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Optimization of the Route of Distribution of LNG using Small Scale LNG Carrier: A Case Study of a Gas Power Plant in the Sumatra Region, Indonesia

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ABSTRACT

In this study, the distribution of LNG for power plants in the islands was designed using the small-scale LNG carrier in the Sumatra region of Indonesia. It was further optimized through the use of the capacitated vehicle routing problem in order to maximize shipload. The research input variables were LNG requirements from receiving terminals, carriers with variations in loading capacity, and distribution distance. The calculation results showed 93 alternative routes with 3 different carrier capacities. The best combination of routes and cargo were found to be 7,500 cbm carrier with route Arun - Sabang - Lampung - Arun, 5,000 cbm carrier with route Arun - Nias - Belitung - Arun, and 2,513 cbm carrier with route Arun - Bangka - Arun. The economic analysis showed that annual USD 74,346,340 capital expenditure and USD 33,704995 operational expenditure at least results in an LNG sales price margin of USD 6.5/mmbtu.

Keywords: Small Scale LNG Carrier, LNG Distribution Optimization, Capacitated Vehicle Routing Problem

JEL Classifications: L95, R41

1. INTRODUCTION

Indonesia has natural gas reserves of around 150.4 Trillion standard Cubic Feet (TCF) located in the Natuna Islands, South Sumatra, East Kalimantan, and Tangguh in Papua (KESDM, 2018) with 0.55 TCF of the production intended for the domestic electricity sector. Most of the LNG, around 19.3 million tons, are intended for export purposes. However, the electricity deficit in the Sumatra system occurred mainly in North Sumatra in 2014 (PT PLN [PERSERO], 2018). This was because the addition of the number of plants was not proportional to the increase in demand. Therefore, the government holds several new power plant development projects, most of which are natural gas power plants and oil and natural gas power plants (PLTMG) (BAPPENAS, 2014). Furthermore, the short-term efforts currently made by the government include building a number of mobile power plant (MPP) or power ships with isolated systems in several regions (PWC, 2015). This is quite effective considering MPP development is relatively faster than the construction of fix power plant. In addition, the geographical condition of the area with the Isolated electricity system does not allow installation of gas pipelines, therefore, MPP is the best choice (Ichsan, 2019).

In 2015, the Indonesian government, through Pertamina, revitalized the Arun LNG facility in northern Sumatra for storage and regasification. The gas was supplied from Tangguh LNG to meet gas supply needs during the peak load period. The facility is supplying several new and existing plants in Aceh and North Sumatra such as 184MW in Arun PLTMG and 250MW in North Sumatra PLTMG. In addition to these, it was also channeled to the Belawan PLTGU through a 400 km pipeline (BKPM, 2015).

Currently, there are five MPP in Sumatra and they are MPP Paya Pasir (3×25MW), MPP Lampung (4×25MW), MPP Bangka (2×25MW), MPP Belitung (1×25MW), and MPP Nias (1×25MW) all receiving supplies from Arun FSRU. However, Nias Island, which is located west of Sumatra, has an isolated electricity system separated from the one being used in Sumatra. This is associated with its geographical condition making it prone to earthquake and which led to the impossibility of constructing a gas pipeline in the area (KESDM, 2016). Therefore, alternative gas suppliers are needed, one of which is the Mini LNG Carrier.

Another province with isolated electricity system is Bangka Belitung Islands which is further divided into Bangka and Belitung System (Belitung, 2019). The province is new, being previously part of the South Sumatra province, and it needs a variety of infrastructure supporting various community activities including electricity. It has limited power generation resources and this makes it necessary to import its primary energy needs from outside the region. However, there are three MPPs already operating in the region and in order to meet supply needs, there is a need for the use of a Mini LNG due to its relatively small capacity (25 MW) which is useful for a small island.

However, mini or small scale LNG Carrier is a small capacity natural gas transport carrier used to supply gas to areas without gas pipelines (Gehl and Rice, 2007; International Gas Union, 2015). The availability of small scale LNG carrier is very limited, one option is converting the vessel into dual-fuel engine us boil of gas as fuels (Pamitran, 2019). The carrier's transport volume ranges from 2,500 cbm to 10,000 cbm with a distance of about 1,000 nautical miles. It usually has a relatively small draft (4-7 m). This type of carrier is continuously needed in Indonesia to increase small-capacity power plants (under 100 MW), especially for isolated small islands (Bashar, 2014; Tanaka, 2014). Based

