-Shape FLNG production output, storage capacity, offloading rate and transportation capacity to achieve optimal performance of the FLNG supply chain and then Visual Basic (VB) is used to simulate the improvement system setting. As a case study, route between Arafuru sea in Indonesia and Osaka, Japan was discussed in the paper.

2 Literature Review

Supply chain management is defined as a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed in the right quantities, at the right locations, at the right time, in order to minimize system-wide costs while satisfying service level requirements [1].

The importance of LNG and effective LNG supply-chain management in the world increased significantly over the last several years due to the increased demand and price of Liquid natural gas. There is a general awareness that the LNG company cannot compete as isolated entities; it is clear that working together in networks would be a lot easier [28]. The supply chain (SC), as a network, is expected to provide the right products and services on time, with the required specifications, at the right place and to the right customer.

There have been many studies related to LNG had been discussed by previous researchers. They provided a mathematical model to allocate natural gas and use a linear programming model to identify the optimal storage and purchase decisions for a natural gas utility company.

Several researchers have conducted research on various integration topics. Lasschuit and Thijssen discussed about supply chain planning and scheduling in the oil and chemical industry employing a mixed integer on-linear programming related to costs, pricing and cargo costs [27]. Tomasgard et al presented a natural gas value chain model and integration applying an upstream perspective and a stochastic portfolio optimization [41]. Run time can be a challenge in integrated applications, especially when closely linked high-fidelity models are tightly connected. The use of integrated optimization in day-to-day operations of the LNG value chain was studied by Foss and Halvorsen [15]. They discussed on dynamic optimization of the LNG Value chain. The system is modeled by simple models of each main component starting at the wells and near well region and ending with the export tanks LNG, LPG and condensate.

The integration of the LNG supply chain is continuously studied by Ozelkan et al in optimizing LNG terminal design for effective supply chain operation using the MIP model [32]. There are four variables were considered in these parameters and decision variables are then incorporated into an MIP formulation The multi-level approach to the four major design factors of throughput, storage, number of vessels and docking capability are linear in their relationship to the optimized object of maximizing profit across a range of market clearing prices. The advantage of modeling these factors to determine optimum profitability is identifying dominance and relativity between the determinants and the impact on costs. Increasing storage reduced costs of delivering LNG over the time horizon. Logically, a large inventory reduces the cost of buying products. However, current supply-chain management concepts support ‘‘just in time’’ inventory of products. The cost–benefit analysis supports this theory showing that the tradeoffs in capital expense will eventually negate the reduction in supply costs. Storage capacity needs to be balanced with deliverability to maximize profits. This then leads to the importance of scheduling deliveries through optimization modeling and availability of supply.

In addition, Jaswar et al studied on Process Facility of Floating Liquefied Natural Gas for 7.8 MTA capacity and they performed simulation at floating LNG Production vessel to the determine the capacity of Absorption Acid Gas Removal Process at Acid Gas Removal Station simulation [21,22].

3 Research Methodology

This research, experiments will be carried out through a simulation. Software Witness and DoE is used to analyze the LNG supply chain performances and then Visual Basic was run to show the future LNG supply chain of Round Shape FLNG. The procedures for the simulation study of the LNG supply chain are explained below.

3.1 Business Process of Supply Chain

3.1.1 Objectives and System Definition

The objective of this project is determining the optimum balancing capacity of the LNG supply chain starting from FEED gas at upstream state, production, round-shaped FLNG storage, and transportationcapacity, number of LNG carrier and receiving terminal using simulation modeling to meet optimal production.

3.1.2 Construction of a conceptual model

Since the operation cost and long term contract agreement system carried out in the LNG business for downstream operations are expensive, it makes difficult for the decision makers to decide the optimal supply chain operation in determining the capacity for storage, offloading flow rate and number of LNG carrier. To determine the guideline that could affect the amount of received LNG in receiving terminal and the interactions among these factors.

