BACHELOR THESIS & COLLOQUIUM – ME141502

A STUDY OF LNG DISTRIBUTION DESIGN BY CONSIDERING TRANSSHIPMENT MODEL FOR EASTERN PART OF INDONESIA

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DOUBLE DEGREE PROGRAM IN
DEPARTMENT OF MARINE ENGINEERING
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SKRIPSI – ME 141502

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APPROVAL FORM

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BACHELOR THESIS & COLLOQUIUM

Submitted to comply one of the requirements obtaining Bachelor Degree Engineering at
Reliability, Availability, Management and Safety (RAMS) Laboratory
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Faculty of Marine Technology
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ABSTRACT

Indonesia is one of the largest archipelago country that the usage of sea transportation is one of the most effective transportation method to distribute energy for power plant. The presence of electrical energy in Indonesia is still not provided due to the limited of the facilities and the distribution of the electrical energy sources. LNG supply chain is needed to distribute LNG to fulfill the demand in the area that have been planned by PLN for power plants. The LNG carrier can reach the requests of the little islands, so it turn out to be more compelling choice for the supply chain. This thesis will design transshipment model scenario of LNG distribution in eastern part of Indonesia and it will be simulated using discrete-event simulation. There will be some of scenario that create in Papua and West Papua regions. The purpose of this thesis is to know the transshipment modelling scenario in discrete-event simulation, to identify variables that affects modelling of supply chain scenario and to find feasible supply chain technically. The chosen methods for this thesis are literature review and collecting data that is done by reviewing on the internet about discrete-event simulation and the project data. The data is processed by using ARENA DES-Software which will be known the simulation of some model and scenario that considered and determined, then will know the feasible scenario and model.

Based on the results of this thesis, there are 2 models of distribution by considering transshipment model. The first model is using 1 transshipment point in Sorong area and the second model is using 2 transshipment points in Sorong and Jayapura area. Each model will have 8 scenarios based on the size of receiving terminal tank capacity and combination of fleet. Each variation of receiving terminal tank capacity will have 2 fleet combination and each fleet combination will follow with the level of inventory to transporting LNG. The scenarios and models that have been designed still have an inaccuracy when running the simulation to make the results achieved is not maximal but still exist in some locations in the LNG supply chain that runs out of LNG as fuel. In the distribution design, for the first model scenario 6, 7 and 8 is the recommended scenario that determining the tank capacity variation with 7 days for safety stock. However, in the second model, scenario 5, 6, 7 and 8 is the recommended scenario with tank capacity variation also including 7 days for safety stock. The recommended scenarios will use LNG vessel with the 7500 m^3, 12000 m^3 and 23000 m^3 capacity. The fleet combination is considered with difference number of vessel. For the same tank capacity variation and same fleet combination will be divided into two scenarios that considered based on the inventory level to make a signal to transporting LNG for the fleet. The consideration of inventory level is 50% and 60% of the LNG inside the inventory.

Keyword: LNG, LNG Carrier, Supply Chain, Transshipment Model, Simulation

STUDI TENTANG DESAIN DISTRIBUSI LNG DENGAN MEMPERTIMBANGKAN MODEL *TRANSSHIPMENT* UNTUK WILAYAH TIMUR INDONESIA

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ABSTRAK

Indonesia merupakan negara kepulauan yang terbesar sehingga membuat penggunaan transportasi laut menjadi metode transportasi yang paling efektif untuk mendistribusi energi ke pembangkit. Kehadiran energi listrik di Indonesia masih tidak tersedia dikarenakan fasilitas dan distribusi sumber energi listrik yang terbatas. Rantai pasok LNG dibutuhkan untuk mendistribusi LNG guna memenuhi kebutuhan di wilayah yang telah direncanakan oleh PLN sebagai pembangkit. Kapal pengangkut LNG dapat menggapai permintaan di pulau-pulau kecil, sehingga menjadikan pilihan yang tepat untuk merancang rantai pasok. Tugas akhir ini akan mendesain model *transshipment* scenario mengenai distribusi di wilayah timur Indonesia dan akan disimulasikan. Akan dirancang beberapa skenario di Papua dan Papua Barat. Tujuan dari tugas akhir ini untuk mengetahui skenario model *transshipment* di dalam diskrit event simulasi, untuk mencari tahu variabel yang memengaruhi model dari skenario rantai pasok dan mencari rantai pasok yang layak secara teknis. Metode yang digunakan untuk tugas akhir ini adalah dengan studi literature dan mengumpulkan data yang dapat diatasi dengan mengulang dari internet tentang simulasi diskrit event dan data proyek. Data diolah dengan menggunakan software ARENA yang akan mengetahui simulasi beberapa model dan skenario yang sudah ditentukan, lalu akan terlihat skenario dan model yang layak.

Berdasarkan hasil tesis ini, ada 2 model distribusi dengan mempertimbangkan model *transshipment*-nya. Model pertama menggunakan 1 titik *transshipment* di daerah Sorong dan model kedua menggunakan 2 titik *transshipment* di daerah Sorong dan Jayapura. Setiap model akan memiliki 8 skenario berdasarkan ukuran kapasitas tangki terminal penerima dan adanya kombinasi armada. Setiap variasi kapasitas tangki terminal penerima akan memiliki 2 kombinasi armada dan setiap kombinasi armada akan mengikuti jumlah persediaan sebagai sinyal untuk mengangkut LNG. Skenario dan model yang telah dirancang masih memiliki ketidaktepatan saat menjalankan simulasi untuk membuat hasil yang dicapai tidak maksimal tetapi masih ada di beberapa lokasi dalam rantai pasokan LNG yang kehabisan LNG sebagai bahan bakar. Dalam desain distribusi ini, untuk model pertama skenario 6, 7 dan 8 adalah skenario yang direkomendasikan dengan menentukan variasi kapasitas tangki sebanyak 7 hari untuk *safety stock*. Namun, dalam model kedua, skenario 5, 6, 7 dan 8 adalah skenario yang direkomendasikan dengan variasi kapasitas tangki juga sebanyak 7 hari untuk *safety stock*. Skenario yang direkomendasikan akan menggunakan kapal LNG dengan kapasitas 7500 m^3, 12000 m^3 dan 23000 m^3.

Kombinasi armada ditentukan dengan perbedaan jumlah kapal untuk mengangkut LNG tiap variasi. Untuk variasi kapasitas tangki yang sama dan kombinasi armada yang sama akan dibagi menjadi dua skenario yang dipertimbangkan berdasarkan tingkat persediaan dalam memberikan sinyal untuk mengangkut LNG. Pertimbangan tingkat persediaan adalah 50% dan 60% di dalam persediaan.

Kata Kunci: LNG, Kapal Pengangkut LNG, Rantai Pasok, Model Transshipment, Simulasi

PREFACE

Praise to Allah SWT who has given grace and hidayah to the author, so the author can finish this thesis with the title “A Study of LNG Distribution Design by Considering Transshipment Model for Eastern Part of Indonesia” on time in order to comply the requirement of obtaining a Bachelor Degree Engineering on Department of Marine Engineering, Faculty of Marine Technology, Sepuluh Nopember Institute of Technology.

The author realizes that this writing can’t be solved without the support of various parties both morally and materially. Therefore, the authors would like to express their gratitude to all those who have helped in the preparation of this bachelor thesis especially to:

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The author realizes that this bachelor thesis remains far away from the perfect form. Therefore, every construction suggestion and idea from all parties are highly expected by author for this bachelor thesis correction and improvement in the future.

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Surabaya, 30 July 2018

Author

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CHAPTER I
INTRODUCTION

1.1. Background

Indonesia is an archipelago or islands country which is consists of 17.504 islands scattered in an area of 1.904.569 km^2. The islands condition is still complicated in developing the aspects of technology, economy and etc. Many islands in Indonesia are not well developed especially in Central Indonesia, even some islands are well developed. All Indonesia's islands and citizen deserved to be well developed for their hometown.

Based on the Handbook of Energy and Economic Statistics of Indonesia issued by Energy and Mineral Resources Ministry, gas fields located in Indonesia have considerable potential and already proven the existence of some large gas fields exist in Indonesia.

Table 1.1 Natural Gas Reserves (per January) Database

Year	Proven (TSCF)	Potential (TSCF)	Total (TSCF)
2007	106.00	59.00	165.00
2008	112.50	57.60	170.10
2009	107.34	52.29	159.63
2010	108.40	48.74	157.14
2011	104.71	48.18	152.89
2012	103.35	47.35	150.70
2013	101.54	48.85	150.39
2014	100.26	49.04	149.30
2015	97.99	53.34	151.33
2016	101.22	42.84	144.06

Source: Directorate General of Oil and Gas

Table 1.1 shows that gas fields owned by Indonesia are large enough to boost the existing economy in the country, can utilize natural gas as a power plant. PT. PLN has successfully utilized natural gas in the form of LNG as a source for power plants in several islands in Indonesia. Based on PLN Statistics and Electricity Statistics from Directorate General of Electricity, the last 5 years until 2016 power plants using natural gas in some areas have been built with installed capacity in the amount of; 4343.82 MW, 4389.08 MW, 4310.50 MW, 4310.50 MW and 4420.50 MW. Thus, PT. PLN will continue to develop and build power plants in various regions of Indonesia using energy from LNG.

Economic conditions in the region of Papua in the last five years is lower than the previous average of 4.9% per year while the West Papua region grew better than the previous average of 10.45% per year. This economic condition will affect the high consumption of electricity in these two provinces. Thus, the electricity needs of these two provinces will met by PLN by adding power plants in these two provinces. This is shown in tables 1.2 and 1.3 below which describes the amount of electricity demand by comparison of the existing economic growth in the two provinces.

Table 1.2 Electricity Power Projection in Papua

Year	Economic Growth (%)	Sales (GWh)	Production (GWh)	Peak Load (MW)	Customer
2017	9.6	1,084	1,210	194	479,561
2018	9.9	1,250	1,394	224	560,879
2019	11	1,432	1,596	256	643,475
2020	11.7	1,629	1,814	291	727,048
2021	11.7	1,841	2,049	329	813,608
2022	11.6	2,049	2,279	365	886,560
2023	11.6	2,215	2,462	395	911,929
2024	11.6	2,397	2,663	427	937,872
2025	11.5	2,593	2,878	461	960,509
2026	11.4	2,807	3,114	499	983,196
Growth	11.2	11.2%	11.1%	11.1%	8.4%

Source: Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PLN 2017-2026

Table 1.3 Electricity Power Projection in West Papua

Year	Economic Growth (%)	Sales (GWh)	Production (GWh)	Peak Load (MW)	Customer
2017	4.9	483	610	108	194,605
2018	5.1	522	655	116	209,047
2019	5.7	564	703	125	223,577
2020	6.1	609	755	134	238,712
2021	6.0	652	802	142	247,797
2022	6.0	695	850	150	254,400
2023	6.0	740	900	159	261,091
2024	6.0	788	952	168	267,912
2025	6.0	838	1,006	178	274,807
2026	5.9	891	1,062	188	281,739
Growth	5.8	7.0%	6.4%	6.3%	4.2%

Source: Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PLN 2017-2026

Based on the electricity power projection needs from PT. PLN in 2017, the peak load on Papua Province requires 499 MW of electricity and the province of West Papua requires 188 MW of electricity. With the large demand difference between the current production capacity, it is necessary to developing the power plants to meet those needs. PLN's plan to build a gas-fired power plant is based on Minister of Energy and Mineral Resources Regulation no. 37 of 2015 on the provisions and procedures for determining the allocation, utilization and natural gas price. The allocation of utilization of natural gas as fuel for power generation gets priority number five after: utilization for transportation, household and small customer; increased national oil and gas production; fertilizer industry; and industry made from natural gas. The government has set a gas allocation produced by Tangguh LNG Train 3 about 75% of the 3.8 Million Ton Per Annum (MTPA) to PLN to operate PLTGU which is a 35,000 MW electricity generation program in Indonesia.

Based on the allocation of gas fuel and the planned power plant construction, the government should also prepare the supporting facilities and the concept of natural gas distribution from the Tangguh LNG Refinery to the power plant in Papua. A scenario of LNG supply chain is necessary since government had committed to allocate local production of natural gas to supply power plants in Indonesia.

1.2. Statement of Problems

Based on the description above the statement of problem of this thesis are:

1. What are possible scenarios (route, receiving terminal capacity, fleet size) to distribute LNG for power plants in Papua and Papua Barat?
2. How to simulate the model and scenario?
3. What is the feasible LNG distribution model and scenario technically?

1.3. Constraints

The constraints of this thesis are;

1. This thesis is focusing on the LNG supply distribution from Tangguh LNG Storage Papua area power plants.
2. Tangguh LNG Storage have port facilities which can provide all type of LNG carrier.
3. All power plants analyzed based from Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PLN 2017-2025 and also for the gas power plants (PLTG/MG).
4. Supply LNG only for the certain power plant aimed.

1.4. Research Objectives

The objectives of this thesis are;

1. To determine a transshipment modelling and some scenarios of LNG distribution.
2. To simulate the model and scenarios using Discrete-Event Simulation method.
3. To find feasible LNG distribution technically.

1.5. Research Benefits

Benefits that can be collected from this thesis writing task are:

1. Deliver solution of LNG supply chain for power plants in eastern Indonesia.
2. Understand the facilities that should be prepared for LNG distribution.
3. Assure efficiency and reliability of LNG supply for power plants in Papua and Papua Barat.

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CHAPTER II
LITERATURE REVIEW

2.1. LNG Basic Concept

Liquefied Natural Gas (LNG) is natural gas that predominantly is methane, CH_4 with some mixture of ethane C_2H_6 that has been converted into liquid form for ease and safety of non-pressurized storage or transport. The natural gas condensed into liquid at -162^{o}C (-260^{o}F) at almost atmospheric pressure. The liquefaction process involves removal of certain components such as dust, acid, gases, helium, water and hydrocarbons which could cause difficulty downstream and processed through desulfurization, dehydration and carbon dioxide cleaning. All this process will make the gas become odorless, colorless, non-toxic and non-corrosive.