Figure 1: Map of the distribution of power plants

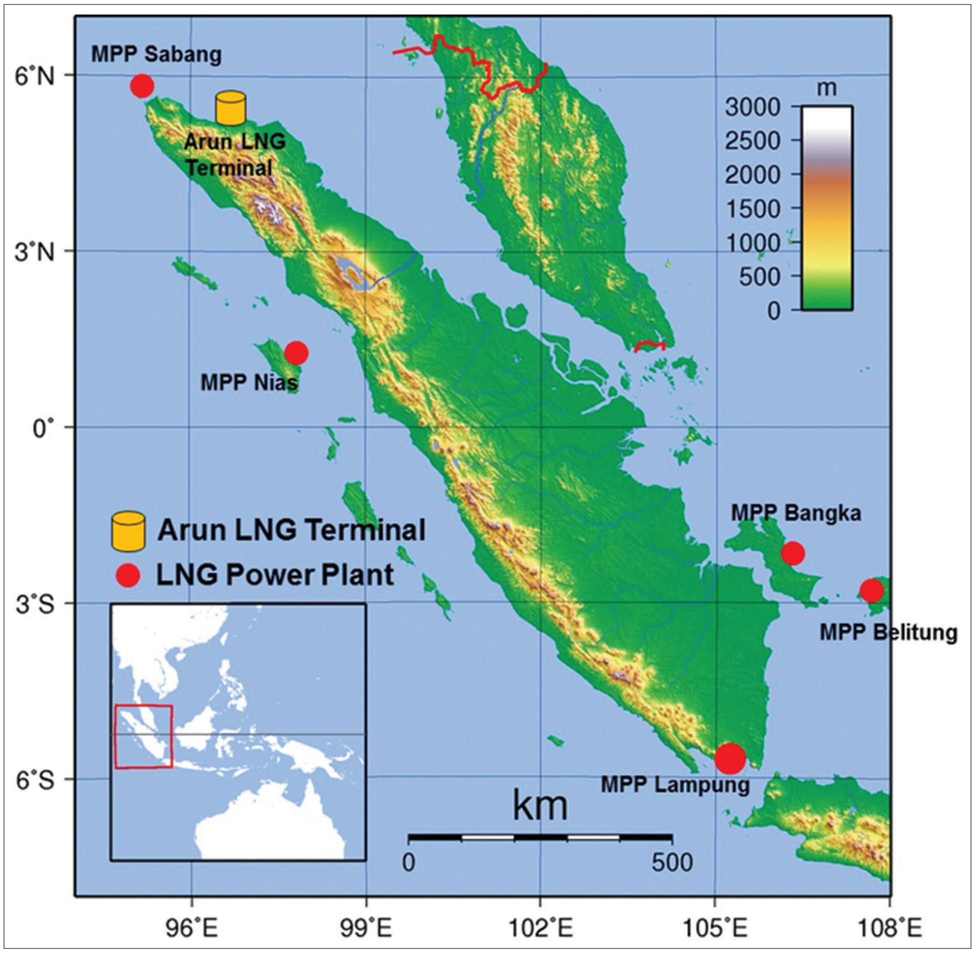

Table 1: Data on small scale generating capacities in the Sumatra region (Accessed from PT PLN [PERSERO], 2018)

No.	Power plants	Capacity (MW)	LNG needs (m³/day)	Locations (Latitude), (Longitude)
1.	MPP Bangka	2×25	274.82	(−2.08), (106.14)
2.	MPP Belitung	1×25	137.41	(−2.89), (107.56)
3.	MPP Lampung	4×25	549.64	(−5.51), (105.34)
4.	PLTMG and MPP Nias	1×25	360.62	(1.21), (97.67)
5.	PLTMG Sabang	1×4	41.22	(5.79), (95.34)

Table 2: Data on small LNG carrier

Type of carriers		Small LNG carrier		
Name of carriers	**Unit**	**Shinju Maru**	**ENGIE Zeebrugge**	**Coral methane (Veder, 2019)**
Capacity	m^3	2513	5000	7500
LOA	m	86.29	107.6	117.8
Breadth	m	15.1	18.4	18.6
Draft	m	4.19	4.77	6.8
Maximum speed	knot	14.5	13.1	15.5
Average speed	knot	12 (Marine Traffic, n.d.)	13 (Veritas, 2016)	11.2 (Traffic, n.d.)

on this background, the aim of this study was to determine the optimization of the distribution of LNG for power plants in Sumatra and get an overview of economic analysis based on the parameters of the financial feasibility of the distribution.

2. MODEL OF LNG DISTRIBUTION OPTIMIZATION

Six main components were used in the design of the LNG distribution optimization model in this study and they include:

1. LNG source

This was from storage at the Arun LNG facility (Pertamina, 2019) with the coordinates Latitude 5.22 and Longitude 97.08

2. LNG Receiving Terminal

Five terminals were receiving LNG and the power plant data used was taken from the electricity supply business plan (RUPTL) PLN 2018-2027 as shown in Table 1 (PT PLN [PERSERO], 2018). This study used data from small-capacity gas power plants located in the Sumatra region with distribution from Arun FSRU.

