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Andi Cahyo Prasetyo Tri Nugroho
Research Center for Hydrodynamics Technology, National Research and Innovation Agency, BRIN

Buddin Al Hakim
Research Center for Hydrodynamics Technology, National Research and Innovation Agency, BRIN

Hendrik, Dany
Research Center for Hydrodynamics Technology, National Research and Innovation Agency, BRIN

Sasmito, Cahyo
Research Center for Hydrodynamics Technology, National Research and Innovation Agency, BRIN

他

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Andi Cahyo Prasetyo Tri Nugroho[1], Buddin Al Hakim[1,*], Dany Hendrik[1], Cahyo Sasmito[1], Teguh Muttaqie[1], Amir Tjolleng[2], Iskendar[3], Mohammad Arif Kurniawan[4], and Siti Komariyah[4]

[1]Research Center for Hydrodynamics Technology,
National Research and Innovation Agency, BRIN, Surabaya, Indonesia,
[2]Department of Industrial Engineering, Bina Nusantara University, Jakarta, Indonesia
[3]Research Center for Transportation Technology,
National Research and Innovation Agency, BRIN, Banten, Indonesia,
[4]Research and Development Division, PT. Biro Klasifikasi Indonesia (Persero), Jakarta, Indonesia

*Author to whom correspondence should be addressed:
E-mail: budd001@brin.go.id

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Abstract: This paper introduces the mission analysis of Small Scaled LNG Carrier (SSLNG) as LNG feeder transportation in Eastern Indonesia. This study aims to obtain an LNG delivery model from the Ambon Hub to all gas power plants in the Maluku and Papua regions. There are currently about 33 prioritized Mini Gas Power Plants (PLTMG) in eastern Indonesia as proof of the Indonesian government's commitment to lowering carbon emissions. With a market share of 14.09 % of the total domestic gas demand, the electricity industry is one of the primary consumers of domestic gas demand. Mission analysis was carried out on a type C tanker as a gas storage system because of its advantages. This analysis studies the primary transportation demand for LNG to create the best LNG supply chain scenario for eastern Indonesia. Supply and demand analysis is also carried out to obtain the optimum ship size. In addition, planning and optimization of shipping routes have also been carried out, considering the limited time for LNG storage. Several Vehicle Routing Problem (VRP) analysis methods found that the Heuristic method is more effective than other methods, with an efficient delivery time of 2-3 days, which is better effective with the choice of a predetermined operational.

Keywords: Mission Analysis; LNG Carrier; Transportation; VRP; Ambon; East Indonesia

1. Introduction

The government's efforts to reduce carbon emissions include increasing the use of environmentally friendly energy sources, one of which is natural gas, where Indonesia has reserves of 142.72 trillion Standard Cubic Feet[1)]. Through Government Regulation Number 79 of 2014 concerning National Energy Policy, domestic natural gas utilization is targeted to increase from 19% to 24% in 2050. In contrast, the use of petroleum will be reduced from the current 42% to 20% in 2050[1)]. The Conversion of fossil fuels to renewable energy can reduce the impact of global warming[2)].

National natural gas users are grouped into several sectors: Oil Lifting, Government Programs (Jargas and SPBG), Fertilizers and Petrochemicals, Electricity, Retail Industries, and Non-Retail Industries. Specifically for the electricity sector to increase the use of natural gas, the government, through the Ministry of Energy and Mineral Resources, has issued[3)]. Use Fuel Oil with Liquefied Natural Gas (LNG) in the Provision of Electricity. In the decree, 33 PLTMGs are a priority for the gasification program for power plants. The Indonesian government has planned the conversion program for passenger ship fuel to LNG[4)] so that the need for LNG supplies to several regions will increase. Energy supply and demand are essential to a country's survival, and competition for natural resources is fierce[5), 6)].

Of the 33 power plant locations that are prioritized, there are 18 power plants located in Eastern Indonesia covering the Maluku and Papua regions, which are located in several islands and have a relatively small indicative volume of gas demand, making the supply system using pipes impossible, so a Mini LNG Carrier ship is needed.

Mini LNG ships have several types of gas containment, one of which is type C gas containment. Type C gas containment has the advantage of being independent and not integrated with the ship's construction, so the fabrication and repair processes can be separated from the ship. Its capacity can also be adjusted to the needs and capabilities of the shipyard.

To get an efficient LNG logistics system using type C gas containment in eastern Indonesia, it is necessary to plan routes following current needs. Supply and demand analysis is carried out to obtain the optimum ship size. In addition, planning and optimization of shipping routes also need to be carried out, considering the limited time for storing LNG in the tank.

This mission analysis produced a design requirement for a mini-LNG vessel with gas containment type C and its operational route to meet gas needs, especially for power plants in eastern Indonesia (Region VI). LNG consists of about 90% Methane with other light hydrocarbons (e.g., Ethane, Propane, butane, and nitrogen). LNG is a cryogenic liquid made by cooling natural gas to a temperature below its boiling point of about -163°C. By converting natural gas to LNG, its volume is reduced by 600 times. LNG is stored and transported normally at around atmospheric pressure[7)].

There are several problems with transportation delivery in Indonesia[8)]. Moving supplies from suppliers to manufacturers, from processing plants to the following production stage, or moving finished goods to clients all require transportation in a logistics system. This scheduling and planning process needs to be calculated before the actual operation. The necessity to coordinate several resources, including machinery, trucks, and other fleets, makes this a difficult task[9)]. The distribution system cannot be separated from the company's business processes, planning the sequence of product distribution routes from sources or hubs. Up to PLTMG, which still relies on experience and subjective decisions, calculating the overall distribution costs will not be easy. Subjective decisions require experience searching for the closest distance, so the company will depend on someone who determines the route. If the route is not determined correctly, the delay in goods can result in additional shipping costs and delays in meeting consumer needs. In planning the distribution of LNG to supply PLTMG with many destinations that have different capacities and needs, a good analysis is needed, one of which can be used to obtain route optimization is route analysis using the Vehicle Routing Problem (VRP) approach[10)].

