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GIS-Based Optimization for Gas Distribution Route Design: A Case Study of PT Gagas Energi Indonesia

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Abstract

PT Gagas Energi Indonesia is a company engaged in the trading and natural gas business, one of which is Gaslink C-Cyl. Route determination for Gaslink C-Cyl distribution is carried out subjectively based on the proximity of locations between customers, thus creating inefficient routes, affecting the number of vehicles needed, and causing high transportation costs. Based on this problem, this study aims to minimize transportation costs by determining the optimal route and number of vehicles needed using the Multi-Trip Vehicle Routing Problem Time Windows Simultaneous Pickup and Delivery (MTVRPTW-SPD). This problem is solved using Geographic Information System (GIS) based optimization. To evaluate GIS-based optimization performance, comparison between existing condition and optimization are done for 50 demand points. Then, two scenario was developed, 100 and 200 demand points to explain the decision implication related to demand uncertainty. Based on the optimization process for 50 demand points gives better solution than existing condition in term of number of fleets needed, total distance travelled, and total transportation cost which result 3 units, 46,5%, and 43,5% respectively.
imasi Berbasis GIS untuk Perancangan Rute Distribusi Gas Bumi: Studi Kasus di PT Gagas Energi In
Keywords: *Transportation Cost, Gas Distribution, GIS-Based Optimization, MTVRPTW-SPD, Route Design*

Abstrak

PT Gagas Energi Indonesia merupakan perusahaan yang bergerak dalam usaha niaga dan gas bumi, salah satunya adalah Gaslink C-Cyl. Penentuan rute untuk distribusi Gaslink C-Cyl dilakukan secara subyektif yang didasarkan pada kedekatan lokasi antar pelanggan, sehingga menciptakan rute yang tidak optimal, mempengaruhi jumlah kendaraan yang dibutuhkan, dan menyebabkan tingginya biaya transportasi. Berdasarkan hal tersebut, penelitian ini bertujuan untuk meminimasi biaya transportasi dengan menetapkan rute dan jumlah kendaraan yang optimal menggunakan *Multi Trip Vehicle Routing Problem Time Windows Simultaneous Pickup and Delivery* (MTVRPTW-SPD). Permasalahan ini diselesaikan menggunakan optimasi berbasis Geographic Information System (GIS). Untuk menunjukkan kinerja hasil optimasi berbasis GIS, dilakukan perbandingan antara kondisi eksiting dan hasil optimasi untuk 50 titik permintaan. Kemudian dikembangkan dua skenario, yakni dengan 100 dan 200 titik permintaan untuk menunjukkan implikasi keputusan terhadap ketidakpastian permintaan. Berdasarkan hasil optimasi untuk 50 titik permintaan didapatkan hasil yang lebih baik dibandingkan kondisi eksisting ditinjau dari sisi jumlah kendaraan yang dibutuhkan, total jarak tempuh, dan total biaya transportasi, dimana masing-masing mengalamani penurunan sebesar 3 unit, 46,5%, dan 43,5% secara berturut-turut.

Kata kunci: Biaya Transportasi, Distribusi Gas, Optimasi berbasis GIS, MTVRPTW-SPD, Penentuan Rute

Introduction

Distribution process is a complex problem because it involves several parties, source (depot) and several destinations. The more nodes- both depot and destinations will affect the performance of distribution. It can be total distance travelled, distribution cost, or etc. PT Gagas Energi Indonesia is a subsidiary of Pertamina Gas Negara (PGN), which is engaged in trading and natural gas, one of which is Gaslink C-Cyl. Gaslink C-Cyl, which contains CNG gas, is distributed to customers; empty Gaslink C-Cyl cylinders will first be filled with CNG gas at the nearest Gas Refueling

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Station (SPBG) from the customer's area. Figure 1 shows that one of the SPBGs with the highest utilization each year is the Klender SPBG (Depot) which is one of the gas suppliers for the DKI Jakarta area. Based on this, the Klender SPBG is a case study of this research because it has the most potential number of potential Gaslink C-Cyl customers, as seen from the high utilization of SPBG from year to year compared to other SPBGs.