3. LNG supply needs of each receiving terminal

Data of gas supply needed in money per million British thermal units (MMBtu) units were converted to m^3/day to facilitate calculation of carrier tank capacity. Table 1 shows most of the gas supply was used in several power ships that have been operating since 2016. While in Sabang, it was used at fix power plant. However, the distribution of power plants in the Sumatra region is shown in Figure 1.

4. LNG carriers

LNG, in this study, was distributed by using Small-Scale LNG Carriers to fulfill the demand for small power plants with a capacity range of 2,500 cbm, 5,000 cbm, and 7,500 cbm. In addition, the power plants were located on small islands with shallow waters that cannot be traversed by large carriers. Small scale carriers generally have a relatively small draft, around 5 m.

The carriers used for comparison include Shinju Maru (2,513 m^3) (NK, 2019), Engie Zeebrugge (5000 cbm)(© ENGIE, n.d.), and Coral Methane (7,500 m^3) (Veder, 2019). The carriers were selected because they are currently operating and have a draft of around 5 m. The data collected from these carriers were used to optimize the distribution of LNG to power plants in the Sumatra region and the include:

Table 3. Distance matrix (Seamiles)

Locations		X1	X2	X3	X4	X5	X6
MPP Sabang	X1		389	864	1073	1562	118
MPP Nias	X2	389		1253	1462	1951	507
MPP Bangka	X3	864	1253		209	698	746
MPP Belitung	X4	1073	1462	209		489	955
MPP Lampung	X5	1562	1951	698	489		1444
Arun LNG Terminal	X0	118	507	746	955	1444	

Table 4: Possible routes and the roaming distances

No.	Routes	Power plants					Sea miles
		X1	X2	X3	X4	X5	
1.	0-1-0	1	0	0	0	0	236
2.	0-2-0	0	1	0	0	0	1014
3.	0-3-0	0	0	1	0	0	1492
4.	0-4-0	0	0	0	1	0	1910
5.	0-5-0	0	0	0	0	1	2888
6.	0-1-2-0	1	1	0	0	0	1014
7.	0-1-3-0	1	0	1	0	0	1728
8.	0-1-4-0	1	0	0	1	0	2146
9.	0-1-5-0	1	0	0	0	1	3124
10.	0-2-3-0	0	1	1	0	0	2506
11.	0-2-4-0	0	1	0	1	0	2924
12.	0-2-5-0	0	1	0	0	1	3902
13.	0-3-4-0	0	0	1	1	0	1910
14.	0-3-5-0	0	0	1	0	1	2888
15.	0-4-5-0	0	0	0	1	1	2888
16.	0-1-2-3-0	1	1	1	0	0	2506
17.	0-1-2-4-0	1	1	0	1	0	2924
18.	0-1-2-5-0	1	1	0	0	1	3902
19.	0-1-3-4-0	1	0	1	1	0	2146
20.	0-1-3-5-0	1	0	1	0	1	3124
21.	0-1-4-5-0	1	0	0	1	1	3124
22.	0-2-3-4-0	0	1	1	1	0	2924
23.	0-2-3-5-0	0	1	1	0	1	3902
24.	0-2-4-5-0	0	1	0	1	1	3902
25.	0-3-4-5-0	0	0	1	1	1	2888
26.	0-1-2-3-4-0	1	1	1	1	0	2924
27.	0-1-2-3-5-0	1	1	1	0	1	3902
28.	0-1-2-4-5-0	1	1	0	1	1	3902
29.	0-1-3-4-5-0	1	0	1	1	1	3124
30.	0-2-3-4-5-0	0	1	1	1	1	3902
31.	0-1-2-5-4-3-0	1	1	1	1	1	3513

1. Shipload capacity

Shipload affects the amount of LNG load per trip. The bigger the tank capacity, the more the amount of LNG to be transported and the more locations that can be reached. In addition, a larger shipload will also reduce distribution costs per unit of LNG volume. However, large shipload means the larger size and more expensive rental costs.

2. Speed

Faster carriers need less shipping time than lower ones for the same distance. This causes the round-trip time to be less and the operational time to be shorter in order to increase the number of trips in a given period.

3. Fuel consumption

Fuel consumption data could be used to calculate transportation costs because fuel is a component that affects 30% of all operational costs (Munandar, 2009).

4. Rental costs

Most of the power plants in this study were power ships that can be moved at any time to another with no electricity. However, the ships will be rented for the period of use and the bigger the size of the carrier, the more expensive the rent. Table 2 shows the ship specifications which later became input data for analysis.