The collected data, started from FEED, production process, storage, transportation and receiving terminal systematically define the FLNG supply chain framework for round shaped FLNG. The supply chain process of FLNG follows certain rules and procedures before operation begins. The FLNG project doing operation for 365 days annually for production process, about 317 days annually for offloading operation while minimum 27 hours and maximum 56 hours delay caused by bad weather, ship breakdown, unforeseen ship stoppages and other time-critical restrictions such as darkness for one trip of LNG carrier operation. The distance from FLNG operation location to receiving port is about 6000 Nautical miles with a LNG carrier speed 19 Knots. This project will be proposed for LNG supply chain from Indonesia to Osaka receiving terminal. To achieve logical details in the simulation model with assumptions that theLNG demand annually was 7.8 MTU, off-loading and unloading operation time was considered equal and no breakdown was considered for LNG carrier.

3.1.3 Validation of Conceptual Model

During this step confirming that the designed model follow the way intended and that the output of the model is trustable and representative of the real system. At each stage of modeling, the built model was executed with a different set of inputs and the results were compared with actual outputs by knowledgeable people step by step to make sure it is matched with reality. Corrective action was done immediately. In this step, validation is done to ensure that accurate results are generated by model in comparison with real situation. The data were collected from various sources. Discussion with subject matter experts (expert judgments) was performed to obtain reasonable estimates. Ultimately, it might come down to making an intelligent guess.

3.1.3 Modeling of Input Data

For the realization of this project, the software Witness was used to measure the performance and Design Expert 6.5 for statistical analysis. The input data were divided into controllable and uncontrollable input data.

3.2 Modelling and Programming

The model was constructed using Witness Software, in constructing the model, there are many icons were used namely machine, compressor, tank, liquid, pipe, delay, shift, variable and time series. For future LNG Supply chain of Round Shape FLNG, the simulation modeling was designed using Visual Basic.

3.2.1 Definition of Experimental Design

In order to design optimal LNG supply chain, there are 4 controllable factors need to be considered before obtaining the objective. They are Storage capacity, number of LNG carrier, offloading flow rate and transportation capacity as shown in Table 1. Factor A presents the number of carriers that will be used by the company to transport the LNG from round shape FLNG to receiving port. Factor B measures the capacity offloading from round shape floating LNG to LNG carrier. This amount was determined based on the current rate implemented in LNG offloading rate. Factor C illustrates the amount of LNG can be stored in a specific time in the tanks before the LNG carrier come to pick up. The capacity was determined by the actual capacity of available LNG storage. Factor D presents the capacity of LNG carrier that can be loaded to carry LNG from round shape FLNG to receiving port. The transportation capacity was determined based on the capacity of LNG carrier size available in the world.

Table 1: Level of Factors

Factors	Low Level		High Level	
Number of LNG carrier (Unit) (Factor A)	_	3	+	10
Offloading flow rate (thousand tonnage) (Factor B)	_	3.973	+	30
Storage Capacity (thousand tonnage) (Factor C)	_	153.9	+	600
Transportation (thousand tonnage/carrier) (Factor D)	_	47.7	+	93.9

3.2.2 Execution of the Experiments

The experiments were run twenty times using simulation modeling, the responds of the simulationas shown in Figure 2. The experiment was performed by changing the input data.