Several studies using VRP have been carried out, such as analysis of LNG supply routes in German ports[11)], LNG supply optimization bunkering[12)], inventory routing for Ammonia supply[13)], distribution problems in maritime transportation studies of LNG distribution for mobile plans in western Indonesia[14), 15)], besides. Therefore, research related to route optimization has been widely used for determining distribution channels, goods, and people transportation. The method choice is adjusted to each case's parameters and conditions. In certain instances, a VRP method is better than other VRP methods, but it does not apply in other issues due to differences in environmental conditions and supporting parameters. In terms of route studies in the Indonesian region, several studies have been carried out, including the distribution of LNG in the area of Bali and Lombok, Indonesia[16)], Sulawesi, Indonesia[15)], as well as distribution in Western Indonesia with various parameters[14)]. A review of several previous studies is presented in Table 1.

This study aims to determine the best route estimates for stakeholders when operating a type C LNG ship with certain specifications. In PT PLN (persero) General Electricity Supply Business Plan (RUPTL)[17)], the gas supply for power plants in the Maluku and Papua regions will be met from the Ambon Hub. This scenario was adopted as the basis for this study because until now. There has never been any research that has raised the issue of Ambon as a hub. In addition, previous studies also did not include daily demand parameters. Finally, this study can provide a new model for developing the distribution of goods to the islands with similar characteristics to Maluku and Papua conditions.

2. Data and research area

This study uses ships with predetermined ship specifications to serve the LNG needs in Eastern Indonesia. The detailed specifications can be seen in Table 2 and Fig. 1. Based on the General Electricity Supply Business Plan (RUPTL) 2021-2030 for Eastern Indonesia, the supply of LNG used for gas power plants (PLTMG) comes from several LNG refineries, including the Bontang LNG Plant, Tangguh LNG Plant and Masela LNG Plant (in the early stages development), the need for PLTMG will be supplied from the Tangguh LNG Plan[17)].

According to the RUPTL document, due to the limited facilities at Tangguh gas stations, an LNG hub is needed to distribute Tangguh LNG to power plants spread across Maluku and Papua. Based on a study conducted by PLN, the location of the Hub, which is planned to be built in Ambon, is used simultaneously for gas fulfilment facilities for power plants in Ambon[3), 17)].

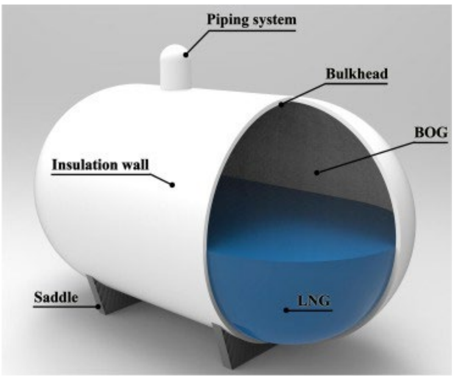
The locations of the Sulawesi and Papua Gas Power Plants, which will receive their LNG supply from the Ambon Hub, are depicted in Fig. 2.

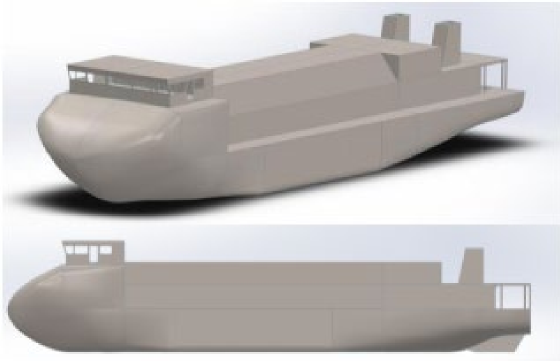
Table 1. Pioneer studies regarding LNG Transportation with VRP

No	Scholar	Subjects	Findings
1	Prause and Prause, 2021 [11)]	Inventory Routing Analysis for Maritime LNG Supply of German Ports	The transportation of LNG from the newly established LNG hub to other ports in Germany can be represented by applying the IRP and VRP methodologies. The optimal approach for distributing LNG throughout Germany can be determined using these methods.
2	Doymus et al., 2022 [12)]	Small-scale LNG supply chain optimization for LNG bunkering in Turkey	This research introduces a model to enhance the efficiency of the ship-to-ship LNG bunkering supply chain. The study focuses on determining the appropriate quantity and dimensions of LNG bunker barges and optimizing the allocation of these barges and the distribution network within a ship-to-ship bunkering framework.
3	Prause, F et al, 2022 [13)]	Inventory Routing for Ammonia Supply in German Ports	The analysis of NH_3 distribution from the established NH_3 hub to various ports in Germany can be examined using an inventory routing problem (IRP) mathematical model. Currently, the most preferred mode of supply for ammonia and LNG in German ports is a combination of vessel and truck distribution.
4	Budiyanta et al, 2020 [14)]	Study on the LNG distribution to mobile power plants utilizing small-scale LNG carriers	The optimization of maritime routing for a small-scale LNG supply chain was achieved by utilizing a capacitated vehicle routing problem model. The cargo demand volume and the shipping distances determine the cost of LNG transportation.
5	Budiyanta et al, 2022 [15)]	Study on the LNG distribution to Mobile Power Plants using a Small-Scale LNG Carrier for the case of the Sulawesi region of Indonesia	The objective is to establish a movable gas-engine power plant in the Sulawesi area of Indonesia. After optimizing the distribution of LNG, the results indicate that two units of SSLNG with a capacity of 5000 m^3 each are required, leaving a total remaining cargo of 1753.1 m^3 to fulfil the LNG requirements at all intended destinations.
6	Pratiwi et al., 2021 [16)]	Economic analysis on the LNG Distribution to power plants in Bali and Lombok by utilizing mini-LNG carriers	Small-scale LNG offers enhanced operational flexibility and lower initial investment costs than conventional LNG or pipeline supply methods. From an economic standpoint, it is feasible to utilize mini LNG carriers, as they require a relatively modest price to meet the demand for LNG in Lombok and Bali.

