Optimization of Hub Location for Tank Car Spare Parts Distribution In East Nusa Tenggara : A Case Study of PT Elnusa Petrofin

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ABSTRACT

PT Elnusa Petrofin (EPN) is a company engaged in the logistics and distribution of fuel oil (BBM) in Indonesia, including supporting the Public Service Obligation (PSO) and One Price BBM programs managed by Pertamina. The reliability of the tank car fleet is a crucial factor in this service, so PT Elnusa Petrofin implements three maintenance programs that include preventive, corrective, and overhaul maintenance. However, in five Fuel Terminals in East Nusa Tenggara, the implementation of this program is constrained by limited spare parts due to the absence of authorized dealers and the lengthy procurement process, which results in a 4% delay in tank car repairs. Therefore, this study proposes the construction of spare parts hubs or warehouses in these five locations, intending to reduce transportation costs and time and reduce repair delays. The method used is Green Field Analysis (GFA) with AnyLogistix software and Center of Gravity (CoG) to determine the optimal location of the warehouse. The GFA results show coordinates (-8.8527219759, 121.6625537826) in Tetandara, Ende Regency, while CoG produces coordinates (-8.59346303874142, 121.010483387574) in Denatana, Ngada Regency. The cost analysis shows that shipping under existing conditions, i.e. directly from Jakarta to five locations in NTT, costs IDR 44,475,500, while through a hub in Ende Regency can save up to 57.80% at a cost of IDR 18,766,000. Meanwhile, the alternative hub in Ngada Regency offers 20.20% savings at a cost of IDR 35,491,000.

1. INTRODUCTION

Fuel oil is a critical component that powers daily activities and supports industrial operations, which plays an important role in the economic growth of countries like Indonesia [1]. Its use spans many sectors, including transportation, manufacturing, and public utilities, critical to social and economic stability. Along with population growth and rapid economic development, the demand for fuel has increased significantly, making the efficiency and reliability of its distribution system a national priority [2]. However, this increase in demand also poses considerable challenges, particularly in ensuring that the supply chain can effectively meet the needs of urban and remote areas [3]. Disruptions in fuel distribution can lead to wider economic consequences, affecting industrial productivity, public transportation, and energy-dependent sectors [4].

In Indonesia, geographical diversity further complicates fuel distribution [5]. East Nusa Tenggara (NTT), which consists of many islands with varying levels of infrastructure, is an example of this challenge. The region relies heavily on an efficient supply chain to meet its energy needs, but logistical constraints make it vulnerable to delays. PT Elnusa Petrofin, a leading fuel logistics provider, manages fuel distribution in 96 locations across the country, including five major terminals in NTT located in Tenau, Waingapu, Ende, Maumere, and Reo. Despite having a fleet of 752 tank trucks, the company faces recurring obstacles in maintaining operational reliability due to late repairs and inadequate spare parts management [6]. Such delays directly impact the efficiency of fuel distribution in the region, thus underscoring the need for a more adaptive and resilient supply chain model designed to address the special logistical challenges posed by remote areas such as NTT.

The reliability and timeliness of fuel distribution in NTT is significantly affected by maintenance-related delays in the tanker fleet. During the first eight months of 2024, data shows that 4% of all fuel deliveries in NTT experienced delays caused by severe mechanical breakdowns. These include critical issues such as transmission failures, differential failures, braking system failures, and cooling system failures. Such severe problems often require extensive repairs, which are then caused by delays in acquiring the required spare parts. The current centralized procurement system, managed by Jakarta, results in extremely long delivery times, ranging from 13 to 45 days for corrective maintenance and 16 to 105 days for repair maintenance. These timeframes far exceed the company's operational standards, which set a maximum tolerance of 14 days for corrective repairs and 30 days for overhaul repairs.

Several factors exacerbated this delay. First, the lack of authorized spare parts dealers in NTT limits the availability of high-quality components that meet manufacturer standards. Second, reliance on air freight to transport parts from Jakarta increases logistics costs and delivery times, further complicating repair schedules. Lastly, the absence of local storage facilities or logistics centers in NTT makes it impossible for companies to keep an inventory of frequently used parts, leading to long vehicle downtimes. These inefficiencies directly reduce fleet availability, causing ripple effects throughout the supply chain, such as missed delivery schedules and increased operational costs.