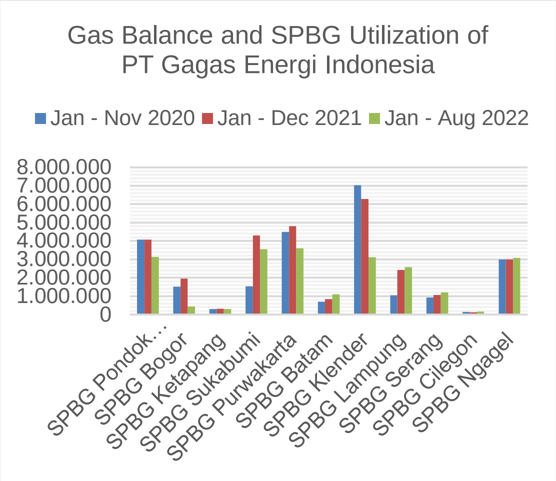

Figure 1. Gas balance and SPBG utilization of PT Gagas Energi Indonesia

In this case, finding the optimum number of vehicles and route are crucial because it will affect the total transportation costs. The transportation costs are affected by number of vehicles used, personnel costs-driver and assistant, and fuel consumption. While in the existing condition, the routes are determined subjectively by considering distance between each customer. This solution does not guarantee the optimality. It causes the number of vehicles rented and the total distance are high.

During the transportation, the delivery and pickup for empty tube are done simultaneously. The vehicles can take several routes as long as they do not violate time windows. Besides, it also considers some restrictions, such as the customers demand must be met, the vehicle capacity, the start and end trip must be at depot. This problem classified as MTVRPTW-SPD. The MTVRPTW-SPD model is combination of MTVRPTW and VRP-SPD. MTVRPTV is extended from VRPTW by allowing multiple trips for vehicles during time horizon (Huang, Li, Zhu, & Qin, 2021) and (Cattaruzza, Absi, & Feillet, 2016). While VRP-SPD is the extension of VRP where the customers have both a pickup and a delivery demand (Koç, Laporte, & Tükenmez, 2020) and (Redi, et al., 2021). In this paper, the term *trip* is used to describe the occasion where a given vehicles leaves the depot to visit customers and return for several times without exceeding the time windows. While the term *route* refers to the sequence of customer visit indicated by a path that a vehicle follows during a trip (Cueto, Gjeroska, Vilalta, & Anjos, 2021).

Based on this problem, this paper aims to determine the optimum distribution routes and number of vehicles used to minimize total transportation cost. To solve this problem, a GIS-based optimization is implemented by adopting MTVRPTW-SPD model. A network analyst tool in GIS is used to design route for CNG distribution. The problem used is based on the real case where the problem is large and based on spatial information.

The gas distribution through cylinder research has been widely studied before. The main characteristic of this problem is pickup and delivery carried out simultaneously and it has been studied by (Singamsetty & Thenepalle, 2021) and (Panicker & Mohammed, 2018). Garside & Laili (2019) implemented Cluster First Route Second (CFRS) heuristics to solve Multi-Trip Periodic Vehicle Routing Problem (MTPVRP). They solved a real case study of Liquefied Petroleum Gas (LPG) distribution to minimize total cost, which is the sum of total vehicle fixed cost and total travelling cost. Yuliza, Puspita, Yahdin, & Emiliya (2020) deal with LPG distribution using hybrid Clarke and Wright Algorithm and LINGO to determine optimum route that provide minimize total distance by implementing Capacitated Vehicle Routing Problem (CVRP).

