Published Online on Journal Page: https://journal.uvers.ac.id/index.php/greeners
Journal of Green Engineering for Sustainability
ISSN (Online) 3025-6895

Optimization of Fuel Distribution in Bengkulu Using Analytical Network Process and the CF-RS Method

Muhamad Yasin[a], Rama Dani Eka Putra[b], Tessa Zulenia Fitri[c], Nia Arfina Foci[d], M. Arif Munanda[e]*

[a,b,c,d,e] *Industrial Engineering Program, Faculty of Engineering, University of Bengkulu, Bengkulu City, Indonesia 38122*

ARTICLE INFORMATION

Received 20 Juli 2025
Received in revised form 23 September 2025
Available Online 30 September 2025

KEYWORDS

fuel distribution
analytical network process
cluster first route second method

CORRESPONDENCE

Telp: 085745713802
E-mail: muhamad.yasin@unib.ac.id

A B S T R A C T

Fuel scarcity in Bengkulu Province has occurred in the last few days. In fact, prices at the retail level have soared to Rp30,000 per liter. This study aims to provide solutions to the fuel distribution problems in Bengkulu that have been explained previously and provide optimal solutions using the Analytical Network Process Method and the Cluster First Route Second (CFRS) Method. so that the determination of the closest route is Tank Truck 11 with the route Lubuklinggau Fuel Terminal - Gas Station 6 Bengkulu City - Lubuklinggau Fuel Terminal with a distance of 234 KM and the farthest route is Lubuklinggau Fuel Terminal - Gas Station 11 - Gas Station 3 - Lubuklinggau Fuel Terminal.

1. INTRODUCTION

PT Pertamina Patra Niaga stated that the recent shortage of fuel (BBM) in Bengkulu Province over the past few days was caused by distribution disruptions. Retail fuel prices also surged drastically, reaching IDR 30,000 per liter. Heppy Wulansari, Corporate Secretary of Pertamina Patra Niaga, explained that this shortage occurred due to the shallowing of the access channel to the Pulau Baai Port dock. This condition prevented fuel transport ships from docking, thereby hindering the supply to the Bengkulu Fuel Terminal. According to Heppy, the shallowing issue has been ongoing since April, and so far, no dredging efforts have been carried out by the relevant authorities [1].

He also mentioned that, as an effort to address the situation and ensure fuel reaches the people of Bengkulu, Pertamina has implemented various measures and accelerations. One of these measures is redirecting fuel supply from the Lubuk Linggau Fuel Terminal and Teluk Kabung Fuel Terminal, as well as increasing supply from the Panjang-Lampung Fuel Terminal. "Although the travel distance from these alternative supply points is longer and quite challenging, Pertamina remains committed to ensuring fuel distribution for the people of Bengkulu continues," Heppy added. The round-trip distance from the Teluk Kabung Fuel Terminal to the Panjang Terminal is nearly 26 hours. Additionally, the company has added 11 tanker trucks. Service hours at the Lubuk Linggau, Teluk Kabung, and Lampung Fuel Terminals have also been extended. Moreover, Pertamina has increased fuel distribution via rail with assistance from PT KAI (Persero). Heppy hopes that dredging of the Pulau Baai port or dock will soon be carried out by the relevant authorities so that fuel supply to the people of Bengkulu can return to normal. "We understand this situation is difficult for the people of Bengkulu, but we continue to make every effort to fulfill their fuel needs," he emphasized.

The reason this research is conducted is to provide a scientific contribution to the problems occurring in the field. Furthermore, this study aims to offer solutions to the previously outlined fuel distribution issues in Bengkulu and to provide optimal solutions using the Analytical Network Process (ANP) method and the Cluster First Route Second (CF-RS) method. The Analytic Network Process (ANP) method is a knowledge-based approach for multi-criteria selection developed from the Analytic Hierarchy Process (AHP), which allows for interconnections and interactions between elements within the system. Meanwhile, the Cluster First Route Second (CF-RS) method is an approach for solving Vehicle Routing Problem (VRP) issues by first grouping customers and then determining routes for each group. This process breaks the VRP into two simpler stages: clustering and route assignment.

The Analytical Network Process (ANP) method and the Cluster First Route Second (CF-RS) method are two different approaches for decision-making problems. ANP is a decision-making method that considers dependencies among various elements (criteria, sub-criteria, etc.) within a network, while CF-RS is a method used for route optimization, particularly in Vehicle Routing Problems (VRP). This research is highly significant in a broader context, both theoretically and practically.