This liquid form makes it possible in transporting the gas at big amount of gas by LNG carrier vessel. It takes up about 1/600 volume of natural gas in the gaseous state at standard conditions for temperature and pressure. It will make the long distance transport destination of gas more economics while there is no pipeline. When transporting the natural gas with pipeline is not possible or not economical, it can be transported by LNG carrier, where many of tank type for LNG are membrane or “moss”.

The energy density that produces by LNG is comparable with petroleum fuel and diesel fuel. LNG is a clean energy, 1 KWH gas energy of LNG contain 446 gram CO_2, also the content of nitrogen oxide is around 20-37% and carbon dioxide 57% that less than coal. Besides that, it because the flash point of LNG is higher than petroleum fuel. These characteristic makes LNG become the safe energy. LNG have higher calories (12000 kcal/kg) than other types of fuel. This gas type produces less pollution, but the production cost is relatively high and requirement for storage that use expensive cryogenic tank for commercial application. Cryogenic is a liquid form from elements or molecule that melting under 100^{o}F temperature. LNG is originated from natural gas that have a mixture from some different gases so that don’t have specific flash point. The flash point is depending on the source of usage gas and the process to liquefied the gas form. The highest flash point for LNG is around 24 MJ/L at -164^{o}C temperature and the lowest point is 21 MJ/L (Oscarino, 2010)

Exploration activities are started on developing the onshore and offshore area in some places. Using seismic technology with hydrocarbon high probability, identification activities are done in the target areas. After done the environmental impact assessment (AMDAL) or environmental management and monitoring studies (UKL/UPL), working area manager could do well drilling test. LNG terminal have facilities to transporting LNG from tanker to LNG storage tank on the land, transferring to high pressure booster pumps, evaporating the LNG to produce high pressure natural gas. LNG terminal designed to receive LNG from some LNG production facilities (Oscarino, 2010)

There is some benefit in utilize natural gas as power plant fuel, include:

- The usage in power plant: natural gas can be used in Combine Cycle Gas Turbine (CCGT) which can make this facility in having higher thermal efficiency than coal or oil for power plant with same capacity for the power plant.

- Environment advantage: natural gas is one of the cleanest source of energy and have more efficient form than other energies, almost produce zero particular and less content of NOx and CO_2 than other fossil fuels.
- LNG have less fire risk than other types of hydrocarbon, LNG leaks is easy to detect because of the cloud humidity is visible, also fire rate of LNG is slower than human movement.

2.2. LNG Supply Chain

Supply chain is a series of relationships between companies or activities that carry out the supply of goods or services from the place of origin to the buyer or customer. Supply chain concerns the ongoing relationship of goods, money and information. Goods generally flow from upstream to downstream, money flows from downstream to upstream, while information flows from upstream to downstream and downstream to upstream. When viewed horizontally, there are five main components or actors in the supply chain, i.e. suppliers, manufacturers, distributors, retailers and customers. Vertically, there are several main components of supply chain, namely buyer, transporter, warehouse, seller and etc. Supply chain management is the planning, design and controlling the flow of information and goods throughout the supply chain that aims to meet the requirements of the customer, efficiently for the present and the future (Schroeder, 2003).

Supply Chain is a travel chain of natural gas taken up to the end user. The initial process of the LNG supply chain involves transporting natural gas from its production fields through pipelines to the liquefaction plant. Prior to the liquefaction of the gas, treatment was first undertaken to remove contaminants to substances such as carbon dioxide, water and sulfur to avoid them freezing and eventually breaking down when the gas was cooled to -162°C. Liquefaction plant is similar to a large refrigerator equipped with compressor, condenser, expansion valve and pressure evaporator. LNG generated through the liquefaction plant is routed through pipes to storage tanks / storage tanks. Pipelines and storage tanks must be isolated to maintain low temperatures so that both items are specially designed to accommodate cryogenic liquids. The LNG is then extracted from a storage tank for loaded into the LNG carrier to the receiving terminal. Before reaching the user, the LNG is first converted into a gas phase back in the regasification plant. The following is a figure of LNG supply chain from the gas field to the last user.

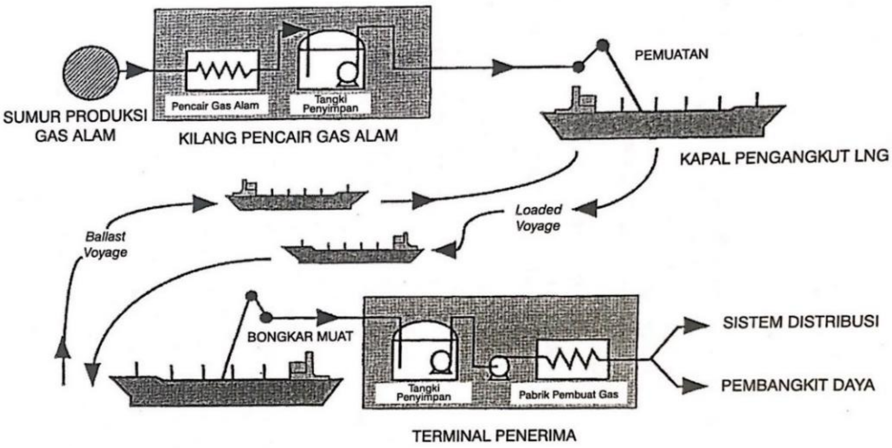


Figure 2.1 LNG Supply Chain (Source: Ketut Buda Artana, 2006)

2.2.1. Gas Reserves

A petroleum reservoir or oil and gas reservoir is a subsurface pool of hydrocarbons contained in porous or fractured rock formations. Petroleum reservoirs are broadly classified as conventional and unconventional reservoirs. In case of conventional reservoirs, the naturally occurring hydrocarbons, such as crude oil or natural gas, are trapped by overlying rock formations with lower permeability. While in unconventional reservoirs the rocks have high porosity and low permeability which keeps the hydrocarbons trapped in place, therefore not requiring a cap rock. Reservoirs are found using hydrocarbon exploration methods.

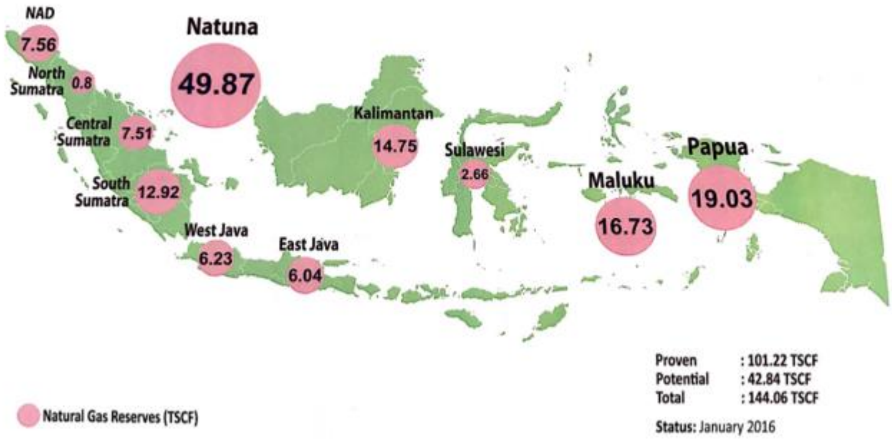


Figure 2.2 Indonesia Natural Gas Reserves (Source: Ditjen Migas, 2016)

Gas reservoirs have been divided into three groups; dry gas, wet gas and retrograde-condensate gas. A dry-gas reservoir is defined as producing a single composition of gas that is constant in the reservoir, wellbore, and lease-separation equipment throughout the life of a field. Some liquids may be recovered by processing in a gas plant. A wet-gas reservoir is defined as producing a single gas composition to the producing well perforations throughout its life. Condensate will form either while flowing to the surface or in lease-separation equipment. A retrograde-condensate gas reservoir initially contains a single-phase fluid, which changes to two phases (condensate and gas) in the reservoir when the reservoir pressure decreases. Additional condensate forms with changes in pressure and temperature in the tubing and during lease separation. From a reservoir standpoint, dry and wet gas can be treated similarly in terms of producing characteristics, pressure behavior, and recovery potential. Wellbore hydraulics may be different. Studies of retrograde-condensate gas reservoirs must consider changes in condensate yield as reservoir pressure declines, the potential for decreased well deliverability as liquid saturations increase near the wellbore, and the effects of two-phase flow on wellbore hydraulics.

2.2.2. LNG Carrier

LNG Carrier is a tank ship designed for transporting liquefied natural gas (LNG). As the LNG market grows rapidly, the fleet of LNG carriers continues to experience tremendous growth. The majority of new ships under construction are in the size of 120,000 – 140,000 m^3 (4,200,000 – 4,900,000 cu ft), but there are orders for ships with capacity up to 260,000 m^3 (9,200,000 cu ft). As of 2016, there were 451 LNG ships engaged in the deep sea movement of LNG. In the case of small scale LNG carriers (LNG carriers below 40,000 m^3 (1,400,000 cu ft)), the optimal size of a ship is determined by the project for which it is built, taking into consideration volume, destination and vessel characteristics.

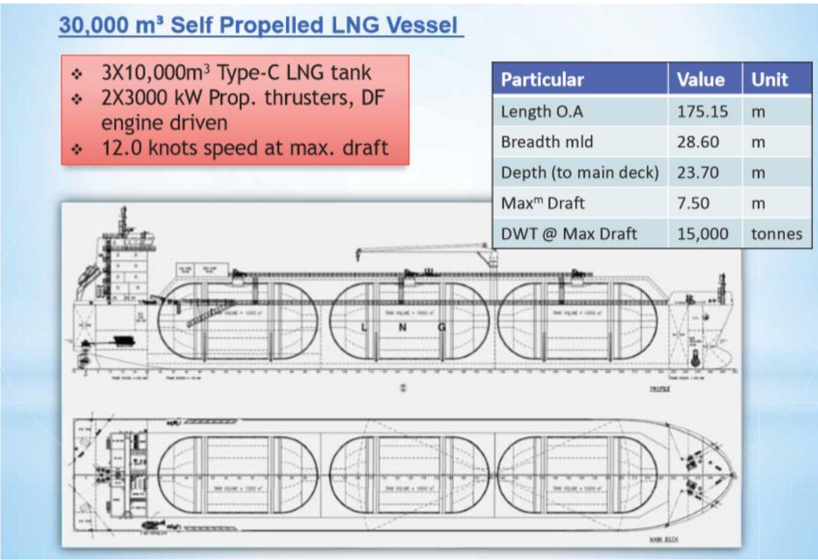


Figure 2.3 Small LNG Vessel (Source: Keppel Offshore & Marine Technology Centre)

2.2.3. Barge Container Skid

Small and medium economy countries are developing their infrastructures in remote locations. They need LNG for:

1. Power production, as those places are not connected to the national power grids
2. Industrial raw materials
3. Transportation fuel

Regular sized LNG vessels can't enter to those locations. Hence small-scale LNG carriers are necessary for transporting LNG to those remote locations. There are challenges in small scale LNG transportation that necessity based on transportation method. Customized designs are required for each case to transport LNG, initial investment is a factor in developing small-scale LNG infrastructures, requires a sustainable transportation model to compete with road transportation in future and it need to consider the problems in coastal and river waterway transportation which will gave an affection in:

1. Designs of small coastal LNG carrier/river barges
2. Design of small LNG terminal, loading/unloading facilities

Also while there are challenges, there will be solutions for small-scale LNG transportation, such as:

1. Based on the propulsion system:
    a. Self-propelled LNG carrier
    b. Non-propelled LNG carrier
2. Based on LNG containment system:
    a. 'Type-C' LNG tanks
    b. 'Membrane Type' LNG tank
3. Based on the draft limitation of the waterways:
    a. Regular draft LNG carriers
    b. Shallow draft LNG carriers

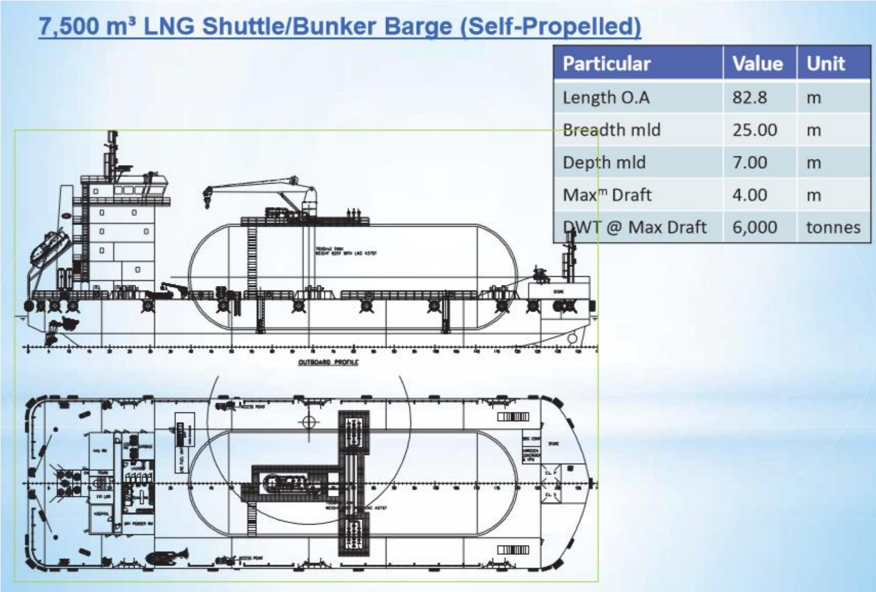


Figure 2.4 LNG Shuttle / Bunker Barge (Source: Keppel Offshore & Marine Technology Centre)

2.2.4. LNG Hub Storage

A liquefied natural gas storage tank or LNG storage tank is a specialized type of storage tank used for the storage of Liquefied Natural Gas. LNG hub storage is a storage that located in one of the power plant demand area and located as the main storage before distribute to the rest power plant in that area. LNG storage tanks can be found in ground, above ground or in LNG carriers. The common characteristic of LNG Storage tanks is the ability to store LNG at the very low temperature of -162 °C (-260 °F). LNG storage tanks have double containers, where the inner contains LNG and the outer container contains insulation materials. The most common tank type is the full containment tank. Tanks vary greatly in size, depending on usage.