5. Distance

The distance between the locations of the LNG distribution is shown in the distance matrix. The input from the calculation of the Capacitated Vehicle Routing Problem (CVRP) model (Raj et al., 2016; Sheldrick, 2017) used in this study was the distance between locations i with location *j (Sij)*, demand for each receiving terminal (on), and type of LNG carrier based on the shipload (Q). The decision variable was symbolized as *Xijk* where carrier *k* will use LNG on the route (R) from location i to location *j*. If the carrier *k* transports LNG from location *i* to location *j* then Xijk is worth 1, and the other will be worth 0 with $i, j = \{0,1,2.,5\}$, $i,j \in R\ i \neq j$ and $k=\{1,2\}$, $k \in \{1,\ldots,K\}$.

$$\mathrm{X}ijk = \{1, \text{ If the carriers transport LNG from } i \text{ to location } j; 0, \text{ if}\} \tag{1}$$

The function of the purpose of this study was to maximize the number of shiploads as formulated below:

$$M_{\max} = \Sigma k \in \mathrm{K}\ \Sigma i \in \mathrm{R} \Sigma j \in R,\ j \neq i\ \mathrm{X}ijk\ Sij \tag{2}$$

With the limiting function as follows:

$$\Sigma i \in R\ di\ \Sigma\ \mathrm{j} \in R, \neq i\ \mathrm{X}ijk \leq Q, \forall k = 1,\{1,2\} \tag{3}$$

Formula 3 shows the limit for ascertaining the number of demands for the receiving terminal (less than or equal) and a shipload of the carrier serving the route.

$$\Sigma\ j \in R\ \mathrm{X}0jk = 1, \forall k = 1,\{1,2\} \tag{4}$$

$$\Sigma\ i \in R\ \mathrm{X}i0k = 1, \forall k = 1,\{1,2\} \tag{5}$$

The above limit ensures each particular carrier route starts from the LNG source, after distribution, and returns.

$$\Sigma\ i \in R,\ i \neq h\ \mathrm{X}ih\ k - \Sigma\ j \in R,\ j \neq h\ \mathrm{X}h\ jk, = 0,$$

Table 5: The calculation of LNG needs in one trip using the 2513 cbm carriers

No.	Route	Total distance (BC)	Demand/ day (m^3)	Shipping Time (h)	Round Trip (h)	Total needs/ trip (Cbm)	Load difference (Cbm)
1.	0-1-0	236	41.2	19.7	38.7	66.4	2446.6
2.	0-2-0	1014	320.6	84.5	103.5	1382.7	1130.3
3.	0-3-0	1492	274.8	124.3	143.3	1641.3	871.7
4.	0-4-0	1910	137.4	159.2	178.2	1020.1	1492.9
5.	0-5-0	2888	549.6	240.7	259.7	5946.9	−3433.9
6.	0-1-2-0	1014	361.8	84.5	106.5	1605.7	907.3
7.	0-1-3-0	1728	316.0	144.0	166.0	2186.0	327.0
8.	0-1-4-0	2146	178.6	178.8	200.8	1494.9	1018.1
9.	0-1-5-0	3124	590.9	260.3	282.3	6951.0	−4438.0
10.	0-2-3-0	2506	595.4	208.8	230.8	5727.1	−3214.1
11.	0-2-4-0	2924	458.0	243.7	265.7	5070.3	−2557.3
12.	0-2-5-0	3902	870.3	325.2	347.2	12588.8	−10075.8
13.	0-3-4-0	1910	412.2	159.2	181.2	3111.8	−598.8
14.	0-3-5-0	2888	824.5	240.7	262.7	9023.4	−6510.4
15.	0-4-5-0	2888	687.1	240.7	262.7	7519.5	−5006.5
16.	0-1-2-3-0	2506	636.7	208.8	233.8	6203.2	−3690.2
17.	0-1-2-4-0	2924	499.3	243.7	268.7	5589.0	−3076.0
18.	0-1-2-5-0	3902	911.5	325.2	350.2	13299.0	−10786.0
19.	0-1-3-4-0	2146	453.5	178.8	203.8	3851.3	−1338.3
20.	0-1-3-5-0	3124	865.7	260.3	285.3	10292.1	−7779.1
21.	0-1-4-5-0	3124	728.3	260.3	285.3	8658.5	−-6145.5
22.	0-2-3-4-0	2924	732.9	243.7	268.7	8204.0	−5691.0
23.	0-2-3-5-0	3902	1145.1	325.2	350.2	16707.2	−14194.2
24.	0-2-4-5-0	3902	1007.7	325.2	350.2	14702.4	−12189.4
25.	0-3-4-5-0	2888	961.9	240.7	265.7	10647.5	−8134.5
26.	0-1-2-3-4-0	2924	774.1	243.7	271.7	8762.2	−6249.2
27.	0-1-2-3-5-0	3902	1048.9	325.2	353.2	15435.0	−12922.0
28.	0-1-2-4-5-0	3902	1048.9	325.2	353.2	15435.0	−12922.0
29.	0-1-3-4-5-0	3124	1003.1	260.3	288.3	12051.2	−9538.2
30.	0-2-3-4-5-0	3902	1282.5	325.2	353.2	18872.4	−16359.4
31.	0-1-2-5-4-3-0	3513	1323.7	292.8	323.8	17856.5	−15343.5