This issue is particularly important for regions such as NTT, where limited infrastructure and geographic isolation make alternative distribution methods impractical. As fuel distribution delays impact industry, public services, and energy supply, the need for an optimized supply chain strategy is critical. Addressing this challenge requires not only decentralizing the procurement process but also establishing regional hubs to store critical spare parts, minimize repair time, and improve overall fleet efficiency.

There are many studies that highlight the importance of optimizing supply chain strategies to improve operational efficiency, especially in geographically challenging regions. [7] identified centralized procurement processes as a significant factor contributing to delays in maintaining critical infrastructure, and emphasized the need for localized inventory management. Similarly, [8] highlighted that frequent mechanical breakdowns of tank trucks, such as broken oil filters, wheel bolts and chambers, are often compounded by delays in acquiring replacement parts. These findings underscore the critical role of spare parts availability in ensuring the operational reliability of the fleet.

The benefits of establishing a local logistics center have been widely documented. [9] showed that incorporating a new hub using the center of gravity method significantly reduced shipping distances by 43 km, equivalent to a 6.91% reduction in costs. Likewise, [10], found that strategically adding logistics hubs can reduce transportation distances by up to 350 km, which translates to cost savings of approximately IDR 2,200,000 per shipment. These studies confirm that regional centers can substantially improve supply chain efficiency, especially in remote and underserved areas.

This study not only addresses a real-world logistical problem but also contributes to the academic literature by applying Green Field Analysis (GFA) and the Center of Gravity (CoG) method in a geographically complex and under-researched region. By integrating these methods with simulation tools, the research offers a practical case of how logistics modeling can be adapted to remote, island-based contexts like NTT. Despite these advancements, the integration of advanced analytical tools for logistics planning remains unexplored. Methods such as Greenfield Analysis (GFA), coupled with simulation software such as AnyLogistix, offer promising avenues to optimize hub locations and inventory strategies. Previous studies have focused more on theoretical frameworks or case studies with limited applicability to Indonesia's unique geographical and logistical challenges. This research seeks to address this gap by applying GFA and the center of gravity method to determine the optimal location for spare parts hubs in NTT. As such, this research aims to provide practical solutions to improve fleet maintenance efficiency, reduce repair time, and ensure uninterrupted fuel distribution across the region. This contribution is expected to serve as a benchmark for supply chain optimization in similarly challenged environments.

2. METHOD

This research adopts a quantitative approach utilizing the Green Field Analysis (GFA) method with AnyLogistix software and the Center of Gravity (CoG) method to determine the optimal location for a spare parts distribution center. The methodology begins with identifying key problems in spare parts distribution, which is conducted through interviews with logistics personnel and relevant stakeholders, along with a literature review. Specifically, two interviews were conducted: one with a Technical & Maintenance Manager at PT Elnusa Petrofin and another with a staff member from the same department. These interviews aimed to gain insights into operational challenges, such as tanker truck breakdowns and spare parts availability. Complementing the interviews, a literature review was carried out to understand existing distribution strategies and best practices in spare parts logistics. Data collected during this phase includes fuel terminal locations, tanker truck breakdown frequencies, spare parts demand distribution, and shipping costs. This data was subsequently verified to ensure accuracy and reliability before analysis.

Following data collection, the Green Field Analysis (GFA) method is applied using AnyLogistix software. GFA is used to evaluate potential locations for the spare parts distribution center by considering factors such as spare parts demand, transportation costs, and warehouse capacity [11]. In this stage, the software helps assess the geographical distribution of demand and the associated shipping costs. The focus is on determining the most efficient location for the distribution center based on minimizing total transportation costs and ensuring a high level of service to meet demand. The analysis involves evaluating multiple potential locations for the distribution center and selecting the one that optimally balances cost and logistical efficiency.