In LNG storage tanks if LNG vapors are not released, the pressure and temperature within the tank will continue to rise. LNG is a cryogen, and is kept in its liquid state at very low temperatures. The temperature within the tank will remain constant if the pressure is kept constant by allowing the boil off gas to escape from the tank. This is known as auto-refrigeration.

The world's largest above-ground tank (Delivered in 2000) is the 180 million liters full containment type for Osaka Gas Co., Ltd. (2) The world's largest tank (Delivered in 2001) is the 200 million liters Membrane type for Toho Gas Co., Ltd.

2.2.5. Receiving Terminal

Liquefied natural gas terminal is a structure for liquefied natural gas to store. It can comprise special tanks, ships or even building structures. Port infrastructures and pipelines are also a part of LNG terminals. Liquefied natural gas is the form used to transport natural gas over long distances, often by sea. In most cases, LNG terminals are purpose-built ports used exclusively to export or import LNG. The function of an LNG import terminal is to receive LNG cargos, store LNG, and re-vaporize the LNG for sale as gas. Odorant injection may be required if gas is to be exported through a transmission grid. There are two main systems used for LNG vaporization: submerged combustion vaporizers and open-rack vaporizers (ORVs). In submerged combustion vaporizers, the LNG passes through tubes immersed in a water bath, which is heated by submerged burners. In ORVs, water runs down the outside of the vaporizer tubes (usually vertical) as a film. River water or seawater is normally used.

2.3. Power Plant in Papua

Papua region is divided into West Papua Province and Papua Province with 40 districts, a total area of 424,500 km2 and 16 million inhabitants. In section will be further explained on the condition of electricity in Papua province and West Papua based on the Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) 2017-2026.

2.3.1. Papua Province

Papua Province consists of 36 districts and 1 municipality with the distribution location of the capital far between each other. The power supply uses a 20 kV system and still isolated, partly using a low voltage 220 Volt network directly to the load. In addition, there are still some district capitals that have not received electricity from PLN. The ratio of the number of PLN electricity household customers in 2015 to the province of Papua is around 45.93%, still very low amount.

Papua province is currently supplied by several power plants whose total peak load reaches 145.9 MW. PLN through RUPTL 2017-2026 projected that electricity demand will increase by 8.4% annually or reach 499 MW in 2026 (see table).

The development plans of power plant facilities, transmission and distribution networks in Papua Province are carried out with due regard to the needs and potential of the local primary energy and population distribution. In order to meet the needs of the load in period 2017-2026, planned an addition of power plant capacity of about 755 MW, the details as shown in table 2.1. In addition to the construction of new power plants, the PLN RUPTL also mentions the planning infrastructure supporting electrical energy distribution that can be seen in Figure 2. The picture describes the development plan of interconnection system of 70 kV and 150 kV Jayapura.

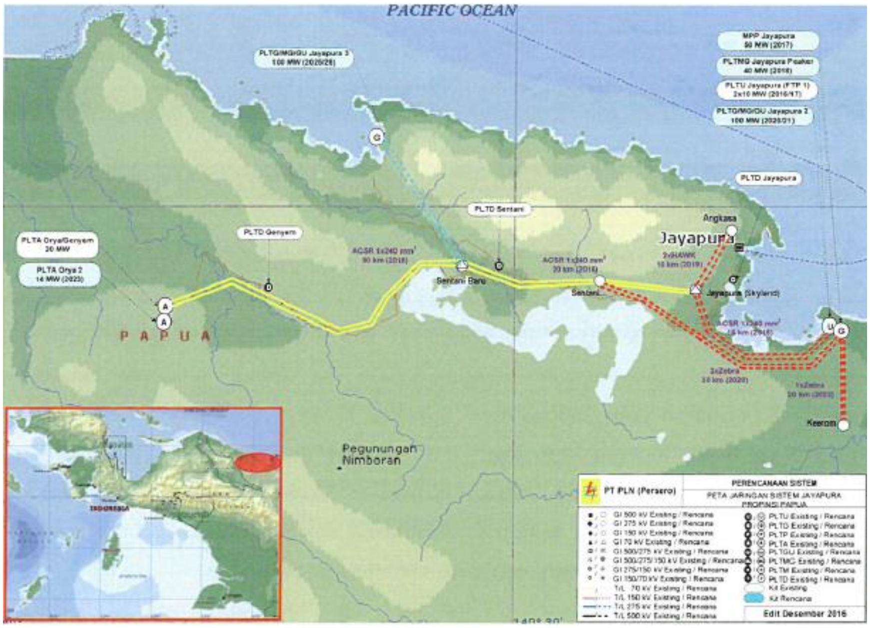


Figure 2.5 Development Planning Map Interconnection System 70 kV and 150 kV Jayapura (Source: RUPTL PLN 2017-2026)

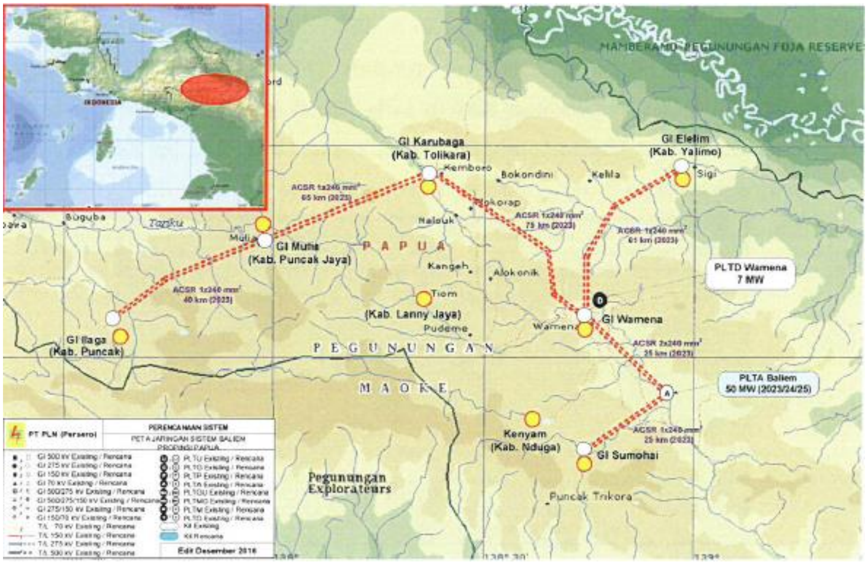


Figure 2.6 Development Planning Map Interconnection System 150 kV Wamena (Source: RUPTL PLN 2017-2026)

Table 2.1 Power Plant Development Planning List

No.	Project	Type	Capacity (MW)	POD
1	Jayapura (FTP1)	PLTU	10	2017
2	MPP Jayapura	PLTG/MG	50	2017
3	MPP Timika	PLTG/MG	10	2018
4	Biak	PLTMG	15	2018
5	Merauke	PLTMG	20	2018
6	Jayapura Peaker	PLTMG	40	2018
7	MPP Nabire	PLTG/MG	20	2017
8	Nabire 2	PLTG/MG	10	2018
9	Merauke 2	PLTG/MG	20	2018
10	Biak 2	PLTG/MG	20	2018
11	Serui 1	PLTMG	10	2018
12	MPP Papua	PLTG/MG	10	2018
13	Timika 2	PLTG/MG	30	2018
14	Timika 2	PLTG/MG	10	2019
15	Sarmi	PLTMG	5	2019
16	Nabire 2	PLTMG	10	2019
17	Digoel	PLTM	3	2019
18	Serui 2	PLTMG	10	2019
19	Jayapura	PLTMG	50	2019
20	Kalibumi	PLTM	2.6	2019
21	Timika 3	PLTMG	20	2020
22	Amai	PLTM	1.4	2020
23	Biak 3	PLTMG	40	2021
24	Merauke 3	PLTMG	20	2021
25	Serui 3	PLTMG	10	2021
26	Walesi Blok II	PLTM	6	2022
27	Timika 4	PLTMG	20	2022
28	Orya 2	PLTA	14	2023
29	Jayapura 2	PLTG/MG/GU	100	2020/21
30	Baliem	PLTA	50	2023-2025
31	Merauke	PLTBM	3.5	2018
32	Nabire - Kalibobo	PLTU	2x7	2020
33	Jayapura 3	PLTG/MG/GU	100	2025/26
Total Amount			755	-

Source: Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PLN

2.3.2. West Papua Province

West Papua Province consists of 10 districts and 1 municipality with the electrical system still isolated, consisting of 6 systems 20 kV and the load above 1 MW are Sorong system, Fakfak, Manokwari, Kaimana, Teminabuan and Bintuni. The ratio number of PLN electricity household customers in 2015 to West Papua province amounted to 82.70 % with a peak load of 70.2 MW supplied from several plants. Figure 2.11 and Figure 2.12 shown the power system development planning in Manokwari and Sorong areas.

Figure 2.7 Electricity Development Planning Map at Sorong System (Source: RUPTL PLN 2017-2026)

Figure 2.8 Electricity Development Planning Map at Manokwari System (Source: RUPTL PLN 2017-2026)

The construction planning of electricity facilities in West Papua Province are necessary is done because most of the power supply comes from excess power or power excess delivered from private companies that have uncertain reliability supply. In addition, the plant with HSD fuel and steam still not sufficient the needs of electricity. To meet the electricity needs until 2026 period, it has planned to build several power plants with total capacity about 321 MW.

Table 2.2 Power Plant Development Planning List

No.	Project	Type	Capacity (MW)	POD
1	MPP Manokwari	PLTG/MG	20	2018
2	Kaimana	PLTG/MG	10	2018
3	MPP Fak-Fak	PLTG/MG	10	2018
4	Sorong	PLTG/MG	30	2018
5	Sorong	PLTG/MG	20	2019
6	Bintuni	PLTMG	10	2018
7	Raja Ampat	PLTMG	10	2018
8	Manokwari 2	PLTMG	20	2019
9	Fak-Fak	PLTMG	10	2020
10	Kaimana 2	PLTMG	10	2020
11	Sorong 2	PLTG/MG/GU	100	2021/22
12	Waigo	PLTM	1.3	2022
13	Sorong 3	PLTG/MG/GU	50	2025
14	Manokwari 3	PLTMG	20	2024
Total Amount			321	-

Source: Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PLN

2.4. System

System is defined as a collection of objects incorporated in a regular interaction and interdependency. Several components that establish a system are:

- **Entity**:
  Entities or object studies in the system are object items that are processed through systems such as products, customers, and documents. Entities can have unique characteristics such as cost, size, priority, quality or condition. Entities can be grouped into human or animal (customer, patient, etc.), non-human (products, components, documents, garbage, etc.) and intangible (phone calls, electronic mail, etc.).
- **Attribute**:
  Attribute is a properties or characteristics of entities that specific
- **Activities**:
  Activities can be interpreted as activities / tasks performed entities within a certain period of time, can also be viewed as tasks performed in the system (either directly or indirectly) in processing entities. Examples of activities are serving customers, cutting components, repairing an equipment, etc. Activity takes time and requires a resource. Activities may be classified as entity-processing activities (check-in, product inspection, fabrication, etc.), entity and resource displacements (forklift displacements, transit in conveyor belts etc), and resource adjustment / repair / maintenance (machine setup, repair engine, etc.).
- **State**:
  State is defined as variable that give a description of status on system in certain relative time against the purpose.

- **Event**:
  Event is an event (instant) that can change the status of the system (variable state). Endogenous event is an activity or event that occurs in the system, for example the incidence of completion of a customer service. Exogenous events are activities or events outside the system (environment) that affect the system, e.g. the arrival of a customer into the bank.
- **Resource**:
  Resources is an object or equipment used in conducting an activity. Resources provide support facilities, equipment, and labor to complete a job. Resources typically have characteristics of capacity, speed, cycle time, and reliability. Resources can be grouped as human or animate (operator, doctor, repair officer, etc.), inanimate (equipment, equipment, workspace, etc.), and intangible (information, electrical power, etc.). Resources can also be classified as dedicated or shared resources, permanent or consumable, and mobile or stationary.
- **Delay**:
  Delay is a duration of time unspecified indefinite length, which is not known until it ends.

2.5. Transshipment Model

Transshipment is a combination between transportation and deconsolidation. Transportation is done during all the stages, from the source to an intermediate storage location through to a final destination. Either the same vessel is used to carry it to its destined locations.

The transshipment problem is a transportation problem in which each origin and destination can act as an intermediate point through which goods can be temporarily received and then transshipped to other points or to the final destination. (Gass, 1969, 232).

Transshipment or Transhipment is the shipment of goods or containers to an intermediate destination, and then from there to yet another destination. This logistics operation could be also named as re-exporting. Transshipment has become an integral part of the logistic strategy of many shipping companies. Indeed, from its origin to its final destination, any given cargo might have transshipped three or four times. Transshipment can be viewed as routing goods in such a way that would decrease shipping costs, take advantage of economies of scale and improve the range of services or routes offered to customers. In particular, transshipment services provide shippers with additional routing options (especially towards final destinations at smaller ports) and reduced transit times. Earlier, before the development of large oceangoing container ships, transshipment was simply an induced operation when a small part of the cargo on the board of a vessel had to be unloaded in an intermediary port due to different destination of the main cargo on the board.

The level of transshipment through a given port or a country is in general the result of strategic decisions made by the shipping companies themselves. In order to satisfy the demands of carriers, transshipment ports need to satisfy a number of attributes:

- Availability of an array of high-frequency feeder services, connecting the hub with its network of feeder ports
- Convenient geographical location with access to major trade routes and other transshipment centers
- Efficient, highly productive and competitively priced port and terminal services
- Availability of modern high-tech infrastructure (e.g., berths, gantry cranes, container storage space) as well as equipment that allows for a quick turnaround time of large vessels

2.6. Simulation

Simulation is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics, behaviors and functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time.