Figure 2: Option 1: The best distribution route for LNG using 7,500, 5,000 and 2,500 cbm carriers

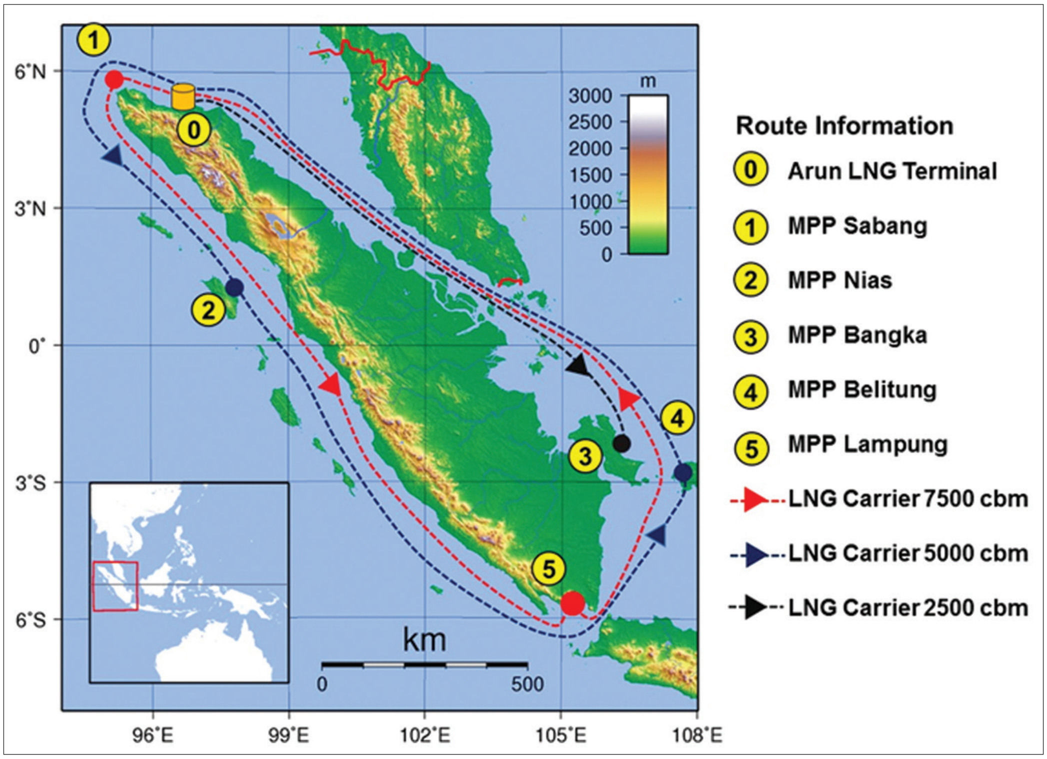

Table 6: The calculation of LNG needs in one trip using the 5000 cbm carriers

No.	Route	Total distance (BC)	Demand/ day (m^3)	Shipping time (h)	Round trip (h)	Total needs/ trip (cbm)	Load difference (cbm)
32.	0-1-0	236	41.2	18.2	37.2	63.8	4936.2
33.	0-2-0	1014	320.6	78.0	97.0	1295.9	3704.1
34.	0-3-0	1492	274.8	114.8	133.8	1531.8	3468.2
35.	0-4-0	1910	137.4	146.9	165.9	950.0	4050.0
36.	0-5-0	2888	549.6	222.2	241.2	5522.9	−522.9
37.	0-1-2-0	1014	361.8	78.0	100.0	1507.7	3492.3
38.	0-1-3-0	1728	316.0	132.9	154.9	2040.2	2959.8
39.	0-1-4-0	2146	178.6	165.1	187.1	1392.5	3607.5
40.	0-1-5-0	3124	590.9	240.3	262.3	6457.9	−1457.9
41.	0-2-3-0	2506	595.4	192.8	214.8	5328.5	−328.5
42.	0-2-4-0	2924	458.0	224.9	246.9	4712.6	287.4
43.	0-2-5-0	3902	870.3	300.2	322.2	11681.8	−6681.8
44.	0-3-4-0	1910	412.2	146.9	168.9	2901.5	2098.5
45.	0-3-5-0	2888	824.5	222.2	244.2	8387.4	−3387.4
46.	0-4-5-0	2888	687.1	222.2	244.2	6989.5	−1989.5
47.	0-1-2-3-0	2506	636.7	192.8	217.8	5777.0	−777.0
48.	0-1-2-4-0	2924	499.3	224.9	249.9	5199.1	−199.1
49.	0-1-2-5-0	3902	911.5	300.2	325.2	12349.0	−7349.0
50.	0-1-3-4-0	2146	453.5	165.1	190.1	3591.4	1408.6
51.	0-1-3-5-0	3124	865.7	240.3	265.3	9569.8	-4569.8
52.	0-1-4-5-0	3124	728.3	240.3	265.3	8050.8	−3050.8
53.	0-2-3-4-0	2924	732.9	224.9	249.9	7631.6	−2631.6
54.	0-2-3-5-0	3902	1145.1	300.2	325.2	15513.8	−10513.8
55.	0-2-4-5-0	3902	1007.7	300.2	325.2	13652.2	−8652.2
56.	0-3-4-5-0	2888	961.9	222.2	247.2	9905.5	−4905.5
57.	0-1-2-3-4-0	2924	774.1	224.9	252.9	8157.7	−3157.7
58.	0-1-2-3-5-0	3902	1048.9	300.2	328.2	14341.8	−9341.8
59.	0-1-2-4-5-0	3902	1048.9	300.2	328.2	14341.8	−9341.8
60.	0-1-3-4-5-0	3124	1003.1	240.3	268.3	11214.2	−6214.2
61.	0-2-3-4-5-0	3902	1282.5	300.2	328.2	17535.8	−12535.8
62.	0-1-2-5-4-3-0	3513	1323.7	270.2	301.2	16614.5	−11614.5