Many previous research utilized GIS-based optimization method to solve optimization problems include VRP and its variants. ÖZCEYLAN, KOÇ, & ERBAŞ (2018) solve Multi-Trip Heterogeneous Fleet Vehicle Routing Problem (MTHFFVRP) using a GIS-based optimization, based on a tabu search algorithm with a real case of retail chain at Turkey. The results show that GIS-based optimization obtain good results in term of number of fleets, vehicle capacity utilization rate, total distance, total travel time, total en-route time, and computation time for a rich VRP characteristic. (Hashi, Hasan, & Zaman (2016) figure out the school bus routing and scheduling to optimize the overall transportation cost by minimizing the number of fleets and time spent. They

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implement GIS based solution to solve this problem. The GIS based solution provides a better solution compared to the existing semi-manual system. GIS is getting popular to address strategic application where data (spatial and nonspatial) are used as an input. In addition, GIS has more advantages in the collection, analysist, and visualize the data (Krichen, Faiz, Tlili, & Tej, 2014). This makes the data presented more attractive and helps the user to interprets data patterns faster than plain text (Rosita, Falahah, & Sanjaya, 2017). ArcGIS 10.8 software uses Djikstra's shortest algorithm to find the shortest path between two points to create a distance matrix so that it is possible to find solutions faster than other algorithms (Rachmawati & Gustin, 2020). In addition, another algorithm used in ArcGIS 10.8 for Optimization is the tabu search algorithm, which is the most widely used metaheuristic method (Faiz, Krichen, & Inoubli, 2014). This method can work by preventing repetition in each iteration, allowing users to obtain local optimal solutions using tabu lists and neighbor generation in reasonable computing time (Faiz, Krichen, & Inoubli, 2014).

The rest of this paper describes about research methods conducted. It includes mathematical model that represents the problem, the data used and procedure to collect the data, and the steps to do this research. Then, we explain and analyze the results in the result and discussion section. The last, draw the conclusion and give the recommendation for future research are mentioned in the conclusion section.

Methodology

The system under description is a distribution system of LNG cylinder tube that deliver and pick up the product from customers simultaneously. The delivery and pickup are proceeded during the time windows. The vehicles used homogenic. When the delivery and pickup demand exceed the vehicle capacity, the vehicle is allowed to have multi trips as long as within its time windows. In this case, the vehicles will back to depot first to unload the empty cylinder and load the full cylinder to meet the rest of customers' demand. The mathematical model used refers from (Kenaka & Suprayogi, 2021). Here is the complete mathematical model of this problem:

Index:

V : Set of nodes, $V = \{0,1,,\dots,n,n+1\}$
A : Set of arcs
R : Set of routes, $R = \{0,1,2,\dots,R'\}$

Parameters:

ω_1 : Cost per vehicle unit
ω_2 : Cost per distance unit
$\emptyset$: Vehicle capacity
ξ_{ij} : Distance in arc $(i,j) \in A$ $\left(\xi_{0j} = \xi_{i,n+1}\ for\ i,j \in V;\ \xi_{0,n+1} = 0\right)$
τ_{ij} : Travel time on arc $(i,j) \in A$ $\left(\tau_{0j} = \tau_{i,n+1}\ for\ i,j \in V;\ \tau_{0,n+1} = 0\right)$
δ_i : Quantity of delivery demand at node $i \in V$ $(\delta_0 = \delta_{n+1} = 0)$
α_i : Earliest time to start the service at node $i \in V$ (α_0 and α_{n+1} are the opening times for the depot or the lower bounds of the planning period)
β_i : Latest time to start the service at node $i \in V$ (β_0 and β_{n+1} are the closing times for the depot or the upper bounds of the planning period)
γ : Loading time
φ : Unloading time
M : Big positive number

Variables:

X_{ijr} : Binary variable indicating whether arc $(i,j) \in A$ is served by route $r \in R$ or not (note that if $X_{0,n+1,r} = 1$, then route r is empty)
Z_{rs} : Binary variable indicating whether route $r \in R$ is followed immediately by route $s \in R$ or not
T_{ir} : Time to start the service at node $i \in V$ on route $r \in R$
L_r : Loading time at the depot for route $r \in R$
D_{ijr} : Delivery load on arc $(i,j) \in A$ of route $r \in R$
K : Number of vehicles deployed

Objective Function:

$$Minimize$$

$$Z = \omega_1 K + \omega_2 \sum_{i\in V} \sum_{j\in V} \sum_{r\in R} \xi_{ij} X_{ijr} \quad (1)$$