At the same time, the Center of Gravity (CoG) method is employed to determine the best location based on shipment volume, distances, and transportation costs. The CoG method uses the following formulas to calculate the optimal coordinates of the distribution center [12]:

$$Cx = \frac{\sum ViRiXi}{\sum ViRi} \quad (1)$$

$$Cy = \frac{\sum ViRiXy}{\sum ViRi} \quad (2)$$

Where :

Vi	:	Shipping frequency
Ri	:	Shipping cost
Xi	:	X-coordinate of the location
Yi	:	Y-coordinate of the location
Cx	:	New X-coordinate of the distribution center
Cy	:	New Y-coordinate of the distribution center

The results from both the GFA and CoG methods are combined to determine the most optimal location for the distribution center, considering both logistical efficiency and cost reduction. Finally, conclusions and recommendations are drawn to improve the operational performance of spare parts distribution, reduce repair delays, and minimize tanker truck downtime.

3. RESULTS AND DISCUSSIONS

This analysis aims to determine the optimal location for the spare parts warehouse center to improve PT Elnusa Petrofin's tanker distribution and maintenance operations. Given the wide geographical spread of the company's operational area, it is imperative to identify a location that can minimize shipping time and transportation costs and ensure timely availability of spare parts for maintenance. Using a combination of Green Field Analysis (GFA) and Center of Gravity (CoG) methods, potential locations were evaluated based on factors such as proximity to fuel terminals, transportation costs, and demand for spare parts. The table below presents data regarding customer locations and the number of parts shipped, including the longitude and latitude of each. This data was used to identify the most strategic location for the warehouse center, ensuring the best logistical advantage for PT Elnusa Petrofin.

Table 1. Fuel Terminal Location & Shipping Frequency

Customer	Code	Longitude (Xi)	Latitutude (Yi)	Frequency (Vi)
FT Ende	C1	121.662889801325	-8.852537679962	79

FT Reo	C2	120.450705118521	-8.283779304332	335
FT Maumere	C3	122.266595795768	-8.636332452761	20
FT Tenau	C4	123.529835626441	-10.195173408542	67
FT Waingapu	C5	120.248920592064	-9.641734470383	6

3.1 Green Field Analysis – Anylogistix

After determining the latitude and longitude for consumer data and spare parts data along with the total demand, the data will then be processed using AnyLogistix software in the green field analysis section. The distribution network obtained based on the input data is as follows.

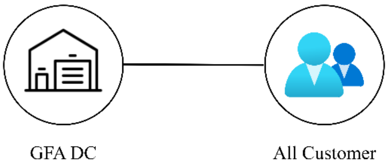

Figure 1. Distribution Network

Based on the experiments that have been carried out, the results of the new hub location are located at latitude -8.8527219759 and longitude 121.6625537826 or more precisely in the Tetandara area, Ende Regency, East Nusa Tenggara as shown in Figure 2.

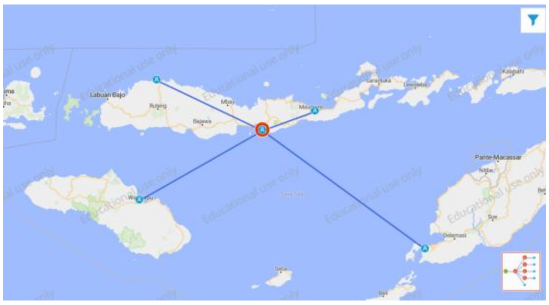

Figure 2. Green Field Analysis Result

The experimental results obtained are results that have considered two main things, namely the location point or distribution distance to be traveled and how much demand for spare parts from consumers. In addition, in this experiment, a straight line is also used for the distribution process because it is located on three different islands so that later it is necessary to consider the use of multiple modes of transportation for each route passed.

3.2 Center of Gravity

To find the optimal location using this method, the first step is to determine the coordinates along with the transportation cost and delivery frequency. These data can be seen in the following table.