Table 2. General Specification of Small-Scale LNG Carrier based on IMO (Design code: IGC, IMDG, ASME)

No.	Parameter	Description
1	Optional LNG Tank	Type C Tank
2	Capacity	3000 m^3
3	Storage capacity	1200 ton
4	Pressure range [int/ext]	7.0 / -0.5 bar
5	Design temperature	-196 to 45 °C
6	Corrosion allowance	1.0 mm
7	Insulation	Super multi-layer insulation spray PU foam
8	Materials	SS 304
9	Outer finishing	Protect surface stainless steel cladding
10	Piping arrangement	All stainless-steel pipe
11	Insulated to ensure long holding times	60 to 110 days
12	Equipment	Safety aids for outside and inside the ship, evaporation system heat exchanger
13	Pressure control regulator regulator	Pressure/temperature sensors, Gas detectors, Check valves, pressure relief valves, overflow valves, manual valves, non-return valves, Leak detection and protection, Dry disconnect quick coupling





(a) (b)

Fig. 1: (a) Model LNG Gas Containment Type C, (b). LNG type c platform[18)]

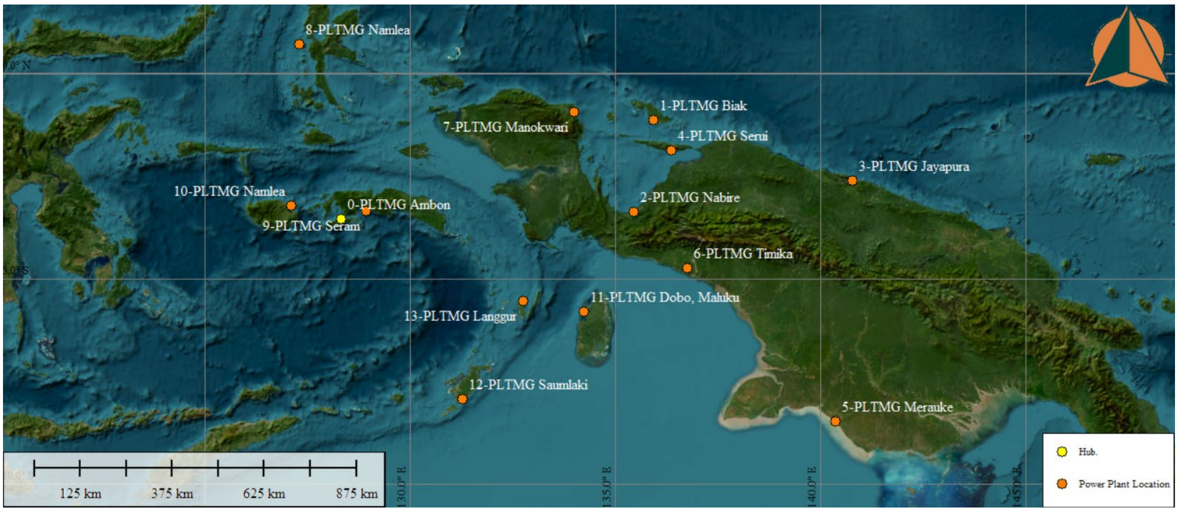


Fig. 2: The prospect of Ambon as a hub terminal between PLTMG to be served in Eastern Indonesia from a geographical point of view

3. Methodology

3.1 Data Processing and Validating

The critical problem for LNG distribution is determining the route and the number of fleets, including their schedule to meet the demand of the consumers/users. This route transportation problem is the Vehicle Routing Problem (VRP). The main solution of VRP is to make the distance, time, and fleet use efficient. The Capacitated Vehicle Routing Problem (CVRP) is a development of the VRP model. VRP was introduced in 1959 by Dantzig and Ramser to solve the problem of gasoline delivery[19)]. Since then, there have been many variants of the model that have proven to be very satisfying. In general, VRP is designed as a single route for the fleet with a source delivery location (Hub) and return back to the Hub. Route determination in this study using CVRP modeling is used to determine route optimization on the distance traveled by the fleet from the LNG Hub in Ambon to several PLTGMs in the Maluku and Papua regions. This Small-scale LNG carrier is subjected to cover a limited total distance with a limited capacity.

There are four general goals of VRP: 1. Minimizing global transportation costs related to distance and fixed costs associated with vehicles; 2. Minimize the number of vehicles (or drivers) needed to serve all consumers; 3. Balancing the route for travel time and vehicle load; 4. Minimizing penalties due to unsatisfactory service from users/consumers. The CVRP method used consists of 3. Nearest Neighbor Method, Saving Matrix Method, and Heuristics.

The research implementation flowchart can be presented in Fig. 3, outlining the general process. By employing a validated calculation model, the optimal method is determined among the three implemented methods. Subsequently, the selected method is further optimized.

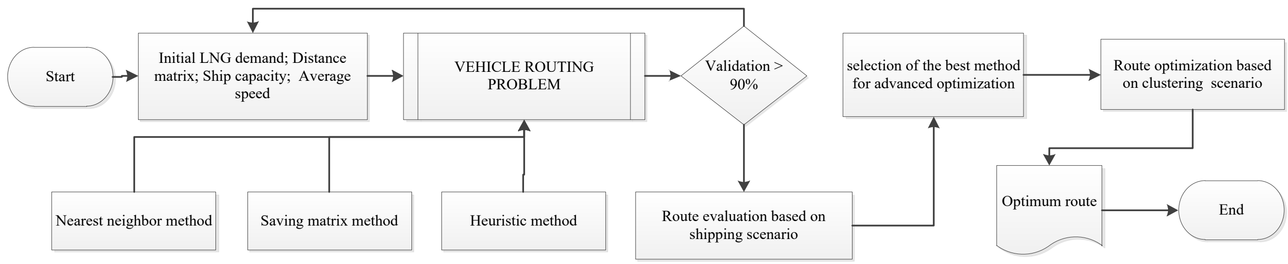


Fig. 3: flowchart of research

VRP is often defined in terms of capacity and route length limitations. In real life, the limits of the VRP model are not as simple as they are formulated. Many things are unexpectedly contrary to the nature of human behavior and natural conditions[20], as well as limitations in calculating and including all parameters in route calculations; for example, there are problems related to weather or loading-unloading problems at one port. With the limitations of each customer's demand must be met, the service route must start and end at the same point (in this case, declared as a hub) and the limited capacity of the transportation means. Thus, VRP highly depends on the characteristics of the route served, the characteristics of the Hub, customer, demand, and service characteristics[21].