Std	Run	Block	Factor 1 A:No of Vesse Units	Factor 2 B:Offloading Fl Ton/Hour (000)	Factor 3 C:Storage Cap Ton (000)	Factor 4 D:Transportatic Ton/Vessel (00	Response 1 Response 1 Ton (000)	Response 2 Response 2 Percentage
2	1	Block 1	10.00	3.97	153.90	47.67	2143.8	87.23
17	2	Block 1	6.50	16.99	376.95	70.79	3183.86	91.82
3	3	Block 1	3.00	30.00	153.90	47.67	1810.08	96.74
6	4	Block 1	10.00	3.97	600.00	47.67	4168.63	87.22
19	5	Block 1	6.50	16.99	376.95	70.79	3183.86	91.82
16	6	Block 1	10.00	30.00	600.00	93.90	4223.93	87.22
4	7	Block 1	10.00	30.00	153.90	47.67	2143.8	87.23
11	8	Block 1	3.00	30.00	153.90	93.90	3566.63	96.74
14	9	Block 1	10.00	3.97	600.00	93.90	4168.63	87.22
1	10	Block 1	3.00	3.97	153.90	47.67	1762.4	96.74
20	11	Block 1	6.50	16.99	376.95	70.79	3183.86	91.82
9	12	Block 1	3.00	3.97	153.90	93.90	3378.82	96.74
8	13	Block 1	10.00	30.00	600.00	47.67	4168.63	87.22
5	14	Block 1	3.00	3.97	600.00	47.67	1762.4	96.74
10	15	Block 1	10.00	3.97	153.90	93.90	4168.63	87.23
13	16	Block 1	3.00	3.97	600.00	93.90	3378.82	96.74
12	17	Block 1	10.00	30.00	153.90	93.90	4223.93	87.22
7	18	Block 1	3.00	30.00	600.00	47.67	1810.08	96.74
18	19	Block 1	6.50	16.99	376.95	70.79	3183.86	91.82
15	20	Block 1	3.00	30.00	600.00	93.90	3566.63	96.74

Figure 2: The experimental response

3.3 Total LNG in Receiving Terminal

Half Normal probability plot is a graphical method to show the significance of factors. A factor that plotted closely to the strait line is indicated as insignificant factors. Those plotted points that far away from straight line are indicated as the most significant factors. The longest bar shows the most significant factors that affect the process and the bar that do not cross the dotted line are considered insignificant factors.

From Figure 3 shows that the significant factors are A, B, C, D, AD, AC, CD and ACD. D is the farthest from the line supporting the Main Effect Plot that indicates transportation capacity is the most significant factor.

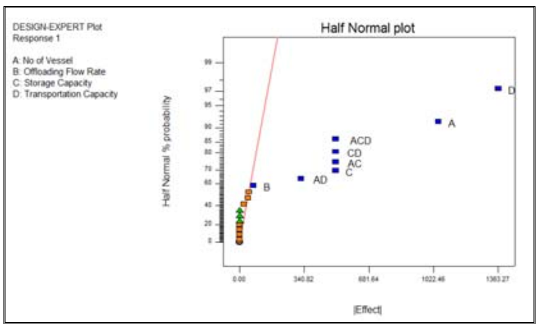

Figure 3: Total LNG in receiving terminal (Half Normal Probability Plot).

3.4 Design of an optimal LNG supply chainof Round Shape FLNG using Visual Basic (VB)

Once the setting of optimal balancing ofthe LNGsupply chain was determined, then the simulation design was built by using Visual Basic to see the future performance of designed model. From the simulation users can enter the required data and get the important information in setting up the optimal supply chain by considering the most significant factors.

The designed simulation modeling was started by determining the coordinate of the FLNG operation area, LNG carrier route, receiving terminal, LNG carrier speed, initial volume, BOG rate and ship loading percentage. The input data based on that information can be directly entered in the simulation program. This simulation modeling can be modified by changing the input and certain information in the system to achieve the optimal LNG supply chain based on the real situation.

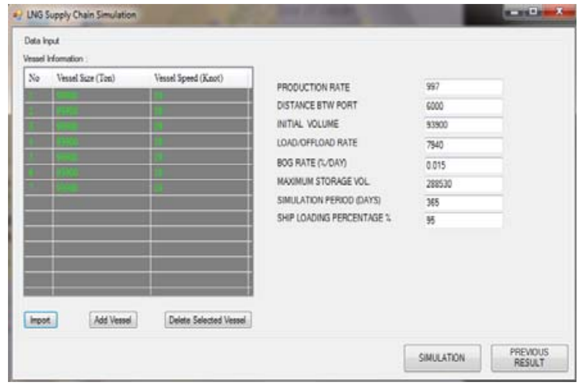

Figure 4: The input data of LNG supply chain simulation.

When the coordinates and the input data were entered, the simulation program can determine the LNG carrier's position during the simulation, the amount of LNG received in receiving terminal and many other performances as shown in Figure 5.

