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Determining the Distribution Route Using the Clustered Generalised Vehicle Routing Problem Model and Dijkstra's Algorithm

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Abstrak

Kegiatan pada sektor industri tidak terpisahkan dari proses distribusi dan logistik, salah satu sektor yang erat kaitannya dengan distribusi adalah penyaluran LPG 3 kg. Permasalahan paling umum yang terjadi pada proses distribusi adalah penentuan rute kendaraan yang sering disebut dengan *Vehicle Routing Problem*. PT Amalia Yusri sebagai salah satu agen penyalur LPG 3 kg di Banda Aceh dan tidak terlepas dari permasalahan penentuan rute distribusi. Salah satu alternatif penentuan rute distribusi adalah menggunakan model *Clustered Generalized Vehicle Routing Problem* yang bertujuan untuk mencari rute optimal pada titik tujuan yang telah dikelompokan. Berdasarkan jumlah permintaan dan kapasitas kendaraan, maka *cluster* dikelompokkan dan dibentuk menjadi dua hari yang terbagi ke dalam lima kelompok. Hari pertama terdiri dari kelompok 1 dan kelompok 2, sedangkan hari kedua terdiri dari kelompok 3, kelompok 4, dan kelompok 5. Metode yang akan diuji untuk mengoptimalkan jarak pendistribusian adalah Algoritma Dijkstra. Dari penerapan model CGVRP dan Algoritma Dijkstra diperoleh total jarak untuk kelompok 1 sebesar 25.582 m, total jarak untuk kelompok 2 sebesar 24.650 m, total jarak untuk kelompok 3 sebesar 39.350 m, total jarak untuk kelompok 4 sebesar 27.500 m, dan total jarak untuk kelompok 5 sebesar 38.500 m.

Kata Kunci: Rute Distribusi Logistik, LPG, CGVRP, Algoritma Dijkstra

Abstract

Distributions and logistics processes are the essential element activities integral to the industrial sector, one of them is the distribution of LPG 3 kg. The most common issue that occurs in the distribution process is determining the vehicle routes which are often called Vehicle Routing Problems. PT Amalia Yusri is one of the distributor agents of LPG 3 kg in Banda Aceh and also had the same issue to determine the distribution routes. The Clustered Generalized Vehicle Routing Problem model is used to determine the optimal distribution route on the vertex destinations that have been grouped. Based on the number of requests and vehicle capacity, the grouping and formation of clusters are divided into two days and split into five groups. The first day consists of group 1 and group 2; while on the second day are group 3, group 4, and group 5. The method that is used to optimise distribution distance is Dijkstra Algorithm. From the application of the CGVRP model and Dijkstra Algorithm obtained a total distance for group 1 is 25.58 Km, group 2 is 24.65 Km, group 3 is 39,35 Km, group 4 is 27.5 km, and group 5 is 38.5 km.

Keywords: Logistic Distribution Route, LPG, CGVRP, Dijkstra Algorithm

1. Introduction

The logistics process is directly connected to distribution process activities, specifically in the industrial sector where the process of supply from production to consumers is affected by the change of optimisation of costs, product quality and delivery time [1]–[3]. The standpoint of logistics is affiliated with planning, distribution, and the transportation linked with factories to warehouses and then to the market location [2], [4]. Technically speaking, the distribution of goods is carried out by the distributor that used vehicles which has different sizes of capacity [5].

The issues of distribution routes are often referred to as Vehicle Routing Problems (VRP) which are related to mathematically analysis to determine vehicle distribution routes from the distribution centre to customers located in different locations [6]. One variation of VRP is the Vehicle Routing Problem with Simultaneous Deliveries and Pickups (VRPSDP) where vehicles are not only necessary to deliver goods to the customer's location but also the delivery and pick-up of goods carried out simultaneously in one vehicle stop [7]. In order to, solve the problems that occur in the distribution process of 3 kg LPG at PT Amalia Yusri in Banda Aceh, this paper uses the Clustered Generalized Vehicle Routing Problem (CGVRP) modelling and Dijkstra's Algorithm.