This study uses a two-step approach, namely the initialization stage, by comparing several route decision calculations to choose the best method from the route calculation formula. This method calculates various available time and fleet scenarios using the best-selected method. VRP mathematical model built on Jupyter Notebook software and verified on Microsoft Excel software. Notebook is one of the software made by Jupyter. Jupyter Notebook combines the code and documents used in coding in one interactive file and can be reused by anyone who opens it[22].

The validation and accuracy assessment of the k-Nearest Neighbor method, k-Saving matrix, and k-Heuristics are performed using the k-Fold Cross algorithm. This evaluation demonstrates the effective division of training and test data. The Jupiter notebook software for Vehicle Routing Problems (VRP) algorithm module is utilized for testing purposes. The evaluation encompasses data from fold-1 to fold-5 and yields an accuracy exceeding 90%. Therefore, it can be concluded that the review of the k-Nearest Neighbor, k-Saving matrix, and k-Heuristics models using k-Fold Cross Validation achieves satisfactory performance for the algorithms utilized in this study.

3.2 Nearest Neighbor Scheme

The method Nearest Neighbour is a method used for route problem-solving. Problem-solving is done by starting at the starting point and then searching for the nearest point. Nearest Neighbor's method starts with selecting a path or route with the minimum distance value each through the area, then selecting the next area considering that the area has not been visited and has the minimum value or distance.

Optimization of shipping routes using the nearest neighbor method. The Nearest Neighbor method algorithm[23] is as follows:

1. Starting from the hub terminal, then looking for the location of the power plant that has not been visited, which has the shortest distance from the hub terminal (Refer as the first location)
2. Proceed to another location that has the closest distance from the previously selected location and the number of shipments does not exceed the ship's capacity
   - If the location is selected as the next location and there is remaining ship capacity, return to step (2).
   - If the vessel has no remaining capacity, return to step (1).
   - If no location is selected because the number of shipments exceeds the ship's capacity, then return to step (1). Start over from Terminal Hub and visit the nearest unvisited power plant.
3. The algorithm ends when all location has been visited.

The problem of determining the route of supplying LNG for power plants (PLTMG) in Eastern Indonesia is defined as a graph = (V, E). Set V consists of a combination of PLTMG, C sets and hub terminals, $V = \{0, 1, \dots, 14\}$. The set C is a location 1 to 13, $C = \{1,2, \dots, 13\}$ and the hub terminal is represented by 0 and 14.

All routing starts and ends at the hub terminal. The fleet of ships represents a homogeneous K value with a capacity of q. Each location (i) has its own demand for each $i \in C$. Therefore the length of travel on the route is limited by the capacity of the ship. Then the set equation $cii = cjj = 0$ for the location must have a distance of zero if the initial and final location is the same. This will be treated the same at the hub terminal locations of X=1 if there is a trip from location i to j. Otherwise, if the value is 0 then there is no trip from location i to generator j. The mathematical model in this study is described in the below equations.

Find the minimum value of

$$Z = \sum_{i=0}^{13} \sum_{j=1}^{14} c_{ij}\, x_{ij} \tag{1}$$

With several conditions as follows:

1. Each PLTMG is visited precisely once on board.

$$\sum_{j=1}^{14} x_{ij} = 1, \quad \forall i \in V \tag{2}$$

2. The total requirement of all PLTMG does not exceed the maximum capacity of the ship (3000 m^3 is the SSLNGC feeder)

$$Z = \sum_{i=0}^{13} d_i \quad \sum_{i=0}^{14} x_{ij} \quad \leq 3000 \tag{3}$$

3. For each route starting from the Hub.

$$\sum_{j=1}^{z14} x_{0j} = 1 \tag{4}$$

4. Every ship that comes to a location will definitely leave the location

$$\sum_{i=0}^{13} x_{ij} - \sum_{j=0}^{14} x_{ij} = 0 \tag{5}$$

5. Each set of route ends at Hub

$$\sum_{i=0}^{13} x_{i14} = 1 \tag{6}$$

$$X_{ijk} \in \{0,1\}, \forall i, j \in V, \forall k \in K \tag{7}$$

In this study, the route search assumptions are as follows: The hub terminal can meet every LNG demand from the power plant. The RUPTL-PLN document states that the LNG demand in Papua and Maluku regions must be supplied from the nearest sources. In this case, Tangguh LNG plant, Papua, is able to be the source [17]. Considering this reason, Ambon is chosen as the hub terminal; The number of generators (n) in this study is known to be 14, meaning there are 13 power plants and one hub terminal. These numbers are based on actual power plants, including under-construction plants in the Maluku and Papua regions[3].

The SSLNGC capacity has a maximum of 3000 m^3. The ship's capacity is based on the design of the LNG carrier on the market. In addition, the 3000 m^3 capacity design refers to the discussion with the power plant's stakeholders. On the other side, Damen shipyard has developed a 3000 m^3 LNG carrier for LNG transporter[24]. The average speed of the ship is 12 knots. This speed is determined based on the ship design specifications released by Small Scale LNG Carrier Development program (IPTM, BPPT 2020-2021). This specification has also been tested at the Indonesian Hydrodynamic Laboratory 2020.

3.3 Saving matrix method

One approach used to address transportation issues to reduce costs is a matrix. The vehicle routing problem (VRP), often known as the transportation problem, is one in which the distribution route of a good between two depots is chosen while considering the vehicle's maximum carrying capacity. The saving matrix method distributes items to delivery zones depending on carrying capacity and the most savings[25].