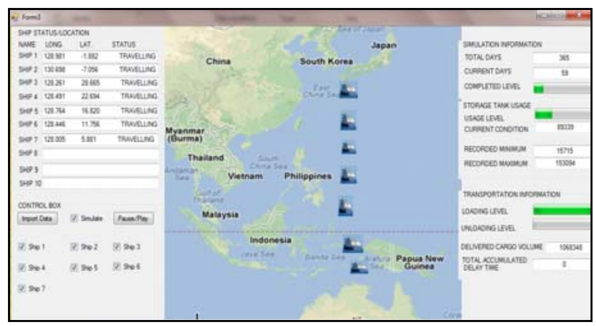

Figure 5: The simulation process of LNG supply chain.

The result of simulation as shown in Figure 6 represents that by running seven LNG carriers with 19 knots per hour with the capacity of LNG Carrier was 93900 tonnages per trip. The amount of received LNG in receiving terminal for 365 was 8.01 Million Tonnage with LNG carrier utilization equal to 99.58 percent. It indicated that the optimal balancing of LNG Supply chain could be achieved.

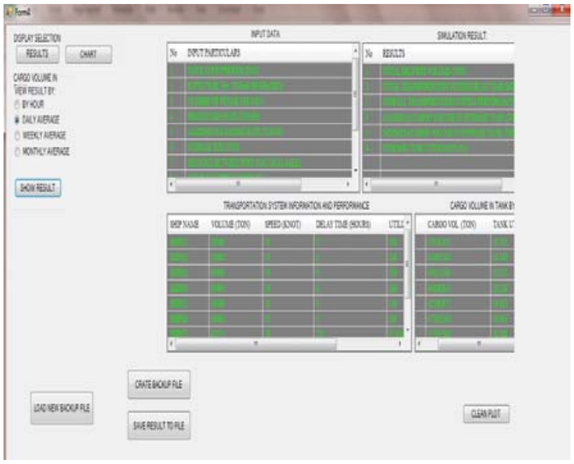

Figure 6: The simulation output display

4 Conclusion

In LNG supply chain, the integration of Front-End Engineering Design (FEED), liquefaction, storage and transportationplay very important rule in achieving high performance of every single stage, facilities utilities, related resources and profitability. By using simulation modeling individual or client is fully able understanding the FLNG supply chain process and possible alternative better solution can be decided for short and long term decision. Although there are many factors associated with the LNG supply chain, this project focused on those key operational factors which affect the amount of received LNG in receiving terminal and the balancing of every stage in the supply chain. There are four controllable factors are consider namely capacity for storage, offloading rate, transportation capacity and number of LNG carrier.

Simulation modeling was run to evaluate the performance of the rounded-shape floating LNG supply chain and Design of Experiment (DoE) was used to analyze the performance measurement and interaction among considered factors. The usage of DoE conjointly with computer simulation allowed a more efficient analysis of the results of the simulated model. The result showed that the most significant factors that can affect the amount of received LNG in receiving terminal were transportation capacity and the number of LNG carrier. The optimum setting was determined for the future operation and the setting was used to design FLNG supply chain simulation using Visual Basic.

The optimal setting was selected based on data analysis presented above. The optimal settings shows as follows: seven units of LNG carriers, offloading rate per hour is 7.94 thousand tonnages, storage capacity is 288.53 thousand tonnage and transportation capacity is 93.90 thousand tonnages. In total, LNG received in the receiving terminal is 8.012 million tonnage with 99.863 % of the LNG carrier utilization.

In conclusion, it is believed that by maintaining the proposed optimal setting as the basis for determining the key factors in upply chain allow the decision makers to take initial design parameters in advanced. As a result, this project can help FLNG company enhance the efficiency and utilities of the related facilities.

5 Recommendation

For future studies, attention can be given to LNG supply chain from receiving terminal to end customers by considering the uncertainty demand. Due to limitation in time and resources, this project has not been fully developed and implemented. It is suggested to do further simulation by considering supply chain cost and by assuming continuous supply chain system the effect if one of the stage not perform very well as well.

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