The CGVRP model is a development of the Generalized Vehicle Routing Problem (GVRP) method in which the distribution is clustered or grouped based on predetermined criteria [8]. The method that will be tested to optimize the distribution distance is Dijkstra's Algorithm, where the algorithm is used to solve the problem of finding the optimal route by calculating the smallest weight of each point [9].

According to the information obtained from PT Amalia Yusri, the current distribution process of Liquefied Petroleum Gas (LPG) cylinders carried out by PT Amalia Yusri has only relied on the intuition and experience of truck drivers. This is of course less effective and efficient because the driver does not analyse in determine the distribution route, so it is not known whether the route currently used is the optimal route [8]. In order to determine the finest solution for PT Amalia Yusri, the implementation of the CGVRP model and Dijkstra's Algorithm is conducted to present the optimal alternative solutions.

2. Research Methods

2.1. Data Modelling

CGVRP is a variation of GVRP as a general issue of vehicle route clusters, where all vertices in each cluster must be visited sequentially in the vehicle route. CGVRP can determine the minimum cost collection of m vehicle routes exactly once by performing a Hamilton path at each vertex, without exceeding the carrying capacity of the vehicle [10], [11].

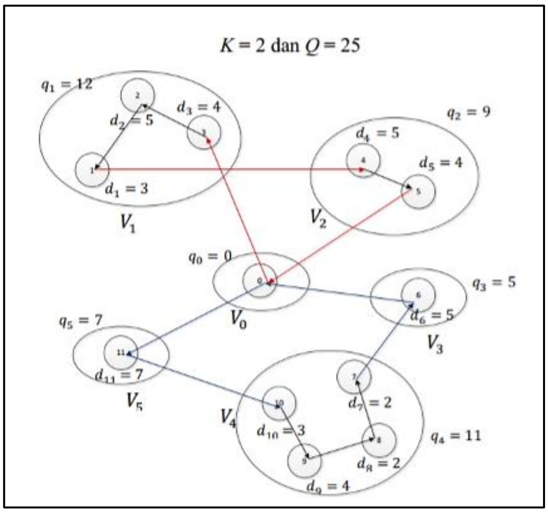

Figure 1. Example of CGVRP Solutions [9], [12]

Figure 1 shows an example of a feasible solution for CGVRP of a distribution process of goods with the vehicle capacity of Q = 25 cylinders, the distribution process is executed by using two identical vehicles. The first vehicle starts distribution from the warehouse (v_0) to vertex v_3 with a request for d_3 = 4 cylinders then goes to vertex v_2 with d_2 = 5 cylinders, and then goes to vertex v_1 with d_1 = 3 cylinders; These vertices are vertex in cluster 1 (V_1) with a total number of requests q_1 = 12 cylinders. Then the first vehicle goes to vertex v_4 with the number of requests d_4 = 5 cylinders, and continues to vertex v_5 with the number of requests d_5 = 4 cylinders; vertices v_4 and v_5 are vertices in cluster 2 (V_2) with the number of requests q_2 = 9 cylinders. Then the first vehicle returns to v_0. The same process occurred in the second vehicle assigned to cluster 5, cluster 4 and cluster 3 [12]. The optimal route of the distribution process is the total distance travelled by the two vehicles.

2.2. Dijkstra Algorithm

Dijkstra's algorithm is one of the variants of the Greedy algorithm that is included in one of the popular algorithms to solve problems related to optimisation. To determine the solution, Dijkstra's algorithm uses the Greedy principle, to find the optimal solution at each step to get the best solution. Dijkstra's algorithm works by using the priority queue principle, in which the point that has the highest priority will be traced. In determining the priority points, Dijkstra's algorithm compares each value or weight of the points that are at one level. Furthermore, the value of the point is saved to be compared with the value that will be discovered from the route that was just found thereupon, and so on until the point needed for inspection is found [13], [14].