Table 7: The calculation of LNG needs in one trip using the 7500 cbm carriers

No.	Route	Total distance (BC)	Demand/ day (m^3)	Shipping time (h)	Round trip (h)	Total needs/ trip (cbm)	Load difference (cbm)
63.	0-1-0	236	41.2	21.1	40.1	68.8	7431.2
64.	0-2-0	1014	320.6	90.5	109.5	1463.4	6036.6
65.	0-3-0	1492	274.8	133.2	152.2	1743.0	5757.0
66.	0-4-0	1910	137.4	170.5	189.5	1085.2	6414.8
67.	0-5-0	2888	549.6	257.9	276.9	6340.6	1159.4
68.	0-1-2-0	1014	361.8	90.5	112.5	1696.7	5803.3
69.	0-1-3-0	1728	316.0	154.3	176.3	2321.5	5178.5
70.	0-1-4-0	2146	178.6	191.6	213.6	1590.0	5910.0
71.	0-1-5-0	3124	590.9	278.9	300.9	7408.8	91.2
72.	0-2-3-0	2506	595.4	223.8	245.8	6097.2	1402.8
73.	0-2-4-0	2924	458.0	261.1	283.1	5402.4	2097.6
74.	0-2-5-0	3902	870.3	348.4	370.4	13431.0	−5931.0
75.	0-3-4-0	1910	412.2	170.5	192.5	3307.1	4192.9
76.	0-3-5-0	2888	824.5	257.9	279.9	9613.9	−2113.9
77.	0-4-5-0	2888	687.1	257.9	279.9	8011.6	−511.6
78.	0-1-2-3-0	2506	636.7	223.8	248.8	6598.9	901.1
79.	0-1-2-4-0	2924	499.3	261.1	286.1	5951.1	1548.9
80.	0-1-2-5-0	3902	911.5	348.4	373.4	14181.1	−6681.1
81.	0-1-3-4-0	2146	453.5	191.6	216.6	4092.6	3407.4
82.	0-1-3-5-0	3124	865.7	278.9	303.9	10962.9	−3462.9
83.	0-1-4-5-0	3124	728.3	278.9	303.9	9222.8	−1722.8
84.	0-2-3-4-0	2924	732.9	261.1	286.1	8735.5	−1235.5
85.	0-2-3-5-0	3902	1145.1	348.4	373.4	17815.4	−10315.4
86.	0-2-4-5-0	3902	1007.7	348.4	373.4	15677.6	−8177.6
87.	0-3-4-5-0	2888	961.9	257.9	282.9	11336.5	−3836.5
88.	0-1-2-3-4-0	2924	774.1	261.1	289.1	9323.6	−1823.6
89.	0-1-2-3-5-0	3902	1048.9	348.4	376.4	16450.0	−8950.0
90.	0-1-2-4-5-0	3902	1048.9	348.4	376.4	16450.0	−8950.0
91.	0-1-3-4-5-0	3124	1003.1	278.9	306.9	12828.4	−5328.4
92.	0-2-3-4-5-0	3902	1282.5	348.4	376.4	20113.6	−12613.6
93.	0-1-2-5-4-3-0	3513	1323.7	313.7	344.7	19009.9	−11509.9