2. LITERATURE REVIEW

2.1. *Analytical Network Process (ANP)*

The Analytic Network Process (ANP) is an extension of the Analytic Hierarchy Process (AHP) method developed by Thomas L. Saaty in 1996. This study uses the ANP method, which is capable of considering the relationships among criteria or alternatives. In the ANP method, there are two types of relationships: relationships within a single group of elements (inner dependence) and relationships among different elements (outer dependence). ANP is used for multi-criteria decision-making by taking into account the dependencies and feedback among elements within a system. Unlike AHP, which is hierarchical and linear, ANP accommodates more realistic complex relationships through a network model [2].

2.1.1. Stages of ANP

A third-level heading follows the style of the second-level heading. Avoid using headings deeper than three levels. ANP consists of four main steps: (1) modeling the problem in the form of a network, (2) pairwise comparison among elements, (3) supermatrix, and (4) synthesis and analysis of results. The supermatrix is a key element in ANP, representing the relative influence among elements in matrix form, and consists of the unweighted, weighted, and limit supermatrix [3].

2.1.2. Benefits and Advantages of ANP

According to Meade and Sarkis (1999), ANP is very useful in decision-making involving interdependent criteria, such as technology selection, supplier evaluation, and supply chain management. ANP has also been applied in various fields such as project management, public policy, transportation planning, and risk assessment [4].

The advantage of ANP lies in its ability to handle complex and dynamic relationships among elements, although its drawback is the complexity of the calculation process and the need for supporting software such as Super Decisions [5]. Nevertheless, the flexibility and richness of information obtained from ANP make it a powerful tool for comprehensive decision-making. In this study, the ANP method is used to determine the primary priority roads that need repair based on road service level variables and other supporting factors.

2.2. *Cluster First, Route Second (CF-RS)*

The Cluster First, Route Second (CF-RS) approach is a problem-solving strategy in route optimization, particularly for distribution issues such as the Vehicle Routing Problem (VRP). This strategy operates in two main stages: first, grouping (clustering) destination points or customers based on certain criteria; second, designing the optimal route for each cluster [6]. According to Caplice, the cluster first route second strategy is used to simplify the problem by creating groups so that destination points can be collected within a single group, making the calculation process easier and faster.

2.2.1. Benefits and Applications of CF-RS

This method is widely used due to its simplicity and efficiency in reducing the complexity of large routing problems. In the clustering stage, popular techniques include the Sweep Algorithm (Gillett & Miller, 1974), K-Means Clustering (MacQueen, 1967), and Density-Based Spatial Clustering (DBSCAN). After clusters are formed, the routing stage is carried out using algorithms such as Nearest Neighbor, Genetic Algorithm, or Ant Colony Optimization [7].

According to Osman and Christofides (1994), this approach is particularly suitable for cases with a large number of geographically dispersed customer points. By dividing a large problem into smaller sub-problems (through clustering), the solution search becomes more manageable. However, this approach has a drawback: it may produce globally sub-optimal solutions because clusters are determined before the optimal routes are identified [8].

In practice, the Cluster First, Route Second approach is widely applied in logistics systems, goods distribution planning, food delivery, and school transportation scheduling [9]. It is also often used as a baseline for developing heuristic and metaheuristic algorithms for VRP and its variations.

3. METHODOLOGY

The stages involved in the research, concept development, or case resolution are described in the methodology section.

3.1. *Analytical Network Process (ANP) Methodology*

To select the best distribution route for PT Pertamina Patra Niaga, clear steps are required, forming part of this research methodology. These steps begin with identifying the decision-makers within the company. The decision-makers are individuals who thoroughly understand the characteristics of each distribution route and know which criteria are suitable for the company. In this study, the decision-makers referred to are the Managers.

After identifying the decision-makers, the next stage is to determine the criteria and sub-criteria used as considerations in selecting distribution routes in Bengkulu. This identification process is conducted through interviews with the Managers. Additionally, to support the identification of criteria and sub-criteria, a literature review is also performed. To ensure the research is well-directed, various steps are followed in the research procedure. The research process conducted can be seen in Figure 1.