Subject to:

$$\sum_{i\in V\setminus\{0\}} X_{0ir} = 1;\ r \in R \quad (2)$$

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$$\sum_{i \in V\setminus\{n+1\}} X_{i,n+1,r} = 1;\ r \in R \quad (3)$$

$$\sum_{i \in V\setminus\{n+1\}, i \neq h} X_{ihr} = \sum_{j \in V\setminus\{0\}, j \neq h} X_{hjr};\ h \in V\setminus\{0, n+1\};\ r \in R \quad (4)$$

$$T_{ir} + \varphi\delta_i + \tau_{ij} \leq T_{jr} + M\left(1 - X_{ijr}\right);\ i \in V\setminus\{n+1\}, j \in V\{0\},, i \neq j, r \in R \quad (5)$$

$$T_{ir} \geq \alpha_i; i \in V\setminus\{0, n+1\}, r \in R \quad (6)$$

$$T_{ir} \leq \beta_i; i \in V\setminus\{0, n+1\}, r \in R \quad (7)$$

$$T_{0r} \geq \alpha_0;\ r \in R \quad (8)$$

$$T_{0r} + L_r \leq \beta_0;\ r \in R \quad (9)$$

$$T_{n+1,r} \geq \alpha_{n+1};\ r \in R \quad (10)$$

$$T_{n+1,r} \leq \beta_{n+1};\ r \in R \quad (11)$$

$$L_r = \gamma \sum_{i \in V\setminus\{0, n+1\}} D_{0jr};\ r \in R \quad (12)$$

$$T_{n+1,r} \leq T_{0s} + M(1 - Z_{rs});\ r \in R, s \in R, r < s \quad (13)$$

$$T_{n+1,r} \geq T_{0s} - M(1 - Z_{rs});\ r \in R, s \in R, r < s \quad (14)$$

$$\sum_{r \in R} \sum_{s \in R, r<s} Z_{rs} \geq R' - K \quad (15)$$

$$\sum_{s \in R, s>r} Z_{rs} \leq 1;\ r \in R \quad (16)$$

$$\sum_{r \in R, s>r} Z_{rs} \leq 1; s \in R \quad (17)$$

$$D_{i,n+1,r} = 0;\ i \in V\setminus\{n+1\};\ r \in R \quad (18)$$

$$\sum_{i \in V\setminus\{n+1\}, i \neq j} \sum_{r \in R} D_{ijr} - \sum_{i \in V\setminus\{n+1\}, i \neq j} \sum_{r \in R} D_{jir} = \delta_j;\ j \in V\setminus\{0, n+1\} \quad (19)$$

$$\sum_{i \in V\setminus\{0, n+1\}} \sum_{r \in R} D_{0ir} = \sum_{i \in V\setminus\{0, n+1\}} \delta_i \quad (20)$$

$$D_{jir} \leq \emptyset X_{ijr};\ i \in V\setminus\{n+1\}, j \in V\setminus\{0\};\ , i \neq j, r \in R \quad (21)$$

$$X_{ijr} \in \{0,1\};\ i \in V\setminus\{n+1\}, j \in V\setminus\{0\};\ , i \neq j, r \in R \quad (22)$$

$$Z_{rs} \in \{0,1\};\ r \in R, s \in R, r < s \quad (23)$$

$$T_{ir} \geq 0;\ i \in V, r \in R \quad (24)$$

$$D_{ijr} \geq 0;\ i \in V, j \in V, r \in R \quad (25)$$

$$L_r \geq 0;\ r \in R \quad (26)$$

$$K \geq 0 \quad (27)$$

The objective function is to minimize total transportation cost-fixed cost and variable cost defined in Eq. (1). Constraints (2)-(3) describe that each vehicle must start and end at depot. Constraint (4) guarantees the route continuity. Constraint (5) ensures the service time at each demand point. Constraints (6)-(11) make sure the time windows for demand point and depot are not violated. Constraint (12) restricts the loading time at depot. The route sequence is defined by constraints (13)-(17). Constraint (18) describes the delivery load when a vehicle returns at the depot. Flow conservation for delivery quantity at each customer is stated at constraint (19). The total load from depot and the vehicle capacity constraint are defined at constraints (20) and (21) respectively, constraints (22)-(27) define the characteristic of decision variables.