In 1964 Clarke and Wright proposed a method called Clarke Wright (CW) savings algorithm. This method intends to find a route with the largest distance saving by a route exchanging mechanism. Originally, the problems handled by the algorithm were those without considering the vehicle's capacity. The principle of the CW saving algorithm is to find the route such that the accumulation of saving distance can be maximized. Saving distance from a pair of the i-th and the j-th nodes (Si, j) is defined as the difference of the distance between the depot-to-the i-th node and the depot-to-the j-node:

$$S_{i,j} = d_{D,i} + d_{D,j} - d_{i,j} \tag{8}$$

In this study, The algorithm can be described in the following steps: Initialize the distance data, number of requests LNG, average Ship speed, and ship capacity as input needed; create a distance matrix between the Hub terminal to the power plant and between power plants to power plants; perform a saving matrix by using equation (8); Perform a list of saving value calculated in step 3 from the largest to the smallest, and determine the array of outlet assigned to the tour by selecting the outlet combination with the largest saving value.

3.4 Heuristics

For the traditional VRP, some families of heuristic algorithms have been put forth; they can be divided into two primary categories: classical heuristics and metaheuristics[23]. The most commonly used standard building and improvement techniques fall within the first class. These techniques only explore a small portion of the solution space and typically deliver high-calibre solutions in a reasonable amount of time[26].

Heuristics is a method for solving combinatorial optimization issues in the best possible way. This method addresses the solution of a primal problem by determining the ideal value for a specific aspect of the primal problem, as opposed to an exact solution, which determines the precise value of the solution. The goal here is to fast identify a computationally possible solution, even though it might not be the best one[27].

4. Result and discussion

4.1 LNG demand for each power plant

The LNG requirement per day for each power plant is presented in the following Table 3. The distance measurement for each power plant is measured using a google map by considering shipping lanes and routes in eastern Indonesia. The results of distance measurements can be seen in Table 4.

Using the scenario of the daily needs of a Power Plant, the simulation is carried out with three methods, namely Nearest Neighbor, Saving Matrix, and Heuristics. The results of the LNG supply route are shown in Table 5.

In the nearest neighbor method, the first iteration of the journey starts from Ambon (T0) and finds the nearest LNG delivery destination. It can be seen in Table 5 that the closest generator from Terminal Hub is PLTU T9 which was later changed to the initial location. The second iteration of the journey starts from Ambon (T9) and looks for the nearest LNG delivery destination. It can be seen in Table 5 that the closest generator from Terminal Hub is PLTU T10 which was later changed to the initial location.

In the same way following the nearest neighbor method algorithm, the LNG distribution route obtained is T0 - T9 - T10 -T8- T7-T1-T4-T2-T3-T13-T11-T12-T6-T5-T0 (Ambon - Seram - Namlea - Ternate - Manokwari - Biak - Serui - Nabire - Jayapura - Langgur - Dobo - Saumlaki - Timika - Merauke - Ambon) With a total distance of 8896 km and LNG requirement of 1474 m^3.

In contrast to the Nearest Neighbor method, the Saving matrix method from the Hub (T0) seeks routes with the largest distance matrix between two locations. The route is obtained using the Heuristics method, which takes into account the prior two methods and is optimistic regarding the distance and load, as shown in Table 5.

Table 3. List of MPP-PLTMG in Maluku and Papua, Indonesia

Code	Power plant	Location		Capacity	Daily demand
		Latitude	Longitude	(MW)	(m^3)
T0	Ambon (hub terminal)	-3.56°	128.33°	-	0*
T1	PLTMG Biak	-1.15°	135.95°	25	102
T2	MPP-PLTMG Nabire	-3.38°	135.46°	33	92
T3	MPP-PLTMG Jayapura	-2.62°	140.79°	99	425
T4	PLTMG Serui	-1.88°	136.37°	10	43
T5	PLTMG Merauke	-8.48°	140.38°	40	179
T6	MPP Timika	-4.76°	136.77°	10	45
T7	PLTMG Manokwari	-0.94°	134.02°	20	115
T8	MPP Ternate	0.71°	127.31°	30	177
T9	PLTMG Seram	-3.36°	128.96°	20	81
T10	PLTMG Namlea	-3.23°	127.11°	10	52
T11	PLTMG Dobo	-5.82°	134.25°	10	46
T12	PLTMG Saumlaki	-7.94°	131.29°	10	40
T13	PLTMG Langgur	-5.55°	132.77°	20	77
		Total demand			1474

Source: [3], Data Processing, 2022

* Ambon demand = 0, because LNG supply to PLTGM Ambon is directly served at Tangguh LNG. Thus, it is not included in the calculation of the fleet service route.

Table 4. Distance from Ambon Hub to All Areas, as well as the distance from one area to another (km)

	Ambon	Biak	Nabire	Jayapura	Serui	Merauke	Timika	Manokwari	Ternate	Seram	Namlea	Dobo	Saumlaki	Langgur
Ambon	0	1200	1311	1776	1250	1615	965	998	578	75	160	710	609	562
Biak	1200	0	292	593	200	2180	1600	220	1145	1315	1500	1370	1595	1260
Nabire	1311	292	0	764	210	2515	1795	321	1277	1380	1239	1505	1736	1390
Jayapura	1776	593	764	0	543	2946	2178	800	1879	1840	1694	1950	2100	1830
Serui	1250	200	210	543	0	1422	1740	295	1369	1340	1200	1469	1617	1354
Merauke	1615	2180	2515	2946	1422	0	880	2135	2180	1690	1625	905	1005	1070
Timika	965	1600	1795	2178	1740	880	0	1465	1370	900	1136	364	770	484
Manokwari	998	220	321	800	295	2135	1465	0	900	1067	930	1188	1328	1073
Ternate	578	1145	1277	1879	1369	2180	1370	900	0	640	454	1100	1198	973
Seram	75	1315	1380	1840	1340	1690	900	1067	640	0	242	673	612	510
Namlea	160	1500	1239	1694	1200	1625	1136	930	454	242	0	857	720	686
Dobo	710	1370	1505	1950	1469	905	364	1188	1100	673	857	0	430	200
Saumlaki	609	1595	1736	2100	1617	1005	770	1328	1198	612	720	430	0	368
Langgur	562	1260	1390	1830	1354	1070	484	1073	973	510	686	200	368	0