Dijkstra's algorithm requires the parameters of the place of origin and destination, where the final result of the algorithm is the shortest distance from the place of origin to the destination and its route [15]. The procedural steps of Dijkstra's algorithm are as follows [12], [14], [16]–[19]:

1. Initialisation: $L = \{\ \}$; $V = \{v_1, v_2, \dots, v_n\}$.
2. For i = 2, 3, ..., n, do $D(i) = W(1, j)$.
3. As long as $v_n \notin L$ (v_n is not a permanent point), do:
   a. Choose $v_n \in V - L$ (non-permanent vertex) with the smallest D (k). $L = L \cup \{v_k\}$ (make v_k as the permanent point).
   b. For every $v_j \in V - L$ do: if $D(k) + W(k, j) < D(j)$ then replace $D(j)$ with $D(k) + W(k, j)$.

3. Results and Analysis

3.1 Grouping and Cluster Formation

PT Amalia Yusri distributes LPG cylinders of 3 kg every day to 50 gas stations in Banda Aceh City using two vehicles, that have the same capacity. The grouping is classified by taking into matter the vehicle capacity with the total number of requests not exceeding the maximum vehicle capacity of 260 of 3 kg LPG cylinders. If the number of requests exceeds the vehicle capacity, a new group will be formed.

Based on the number of requests and vehicle capacity, the clusters are grouped and formed into two days which are divided into five groups. The first day consisted of group 1 and group 2, while the second day consisted of group 3, group 4, and group 5, with one group consisting of 2 trucks operating. Hence, by using Dijkstra Algorithm that determining the shortest travel distance at a one-time process of delivering process can be concluded as the optimum routes. Therefore, the results will serve as a guideline for the drivers and company while distributing the goods of LPG 3 Kg. Through the route order of delivering one trip route determined of both vehicles need to execute, it can save the cost of time and fuel consumption.

3.2. Distance Determination

Determination of the distance from the warehouse to each LPG base and the distance between each base in the cluster is utilised with the Google Maps application.

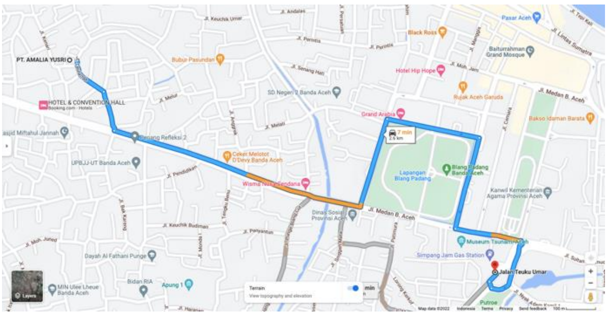

Figure 2. Route measurement using the Google Maps application

Table 1. LPG station grouping

Sub-district	Station name	Store code	Request quantity	Truck capacity	Truck
Punge Ujong	Berkah Gas II	13	12	248	1
	Moeda Bejaya	27	12		
	Punge Gas	33	12		
	UD. Puma Kelana	43	12		
Punge Jurong	Anggrek	9	29		
	Umaira	46	29		
	Usaha Loen	49	29		
Gampong Baro	Afraff	5	29		
Lambung	Tekad Gas	34	21		
Deah Baro	CV. Mama Energi	15	17		
Surien	Dersi Gas	50	30		
Asoe Nanggroe	Amiruddin Gas	7	17		
Punge Blang Cut	Berkah Gas	12	135	236	2
Bitai	CV. Pratama Cipta Jaya	17	29		
Lampoh Daya	Nuansa Barokah	30	35		
Lamjamee	UD. Khadafi	41	37		
Emperom	Bunda Gas	14	30	223	1
	Usaha Baru	47	30		
Lamteumen Barat	UD. Mulia Gas	42	59		
Geuceu Meunara	UD. Saniah	44	56		
Lampaseh Kota	Dedex Gas	18	48		
Gampong Jawa	Andri Gas	8	49	165	2
Gampong Pande	Adia Ari Gas	4	17		