Simulation is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, training, education, and video games. Often, computer experiments are used to study simulation models. Simulation is also used with scientific modelling of natural systems or human systems to gain insight into their functioning, as in economics. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Simulation is also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist.

There are three type of simulation; discrete event simulation, static and dynamic, and Monte Carlo. They were defined as:

1. Monte Carlo Simulations:
   This type of simulation techniques is a simulation that sampling from a particular probability distribution involves the use of random numbers. Monte Carlo simulation is sometimes called Stochastic Simulation. This technique considered using random or pseudo random numbers. It is important to know what random numbers are. The example is when tossing a coin, if coin is unbiased, probability of coming head is 0.5. This simulation technique does not play time as substantial role, the observations as a rule are independent and it is possible to express the response as a rather simple function of the stochastic input variates.

2. Static and Dynamic Simulations:
   Static model of simulation doesn’t consider time, so the model is comparable to a snapshot or a map. A simulation of a system at one specific time, or a simulation in which time is not a relevant parameter for example. The example a model of the weight of a salamander as being proportional to the cube of its length has variables for weight and length, but not for time. Dynamic model of simulation is changes by the time. A simulation representing a system evolving over time. The example is the

number of salamanders in an area undergoing development changes with time and model of such a population is dynamic.

3. Discrete-event Simulation:
   This simulation is a models the operation of a system as a Discrete Sequence of Events in time. Each event occurs at a particular instant in time and marks a change of state in the system. Between consecutive events, no change in the system is assumed to occur; thus the simulation can directly jump in time from one event to the next.
   Consider simulation of some system which evolves through time. There is a huge variety of such applications. One can simulate a weather system, for instance. A key point, though, is that in that setting, the events being simulated would be *continuous*, meaning for example is to simulate the operation of a warehouse. Purchase orders come in and are filled, reducing inventory, but inventory is replenished from time to time. Here a typical variable would be the inventory itself, i.e. the number of items currently in stock for a given product. To graph that number against time, get what mathematicians call a *step function*, i.e. a set of flat line segments with breaks between them. The events which decreases and increases in the inventory are discrete variables, not continuous. (Matloff, 2008)

To solve problem about supply chain, several methods is developed. Discrete event simulation and system dynamics will give as an understanding behavior of systems over time and compare their performance under different conditions. Discrete event simulation is mainly used to study and evaluate the detailed operations of a supply chain in high level of accuracy. Discrete event simulation is more often modelling system performance, inventory planning/management, production planning and scheduling. While system dynamics commonly used to model issues regarding information sharing, bull-whip effect and inventory planning/management.

2.7. ARENA DES-Software

ARENA is one of some software that can be used and have a specialty in simulation including discrete-event simulation that usually using this software to create a computer simulation of a system. Computer simulation is refer to methods for studying a wide variety of models of real-world systems by numerical evaluation using software designed to imitate the system’s operations or characteristics. Simulation is the process of designing and creating a computerized model of a real or proposed system for the purpose of conducting numerical experiments to give us a better understanding of the behavior of that system for a given set of conditions.

Simulation models are start by create a system that will be simulated e.g. *a simple processing system*. The simulation usually involves waiting lines or queue as building blocks. Then after the system is create, the next step is deciding and collecting the output performance measures. The output performance measures are:

- *The Total Production* is number of parts that complete their service at the drill press and leave.
- *The Average Waiting Time in Queue* is a time in queue records that only the time a part is waiting in the queue and not the time it spends being served at the drill press. The average algorithm is:

$$\frac{\sum_{i=l}^{N} WQ_i}{N} \tag{2.1}$$

Where:
WQ_i : Waiting time in queue of the *i* part.
N : Number of parts leave the queue during the running time.

This is generally called a discrete-time or discrete-parameter statistic since it refers to data. These are called tally statistics since values of them are "tallied" when they are observed.
- *The Maximum Waiting Time in Queue* is a worst-case measure, which might be of interest in giving service-level guarantees to customers. Small is good.
- *The Time Average Number of Parts Waiting in the queue* is a weighted average of the possible queue lengths weighted by the proportion of time during the run that the queue was at that length. In integral calculus terms, this is:

$$\frac{\int Q(t)dt}{length\ of\ run} \tag{2.2}$$

Where:
Q(t) : Number of parts in the queue at (t) time.
Length of run : Length of the simulation is running.

Such time-persistent statistics are common in simulation. This indicates how long the queue is (on average).
- *The maximum number of parts that were ever waiting in the queue* is a better indication of how much floor space is needed than is the time average.
- *The Average* and *maximum total time in system* also called *cycle time* is the time that elapses between part's arrival and departure.
- *The Utilization* is defined as the proportion of time it is busy during the simulation. The utilization is:

$$\frac{\int B(t)dt}{length\ of\ run} \tag{2.3}$$

Where:

B(t) : Time of the utilization is busy during the simulation.

Length of run : Length of the simulation is running.

Resource utilizations are obvious interest in many simulation, but it's hard to say whether they considered to be high (close to 1) or low (close to 0).

Then the next are the *Queueing Theory*. The most popular queueing theory is M/M/1 queue. The first M states that the arrival process is Markovian. The second M is stands for the service-time distribution and here is also an exponential. The "1" indicates that there's just a single server. Most of the output performance measures can be expressed as simple formulas, it is:

$$\frac{\mu_S^2}{\mu_A - \mu_S} \qquad (2.4)$$

Where:

μ_A : the expected value of the interarrival-time distribution.

μ_S : the expected value of the service-time distribution.

For the expert user of ARENA there are some of algorithm that provided by the software. The algorithm especially about probability and statistics that can be used for simulating. For the probability algorithm, there is the random variables algorithm that can be used to quantifying and simplifying events by defining random variables. There are two basic forms in random variables, discrete and continuous. In this research discrete event simulation is used, so here the explanation for the discrete random variable.

1. Discrete

   For discrete random variable, there will be a list of random possible values. There are also some of the function that related to the discrete random variables. First is the *Probability Mass Function (PMF)*, the function that gives the probability that X will take on each of the possible values. Here is the function (Kelton, 2010).

   $$p(x_i) = P(X = x_i) \qquad (2.5)$$

   Where:

   X : Random variable.

   x_i : Non-random values.

   Statement "$X = x_i$" is an event that may or may not happen. The PMF may be expressed in a variety different ways, a numerical list or table, graph, or some kind of mathematical formula. Then, the second is *Cumulative Distribution Function (CDF),* this function is a function that gives the probability that X will be less than or equal to argument, the following function is describe CDF (Kelton, 2010).

$$F(x) = \sum_{\substack{all\ i\ such\ that \\ x_i \le x}} p(x_i) \tag{2.6}$$

This summation is taken over all possible values x_i that are ≤ the argument x of F. Note that $0 \le F(x) \le 1$ for all x, that $F(x) \to 0$ as $x \to -\infty$, and that $F(x) \to 1$ as $x \to +\infty$. Thus, F(x) is a non-decreasing function going from 0 up to 1 as x goes from left to right. F(x) is a "step" function that's flat between adjacent possible values x_i, and takes a "jump" of height $p(x_i)$ above x_i.

The next function is Probability of an event involving a discrete random variable X that generally can be found by adding up the appropriate values of the PMF, for instance,

$$P(a \le X < b) = \sum_{\substack{all\ i\ such\ that \\ a \le x_i < b}} p(x_i) \tag{2.7}$$

This just says to add up the probabilities of those x's that are at least a but (strictly) less than b. Note that with discrete random variables, should be careful about weak vs strong inequalities.

Just as data sets have a "center" measured by the average of the data, random variables have a "center" in a certain sense. The *Expected Value* of the discrete random variable X is defined as,

$$E(X) = \sum_{all\ i} x_i p(x_i) \tag{2.8}$$

This function is also called the mean or expectation of X and is often denoted by μ or, if there's need to identify the random variable, μ_x. This is a weighted average of the possible values, with the weights being the respective probabilities of occurrence of each x_i. Those x_i's with high probability of occurrence are counted more heavily than are those that are less likely to occur. E(X) is just the simple average of the x_i's since they all "count" the same. E(X) is not to be interpreted as the value of X that expected to get when do the experiment defining X. Indeed, E(X) might not even be a possible value of a discrete random variable X (the x_i's might be integers but, depending on the situation, E(X) need not be an integer).

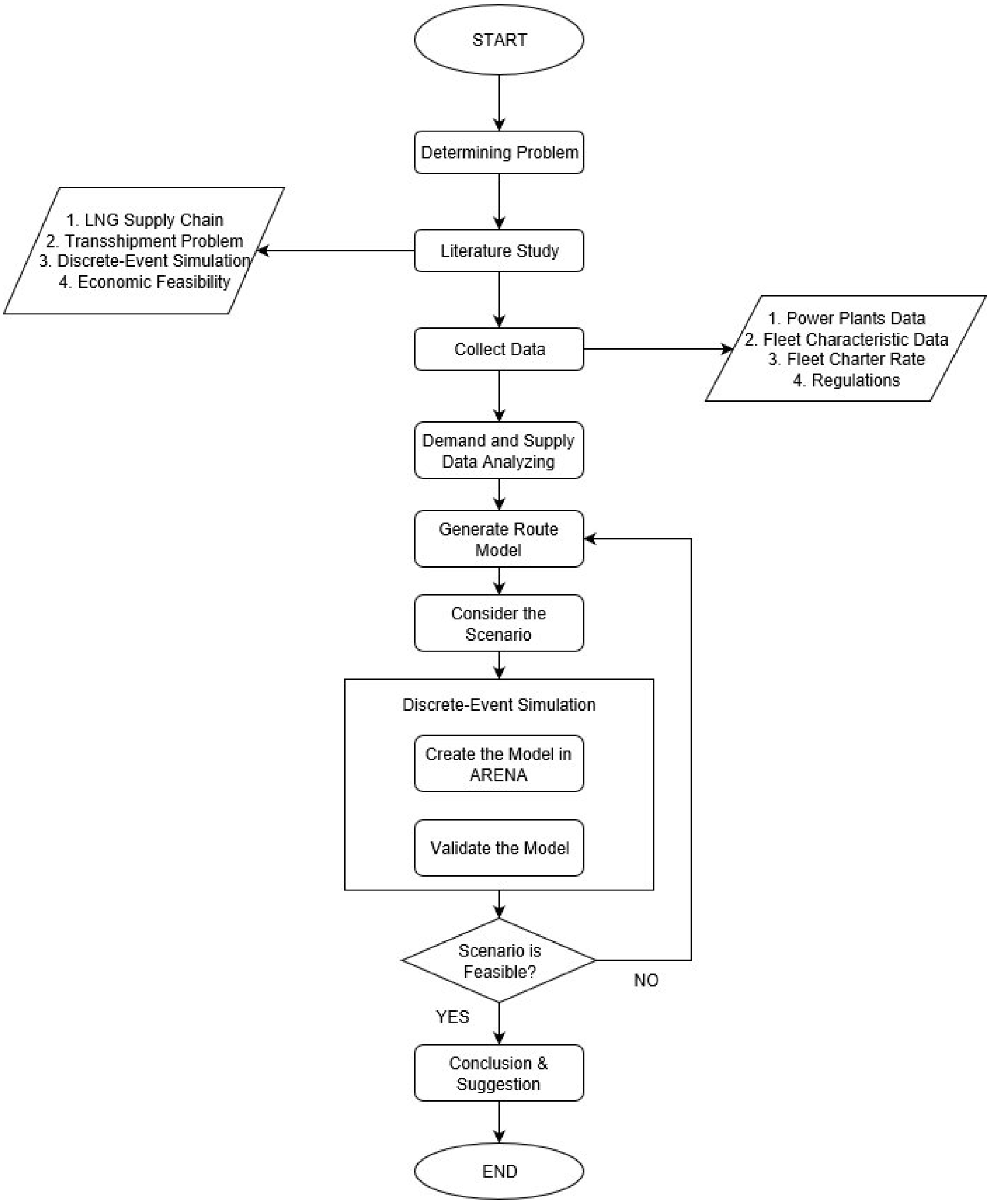
The last thing, as the data sets have a measure of variability, so to do random variables. The *variance* of the discrete random variable X is defined as

$$\mathrm{Var(X)} = \sum_{all\ i} (x_i - \mu)^2 p(x_i) \tag{2.9}$$

For a discrete random variable the variance is calculated by summing the product of the square of the difference between the value of the random variable and the expected value and the associated probability of the value of the random variable, taken over all of the values of the random variable. From the equation above the equivalent formula for the variance of the discrete random variable is $Var(X) = E(X^2) - [E(X)]^2$. This is weighted average of the squared deviation of the possible values x_i around the expectation, with the weights being the probability of occurrence of each x_i. The variance is a measure of the "spread" of the random variable about its mean.

CHAPTER III
METHODOLOGY

3.1. Methodology Flow Chart



3.2. Definition of Methodology Flow Chart

3.2.1. Determining Problem

This stage is an early stage to construct the thesis. In this stage, questions and problems are being prepared specifically in order to determine the specific objectives of this thesis. The content of the thesis is to overcome the statement of the problems mentioned earlier and it will be done by collect some information about the problems. Therefore, the purpose of this thesis can be understood in this stage.

3.2.2. Literature Study

After the problems is raised, the next step is literature study with the goal to explaining the review, give summary of the basic theory of this research and give information related to this research. Since this thesis is an implementation of some theories to reach a goal, various literature of a topic is required to construct into one project. The study of literature is done by reading papers, journals, thesis, media and literature books that relates and able to support this thesis.