Table 5. LNG Supply Distribution Route Results

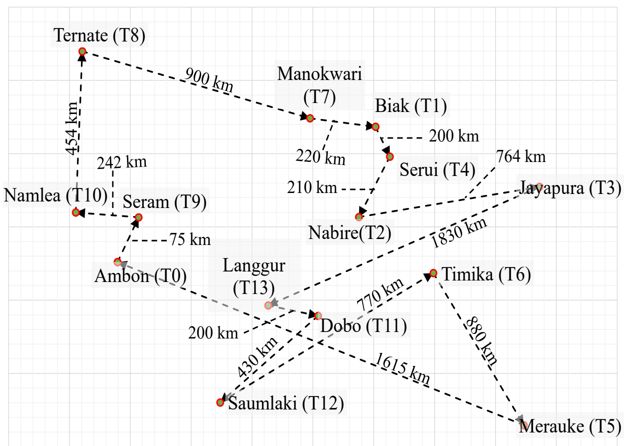
No	**Method**	**Routes distribution**	**Trajectory length (km)**	**Duration (Days)**
1	Nearest Neighbor	Ambon – Seram -Namlea – Ternate – Manokwari – Biak – Serui – Jayapura – Langgur – Dobo – Saumlaki – Timika – Merauke - Ambon	8896	16.7

2	Saving Matrix	Ambon-Serui-Jayapura-Biak-Nabire-Manokwari-Timika-Merauke-Dobo-Saumlaki-Langgur-Ternate-Namlea-Seram-Ambon	8411	15.8
3	Heuristics	Ambon - Namlea- Ternate - Manokwari - Nabire - Biak - Jayapura - Serui - Merauke - Timika - Dobo - Langgur- Saumlaki- Seram- Ambon	7184	13.5

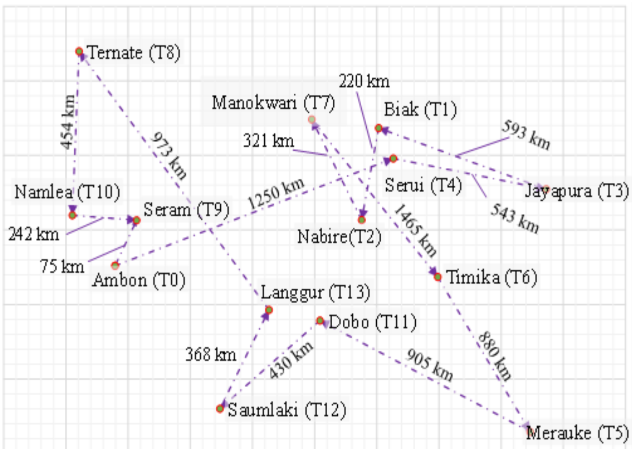
4.1 LNG distribution route optimization results

The calculation results of the three neighbouring methods show that the Heuristic method has advantages related to the travel time required to distribute LNG demand in all locations. The advantages of the heuristic method compared to the saving matrix method have also been carried out in several previous studies[28),29)]. One of the important differences in the heuristic method is calculating the destination location and consumer needs at the beginning of the calculation. Fig. 4 and Fig 5. shows a visualization of routes that pass through inter-island shipping lanes in eastern Indonesia. The results of the heuristic method show a shorter duration of 3 days than the neigboard method and two days more effective than the method of determining the route with the saving matrix. In the next analysis, this method is applied to consider the LNG demand capacity using a fleet capacity of 3000 m^3 with an average ship speed of 12 knots. The results of the routes that can be served are presented in Table 6.

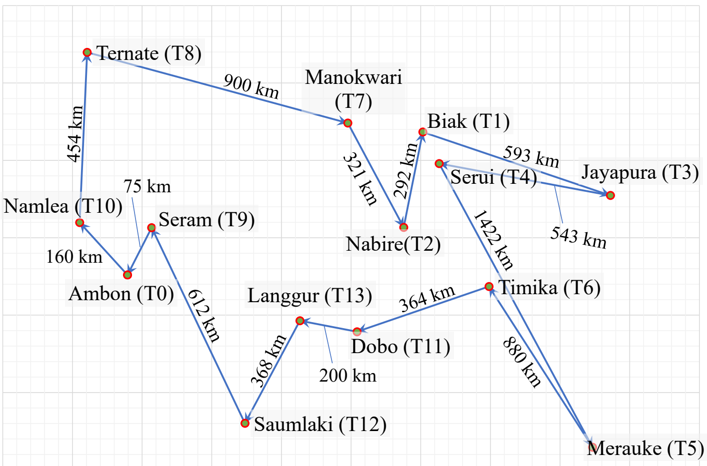
The results of calculations using the Heuristic method with MPP/PLTMG targets spread across Maluku and Papua are presented in Table 6. The scenario of meeting the needs of up to 6 days in each PLTMG is not met, where the time required to complete LNG shipments to all locations turns out to be more than the target. These results indicate that the most effective scenario is obtained with a 7-day delivery scenario. The total demand value is the need for each PLTMG for 7 days, with the hope that if sent every 7 days, the PLTMG can still operate without a shortage of LNG supply. The 1-6 day delivery scenario is not effective because the travel time exceeds the duration, it turns out that the time it takes is more than 6 days, the scenario takes 6 days and the time it takes > 6 days. The time requirements exceed the initial scenario.



(a) Route evaluation based on the Nearest Neighbour method



(b) Route evaluation based on the Saving Matrix method



c) Route evaluation based on the Heuristic method

Fig. 4: (a) (b) (c) Shipping route of LNG platform through inter-island shipping lanes