Sub-district	Station name	Store code	Request quantity	Truck capacity	Truck
Sukaramai	14.232.485	3	99		
Peuniti	Maju Jaya	24	64		
	UD. Hawana	40	64		
Ateuk Jawo	Barokah Gas	11	21	224	1
	Nasriah Johan	29	21		
Lam Ara	UD. Cek Poel	38	54		
Mibo	Agaz Water	6	12		
	CV. Mita Bacut	16	12		
	UD. Fahrol Gas	39	12		
Panteriek	Toko Laris	35	89	236	2
Lamseupeung	Usaha Baru Gas	48	41		
Cot Mesjid	Pintoe Raseuki	32	69		
Lamdom	Pinto Aceh	31	34		
Laksana	Kana Usaha Gas	21	112	252	1
Mulia	14.231.482	2	106		
Keuramat	H Amin Gas	19	55		
	Tsani Gas	36	55		
Beurawe	Aulia Gas	10	53	215	2
	Kedai Hemi	22	53		
Lamdingin	Mulia Sakti	28	69		
Lambaro Skep	Keupula	23	57	182	1
	Makmur Gas	25	57		
Kota Baru	Menjemput Rezeki	26	27		
Ie Masen Ulee Kareng	UD. Tabarak	45	45		
Peurada	UB. Al-Mukmin	37	69	257	2
Lamgugob	14.231.450	1	58		
	Idola Remaja	20	58		

3.3 Dijkstra Algorithm application constructing CGVRP model

The beginning of destination vertex for each cluster and the analysing calculations using the Dijkstra algorithm to develop a CGVRP model for each group were done with the Google Maps application. Therefore, the distance between warehouses to each LPG station and the distance between the LPG station assigned to each vehicle can be determined. In group 1 the first vehicle was assigned to visit seven clusters. Determination of the initial destination vertex of the first vehicle, specifically the point that has the closest distance from the seven clusters.

Table 2. Distance matrix first vehicle of group 1 (m)

Stations code	0	13	27	33	43	9	46	49	5	34	15	50	7
0	0												
13	190	0											
27	200	170	0										
33	220	190	100	0									
43	210	64	230	220	0								
9	850	800	700	700	900	0							
46	900	800	650	600	850	280	0						
49	950	900	750	650	1000	92	350	0					
5	2100	1800	2000	1900	1700	2400	2700	2400	0				
34	1800	1100	1300	1300	1000	1700	2000	1800	1800	0			
15	1600	1700	2000	1900	1600	2300	2500	2400	2400	1200	0		
50	3300	3100	3400	3400	3100	3600	4000	3500	1700	2600	3800	0	
7	3700	3700	3900	3900	3000	3700	4000	3800	2200	2600	2800	1400	0

Based on the distance matrix from table 2, it shows the initial destination vertex is the base with code 13 since it has the closest distance from the starting point, which PT Amalia Yusri has a code of 0. Additionally, calculations are conducted using Dijkstra's Algorithm, the results of the analysis of these calculations are shown in table 3.

Table 3. Application of Dijkstra's Algorithm to the First Vehicle Distribution of Group 1