3.2.3. Collecting Data

After literature study has been done, collecting data is being performed. A specific data as required in this thesis are being gathered in this stage, these are:

1. Type, Capacity and Location of power plants
2. Size, speed, fuel consumption and capacity of carrier
3. Geography of Papua and Papua Barat
4. Location, facility and characteristic of LNG source

3.2.4. Demand and Supply Data Analyzing

On this stage, all possible scheme of LNG supply chain whether by all modes of transportation is assessed with the current condition of sites. Afterwards, distances between LNG suppliers, transshipment point and power plants are calculated, also the distance between each power plants for each possible modes of distribution. Daily demand of LNG for each power plant is also calculated by converting its capacity with several equations depending on type of power plants.

3.2.5. Generate Route Model

On this stage, determine the supply chain possible routes, round trip time and total amount of LNG that have to be carried scenario using transshipment models by considering the data of distances and daily demands of LNG. Each scenario will be generated by qualitative judgement of researcher by considering the available data. Afterwards will be used to determine capacity of fleets, capacity of receiving terminal and number of fleets required.

3.2.6. Consider Scenario

In this step, after have the model of the transshipment for the LNG distribution in Papua and West Papua region, scenario will be needed to make some possibilities for the distribution. The determination of some scenario for each distribution model will consider the variation of receiving terminal tank capacity, fleet combination for each route and the level of inventory for each receiving terminal tank for signal to transport.

3.2.7. Discrete-Event Simulation

a. Create Model in ARENA Software

Next step after analyzing scenario of LNG distribution is to make conceptual model which is represent the scenario. Model is made in software with modules that available which may vary in different software. The model is simulated to assess whether the scenario is acceptable when demand of LNG is increased over time, as follows the increasing of produced electricity by power plants. Discrete-event simulation is a tool to be applied in order to achieve the objective.

b. Verification and Validation Model

Model verification is performed simultaneously with the running model simulation process by ensuring that the model can run (not error) on the model. While the verification is done to determine whether the model is in accordance with the real system. The validation process is done by performing a real output comparison of the system with the output of the simulation model. In this research, the validation is not needed because this model is not the real case that already constructed.

3.2.8. Conclusion & Suggestion

Last stage is to make a conclusion from the whole process that have been done before from the statement of problems.

From conclusions there is a suggestion that can be given based on the results from analyzing to become the next project. So that the next project can be better than this research.

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CHAPTER IV
DATA ANALYZING AND DISCRETE-EVENT SIMULATION

4.1. Data Analyzing

4.1.1. Power Plants Identification

In this research, the power plants data is chosen based on *Rencana Usaha Penyediaan Tenaga Listrik* (RUPTL) 2017-2026. Power plants that used for this research are power plants that use gas for the fuel and located in Papua and West Papua Provinces. In the Papua and West Papua Provinces, there are two types of power plant that fueled by gas, such as; Gas Power Plants and Gas Mechanical Power Plant. The difference between that two types of power plants is for Gas Power Plants use gas turbine to generate the mechanical energy which is converted into electrical energy, meanwhile for the Gas Mechanical Power Plants use internal combustion engine to generate mechanical movement that converted to electrical energy.

Data of Gas Power Plants and Gas Mechanical Power Plants that already constructed and still on progress or planned according to RUPTL 2017-2026 are shown in table 4.1.

Table 4.1 Power Plants Gas Fueled in Eastern Part of Indonesia

No	Project	Type	Capacity (MW)	COD
1	Biak	PLTMG	15	2018
2	Biak 2	PLTMG	20	2018
3	Biak 3	PLTMG	40	2021
4	Bintuni	PLTMG	10	2018
5	Fakfak	PLTMG	10	2020
6	Jayapura 1	PLTMG	50	2019
7	Jayapura Peaker	PLTMG	40	2018
8	Jayapura 2	PLTMG	100	2020/21
9	Jayapura 3	PLTMG	100	2025/26
10	Kaimana	PLTMG	10	2018
11	Kaimana 2	PLTMG	10	2020
12	Manokwari 2	PLTMG	20	2019
13	Manokwari 3	PLTMG	20	2024
14	Merauke	PLTMG	20	2018
15	Merauke 2	PLTMG	20	2018
16	Merauke 3	PLTMG	20	2021
17	MPP Fakfak	PLTMG	10	2018
18	MPP Jayapura	PLTMG	50	2017
19	MPP Manokwari	PLTMG	20	2018

Table 4.2 Power Plants Gas Fueled in Eastern Part of Indonesia (Continued)

20	MPP Nabire	PLTMG	20	2017
21	MPP Papua	PLTMG	10	2018
22	MPP Timika	PLTMG	10	2018
23	Nabire 2	PLTMG	10	2018
24	Nabire 3	PLTMG	10	2019
25	Raja Ampat	PLTMG	10	2018
26	Sarmi	PLTMG	5	2019
27	Serui 1	PLTMG	10	2018
28	Serui 2	PLTMG	10	2019
29	Serui 3	PLTMG	10	2021
30	Sorong	PLTMG	30	2018
31	Sorong	PLTMG	20	2019
32	Sorong 2	PLTMG	100	2021/22
33	Sorong 3	PLTMG	50	2025
34	Timika 2	PLTMG	30	2018
35	Timika 2	PLTMG	10	2018
36	Timika 3	PLTMG	20	2020
37	Timika 4	PLTMG	20	2022
Total Amount			970	

The table above shown all power plants in Papua and West Papua region to proceed the LNG distribution scheme. The least capacity demand is at 5 MW in Sarmi power plant and the most capacity demand is at 100 MW in several power plants such as; Jayapura 2 & 3 and Sorong 2. As explained in chapter 2 that government allocated LNG to produced domestic power plants and in this occasion the source of LNG is supplied from Tangguh LNG Plant.

To analyzing the LNG demand in this thesis is furthermore conducted by counting fuel consumption. To simplify the calculation, several assumption is applied to estimate natural gas needed by power plants, there are:

1. Power plants consume 0.143 MMSCFD (Metric Million Standard Cubic Feet per Day) natural gas for every 1 MW power rate.
2. 1 MMSCFD is equal to 46 m^3 LNG.
3. 1 MMSCFD is equal to 1000 MMBTU (Metric Million British Thermal Unit).

All of the power plants that analyzed will determined for the receiving terminal location. Power plants which located in the same region will served by one receiving terminal and known in this case that there is no receiving terminal which only served one power plant. Subsequently calculation of LNG consumption is the accumulation of LNG consumption at each power plants that served by the receiving terminal.

Table 4.3 LNG Demand Calculation

NO	Area	Total Capacity (MW)	Gas Cons. (MMSCFD)	LNG Cons. (M^3/Days)	LNG Cons. (M^3/Year)
1	Biak	75	10.7	492.9	179,892.9
2	Bintuni	10	1.4	65.7	23,985.7
3	Fakfak	20	2.9	131.4	47,971.4
4	Jayapura	350	50.0	2,300.0	839,500.0
5	Kaimana	20	2.9	131.4	47,971.4
6	Manokwari	60	8.6	394.3	143,914.3
7	Merauke	60	8.6	394.3	143,914.3
8	Nabire	40	5.7	262.9	95,942.9
9	Raja Ampat	10	1.4	65.7	23,985.7
10	Sarmi	5	0.7	32.9	11,992.9
11	Serui	30	4.3	197.1	71,957.1
12	Sorong	200	28.6	1,314.3	479,714.3
13	Timika	90	12.9	591.4	215,871.4
Total Amount			138.6	6,374.3	2,326,614.3

The table above shown that the total capacity of power plant in Papua and West Papua Region is 970 MW are converted into LNG consumption for daily requirement is around 6,374.3 m^3 and for a year operation will required around 2,326,614.3 m^3 LNG to supply the power plants in this area. This amount of LNG is not automatically considered as amount that will transported per round trip, since the total round trip time of vessel that serves each power plant will affect the total number of LNG to be transported and the path is affecting as well. Later these numbers of gas and LNG amount will be considered to determine the possible scenario of distribution, which demands of power is one of consideration.

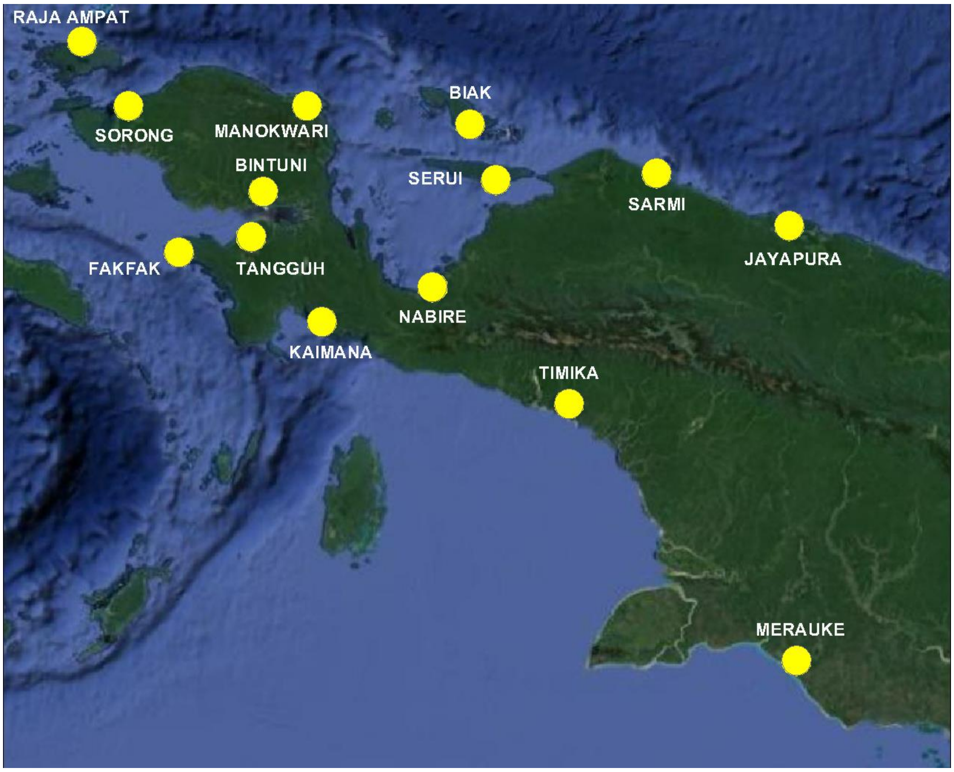

Figure 4.1 Receiving Terminal Location

4.1.2. Fleet Identification

In this study research, fleets are needed to distribute LNG across Papua and West Papua regions. Determination of this fleet is considered by several factors. As the demand is considerably not so much at each receiving terminal and each receiving terminal is spread around Papua and West Papua regions.

Range of ships size vary from 2500 m^3 until around 35000 m^3 that categorized as small/medium scale LNG carrier. Several important aspects that must be understand from ships are cargo capacity and draught during technical analysis. There will be required data is gathered in order to calculate the transportation cost. Those data are:

1. Cargo Capacity
   Cargo capacity is considered because it will affect the amount of LNG that distribute from one point to another point. In one trip with higher cargo capacity, a ship will probably has longer waiting time before assigned for the next trip, as LNG consumption at each point is remain the same. However, a ship with larger cargo capacity has higher charter rate and fuel consumption compared to smaller one.
2. Service Speed
   Service speed will help to consider the round trip time as in the same distance, a ship with higher speed will make a less time to travel and compared to a ship with slower speed. but

3. Pump Rate
   Pump rate are useful for the unloading process from ship cargo hold to receiving terminal. The process is done by a pump installed onboard. Pump capacity will affect unloading time and the roundtrip time as well.
4. Daily Fuel Consumption
   Fuel consumption will be considered as well because medium/small LNG carrier is driven by internal combustion engine as prime mover and required fuel which are either HFO or MDO. Fuel consumption is a variable that affect the transportation cost in this research.
5. Charter Rate
   Charter rate is considerably important variable in transportation cost. This research is determined all scenario charter ship number of charter rate of ship is mandatory.

The detail of ship particular is shown on table 4.4 below as refer to Widodo (2017) research and another source.

Table 4.4 Ship Particular

Parameter	Amount			Unit
Cargo Capacity	7500	12000	23000	m
LOA	117.8	152.3	151	m
Draft	7.15	6.7	8	m
Breadth	18.6	19.8	28	m
Service Speed	16	16	17	knot
Charter Cost	9500	15000	25000	USD/Day
Fuel Consumption	11	23	19.7	Ton/Day
Pump Capacity	450	600	850	m^3/Day

4.2. Generate Distance Matrix

Ships are the only consideration mode of transportation of LNG for receiving terminals that supply power plants in Papua and West Papua regions. After ships chosen, inter connection path or route is generated. Then matrix distance of receiving terminals and Tangguh LNG Plant is found out. The matrix distance of receiving terminals and Tangguh LNG Plant need to be measured. Refer to Antara (2017) the measurement of the matrix distance is shown in the attachment chapter.

4.3. Simulation LNG Distribution

The simulation for this modelling is simulated using DES Software (ARENA). The function of this software is to simulate the logical process of LNG distribution based on generating route and process. Inside the simulation process there are some variable that will be used for simulating such as LNG demand variable, transportation process variable and cost variable. In this research, the cost variable will be ignored because it will simulate to find the feasible route technically. This two kind of variable, will be the main variable in simulating the LNG distribution to the power plants in Papua and West Papua provinces. The LNG demand variable and transportation process is used to calculate and generating route. For example, calculating the round trip sail duration to get the demand in each power plants. Round trip sail duration can be collect from the calculation of the distance between supply to transshipment point or transshipment point to each receiving terminal based on the route that generated, vessel service speed and also vessel unloading duration.

To make the LNG distribution, the main variable for power plants are the LNG refinery, LNG vessel also the power plant itself. LNG refinery is the supply unit that provide LNG to be distributed and then will be used as the fuel for the power plants. LNG vessel is the transportation unit, to transport LNG from the supply unit and will distribute to each power plant by receiving terminal to collect the LNG. Meanwhile the power plant will become the demand unit that need LNG for their fuel to produce electricity.