In this research, we compare the existing condition and the result of GIS-based optimization for 50 demand points then we develop two scenarios for the larger demand point-100 and 200 demand points to illustrate the uncertainty of the demand itself. The determination of number of demand point is based on the minimum, average, and maximum demand point from expert judgement.

This research is solved following six steps. First, define a network dataset. Second, run vehicle routing problem in Network Analyst extension. The several examples of Network Analyst Input Parameter Interface can be seen at Figure 2(a)-(c). To solve the problem, we used the primary and secondary data. The data collected are maps of Jakarta, road network, set of location (depot and customers), attribute of location, attribute of vehicle, cost component, and processing time. The vehicle attribute, cost component, set of locations, and demand data are shown at Table 1, Table 2, and Table 3 respectively. Third step is verification and validation, verification is carried out by identifying the error in GIS, while validation is done by checking the result that it is not violated the constraints. The validation is made by comparing the GIS results and manual computation related to total time, total cost, and vehicle capacity constraint in Table 4-6. Fourth, we compare the existing condition and GIS-based optimization results to see the efficiency of the model proposed. Fifth, develop two scenarios to see the implication of the demand uncertainty so the managerial implication can be carried out based on the real situation. Finally, we draw a conclusion under limitations of our research and give potential future research.

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Table 1. Vehicle specifications

Vehicle Type	Size	Capacity (tube)
Truk Engkel 125 PS	10 feet	24

Table 2. Transportation cost component

Class	Cost Component	Unit Price (Rp)	Total (Rp)
Fixed Cost	Truck Rental	366,667	709,868
	Driver	326,534	
	Driver Assistant	16,667	
Var. Cost	Fuel (/Km)	2,138	2,138

Table 3. Data Location and Demand

No	Prospect Customers	Latitude	Longitude	Delivery (tube)	Pickup (tube)
0	Depot	-6,21400069571067	106,905176783968	-	-
1	PC 1	-6,25634111611096	106,812930830703	3	2
2	PC 2	-6,24517635286587	106,872400964417	2	1
3	PC 3	-6,14736767558572	106,815498008317	2	2
4	PC 4	-6,17178943357262	106,787870193253	2	1
5	PC 5	-6,1895976297172	106,844831960844	3	3
6	PC 6	-6,16718993092418	106,792244323939	2	2
7	PC 7	-6,1466246283882	106,87939189672	3	2
8	PC 8	-6,1869606618592	106,829238683229	3	3
9	PC 9	-6,1943031728773	106,838789456073	3	3
10	PC 10	-6,25383982989547	106,801708638552	3	2
11	PC 11	-6,14939143094326	106,817362935582	2	2
12	PC 12	-6,24675423224589	106,872846608595	2	1
13	PC 13	-6,19902897374009	106,79921366436	2	1
14	PC 14	-6,24404861162987	106,795928478124	3	2
15	PC 15	-6,16560062809983	106,781790869734	2	1
16	PC 16	-6,18985569778999	106,79768516604	2	2
17	PC 17	-6,16057229103651	106,853050373459	3	3
18	PC 18	-6,23957587900046	106,830862909439	3	3
19	PC 19	-6,30310805008227	106,886340035115	2	2
20	PC 20	-6,26983117145437	106,870793764417	3	3
21	PC 21	-6,1085379835163	106,900187283637	2	2
22	PC 22	-6,12471030390395	106,917719542863	3	2
23	PC 23	-6,15188531241276	106,858483627323	2	2
24	PC 24	-6,15193598090771	106,89734615374	2	1
25	PC 25	-6,28979246365601	106,889279637402	2	2
26	PC 26	-6,15281801195175	106,712207347097	2	2
27	PC 27	-6,25314131497977	106,826693935582	2	1
28	PC 28	-6,29501239557488	106,796475648764	2	1
29	PC 29	-6,23717231199637	106,899053501116	3	2
30	PC 30	-6,23197783375933	106,909487891058	2	2
31	PC 31	-6,24398110443122	106,790678093253	2	2
32	PC 32	-6,16626697055227	106,785511049741	2	1
33	PC 33	-6,16771346653292	106,900529750924	2	2
34	PC 34	-6,23278738444615	106,81130625296	2	1
35	PC 35	-6,27823342316345	106,807248741271	2	1
36	PC 36	-6,25687201083865	106,818593144300	3	3
37	PC 37	-6,13429539006205	106,812752535582	2	1
38	PC 38	-6,20074980901417	106,854961964417	3	3