Iteration	0	13	27	33	43	9	46	49	5	34	15	50	7	L
1	0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	{0}
2	-	Min {∞, 0 +190} = 190	Min {∞, 0 +200} = 200	Min {∞, 0 +220} = 220	Min {∞,0 +210} = 210	Min {∞, 0 +850} = 850	Min {∞, 0 +900} = 900	Min {∞, 0 +950} = 950	Min {∞, 0 +2100} = 2100	Min {∞, 0 +1800} =1800	Min {∞, 0 +1600} = 1600	Min {∞, 0 +3300} = 3300	Min {∞, 0 +3700} =3700	{0, 13}
3	-	-	Min {200, 190 +170} = 200	Min {220, 190 +190} = 220	Min {210, 190 +64} = 210	Min {850, 190 +800} = 850	Min {900, 190 +800} = 900	Min {950, 190 +900} = 950	Min {2100, 190 +1800} = 1990	Min {1800, 190 +1100} = 1290	Min {1600, 190 +1700} = 1600	Min {3300, 190 +3100} = 3290	Min {3700, 190 +3700} = 3700	{0, 13, 27}
4	-	-	-	Min {220, 200 +100} =220	Min {210, 200 +230} =210	Min {850, 200 +700} = 850	Min {900, 200 +650} = 850	Min {950, 200 +750} = 950	Min {1990, 200 +2000} = 1990	Min {1290, 200 +1300} =1290	Min {1600, 200 +2000} =1600	Min {3290, 200 +3400} = 3290	Min {3700, 200 +3900} = 3700	{0, 13, 27, 43}
5	-	-	-	Min {220, 210 +220} = 220	-	Min {850, 210 +900} = 850	Min {850, 210 +850} = 850	Min {950, 210 +1000} = 950	Min {1990, 210 +1700} = 1910	Min {1290, 210 +1000} = 1210	Min {1600, 210 +1600} = 1600	Min {3290, 210 +3100} = 3290	Min {3700, 210 +3000} = 3210	{0, 13, 27, 43, 33}
6	-	-	-	-	-	Min {850, 220 +700} = 850	Min {850, 220 +600} = 820	Min {950, 220 +650} = 870	Min {1910, 220 +1900} = 1910	Min {1210, 220 +1300} = 1210	Min {1600, 220 +1900} = 1600	Min {3290, 220 +3400} = 3290	Min {3210, 220 +3900} = 3210	{0, 13, 27, 43, 33, 46}
7	-	-	-	-	-	Min {850, 820 +280} = 850	-	Min {870, 820 +350} = 870	Min {1910, 820 +2700} = 1910	Min {1210, 820 +2000} = 1210	Min {1600, 820 +2500} = 1600	Min {3290, 820 +4000} = 3290	Min {3210, 820 +4000} = 3210	{0, 13, 27, 43, 33, 46, 9}
8	-	-	-	-	-	-	-	Min {870, 850 +92} = 870	Min {1910, 850 +2400} = 1910	Min {1210, 850 +1700} = 1210	Min {1600, 850 +2300} = 1600	Min {3290, 850 +3600} = 3290	Min {3210, 850 +3700} = 3210	{0, 13, 27, 43, 33, 46, 9, 49}
9	-	-	-	-	-	-	-	-	Min {1910, 870 +2400} = 1910	Min {1210, 870 +1800} = 1210	Min {1600, 870 +2400} = 1600	Min {3290, 870 +3500} = 3290	Min {3210, 870 +3800} = 3210	{0, 13, 27, 43, 33, 46, 9, 49, 34}
10	-	-	-	--	-	-	-	-	Min {1910, 1210 +1800} = 1910	-	Min {1600, 1210 +1200} = 1600	Min {3290, 1210 +2600} = 3290	Min {3210, 1210 +2600} = 3210	{0, 13, 27, 43, 33,46, 9, 49, 34, 15}
11	-	-	-	-	-	-	-	-	Min {1910, 1600 +2400} = 1910	-	-	Min {3290, 1600 +3800} = 3290	Min {3210, 1600 +2800} = 3210	{0, 13, 27, 43, 33, 46, 9, 49, 34, 15, 5}
12	-	-	-	-	-	-	-	-	-	-	-	Min {3290, 1910 +1700} = 3290	Min {3210, 1900 +2200} = 3210	{0, 13, 27, 43, 33, 46, 9, 49, 34, 15,5,7}
13	-	-	-	-	-	-	-	-	-	-	-	Min {3290, 3210 +1400} = 3290	-	{0, 13, 27, 43, 33, 46, 9, 49, 34, 15, 5, 7, 50}