LNG refinery data must be identified to calculate the distance between LNG refinery with each receiving terminal. LNG refinery production capacity is needed to know the production is fulfilled the demand from all power plant that will be served. LNG vessel data that needed to be identified are tank capacity, vessel speed, pump rate in the vessel. The data of vessels already explained in the last chapter. Demand power plant data that needed to identified are the location and the power capacity from the power plant. Power plant location can be used to help consider the location of receiving terminal and power capacity of power plant is used to help consider the demand of LNG every day.

From the main variable, identify the data are needed and connected so can earn the derived variables that is transportation economy cost. Derived variables that can earn among others distance between LNG refinery with receiving terminal, possibility route and round trip sail duration. The distance of LNG refinery and receiving terminal can be collect after consider the receiving terminal and refinery location. For the possibility route are considered based on the judgement which means generating route by the logical way of thinking. Round trip sail duration can earn from the distance between refinery and receiving terminal, vessel speed and also the duration while loading unloading activities.

4.3.1. Voyage

Voyage is the cost that issued to transporting the goods from the source or origin to the destination point. The variables to calculate the voyage cost among others are fuel consumption cost and also the port charge cost. Voyage cost can be calculated with summing up the fuel consumption for each vessel that used to transport LNG in one round trip with some distribution are multiplication function between the sail duration of round trip route with the vessel fuel consumption. Because of the cost variable is ignored, in this chapter there will be the voyage calculation that means the sail duration for the round trip route that earn from the route that are generated.

Round trip day not only the duration time while the vessel is sailing or usually called sea time route of vessel, but it also included the cargo handling time in the port or usually called port time and slack time. Sea time is the time that the vessel needs to transport the product through the distribution route with the service speed of the vessel. Meanwhile the port time is the time that needed while loading and unloading LNG process. LNG loading is done in the LNG refinery and in the transshipment point, also the unloading LNG is happened while the LNG is transferred from the vessel to receiving terminal and transshipment point. The time of LNG unloading to the vessel is assumed with the same time that use for LNG unloading in all capacity of LNG vessel by using the pump in the vessel.

Table 4.5 Round Trip Sail Duration Model 1 Calculation

Route	From	To	Sail Duration (Days)
1	Tangguh	Bintuni	0.25
	Bintuni	Sorong	1.88
	Sorong	Tangguh	1.66
		Total	3.79
2	Sorong	Manokwari	1.20
	Manokwari	Raja Ampat	1.15
	Raja Ampat	Fakfak	1.47
	Fakfak	Sorong	1.19
		Total	5.01
3	Sorong	Biak	1.98
	Biak	Serui	0.67
	Serui	Nabire	0.62
	Nabire	Sorong	2.36
		Total	5.63
4	Sorong	Sarmi	3.04
	Sarmi	Jayapura	0.93
	Jayapura	Sorong	3.84
		Total	7.81
5	Sorong	Kaimana	2.53
	Kaimana	Timika	1.37
	Timika	Merauke	2.44
	Merauke	Sorong	5.37
		Total	11.71

The table above is shown the sail duration time for the round trip in each route for the first model.

Table 4.6 Round Trip Sail Duration Model 2 Calculation

Route	From	To	Sail Duration (Days)
1	Tangguh	Bintuni	0.20
	Bintuni	Sorong	1.53
	Sorong	Jayapura	3.12
	Jayapura	Tangguh	4.76
		Total	9.60
2	Sorong	Manokwari	1.20
	Manokwari	Raja Ampat	1.15
	Raja Ampat	Fakfak	1.47
	Fakfak	Sorong	1.19
		Total	5.01
3	Sorong	Kaimana	2.05
	Kaimana	Timika	1.11
	Timika	Merauke	1.98
	Merauke	Sorong	4.36
		Total	9.51
4	Jayapura	Sarmi	0.75
	Sarmi	Biak	0.92
	Biak	Serui	0.55
	Serui	Nabire	0.50
	Nabire	Jayapura	2.27
		Total	4.99

From the data that collect from the research before, the charter rate of the vessel to calculate the time charter time whereas that known rate is the rate of charter per days. In calculating the cost of vessel charter will ignore the operational cost except fuel consumption cost, because the operational cost except fuel consumption cost are certified with the owner of vessel. To calculate the cost transportation in one year can be done by multiply the vessel charter rate per day with 365 days.

4.3.2. Receiving Terminal

Receiving terminal investation cost is calculated for the initial investment or usually called by Capital Expenditure (CAPEX) and operational cost for receiving terminal is called as Operational Expenditure (OPEX). The calculation for CAPEX and OPEX is done with estimating the primary equipment that needed for one receiving terminal and the operational in the receiving terminal. In this research, there will only some of calculation of the cost that affect and calculated for the CAPEX and OPEX such as, LNG storage tank; LNG loading pump; jetty; office; cryogenic pipe and land investation for the CAPEX calculation, but for the OPEX calculation there are the Energy Cost, office building inventory, employee salary and accommodation, operating cost and equipment maintenance cost.

Capacity of the receiving terminal are considered based on the sail duration time of the vessel, vessel size and also the gas consumption for the power plant every day. The higher power capacity that can produced by the power plants will affect the gas consumption will become increase. Receiving terminal should provide the gas, at least same with the gas consumption that needed by the power plant. However, the receiving terminal should have the tank capacity that suitable with the demand of the power plant that served. Tank capacity is depending on the duration time of the vessel in one round trip while distributing the LNG. So there is connection between the time that needed to distribute the LNG with the capacity that should be provided by receiving terminal to collect the LNG. The longer duration for distribution, so it will make the tank capacity become higher that should provide.

4.3.3. LNG Distribution Route Simulation

LNG distribution route simulation will be used the ARENA DES-Software. Simulation process is only done to find the real-time results of distribution design that already made by logical judgement. In this research, the simulation has some considered parameter such as the type of vessel based on the capacity for each vessel that will follow the demand that needed for each receiving terminal. Route simulation will have deliberation with the vessel capacity variable, vessel speed, distance of the delivery point, transportation cost, the demand of power plants and the location of transshipment point. To finish the problem of this LNG distribution after generating route, DES software should be finish make the model.

To decrease the complexity in simulation process there are some assumption are made, such as:

1. The service speed of the vessel is constant 16 knot
2. The simulation will not count the unsure real condition in the field and the reduce time of the voyage is not counted.
3. Safety stock variable is decided as 7 days and 3 days only.

For the simulation of LNG distribution is made 2 models with 8 scenarios each model. The first model is considering 1 transshipment point and the second model is considering there are 2 transshipment point. The figure below will show the generated route to be simulated.

Figure 4.2 LNG Distribution Route Model 1

Description:

White Line	: Route One (Tangguh – Sorong – Tangguh)
Pink Line	: Route Two (Sorong – Manokwari – Raja Ampat – Fakfak – Sorong)
Yellow Line	: Route Three (Sorong – Biak – Serui – Nabire – Sorong)
Green Line	: Route Four (Sorong – Sarmi – Jayapura – Sorong)
Blue Line	: Route Five (Sorong – Kaimana – Timika – Merauke – Sorong)

Figure 4.3 LNG Distribution Route Model 2

Description:

Yellow Line	: Route One (Tangguh – Sorong – Jayapura – Sorong)
Pink Line	: Route Two (Sorong – Manokwari – Raja Ampat – Fakfak – Sorong)
Blue Line	: Route Three (Sorong – Kaimana – Timika – Merauke – Sorong)
Green Line	: Route Four (Jayapura – Sarmi – Biak – Serui – Nabire – Jayapura)

From the two model above then the simulation model in ARENA software are made. The demand of power plants in the models is defined as variable that each receiving terminal has its own number of LNG consumed to be converted to electrical power. The demand is summing up to consider total of the demand in Papua region and calculate how much the supply point will supply LNG to the demand point or receiving terminal. LNG is shown in the software as an entity that will transported to the demand point. These logical thinking will convert into the software in the figures below.

Figure 4.4 Create Module of LNG

Every logical way of thinking of a model, it should be transformed into the modules in the software. To create the model, first thing that should be create is the "create" module that will create an entity that will simulated. In this research, the "create" module were designed so many because it is represented as entity that will functioned in the supply model to be transported to the transshipment point, in the transshipment model to be transported from the transshipment point to the demand point and in each receiving terminal to be represented as the demand that need LNG and to help record the amount of LNG as an entity in the storage.

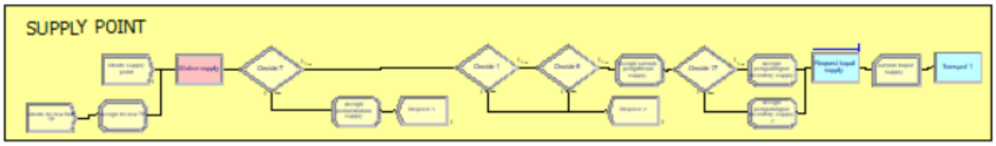

Figure 4.5 Route 1 Distribution Design

From the supply point to the transshipment point or appointed as route 1 is shown as the figure above. It started with the "create" module as the beginning of the simulation and to create the entity. After that there is a red square module that represent the supply will be a station for the transportation to transport the entity. Next module is a "decide" module, it is functioned as a decision maker for the logical and to separate two logical way of thinking that converted into the software. The decide module is created to decide the amount of entity that will transported. There is also "assign" module that functioned to assign the decision from the decide module. If from the decide module there is a decision to decrease the LNG so it must be continued in the decision side with "dispose" module. The dispose module is functioned as releasing the entity in the system. The blue module in the figure above is shown as the transportation module. The first blue module is represented to request the supply ship to transport the entities to transshipment point or the destination point. The second blue module is represented as the ship and it can control the ship as the specification that already determined.

In this research, for the signal to order ship to transporting the LNG is in the simplest way. Because the decision is only based on the inventory level of the storage tank in each destination point. It is created only using the decide module that already create in each network of route. The figure below will show the example of the signal to order ship to transporting LNG.

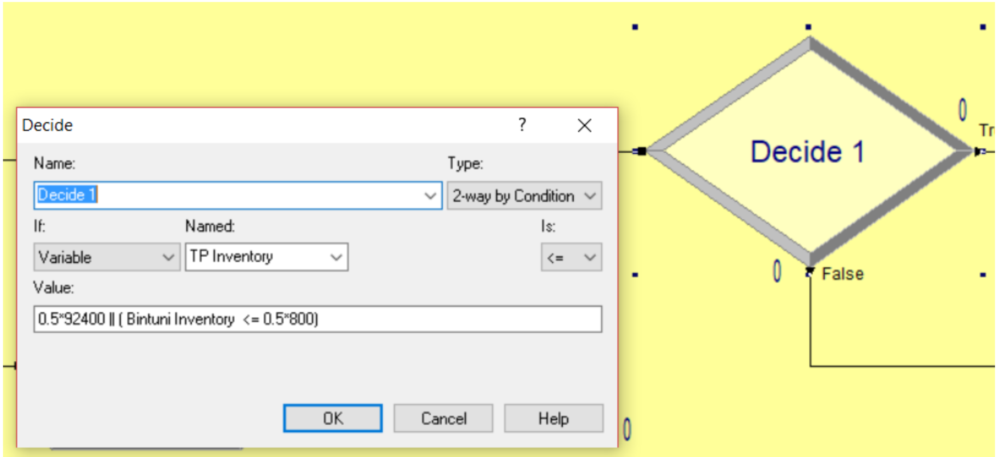

Figure 4.6 Decide the Signal to Transport

From the decision above, it shown that if the inventory in Bintuni or the transshipment point is less than equal to 50% of the tank capacity, the transport mode transporting the LNG to the destination point. To create this logical, can be manually created by using “build expression” feature.

The next thing that should be created is the “process” module that will represented as the loading/unloading process in the simulation of these LNG distribution. It can be created in the different position and logic. The process module is shown in the figure below.

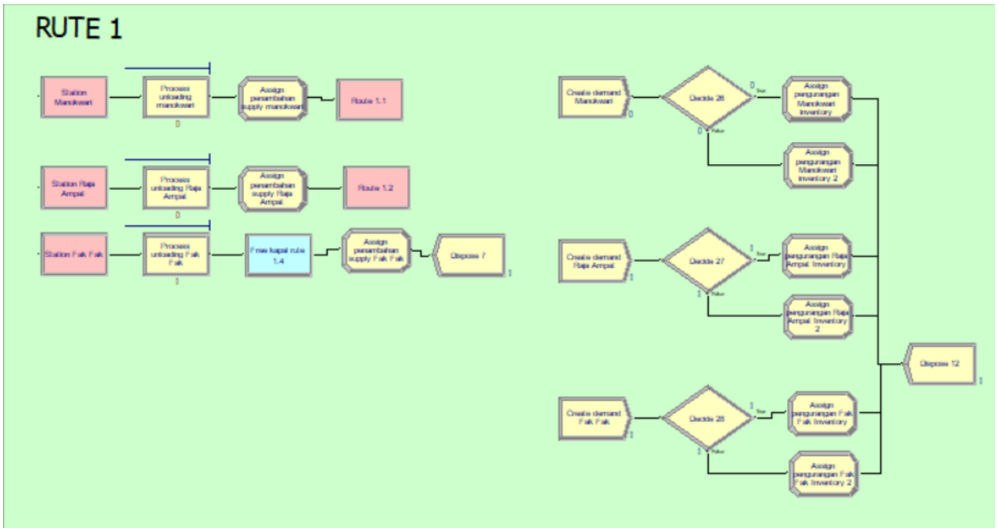

Figure 4.7 Unloading Distribution Design for Route 1

It represents the route 1 loading/unloading process for the distribution design. Process module is shown as the module that have a queue line above the module. In this processing in each receiving terminal representation, there are two side of logical way of thinking. The left side is represented for the unloading process and the right side is represented the amount of entity that reduce all along the time, it means the LNG consumption in each receiving terminal.