Table 8: The best alternative route selection with a shipload

Route option	No.	Route	Total distance (BC)	Demand/ day (m^3)	Shipping time (h)	Round trip (h)	Total needs/ trip (cbm)	Ship capacity (cbm)	Load difference/ trip (cbm)	Total excess cbm load
Option 1	9	0-1-5-0	3124	590.9	278.9	300.9	7408.8	7500	91.2	1250.3
	11	0-2-4-0	2924	458.0	224.9	246.9	4712.6	5000	287.4	
	3	0-3-0	1492	274.8	124.3	143.3	1641.3	2513	871.7	
Option 2	9	0-1-5-0	3124	590.9	278.9	300.9	7408.8	7500	91.2	1538.1
	11	0-2-4-0	2924	458.0	224.9	246.9	4712.6	5000	287.4	
	5	0-5-0	2888	549.6	257.9	276.9	6340.6	2513	1159.4	
Option 3	9	0-1-5-0	3124	590.9	278.9	300.9	7408.8	7500	91.2	3320.0
	2	0-2-0	1014	320.6	84.5	103.5	1382.7	2513	1130.3	
	13	0-3-4-0	1910	412.2	146.9	168.9	2901.5	5000	2098.5	

$$\forall h = 1, \forall k = 1, \{1,2\} \quad (6)$$

The above limits ensure the continuation of the LNG distribution route. This means each carrier will leave one receiving terminal to distribute LNG to another or return to the source.

$$Xijk \in \{0,1\}, \forall i,j = \{0,1,2,\ldots,5\}, i,j \in R, i \neq j, \forall k = \{1,2\} \quad (7)$$

3. OPTIMIZATION OF LNG DISTRIBUTION ROUTES

Optimization of LNG distribution routes was influenced by the type of carrier and distribution route. The loading capacity parameter determined the number of receiving terminals to be served. Furthermore, the carrier's loading capacity is directly proportional to the LNG distributions that can be conducted in one trip, therefore, shipping route is affected. In optimization, there are variations in the distribution routes based on the size of carriers and the process is calculated using the Greedy algorithm which considers the load capacity, screen speed, distance between the delivery point, transportation costs (toll fee), and demand variables (Leggieri and Haouari, 2018; Nucamendi-Guillén et al., 2018). The completion of distribution problems was later developed in a program by using heuristic methods. However, several assumptions were used to reduce the complexity of the optimization process and they include

- The loading and unloading time is constant 3 h for all types of carriers (Yusman, 2017).

- The time at the port is a constant 6 h for all types of carriers (Yusman, 2017).
- To overcome the uncertainty of shipping conditions, each distribution gets an additional 10 h (buffer time) from one location to another (Schragenheim and Ronen, 1991).

The process used to determine the route is as follows:

3.1. Formation of the Distance Matrix

The distance matrix was made to simplify the calculation of the distance between the receiving terminals. This is in accordance with the existing international shipping lanes and calculated using Netpas distance application (Guide, 2015). The results are shown in Table 3.

3.2. Making Alternative Routes

After the distance between the receiving terminals has been obtained, all other possible routes (alternative) were formed. In this case, 31 possible route combinations with varying distances between routes were found and shown in Table 4.

3.3. The Result of a Combination of Routes and Shiploads Optimization

Load allocation requirement was calculated for each of these 31 routes determined with a combination of 3 predetermined carriers as shown in Tables 5-7. The data processing showed 93 alternatives which were selected to get the best combination of routes and optimal load.

1. Selected routes

Of the 93 possible routes, the best combination of 3 alternative routes was chosen based on needs, distance, and shipping time. In this case, the optimum value was the smallest reference point between the total needs/trip needs and shipload capacity. In this study, the researcher made three alternative routes as shown in Table 8 and the illustration can be seen in Figure 2.

Table 9: Assumption of investment costs for LNG terminal facilities (Accessed from Antara, 2017)

Details	Costs
Inv. On LNG feed pump (USD)	$80,000
Inv. On LNG vaporizer (USD)	$240,000
Inv. On BOG compressor (USD)	$700,000
Inv. On booster compressor (USD)	$700,000
Inv. On terminal power generator (USD)	$1,200,000
Inv. On fire fighting system (USD)	$10200
Inv. On building (USD)	$80,000
Inv. On purging system (USD)	$22,000
Inv. On PCS and DCS (USD)	$800,000
Inv. On jetty (USD)	$8,208,000
Inv. On jetty offloading and send-out (USD)	$2,028,068
Inv. Crane/tractor (USD)	$140,000
Inv. On cryogenic line pipe (USD)	$539,000
Inv. Terminal (USD)	$14,747,268

4. ECONOMIC ANALYSIS

The economic analysis conducted include the parameters of financial feasibility related to costs incurred in distribution activities using LNG carrier and those expended on receiving terminal facilities using the assumption of income received from the LNG toll fee. This analysis used option 1 which is a 3-routes-with-3-carriers option. The toll fee becomes the selling price margin for LNG. Practically, this should be the cost the buyer must pay to the supplier who buys LNG from the producer and then sends it to the buyer.