Based on the results of the implementation of the Dijkstra Algorithm listed in table 3, the distribution route for the first vehicle in group 1 starts from the warehouse (0) to vertex 13 → vertex 27 → vertex 43 → vertex 33 → vertex 46 → vertex 9 → vertex 49 → vertex 34 → vertex 15 → vertex 5 → vertex 7 → vertex 50. The same way applied to the second vehicle and attained the distribution route starting from the warehouse (0) to vertex 12 → vertex 17 → vertex 41 → vertex 30. In addition, the CGVRP modelling distribution route is shown in Figure 3.

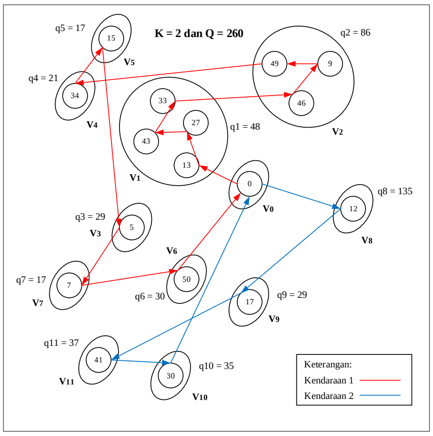

Figure 3. CGVRP model route distribution of group 1

The same steps were applied to the other groups and obtained a CGVRP model for all groups as shown in the following figures.

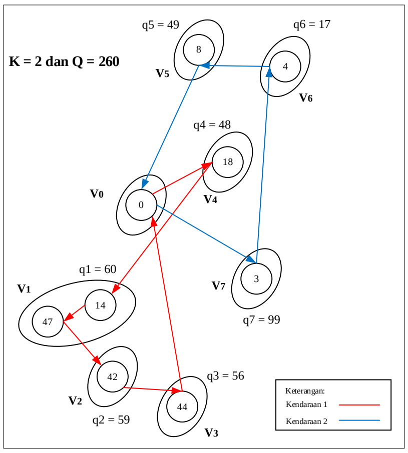

Figure 4. CGVRP model route distribution of group 2

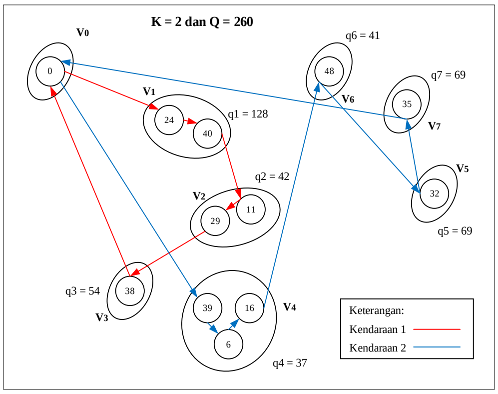

Figure 5. CGVRP model route distribution of group 3

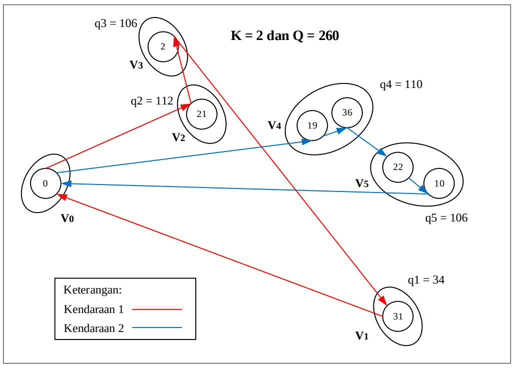

Figure 6. CGVRP model route distribution of group 4

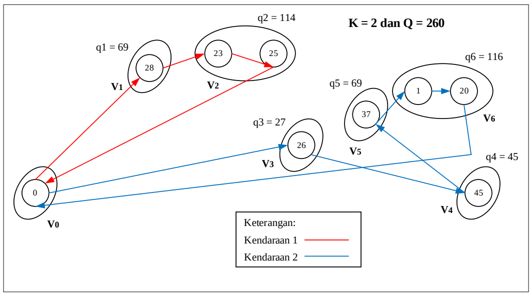

Figure 7. CGVRP model route distribution of group 5

The calculation of the mileage of groups 1 to 5 is based on table 3 on determining the distribution route of 3 kg LPG by PT Amalia Yusri using the Dijkstra algorithm shown in table 4.