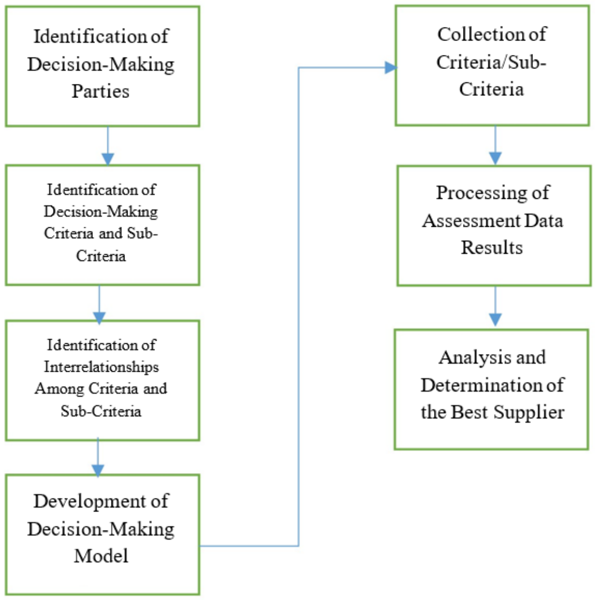

Figure 1. Research Procedure Steps

In the data processing stage, several steps are carried out step by step using the ANP method. This produces analyses and conclusions that must be addressed first. The information is presented along with data details and mapping [10].

4. RESULTS AND DISCUSSION

4.1. *Results of Analytical Network Process (ANP) Discussion*

In the previous literature review, the stages of the Analytical Network Process (ANP) have already been explained. However, before presenting the results and discussion, it is necessary to identify the target market or customers as the goal, in this case, the gas stations (SPBU) in Bengkulu city. The following table lists the SPBUs along with their addresses:

Table 1. List of SPBUs and Addresses in Bengkulu City

No	Kode SPBU	Alamat SPBU
1	SPBU 21.38109	Jl. Kalimantan Rawa Makmur, Kota Bengkulu
2	SPBU 23.38207	Jl. RE Marthadinata, Kota Bengkulu
3	SPBU 23.38225	Jl. Putri Gading Cempaka, Kota Bengkulu
4	SPBU 24.38101	Jl. Bali Kel. Kampung Kelawi, Kota Bengkulu
5	SPBU 24.38202	Jl. S. Parman, Padangjati, Kota Bengkulu
6	SPBU 24.38203	Jl. Air Sebakul, Kota Bengkulu
7	SPBU 24.38204	Jl. P. Natadirja NO.1 Km.8, Kota Bengkulu
8	SPBU 24.38205	Jl. MERAPI PANORAMA, Kota Bengkulu
9	SPBU 24.38216	Lokasi Betungan, Kota Bengkulu
10	SPBU 24.38219	Jl. Depati Payung Negara No.31, Kota Bengkulu
11	SPBU 24.38220	Jl.Pangeran Natadirja, Kota Bengkulu
12	SPBU 24.38226	Jl. RE Martadinata RT.34/06, Kota Bengkulu

4.2. *Problem Modeling and Cluster First*

This section explains the initial stage in the Analytical Network Process (ANP), namely problem modeling and pairwise comparison among elements, while also determining the Cluster First in the CF-RS Method. The following figure shows the network diagram for the distribution problem modeling. In the diagram, it is identified that the fastest distribution route is from the Lubuk Linggau Fuel Terminal to the gas stations (SPBU) in Bengkulu City. The next step is to determine the Route Second with the most optimal route and distance.

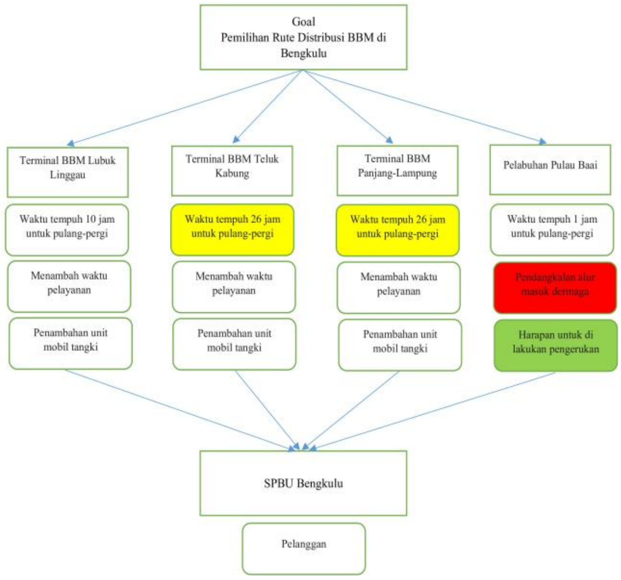

Figure 2. Distribution Problem Modeling Network

The identification of these criteria is derived from the Introduction, which explains the field problems. These problems are then represented in the form of a diagram, as shown in Figure 2, with the aim of making it easier for readers to identify the issues in this study.