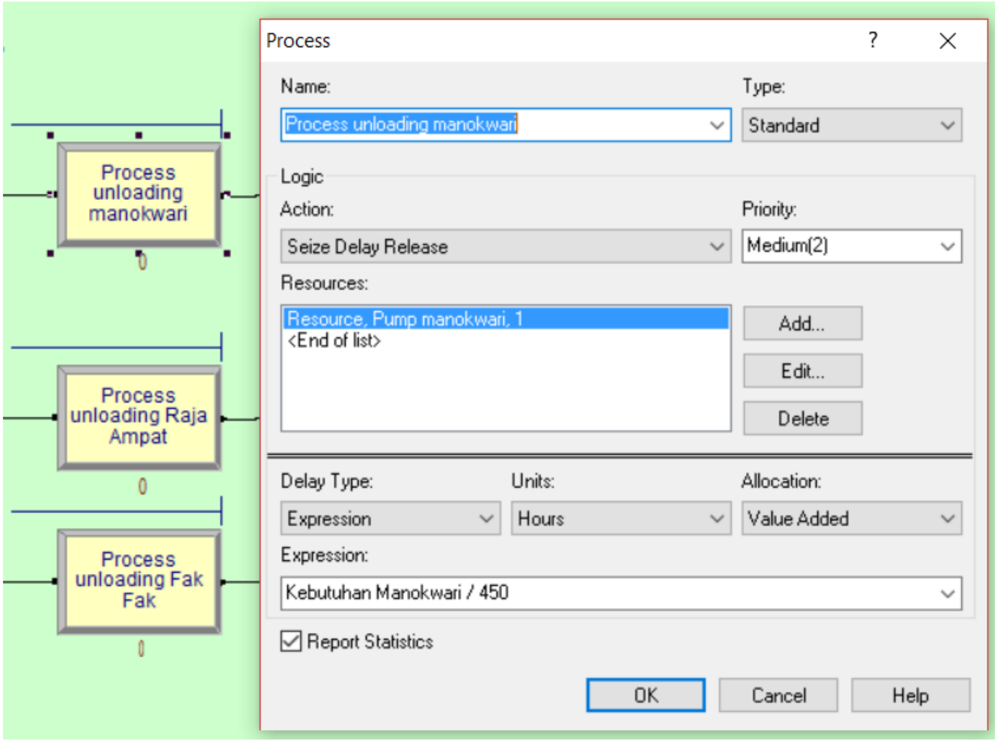

Figure 4.8 Process Module Ribbon

Unloading process logical way of thinking is shown in the figure above. These process module will use the pump rate specification that already set in the resource module. The process is controlled by the expression that were made. The expression is means that the time that will take on this process is based on the chosen variable divided with the pump rate capacity and the unit should be hours.

While creating the representation of the logical way of thinking for the LNG distribution design in the software, "ReadWrite" module is needed to collect the amount of entity in each process that were made. The readwrite module will linked with an excel and distribute the data in some columns. The functioned of these data is to continue the simulation process that are the next step of simulation using this software is verification data to correct and re-check the logical that already made. Then the next step after verification data is validation data that should be made. After the model in the software is validated, then the created model can be used for the system and to be simulated.

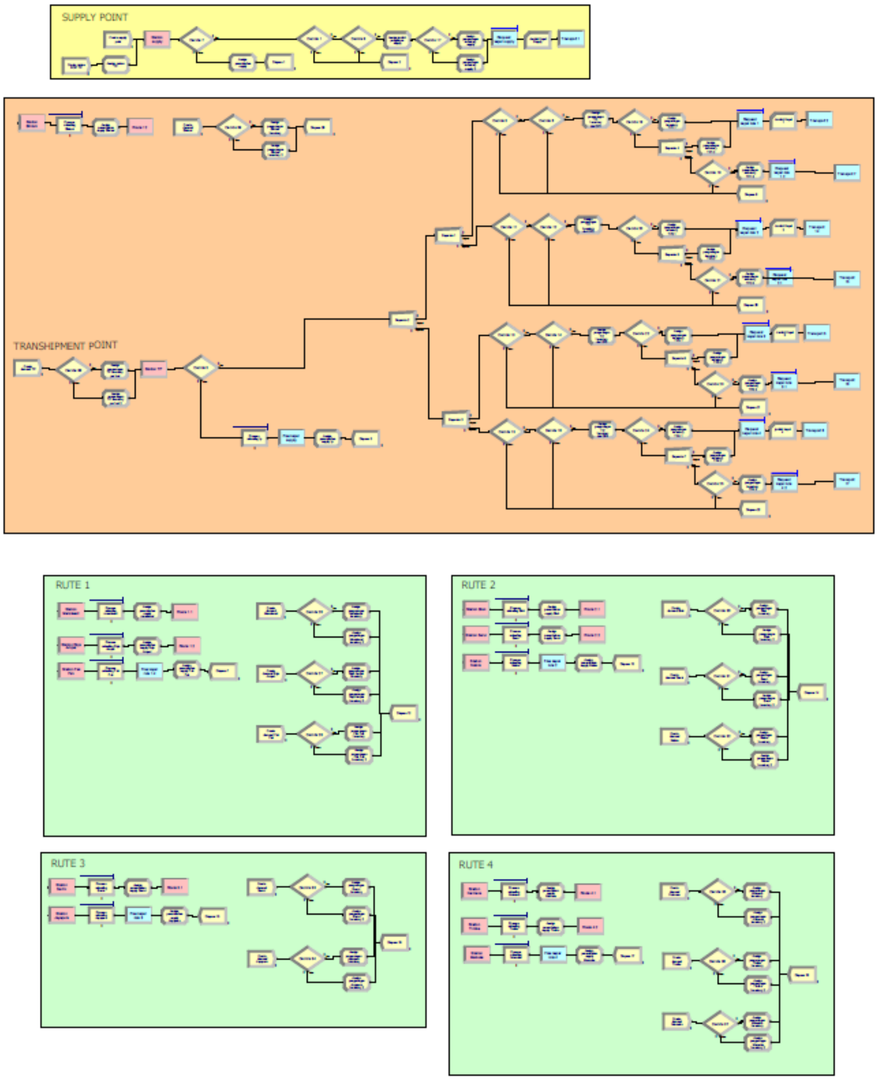

Figure 4.9 ARENA Logical Model (Model 1)

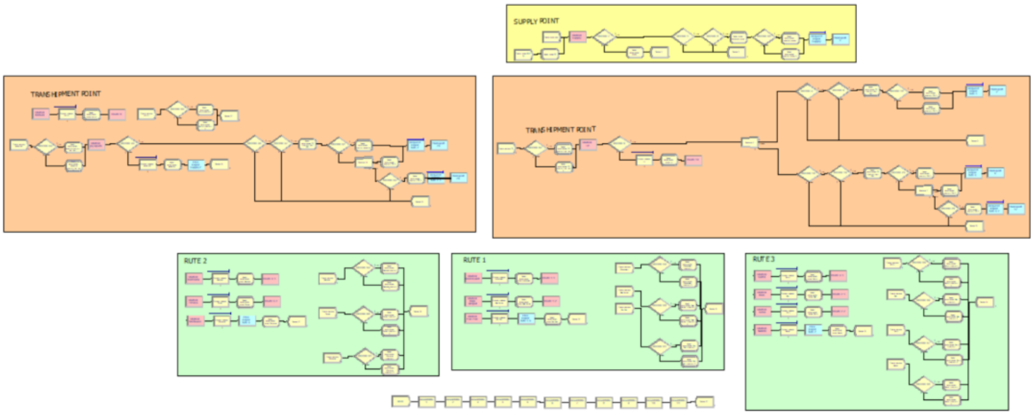

Figure 4.10 ARENA Logical Model (Model 2)

From the logical model in ARENA software to be simulated, there are some consideration to make a scenario between these two models. The scenario is based on the variation of receiving terminal tank capacity that used 3 days safety stock and 7 days safety stock, fleet combination based on the description in the last chapter and the inventory level to call the vessel to deliver the LNG. The scenario can be seen in the table below.

Table 4.7 Scenario Consideration

	Receiving Terminal Capacity	Fleet Combination	Inventory Level	Scenario Number
Route	Variation 1	Combination 1	60%	1
			50%	2
		Combination 2	60%	3
			50%	4
	Variation 2	Combination 3	60%	5
			50%	6
		Combination 4	60%	7
			50%	8

The result of the simulation in the first model above, can be concluded that using the 3 days safety stock is not feasible technically because in 1 year simulation of distribution, the inventory for some receiving terminal become empty so it is not feasible technically. But for the 7 days safety stock, using 1 fleet combination with the considered inventory level are not feasible, because the fleet is too small and it can't reach the receiving terminal on time with the LNG that the fleet transported.

In the second model the simulation result can be concluded that all of the 7 days safety stock of inventory is the most feasible technically than the 3 days safety stock. For the details of receiving terminal capacity variation, fleet combination that considered can be seen in attachment chapter.

Table 4.8 Model 1 Simulation Results

Scenario	Inventory (days)					
	Sorong	Manokwari	Raja Ampat	Fakfak	Bintuni	Biak
1	0	0	0	30	0	0
2	0	0	0	30	0	0
3	0	0	0	30	0	0
4	0	0	0	30	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0

Table 4.9 Model 1 Simulation Results (continued)

Scenario	Inventory (days)						
	Serui	Nabire	Sarmi	Jayapura	Kaimana	Timika	Merauke
1	0	0	0	46	0	0	19
2	0	0	0	24	0	0	19
3	0	0	0	25	0	0	19
4	0	0	0	24	0	0	19
5	0	0	0	10	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0

Table 4.10 Model 2 Simulation Results

Scenario	Inventory (days)					
	Sorong	Manokwari	Raja Ampat	Fakfak	Bintuni	Biak
1	4	0	0	55	0	0
2	1	0	0	47	0	0
3	0	0	0	55	0	0
4	0	0	0	52	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0

Table 4.11 Model 2 Simulation Results (continued)

Scenario	Inventory (days)						
	Serui	Nabire	Sarmi	Jayapura	Kaimana	Timika	Merauke
1	0	0	0	81	0	53	72
2	0	0	0	83	0	51	68
3	0	0	0	61	0	35	70
4	0	0	0	58	0	35	72
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0

The table above shown the amount of days that reach empty for each receiving terminal. The amount is calculated in a year simulation, so for example in Sorong for model 2, the tank capacity there reach empty for 4 days in 1 year. That case made the route, scenario, variation of tank capacity become not feasible technically to be created.

For this results, in the first model the distribution from supply to the transshipment point is using 75,000 m^3 capacity of vessel in altogether. But for the second model, 100,000 m^3 capacity of vessel that is used. It has to be done to decrease the complexity between these two models.

CHAPTER V
CONCLUSION AND SUGGESTION

5.1. Conclusion

Based on the data analyzing and simulation that already run in this study of LNG distribution design, can make conclusions, such as:

1. The model is generated with 1 transshipment point in Sorong and 2 transshipment point in Sorong and Jayapura. From the transshipment point is divided into 4 route in first model and 3 route for the second model. Then the scenario is generated from the capacity of safety stock for 3 days and 7 days with 2 kind of fleet combination each variation.
2. Simulating using discrete-event simulation can be done in both model and scenario by considering the receiving terminal tank capacity variation to earn the receiving terminal cost and sail duration variable to earn the voyage cost. The scenario is based on the inventory level as a signal for transport between 50% and 60%.
3. The model simulation results are:
    a. First model with one transshipment point in Sorong, with first tank capacity variation and first fleet combination reach empty tank condition in a year simulation.
    b. First model with one transshipment point in Sorong, with first tank capacity variation and second fleet combination reach empty tank condition in a year simulation.
    c. First model with one transshipment point in Sorong, with second tank capacity variation and third fleet combination reach empty tank condition in Jayapura with 50% level of all inventory and never reach empty tank condition with 60% level of all inventory in a year simulation.
    d. First model with one transshipment point in Sorong, with second tank capacity variation and fourth fleet combination never reach empty tank condition in a year simulation.
    e. Second model with two transshipment points in Sorong and Jayapura with first tank capacity variation and first fleet combination reach empty tank condition in a year simulation.
    f. Second model with two transshipment points in Sorong and Jayapura with first tank capacity variation and second fleet combination reach empty tank condition in a year simulation.
    g. Second model with two transshipment points in Sorong and Jayapura with second tank capacity variation and third fleet combination never reach empty tank condition in a year simulation.
    h. Second model with two transshipment points in Sorong and Jayapura with second tank capacity variation and fourth fleet combination never reach empty tank condition in a year simulation.

   The model simulation results shown that from the first model there are three scenarios that feasible technically for the distribution design by considering transshipment model and from the second model there are four scenarios that feasible technically for the distribution design. There is scenario 6, 7 and 8 in the first model with second capacity tank variation and scenario 5, 6, 7 and 8 in the second model with second capacity tank variation. The second capacity tank variation is considering based on the safety stock for 7 days operation.

5.2. Suggestion

After the simulation of LNG distribution design by considering transshipment model for eastern part of Indonesia, suggestion that could be given for the next research are:

1. When considering scenario, variable and parameter should find another consideration variable and combine it to make the simulation more detail in simulating a scenario. Besides that, considering a make sense scenario can be make a good decision for the simulation.
2. In the next research analyzing economical aspects about the investment for rate of return and NPV possible to be done to find more efficient and promising scenario for this LNG distribution.