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Table 3. (Cont.) Data Location and Demand

No	Prospect Customers	Latitude	Longitude	Delivery (tube)	Pickup (tube)
39	PC 39	-6,24759876283102	106,913871593253	3	2
40	PC 40	-6,29201510553276	106,881423580984	3	2
41	PC 41	-6,17919880431451	106,818070558384	3	2
42	PC 42	-6,19172550690877	106,828586564417	3	3
43	PC 43	-6,18692268892264	106,823538253511	1	1
44	PC 44	-6,18229279825079	106,824948225558	3	2
45	PC 45	-6,17321898778722	106,876188218477	3	3
46	PC 46	-6,16399094509995	106,903426721576	3	2
47	PC 47	-6,16221463209495	106,904562606746	3	2
48	PC 48	-6,16184859944589	106,904230008595	3	2
49	PC 49	-6,14957722402977	106,902990192058	3	3
50	PC 50	-6,12594002700592	106,831082806746	2	2

Table 4. Total Time Validation

Vehicle	Route	Total Time Component		Total Time (hours)
		Total travel time (hours)	Total service time (hours)	
Truck A	Depot - PC 2 - PC 12 - PC 20 - PC 40 - PC 19 - PC 25 - PC 39 - PC 30 -Depot - PC 46 - PC 47 - PC 33 - Depot	1,60	8,50	10,1

Table 5. Total Cost Validation

Vehicle	Route	Total Cost Component		Total Cost (Rp)
		Total fixed cost (Rp)	Total variable cost (Rp)	
Truck A	Depot - PC 2 - PC 12 - PC 20 - PC 40 - PC 19 - PC 25 - PC 39 - PC 30 -Depot - PC 46 - PC 47 - PC 33 - Depot	709.866	820.800	812.455

Table 6. Capacity Validation

Trip	Capacity (tube)	Route	Trip Capacity	
			Delivery (Tube)	*Pickup* (Tube)
Trip 1	20	Depot - PC 2	2	1
		Depot - PC 2 - PC 12	4	2
		Depot - PC 2 - PC 12 - PC 20	7	5
		Depot - PC 2 - PC 12 - PC 20 - PC 40	10	7
		Depot - PC 2 - PC 12 - PC 20 - PC 40 - PC 19	12	9
		Depot - PC 2 - PC 12 - PC 20 - PC 40 - PC 19 - PC 25	14	11
		Depot - PC 2 - PC 12 - PC 20 - PC 40 - PC 19 - 25 - PC 39	17	13
		Depot - PC 2 - PC 12 - PC 20 - PC 40 - PC 19 - 25 - PC 39 - PC 30 - Depot	19	15
Trip 2	20	Depot - PC 46	3	2
		Depot - PC 46 - PC 47	6	4
		Depot - PC 46 - PC 47 - PC 33 - Depot	8	6

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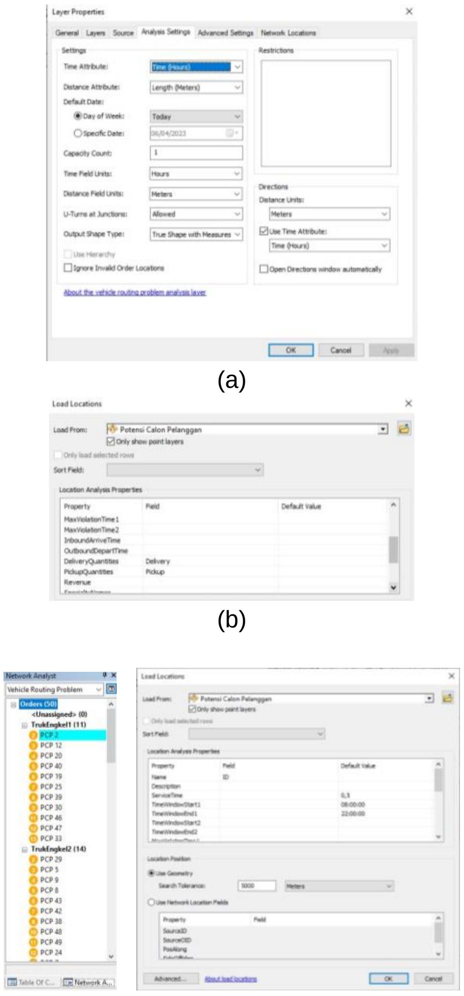