From the figure, the criteria used to evaluate each alternative can be identified from the boxes containing the consideration factors. These criteria include:

1. **Travel time**
   a. Lubuk Linggau Fuel Terminal – Bengkulu SPBU: 10 hours (round trip)
   b. Teluk Kabung Fuel Terminal – Bengkulu SPBU: 26 hours (round trip)
   c. Panjang Lampung Fuel Terminal – Bengkulu SPBU: 10 hours (round trip)
   d. Pulau Baai Port – Bengkulu SPBU: 1 hour (round trip)
2. **Additional service time**
   a. Extended operational hours of terminals and SPBUs
   b. Increased distribution fleet
   c. Monitoring and supervision by relevant authorities
   d. Improving supply and distribution
3. **Additional tanker costs**
   a. Rental prices and leasing contracts
   b. Fleet availability and efficiency
   c. Infrastructure and weather conditions
   d. Infrastructure and weather conditions
4. **Infrastructure conditions**
   Pulau Baai Port faces challenges: channel shallowing at the pier entrance (risky, marked in red) and the expectation for dredging (marked in green).

In other words, the criteria can be explained and identified from the information in the boxes under each distribution route alternative (such as travel time, cost, service, and infrastructure conditions).

4.3. *Analysis of Route Second Results*

To ensure smooth and efficient distribution activities, the company requires a clear sequence in determining transportation routes. The determination of these routes can be carried out using the Savings Matrix method. This method calculates distances and determines the appropriate routes, time, and costs involved in delivering products from the depot to various terminals. At this stage, Route Second is solved using the Savings Matrix method to determine efficient and optimal routes by maximizing vehicle capacity with the goal of reducing distribution costs [11–14].

Table 2 shows the distances between Lubuk Linggau Fuel Terminal, the fastest distributor to the SPBUs in Bengkulu City as explained earlier, with all SPBUs and the distances between SPBUs in kilometers, as well as the order quantities in liters for each SPBU.

Table 3 contains the results of the Savings Matrix calculations. The purpose is to determine the best distribution route by minimizing travel distance and transportation costs using the formula:

$$\mathbf{S(x,y) = J(x,0)+J(0,y)-J(x,y)}$$

Table 4 presents the determined route results, noting that there are 11 fuel tanker trucks, each with a capacity of 10,000 liters. The order data for each customer or SPBU is listed in Table 2. The smallest order is SPBU 6 with 143 liters, while the largest order is SPBU 1 with 972 liters.

Table 2. Order Data for Each Customer

Customer	**Order Quantity**
SPBU 1	972
SPBU 2	271
SPBU 3	402
SPBU 4	469
SPBU 5	312
SPBU 6	143
SPBU 7	703
SPBU 8	291
SPBU 9	367
SPBU 10	266
SPBU 11	509
SPBU 12	266

Table 3. List of Distances Between Lubuk Linggau Fuel Terminal and SPBUs with Order Quantities

Customer	**BBM LL**	**SPBU 1**	**SPBU 2**	**SPBU 3**	**SPBU 4**	**SPBU 5**	**SPBU 6**	**SPBU 7**	**SPBU 8**	**SPBU 9**	**SPBU 10**	**SPBU 11**	**SPBU 12**	**Order**
SPBU 1	122	0												972
SPBU 2	139	17	0											271
SPBU 3	146	6,6	6,8	0										402
SPBU 4	120	2,8	13	3,6	0									469
SPBU 5	121	6,6	10	2,7	2,9	0								312
SPBU 6	117	17	14	12	15	12	0							143
SPBU 7	124	11	6,8	4,3	7,9	6,4	6,5	0						703
SPBU 8	119	7,2	8,8	4,1	4,8	3,2	8,4	4,1	0					291
SPBU 9	132	18	8,1	14	15	13	6,9	7,6	10	0				367
SPBU 10	118	17	4,3	9,7	11	8,1	4,9	3,4	5,7	4,7	0			266
SPBU 11	141	9,6	5,5	6,5	7,9	4	7,9	2,6	4,1	8,6	4,9	0		509
SPBU 12	138	13	2,5	9,1	12	9,1	5,9	5,2	6,9	6,6	6,3	6,8	0	266

The general formula to calculate the saving value between two points (for example, SPBU x and SPBU y) with the Fuel Terminal (distribution center) is:

$$S(x,y) = J(x,0)+J(0,y)-J(x,y)$$

with the following explanation:

Sxy = saving value (distance/cost savings) if the route is 0 → x → y → 0, compared to separate routes 0 → x → 0 and 0 → y → 0.