In economic analysis, there are capital expenditure (CAPEX) and operational expenditure (OPEX). The financial feasibility parameters used are the internal rate of return (IRR), payback periods (PP), and net present value (NPV).

4.1. CAPEX

CAPEX includes all initial investment costs incurred to build facilities at the receiving terminal. The facilities include jetty, offloading facilities, cryogenic pipes, storage tanks, pumps, vaporizers, BOG compressors, generators, supporting building, and component installations. The optimization results of route selection with the lowest investment costs indicated the estimated total investment cost of all receiving terminals to be around USD 14,747,268. The assumption are shown in Table 9 (Accessed from Antara, 2017).

4.2. OPEX

OPEX include all costs incurred to support distribution operations such as the receiving terminal operational costs and the cost of sending LNG from refineries to the terminals. Operational costs consist of costs for the carrier rental, fuel, port, receiving terminal operating and fuel costs, maintenance and workers. The results of the optimization of route selection with the lowest investment costs indicated the estimated total operational cost for the carrier to be $19,166,417 and the receiving terminal to be $14,747,268. The details for the receiving terminal are shown in Table 10.

4.3. Revenue

Revenue referred to the income obtained from transportation services and LNG regasification. Profits are derived from the difference between the purchase price and the selling price and this is called the LNG sales margin. The unit of LNG

Table 10: Receiving terminal operational cost (OPEX)

Locations	LNG consumption (m^3)	MPTA (ton)	Operating cost (USD)	Power and fuel cost (USD)	Maint. cost (USD)	Manning cost (USD)
Sabang	41.22	6921	$69,213	$276,852	$103,820	$207,639
Nias	320.62	53832	$538,323	$2,153,294	$807,485	$1,614,970
Bangka	274.82	46142	$461,420	$1,845,680	$692,130	$1,384,260
Belitung	137.41	23071	$230,710	$922,840	$346,065	$692,130
Lampung	137.41	23071	$230,710	$922,840	$346,065	$692,130

Table 11: Revenue calculation with sales margins variations

Total gas processing	
Daily MMBTU	19900
Annual MMBTU	6467500
Revenue	
Margin	**Income**
6.00	$38,805,000
6.50	$42,038,750
7.00	$45,272,500
7.50	$48,506,250

Table 12: Table of investment feasibility

Margin (USD)	IRR (%)	PP (year)	NPV
6.00	13.05	15.4	15919474
6.50	7.98	9.8	71626300
7.00	8.68	7.5	67525121
7.50	7.83	5.6	90107345

sales is MMBtu and for the purpose of this study, it was $/MMBtu. MMBtu is a unit of heat energy produced by natural gas per unit volume. In order to study the sensitivity of LNG sales margins at the end of the 20th year period, variations in the margin of sales prices are made. However, six margin variations were used with an increase of $0.5 from USD6 to USD7.5/MMBtu. The sales margin was multiplied by the amount of LNG sold in one year to obtain revenue per sales margin. The income obtained is certainly different for each variation in sales margins. The difference in revenue affects the PP which is the period of return on investment capital. The total revenue calculation for the six LNG sales margins can be seen in Table 11.

With a sales margin of USD6.5/MMBtu, the amount of gas distributed for 1 year was 6,467,500 MMBtu and the annual income was US$42,038,750. The average amount of LNG distributed annually is assumed to be constant because the gas is being used by power plants as shown in Table 11.

After the income was obtained, the PP, IRR, and the NPV were calculated. This was necessary to ensure the feasibility of LNG distribution investment from financial parameters.

Table 12 shows the calculation of the economic analysis of LNG distribution investments for power plants in Sumatra with a sales margin of USD6.5/MMBtu with an assumption of an investment period of 20 years, a sales margin of USD6.5/MMBtu, revenue of USD 42,038,750/year, and a PP of 10 years. Furthermore, the IRR was found to be 7.98% and the NPV was obtained after 20 years of USD 71,626,300.

5. CONCLUSION

Based on data analysis and discussion on the distribution of LNG for power plants in the Sumatra, it can be concluded that a distribution route has been established using the CVRP method with due consideration for the distance, demand for each receiving terminal, and shipload capacity. Furthermore, 93 alternative routes were produced with 3 types of shiploads and 3 best alternative routes in carrier loading were found to be 7,500 cbm carriers serving Arun - Sabang - Lampung - Arun routes, 5,000 cbm carriers serving Arun - Nias - Belitung - Arun routes, 2,513 cbm carriers serving Arun - Bangka - Arun routes.

Moreover, the economic analysis showed that with total CAPEX of USD 74,346,340 and annual OPEX o USD 33,704,995, a margin of LNG sales price of USD 6.5/MMBtu was produced and this indicates the distribution of LNG is financially feasible with 10 years PP, IRR 7.97% and positive NPV of US $71,626,300 at the end of 20 years.

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