Figure 2(a)-(c). *Several examples of network analyst input parameter interface*

Results and Discussion

In this section we compare the result based on GIS and existing condition which can be seen at Table 7 and Table 8 respectively. The routes representation of GIS-based Optimization is shown in Figure 3.

Based on Table 7 and Table 8 we can see that the optimization results give the better solution in terms of number of vehicles used, total distance, and total cost. The existing condition for delivery and pick up 50 demand points need seven vehicles while in the optimization only need 4 vehicles. Because in the optimization model, we allowed multi-trips. So, the vehicles are allowed to return to the depot and start deliver again if the time windows are not violated. This policy benefits the company to minimize the vehicle rent cost and it will impact the total transportation cost.

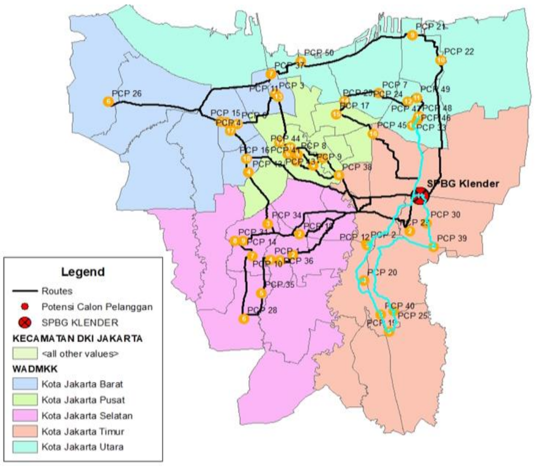

Figure 3. Routes visualization of 50 demand points

In term of the total distance, the optimization results shorter than existing condition. It reduces about 222,73 Km. It proves that the GIS-based Optimization gives better solution than trial and error that carried out at the real condition. The route planning optimization is crucial for the company if they want to minimize the transportation cost.

The total cost decreases about 2.605.798 rupiahs. This condition is affected by some factors, such as the number of vehicles used and the total distance. The number of vehicles used has a linear relation to the total cost. The least number of vehicles used, the smaller total cost incurred, as well as the total distance travelled.

Finally, we compare the result from different number of demand points. The greater number of demand points lead to higher number of vehicles need to deliver and pick up LNG. The number of demand points also affect the total distance travelled. they have a linear relation.
Based on this optimization, the managerial implication for the company is determining the optimum routes is one of the key factors to minimize the total transportation cost. Based on the expert judgement, the demand points are between 50 to 200, in this case we can suggest the company to rent between 5-11 trucks depend on the number of demand points. Besides, the other important factor is the transportation policy.

Table 7. Existing Condition for 50 Demand Points

No	Vehicle	Route	Total Distance (Km)	Fixed Cost (Rp)	Variable Cost (Rp)	Total Cost (Rp)
1	Truck A	Depot - 39 - PC 12 - PC 19 - PC 20 - PC 2 - PC 25 - PC 29 - PC 30 - Depot	52,20	709.868	111.604	821.472
2	Truck B	Depot - PC 40 - PC 5 - PC 9 - PC 8 - PC 24 - PC 17 - PC 41 - Depot	74,30	709.868	158.853	868.721
3	Truck C	Depot - PC 38 - PC 44 - PC 45 - PC 1 - PC 9 - PC 10 - PC 27 - Depot	83,00	709.868	177.454	887.322
4	Truck D	Depot - PC 18 - PC 34 - PC 27 - PC 14 - PC 31 - PC 35 - PC 28 - PC 36 - Depot	57,90	709.868	123.790	833.658
5	Truck E	Depot - PC 3 - PC 6 - PC 4 - PC 11 - PC 16 - PC 13 - PC 15 - PC 26 - Depot	96,80	709.868	206.958	916.826
6	Truck F	Depot - PC 32 - PC 37 - PC 23 - PC 50 - PC 49 - PC 7 - PC 21 - PC 22 - Depot	96,20	709.868	205.676	915.544
7	Truck G	Depot - PC 48 - PC 47 - PC 46 - PC 33 - Depot	18,70	709.868	39.981	749.849
TOTAL			**479,1**	**4.969.076**	**1.024.316**	**5.993.392**