Jx,0 = distance from Fuel Terminal (0) to customer x.

J0,y = distance from Fuel Terminal (0) to customer y.

Jx,y = direct distance between customer x and customer y.

Thus:

Distance from Fuel Terminal to SPBU 1: J1,0 = 122

Distance from Fuel Terminal to SPBU 2: J2,0 = 139

Distance from SPBU 1 to SPBU 2: J1,2 = 17, and so on.

Therefore, the saving matrix calculation result for customer 1 and customer 2 is:

$$S_{1,2} = 122 + 139 - 17 = 244$$

This means there is a saving of 244 if SPBU 1 and SPBU 2 are combined into a single route. The following Table 4 shows the Saving Matrix calculation results for all routes from SPBU 1 to SPBU 12.

Table 4. Saving Matrix Calculation Results

Customer	SPBU 1	SPBU 2	SPBU 3	SPBU 4	SPBU 5	SPBU 6	SPBU 7	SPBU 8	SPBU 9	SPBU 10	SPBU 11	SPBU 12
SPBU 1	0											
SPBU 2	244	0										
SPBU 3	261,4	278,2	0									
SPBU 4	239,2	246	262,4	0								
SPBU 5	236,4	250	264,3	238,1	0							
SPBU 6	222	242	251	222	226	0						

SPBU 7	235	256,2	265,7	236,1	238,6	234,5	0					
SPBU 8	233,8	249,2	260,9	234,2	236,8	227,6	238,9	0				
SPBU 9	236	262,9	264	237	240	242,1	248,4	241	0			
SPBU 10	223	252,7	254,3	227	230,9	230,1	238,6	231,3	245,3	0		
SPBU 11	253,4	274,5	280,5	253,1	258	250,1	262,4	255,9	264,4	254,1	0	
SPBU 12	247	274,5	274,9	246	249,9	249,1	256,8	250,1	263,4	249,7	272,2	0

Next, the delivery groups are determined using the 11 fuel tanker trucks mentioned in the Introduction. This is done by ranking the Saving Matrix results from the highest to the lowest value. Then, the 12 SPBUs are grouped into 11 groups to match the 11 tanker trucks, referred to as rankings from 1 to 11.

For Ranking 1, the highest Saving Matrix value is 280.5, which is between SPBU 3 and SPBU 11, as shown in Table 4. These two SPBUs are placed in Ranking 1 with the route: Fuel Terminal Lubuk Linggau → SPBU 11 → SPBU 3 → back to Fuel Terminal Lubuk Linggau. The total distance is 293.5 km, calculated by summing the distances in Table 3.

(BBM LL – SPBU 11) + (SPBU 11 – SPBU 3) + (SPBU 3 – BBM LL) = 141+6.5+146=293.5

This process continues for Rankings 1 through 11, and the resulting routes and distances are presented in Table 5.

Table 5. Route Determination

Level	Rute	Distance/ KM
1	BBM LL - SPBU 11 - SPBU 3 - BBM LL	293,5
2	BBM LL - SPBU 2 - BBM LL	278
3	BBM LL - SPBU 12 - BBM LL	276
4	BBM LL - SPBU 7 - BBM LL	248
5	BBM LL - SPBU 9 - BBM LL	264
6	BBM LL - SPBU 5 - BBM LL	242
7	BBM LL - SPBU 4 - BBM LL	240
8	BBM LL - SPBU 1 - BBM LL	244
9	BBM LL - SPBU 8 - BBM LL	238
10	BBM LL - SPBU 10 - BBM LL	236
11	BBM LL - SPBU 6 - BBM LL	234

5. CONCLUSION

In this study, the Analytical Network Process (ANP) method produced a problem modeling network, and the problem was solved using the Cluster First – Route Second (CF-RS) Method. The next step in determining Cluster First resulted in the fastest fuel delivery route to Bengkulu City in the event of issues at Pulau Baai Port, which is via the Lubuk Linggau Fuel Terminal, with a round-trip travel time of approximately 10 hours.