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ATTACHMENT 1
DATA OF LNG CARRIER

SHIP COMPARISON DATA		
Coral Methane		
Cargo Capacity	7500	m^3
DWT	3450	ton
Gross Tonnage	7833	tonnage
Service Speed	16	knot
Pump Capacity	450	m^3/hour
Main Machinery	6700	BHP
Ship's Crew	12	Persons
Norgas Vision		
Cargo Capacity	12000	m^3
DWT	8200	ton
Gross Tonnage	11320	tonnage
Service Speed	16	knot
Pump Capacity	600	m^3/hour
Main Machinery	8280	BHP
Ship's Crew	12	Persons
Surya Satsuma		
Cargo Capacity	23000	m^3
DWT	10580	ton

Gross Tonnage	20017	tonnage
Service Speed	17	knot
Pump Capacity	850	m^3/hour
Main Machinery	10447	BHP
Ship's Crew	16	Persons
Unit Conversion		
1 Million Ton Per Year	140	MMSCFD
100 MMSCFD	730000	TPY LNG
100 MMSCFD	2100	TPD LNG
100 MMSCFD	700	MW
1 m^3 LNG	21.2	mmbtu
1 MMSCFD	46	m^3 LNG
Specific Gravity LNG	0.46	

ATTACHMENT 2
MATRIX DISTANCE

-	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
X1	-	1140	1006	617	1356	238	2225	283	604	353	210	619	1608	1243
X2		-	286	1717	631	976	1516	1255	693	1461	1208	586	892	78
X3			-	1590	379	851	1261	1128	566	1338	1081	458	642	211
X4				-	1931	825	2805	872	1179	289	800	1197	2189	1827
X5					-	1189	1045	1466	902	1678	1426	789	427	560
X6						-	2076	328	440	563	289	461	1448	1087
X7							-	2350	1778	2555	2299	1675	762	1456
X8								-	722	611	192	737	1732	1356
X9									-	926	675	117	1165	665
X10										-	536	950	1938	1572
X11											-	696	1683	1319
X12												-	1059	517
X13													-	822
X14														-

Annotations:

X1 : Biak
X2 : Bintuni
X3 : Fak-fak
X4 : Jayapura
X5 : Kaimana
X6 : Manokwari
X7 : Merauke
X8 : Nabire
X9 : Raja Ampat
X10 : Sarmi
X11 : Serui
X12 : Sorong
X13 : Timika
X14 : Tangguh

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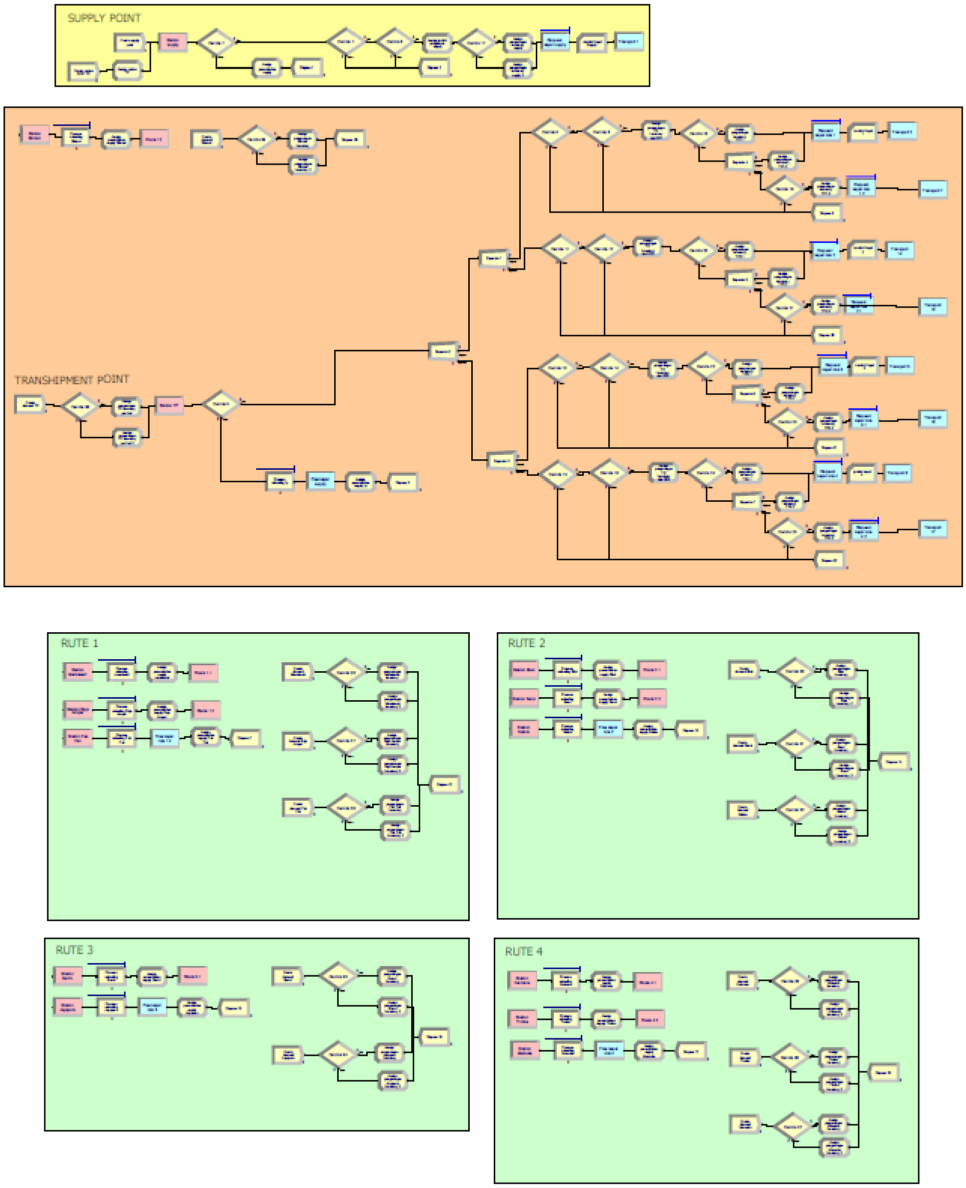
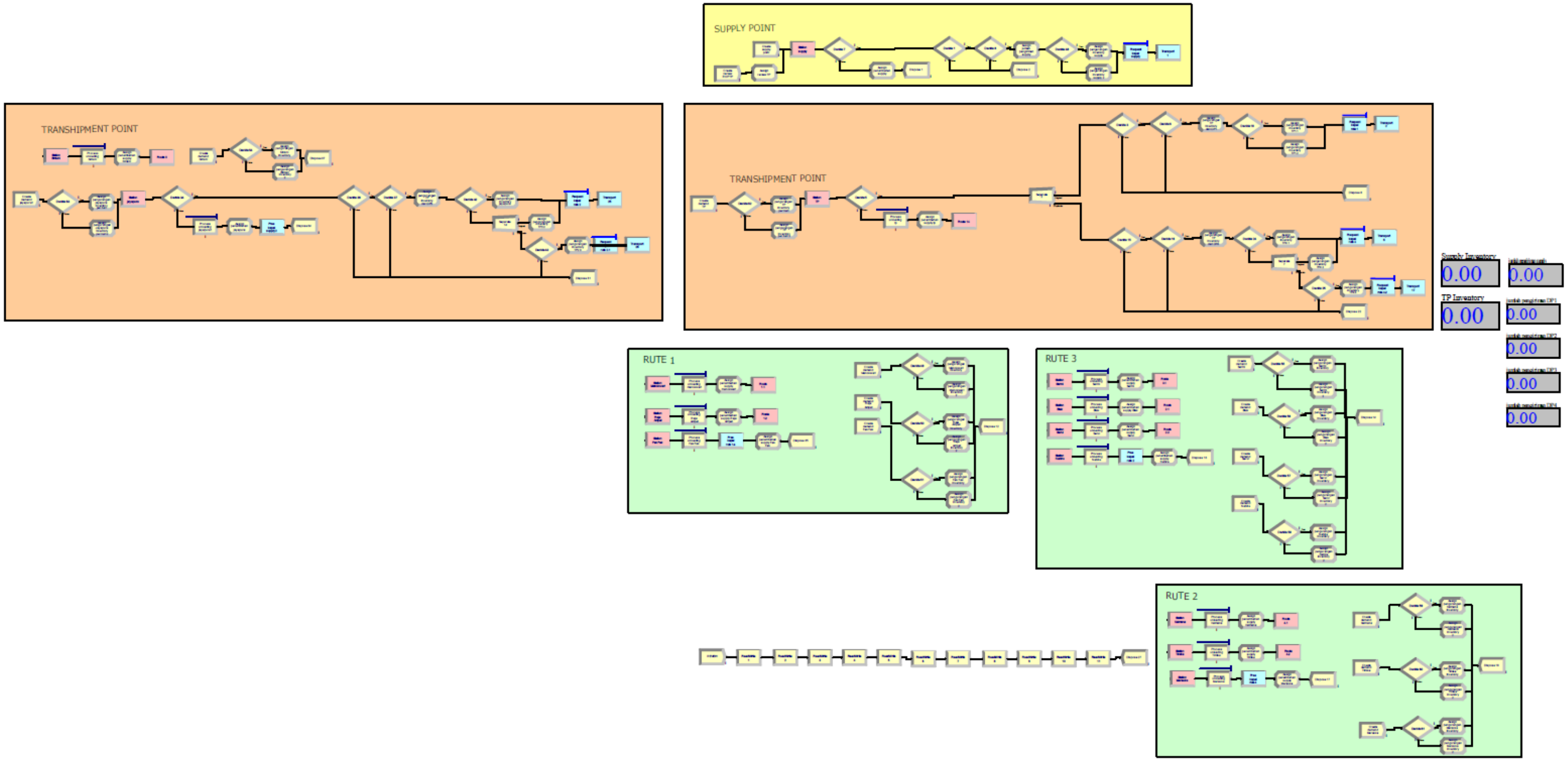
ATTACHMENT 3
ARENA SOFTWARE

ARENA Software Model 1



ARENA Software Model 2



Model 1 Minimum Tank Variation Calculation

Location	LNG Cons./ Per Round Trip	Safety Stock 1	Min Tank Variation 1	Safety Stock 2	Min Tank Variation 2
Sorong	4974.9	3942.9	8917.8	9200.0	14174.9
Bintuni	248.7	197.1	445.8	459.9	708.6
Manokwari	1976.6	1182.9	3159.5	2760.1	4736.7
Raja Ampat	329.4	197.1	526.5	459.9	789.3
Fakfak	658.7	394.2	1052.9	919.8	1578.5
Biak	2777.3	1478.7	4256.0	3450.3	6227.6
Serui	1110.6	591.3	1701.9	1379.7	2490.3
Nabire	1481.3	788.7	2270.0	1840.3	3321.6
Sarmi	256.9	98.7	355.6	230.3	487.2
Jayapura	17957.7	6900	24857.7	16100.0	34057.7
Kaimana	1538.5	394.2	1932.7	919.8	2458.3
Timika	6924.6	1774.3	8698.9	4140.0	11064.6

Model 1 Consideration Tank Variation

Route	Location	Variation 1	Variation 2
1	Sorong	66400	91600
	Bintuni	800	800
2	Manokwari	3200	5200
	Raja Ampat	800	800
	Fakfak	1200	1600
3	Biak	4400	6400
	Serui	2000	2800
	Nabire	2400	3600
4	Sarmi	400	800
	Jayapura	26000	34400
5	Kaimana	2000	2800
	Timika	8800	11200

Model 1 Fleet Combination 1

Route	Variation 1	Ship Capacity	Amount
1	67200	100000	1
2	5200	7500	1
3	8800	7500	2
4	26400	12000	3
5	16800	12000	2

Model 1 Fleet Combination 2

Route	Variation 1	Ship Capacity	Amount
1	67200	100000	1
2	5200	7500	1
3	8800	12000	1
4	26400	23000	2
5	16800	23000	1

Model 1 Fleet Combination 3

Route	Variation 2	Ship Capacity	Amount
1	92400	100000	1
2	7600	7500	2
3	12800	7500	2
4	35200	12000	3
5	21600	12000	2

Model 1 Fleet Combination 4

Route	Variation 2	Ship Capacity	Amount
1	92400	100000	1
2	7600	12000	1
3	12800	12000	1
4	35200	23000	2
5	21600	23000	1

Model 2 Minimum Receiving Terminal Capacity Calculation

Location	LNG Cons./ Round Trip	Safety Stock 1	Min Tank Variation 1	Safety Stock 2	Min Tank Variation 2
Sorong	12622.62	3942.9	16565.48	9200.0	21822.62
Jayapura	22089.58	6900.0	28989.58	16100.0	38189.58
Bintuni	630.99	197.1	828.09	459.9	1090.89
Manokwari	1976.63	1182.9	3159.53	2760.1	4736.73
Raja Ampat	329.36	197.1	526.46	459.9	789.26
Fakfak	658.71	394.2	1052.91	919.8	1578.51
Kaimana	1250.01	394.2	1644.21	919.8	2169.81
Timika	5626.27	1774.3	7400.56	4140.0	9766.27
Merauke	3750.98	1182.9	4933.88	2760.1	6511.08
Sarmi	164.16	98.7	262.86	230.3	394.46
Biak	2459.37	1478.7	3938.07	3450.3	5909.67
Serui	983.45	591.3	1574.75	1379.7	2363.15
Nabire	1311.76	788.7	2100.46	1840.3	3152.06

Model 2 Consideration Tank Variation

Route	Location	Variation 1	Variation 2
1	Sorong	36800	48400
	Jayapura	37600	50400
	Bintuni	1200	1200
2	Manokwari	3200	4800
	Raja Ampat	800	800
	Fakfak	1200	1600
3	Kaimana	2000	2400
	Timika	7600	10000
	Merauke	5200	6800
4	Sarmi	400	400
	Biak	4000	6000
	Serui	1600	2400
	Nabire	2400	3200

Model 2 Fleet Combination 1

Route	Variation 1	Ship Capacity	Amount
1	75600	100000	1
2	5200	7500	1
3	14800	7500	2
4	8400	7500	2

Model 2 Fleet Combination 2

Route	Variation 1	Ship Capacity	Amount
1	75600	100000	1
2	5200	7500	1
3	14800	12000	2
4	8400	12000	1

Model 2 Fleet Combination 3

Route	Variation 2	Ship Capacity	Amount
1	100000	100000	1
2	7200	7500	1
3	19200	12000	2
4	12000	7500	2

Model 2 Fleet Combination 4

Route	Variation 2	Ship Capacity	Amount
1	100000	100000	1
2	7200	12000	1
3	19200	23000	1
4	12000	12000	1

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