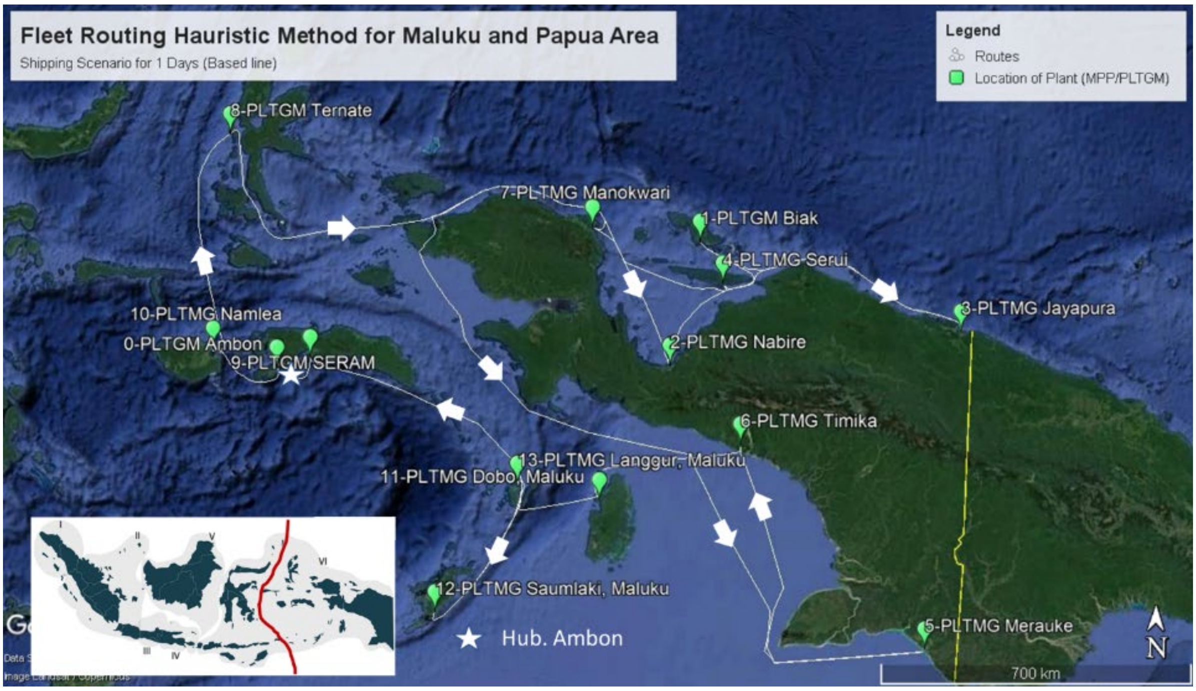


Fig. 5: Ilustration Shipping route of LNG platform through inter-island shipping lanes from the Heuristic method

Table 6. The best-optimum route for each daily LNG needs accounted with 4 vessels

Shipping scenario	**LNG Demand (m^3)**	**Fleet-01**				**Fleet-02**			
		Routes service	LNG Demand per route (m^3)	Length of routes (km)	Duration (day)	Routes service	LNG Demand per route (m^3)	Length of routes (km)	Duration (day)
1 Day	1474	T0 -T10-T8 -T7 - T2 - T1 - T3 - T4 - T5 -T6-T11 -T13-T12-T9-T0	1474	7184	13.47	-	-	-	-
2 Days	2948	T0 -T10-T8 -T7 -T2 -T1 -T3 -T4 -T5 -T6 -T11-T13-T12-T9-T0	2948	7184	13.47	-	-	-	-
3 Days	4422	T0-T8-T7-T2-T4-T3-T1-T0	2862	4345	8.15	T0-T9-T13-T11-T6-T5-T12-T10-T0	1560	3914	7,34*
4 Days	5896	T0-T10-T8-T7-T13-T11-T6-T5-T12-T0	2924	5645	10.58	T0-T1-T3-T4-T2-T9-T0	2972	4001	7,5*
5 Days	7370	T0 - T4 - T3 - T1 - T0	2850	3586	6.72	T0- T12 - T5 - T6 - T11 - T13 - T9 - T0	2340	3643	6,83*
6 Days	**8844**	**T0-T3-T4-T0**	**2808**	**3569**	**6.69**	**T0-T8-T7-T2-T1-T0**	**2916**	**3291**	**6,17***
7 Days	**10318**	**T0 -T3 -T0**	**2975**	**3552**	**6.66**	**T0-T1-T4 -T2 - T7-T0**	**2464**	**2929**	**5.49**

*not effective because the ship's shipping day exceeds the shipping scenario

Table 6. The best-optimum route for each daily LNG needs accounted with 4 vessels (con't)

Shipping scenario	LNG Demand (m^3)	Fleet-03				Fleet-04			
		Routes service	LNG Demand per route (m^3)	Length of routes (km)	Duration (day)	Routes service	LNG Demand per route (m^3)	Length of routes (km)	Duration (day)
1 Day	1474	-	-	-	-	-	-	-	-
2 Days	2948	-	-	-	-	-	-		-
3 Days	4422	-	-	-	-	-	-	-	-
4 Days	5896	-	-	-	-	-	-	-	-
5 Days	7370	T0 - T10 - T8 - T7 - T2 - T0	2180	3146	5,9*	-	-	-	-
6 Days	**8844**	**T0-T12-T5-T6-T11-T13-T9-T0**	**2808**	**3643**	**6,83***	**T0-T10-T0**	**312**	**320**	**0.60**
7 Days	**10318**	**T0-T12 -T5 -T6 -T11 -T13 -T0**	**2709**	**3620**	**6.79**	**T0-T10-T8-T9-T0**	**2170**	**1329**	**2.49**

*not effective because the ship's shipping day exceeds the shipping scenario

Table 7. Results of Optimizing Routes Considering the daily demand and clustered location