After obtaining the Cluster First results, the next step is to determine the Route Second, in this case using the Savings Matrix Method, with the aim of achieving optimal, efficient, and effective distribution routes. Based on the introduction description, 11 tanker trucks with a capacity of 10,000 liters each were assigned to distribute fuel to 12 SPBUs in Bengkulu City. This resulted in the determination of the closest route, which is Tanker Truck 11 with the route: Lubuk Linggau Fuel Terminal → SPBU 6 Bengkulu → Lubuk Linggau Fuel Terminal, covering a distance of 234 km, and the longest route being Lubuk Linggau Fuel Terminal → SPBU 11 → SPBU 3 → Lubuk Linggau Fuel Terminal.

REFERENCE

[1] M. R. Hidayatullah, "Pertamina Ungkap Penyebab BBM di Bengkulu Langka," *Bisnis.com*, 27 Mei 2025. [Online]. Available: https://ekonomi.bisnis.com/read/20250527/44/1880437/pertamina-ungkap-penyebab-bbm-di-bengkulu-langka

[2] T. L. Saaty, *Decision Making with Dependence and Feedback: The Analytic Network Process*. RWS Publications, 1996.

[3] T. L. Saaty and L. G. Vargas, *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process*. Springer, 2001.

[4] J. L. Yang and D. S. Chang, "Integrating the ANP and TOPSIS for selecting the optimal outsourcing strategy," *Journal of Global Business Management*, vol. 4, no. 2, pp. 114–122, 2008.

[5] T. L. Saaty, *Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs, and Risks*. RWS Publications, 2005.

[6] G. Laporte, M. Gendreau, J.-Y. Potvin, and F. Semet, "Classical and modern heuristics for the vehicle routing problem," *International Transactions in Operational Research*, vol. 7, no. 4–5, pp. 285–300, 2000.

[7] B. Golden, S. Raghavan, and E. Wasil, Eds., *The Vehicle Routing Problem: Latest Advances and New Challenges*. Springer, 2008.

[8] I. H. Osman and N. Christofides, "Capacitated clustering problems by hybrid simulated annealing and tabu search," *International Transactions in Operational Research*, vol. 1, no. 3, pp. 317–336, 1994.

[9] P. Toth and D. Vigo, *The Vehicle Routing Problem*. SIAM, 2002.

[10] D. B. Pailin and F. M. Kaihatu, "Implementasi Metode Saving Matrix Dalam Penentuan Rute Terbaik Untuk Meminimumkan Biaya Distribusi," *ARIKA*, vol. 12, no. 2, Aug. 2018.

[11] B. S. Kusnadia and W. A. S., "Implementasi Metode Analytic Network Process Untuk Penentuan Prioritas Penanganan Jalan Berdasarkan Tingkat Pelayanan Jalan," *Jurnal Sistem Informasi Bisnis*, vol. 6, no. 2, pp. 105–113, 2016, doi: 10.21456/vol6iss2pp105-113.

[12] K. A. M. and A. E., "Penentuan Jalur Distribusi Gas LPG dengan Metode Savings Matrix dan Nearest Neighbor pada PT. XYZ," *Jurnal Rekayasa Industri (JRI)*, 2022.

[13] S. A. T., B. P., and E. N., "Penerapan Metode Saving Matrix Dalam Meminimumkan Biaya Distribusi," *Buletin*

Ilmiah Math. Stat. dan Terapannya (Bimaster), vol. 13, no. 4, pp. 543–552, 2024.

[14] I. M. J. A. and O. S. S., "Aplikasi Metode Analytical Network Process (ANP) Dalam Penentuan Prioritas Pengembangan Lanal (Pangkalan TNI AL) Menjadi Lantamal (Pangkalan Utama TNI AL)," 2017. [Online]. Available: https://sttal.ac.id/wp-content/uploads/2017/05/JURNAL-materi-3

[15] J. Sutrisno, J. A. Jauhari, and P. Audi, "Business Process Improvement Rute Distribusi Menggunakan VRP dengan Pendekatan Strategi Cluster First Route Second (Studi kasus CV Bintang Globalindo Karawang)," vol. VIII, no. 2, pp. 5543–5552, Apr. 2023.