Table 2. Destination Coordinates, Transportation Costs and Delivery Frequency

Customer	Coordinates		Shipping Rates (Ri)	Frequency (Vi)
	x	y		
FT Ende	-8.852537679962	121.662889801325	IDR 74,000	79
FT Reo	-8.283779304332	120.450705118521	IDR 94,500	335
FT Maumere	-8.636332452761	122.266595795768	IDR 84,000	20
FT Tenau	-10.195173408542	123.529835626441	IDR 72,000	67
FT Waingapu	-9.641734470383	120.248920592064	IDR 78,000	6

Source : Primary Data (2024)

Once the coordinates and demand frequency for each terminal are known, the next step is to compute the weighted X and Y coordinates based on the formula:

$$Cx = \frac{\sum ViRiXi}{\sum ViRi} \quad (1)$$

$$Cy = \frac{\sum ViRiXy}{\sum ViRi} \quad (2)$$

The results of this calculation are shown in **Table 3.**

Table 3. Weighted Coordinate Calculations for Center of Gravity Method

Customer	ViRiXi	ViRiYi	ViRi
FT Ende	- 51,751,935.28	711,241,253.78	5,846,000.00
FT Reo	-262,243,743.33	3,813,168,197.29	31,657,500.00
FT Maumere	-14,509,038.52	205,407,880.94	1,680,000.00
FT Tenau	-49,181,516.52	595,907,927.06	4,824,000.00
FT Waingapu	-4,512,331.73	56,276,494.84	468,000.00
Total	-382,198,565.38	5,382,001,753.90	44,475,500.00

Source : Result Data (2024)

Based on these calculations, the optimal coordinates for the spare parts hub using the Center of Gravity method are:

$$Cx = \frac{-382{,}198{,}565.38}{44{,}475{,}500.00} = \text{-}8.593463039 \quad (1)$$

$$Cy = \frac{5{,}382{,}001{,}753.90}{44{,}475{,}500.00} = 121.0104834 \quad (2)$$

These coordinates represent the ideal central point that minimizes the weighted transportation distance and cost, taking into account delivery frequency and shipping rates for each terminal.

After calculating using the center of gravity method, the potential location for hub construction is obtained at the point (-8.59346303874142, 121.010483387574) located in the Denatana area, Ngada Regency, East Nusa Tenggara. The results of using this method are obtained based on the calculation of three main components, namely the location point using x coordinates and y coordinates, shipping costs and frequency so that it is quite accurate if the company wants to determine a new location at minimum cost. For the exact location can be seen in Figure 4.4.

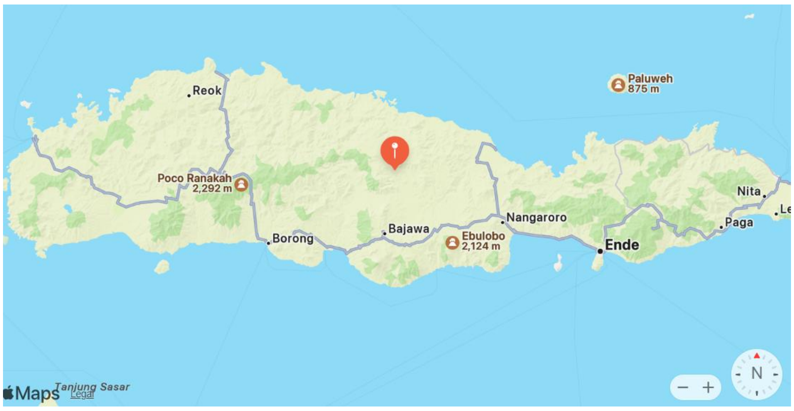

Figure 3. Center of Gravity Result

3.3 Distribution Cost Comparison

After obtaining a new hub location using anylogistix software and the center of gravity method, it is necessary to calculate the total distribution costs incurred for shipping goods from the new hub location to the fuel terminal location as a consumer. The calculation of distribution costs can be seen in the tables below.

Table 4. Distribution Cost Hub Ende – Green Field Analysis

Customer	Frequency (Vi)	Shipping Rates (Ri)	Total Cost
FT Ende	79	IDR 0	IDR 0
FT Reo	335	IDR 46,000	IDR 15,410,000
FT Maumere	20	IDR 38,000	IDR 760,000
FT Tenau	67	IDR 34,000	IDR 2,278,000
FT Waingapu	6	IDR 53,000	IDR 318,000
Total	507	IDR 171,000	IDR 18,766,000

Source : Result Data (2024)