Table 8. GIS-based Optimization for 50 Demand Points

No	Vehicle	Route	Total Distance (Km)	Fixed Cost (Rp)	Variable Cost (Rp)	Total Cost (Rp)
1	Truck A	Depot - PC 2 - PC 12 - PC 20 - PC 40 - PC 19 - PC 25 - PC 39 - PC 30 -Depot-PC 46 - PC 47 - PC 33 - Depot	47,99	709.868	102.613	812.481
2	Truck B	Depot- PC 29 - PC 5 - PC 9 - PC 8 - PC 43 - PC 42 - PC 38 - Depot- PC 48 - PC 49 - PC 24 - PC 7 - PC 23 - PC 17 - PC 45 - Depot	55,46	709.868	118.579	828.447
3	Truck C	Depot- PC 27 - PC 36 - PC 1 - PC 35 - PC 28 - PC 10 - PC 31 - PC 14 - Depot-PC 44 - PC 41 - PC 11 - PC 3 - PC 6 - PC 32 - PC 4 - PC 16 - Depot	81,68	709.868	174.639	884.507
4	Truck D	Depot- PC 18 - PC 34 - PC 13 - PC 15 - PC 26 - PC 37 - PC 50 - PC 21 - PC 22 - Depot	71,23	709.868	152.292	862.160
Total			**256,37**	**2.839.472**	**548.122**	**3.387.594**

Table 9. Comparison between Existing Condition and Optimization for 50 Demand Points

No	Condition	Number of Vehicle Needed	Total Distance (Km)	Fixed Cost (Rp)	Variable Cost (Rp)	Total Cost (Rp)
1	Existing	7	479,1	4.969.076	1.024.316	5.993.392
2	GIS-based Optimization	4	256,37	2.839.472	548.122	3.387.594
Delta		**3**	**222,73**	**2.129.604**	**476.194**	**2.605.798**

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Table 10. Recapitulation for Each Scenario

Scenario	Number of Vehicles	Total distance (km)	Total Fixed Cost (Rp)	Total Variable Cost (Rp)	Total Transportation Cost (Rp)
50 Demand Points	4	256,37	2.839.472	548.122	3.387.594
100 Demand Points	7	407,63	4.969.076	871.503	5.840.579
200 Demand Points	11	671,86	7.808.548	1.436.054	9.244.602

In this result, we can conclude that by implementing multi-trips is more beneficial for the company than doing single trip. By allowing the vehicles to have multi trips, it will rise the time utilization for the vehicle. The company should consider the safety aspect for the worker (drivers and their assistant). However, in the real case the company already mitigate this condition by assigning two drivers and an assistant in each vehicle.

Conclusion

In this research, a GIS-based Optimization is used by adopting MTVRPTW-SPD model. Implementing this model is beneficial for the company because it allowed the vehicles have several trips in a day. The model proposed can reduce the number vehicle used and the total distance. This condition leads to improve the total transportation spent.

Based on the optimization process for 50 demand points, it reduces the number of vehicles, the total distance, and the total cost about 3 unit, 46,5%, and 43,5% respectively. Other finding is if the demand points at the range 50-200 the company should consider vehicle rented about 4-11 trucks, with the detail at the Table 10.

The limitations of this research are considering the average of vehicle speed and not considering the road restriction. For the future research, the vehicle speed can be used as one factor to generate the scenario and developing model that considering road restriction.

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