Shipping Day Scenario	LNG Demand (m^3)	Fleet-01				Fleet-02				Fleet-03			
		Routes service	LNG Demand per route (m^3)	Length of routes (km)	Duration (Day)	Routes service	LNG Demand per route (m^3)	Length of routes (km)	Duration (Day)	Routes service	LNG Demand per route (m^3)	Length of routes (km)	Duration (Day)
1 Day	697	T0-T10-T8-T13-T11-T6-T5-T12-T9-T0	697	4260	7,99*	-	-	-	-	-	-	-	-
2 Days	1394	T0-T10-T8-T13-T11-T6-T5-T12-T9-T0	1394	4260	7,99*	-	-	-	-	-	-	-	-
3 Days	2091	T0-T10-T8-T13-T11-T6-T5-T12-T9-T0	2091	4260	7,99*	-	-	-	-	-	-	-	-
4 Days	2788	T0-T10-T8-T13-T11-T6-T5-T12-T9-T0	2788	4260	7,99*	-	-	-	-	-	-	-	-
5 Days	3485	T0-T9-T13-T11-T6-T5-T12-T0	2340	3643	6,83*	T0-T8-T10-T0	1145	980	1.84	-	-	-	-
6 Days	4182	T0-T12-T5-T6-T11-T13-T9-T0	2808	3643	6.83*	T0-T8-T10-T0	1374	980	1.84	-	-	-	-
7 Days	4879	T0-T12-T5-T6-T11-T13-T0	2709	3620	6.79	T0-T9-T8-T10-T0	2170	1117	2.09	-	-	-	-
8 Days	5576	T0-T6-T5-T11-T13-T0	2767	3512	6.58	T0-T10-T8-T12-T9-T0	2800	1913	3.59	-	-	-	-
9 Days	6273	T0-T11-T6-T5-T12-T0	2790	3568	6.69	T0-T9-T0	729	150	0.28	T0-T10-T8-T13-T0	2754	1686	3.16
10 Days	6970	T0-T6-T5-T12-T0	2640	3459	6.49	T0-T8-T10-T0	2290	980	1.84	T0-T9-T13-T11-T0	1495	2040	3.82
11 Days	7667	T0-T6-T5-T12-T0	2904	3459	6.49	T0-T8-T10-T0	2519	980	1.84	T0-T9-T13-T11-T0	2244	1495	2.80
12 Days	8364	T0-T6-T5-T0	2688	3460	6.49	T0-T8-T10-T0	2748	980	1.84	T0-T9-T13-T11-T12-T0	2928	1824	3.42

*not effective because the ship's shipping day exceeds the shipping scenario

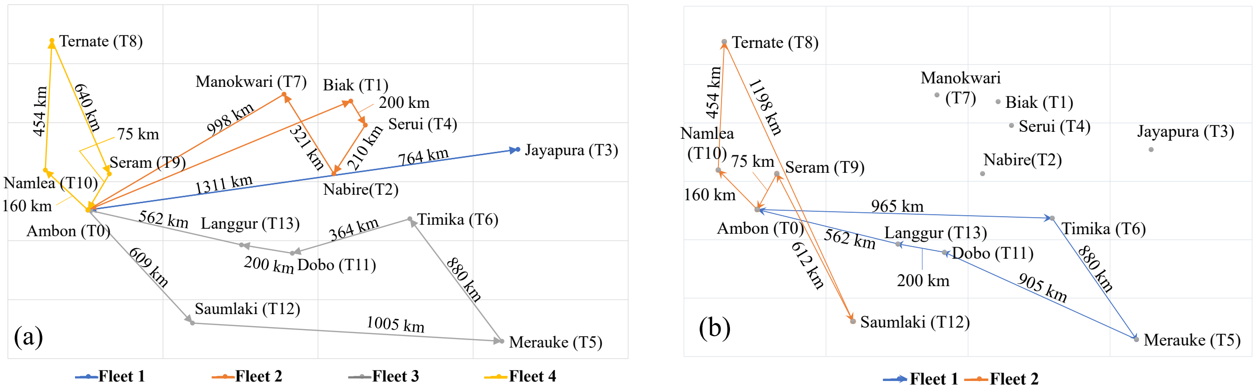


Fig. 6: Comparison of optimization routes with cluster; (a) Routes of fleets without clustering for seven days scenario; (b) Routes of fleets with clustering for eight days scenario

Table 6 shows the route evaluation using the Heuristic method. The results show that the delivery of LNG to all locations takes longer than expected. The demand of Each PLTMG cannot accommodate for up to 6 days. It is also important to note that two fleets may not be used because the ship cannot operate optimally with a cargo load that is less than its 3000 m^3 capacity and because the number of days required is less than the allotted time. If there is still a lot of operating or shipping time available, it may be possible to reduce the ship's operation speed in order to reduce fuel consumption.

An analysis was carried out for maximum results by clustering the shipping area. In Table 7, starting from scenarios 5-7, the northern Papua region was served by a special fleet (Fig. 6). This northern Papua cluster is recommended to be performed by its route or can be operated from Sorong. The distance between Ambon as a Hub with the North Papua region is less effective for the distribution of this area. The results of the effective calculation for clusters outside North Papua have been presented in Table 7. The 1-6 day delivery scenario is ineffective because the travel time exceeds the day scenario. The most effective scenario is obtained in the 8-day delivery scenario because it takes <8 days with the most appropriate time approaching the amount of MPP-PLTMG needed.

The plan for selecting the Ambon Hub as a Hub to serve LNG supplies in the Maluku and Papua Regions also needs to be reviewed for effectiveness because, based on previous calculations, there is a distance between destinations > 2100 km; the distance needs more than four days. In addition to PLTMG Ambon Peaker, port facilities are ready to serve LNG distribution in Maluku and Papua regions[30]. Port readiness can be used as an alternative hub for the surrounding area to increase the effectiveness of LNG shipments.

This study has not considered that it is related to the time required for the LNG delivery process at each PLTMG destination. In general, the need for LNG unloading time is 12 hours each[30]. The time needed for loading depends on the available facilities[19], the differences in facilities, and the ability of each PLTMG to receive LNG supply or delivery to each need to be calculated in detail. Each PLTMG can then be entered as an input parameter in calculating the LNG distribution again in future studies.

Conclusion

The ship route analysis in this study supports the performance of ships planned to distribute LNG in 13 PLTMG Maluku and Papua Regions. The Ship specifications have been determined, namely the type of LNG carrier ship Type C, the capacity of 3000 m^3 with a speed of 12 knots. Detailed calculations related to the analysis of the effective route that serves all PLTMG in Maluku and Papua have been presented.

In addition, clustering areas can be done to achieve the best results. These are some clustering options: Papua's northern region is made up of PLTMG Manokwari, PLTMG Biak, MPP-PLTMG Nabire, PLTMG Serui, and PLTMG Jayapura. Services for this cluster are carried out by a special fleet that does not mix with other regions. It is advised that Sorong can be used as a point of access, considering how inefficient it will be if it is served from Ambon as the Hub.

For further research purposes, the analysis will consider the delivery time (unloading and loading to onshore facilities) of LNG. Of course, the loading and unloading speed will depend on the facilities and capabilities of each PLTMG.

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