Table 5. Distribution Cost Hub Ngada – Center of Gravity

Customer	Frequency (Vi)	Shipping Rates (Ri)	Total Cost
FT Ende	79	IDR 68,500	IDR 5,411,500
FT Reo	335	IDR 76,000	IDR 25,460,000
FT Maumere	20	IDR 76,000	IDR 1,520,000
FT Tenau	67	IDR 39,500	IDR 2,646,500
FT Waingapu	6	IDR 75,500	IDR 453,000
Total	507	IDR 335,500	IDR 35,491,000

Source : Result Data (2024)

Table 6. Total Cost Comparison

Customer	**Total Cost**		
	Existing	**Hub Ende**	**Hub Ngada**
FT Ende	IDR 5.846.000,00	IDR -	IDR 5,411,500
FT Reo	IDR 31.657.500,00	IDR 15,410,000	IDR 25,460,000
FT Maumere	IDR 1.680.000,00	IDR 760,000	IDR 1,520,000
FT Tenau	IDR 4.824.000,00	IDR 2,278,000	IDR 2,646,500
FT Waingapu	IDR 468.000,00	IDR 318,000	IDR 453,000
Total	IDR 44.475.500,00	IDR 18,766,000	IDR 35,491,000

Source : Result Data (2024)

The data in Table 6. shows a comparison of shipping costs that must be incurred by the company. From a cost-saving perspective, Tetandara offers the most substantial advantage. As shown in the cost simulation, direct shipping from Jakarta to all five terminals currently costs approximately IDR 44,475,500. Establishing a hub in Ende District could reduce this cost to IDR 18,766,000, representing a 57.80% reduction. In contrast, the Ngada-based hub scenario offers a more modest savings of 20.20%, lowering the cost to IDR 35,491,000. However, the CoG result (Ngada) places the hub in a more central position relative to the five terminals, which may result in more balanced travel distances in the long term, especially if delivery volumes change or expand. This raises a trade-off between immediate cost savings (Ende) and geographical centrality with potential long-term scalability (Ngada).

Additionally, other non-cost factors must be considered. Infrastructure readiness, road access, proximity to ports, and local policy environments could either support or hinder hub performance. For instance, Ende is already a fuel terminal location, which may simplify administrative and logistical integration. Meanwhile, Ngada's less congested location may offer flexibility for future expansion or inter-island connections.

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4. CONCLUSION

This research identified through two methods. The first method is Green Field Analysis (GFA) and the second one is Center of Gravity (CoG). The GFA method identified Tetandara in Ende District as the most cost-efficient option, offering potential transportation savings of 57.80%. In comparison, the CoG method pointed to Denatana in Ngada District, which, while more centrally located, provides a lower cost reduction of 20.20%. These findings suggest that Ende is the more financially advantageous location. However, a well-informed decision should go beyond cost considerations alone. Factors such as infrastructure readiness, regulatory environment, and long-term operational risks must be evaluated to ensure sustainable performance. To support this, the use of simulation tools like AnyLogistix and a multi-criteria decision analysis is recommended. This would enable PT Elnusa Petrofin to account for real-world uncertainties—such as disruptions, demand variability, and routing changes—ensuring that the chosen hub location supports both efficiency and resilience across the supply chain.

5. RECOMMENDATION

This study has several limitations that should be acknowledged. One key limitation is the use of straight-line (Euclidean) distances to determine the optimal hub location. This method tends to oversimplify actual transportation conditions in East Nusa Tenggara, a region characterized by complex geography, including dispersed islands and varied infrastructure quality. Furthermore, the current analysis does not account for multimodal transportation options, such as the integration of sea and land freight, which are essential for effective logistics across island chains. As a result, the estimated transportation costs and hub efficiency may not fully reflect real-world operational constraints.

To enhance the accuracy and applicability of future studies, it is recommended that researchers incorporate detailed transportation network data, including road conditions, port accessibility, and logistical constraints such as travel times and delivery schedules. The use of advanced simulation tools to model multimodal logistics scenarios—involving both sea and land transportation—would provide more realistic insights into hub placement and supply chain performance. This approach would lead to more robust and practical recommendations, especially for companies like PT Elnusa Petrofin operating in geographically challenging regions.

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