Table 4. Calculation of the proposed route distance

Group	Vehicle	Route	Vehicle capacity	Total Capacity	Travel distance (m)	Total Travel (m)
1	Vehicle 1	PT Amalia Yusri (0) → Berkah Gas II (13) → Moeda Bejaya (27) → UD. Puma Kelana (43) → Punge Gas (33) → Umaira (46) → Anggrek (9) → Usaha Loen (49) → Tekad Gas (34) → CV. Mama Energi (15) → Afraff (5) → Amiruddin Gas (7) → Dersi Gas (50) → PT Amalia Yusri (0)	248	484	190 + 170 + 230 + 220 + 600 + 280 + 92 + 1800 + 1200 + 2400 + 2200 + 1400 + 3300 = 14082	25,582

Group	Vehicle	Route	Vehicle capacity	Total Capacity	Travel distance (m)	Total Travel (m)
	Vehicle 2	PT Amalia Yusri (0) → Berkah Gas (12) → CV. Pratama Cipta Jaya (17) → UD. Khadafi (41) → Nuansa Barokah (30) → PT Amalia Yusri (0)	236		2000 + 1100 + 2000 + 1600 + 4800 = 11500	
2	Vehicle 1	PT Amalia Yusri (0) → Dedex Gas (18) → Bunda Gas (14) → Usaha Baru (47) → UD. Mulia Gas (42) → UD Saniah (44) → PT Amalia Yusri (0)	223	388	1700 + 4800 + 600 + 1100 + 1900 + 4800 = 14900	24,650
	Vehicle 2	PT Amalia Yusri (0) → 14.232.485 (3) → Adia Ari Gas (4) → Andria Gas (8) → PT Amalia Yusri (0)	165		2200 + 3300 + 750 + 3500 = 9750	
3	Vehicle 1	PT Amalia Yusri (0) → Maju Jaya (24) → UD. Hawana (40) → Barokah Gas (11) → Nasriah Johan (29) → UD. Cek Poel (38) → PT Amalia Yusri (0)	224	460	3500 + 450 + 1900 + 400 + 4000 + 6600 = 16850	39,350
	Vehicle 2	PT Amalia Yusri (0) → UD. Fahrol Gas (39) → Agaz Water (6) → CV. Mita Bacut (16) → Usaha Baru Gas (48) → Pintoe Raseuki (32) → Toko Laris (35) → PT Amalia Yusri (0)	236		3700 + 1000 + 800 +5000 + 3300 + 3100 + 5600 = 22500	
4	Vehicle 1	PT Amalia Yusri (0) → Kana Usaha Gas (21) → 14.231.482 (2) → Pinto Aceh (31) → PT Amalia Yusri (0)	252	467	3700 + 450 + 4700 + 6500 = 15350	27,500
	Vehicle 2	PT Amalia Yusri (0) → H. Amin Gas (19) → Tsani Gas (36) → Kedai Helmi (22) → Aulia Gas (10) → → PT Amalia Yusri (0)	215		3300 + 600 + 1400 + 650 + 6200 = 12150	
5	Vehicle 1	PT Amalia Yusri (0) → Mulia Sakti (28) → Keupula (23) → Makmur Gas (25) → PT Amalia Yusri (0)	182	439	5100 + 1500 + 2100 + 6000 = 14700	38,500
	Vehicle 2	PT Amalia Yusri (0) → Menjemput Rezeki (26) → UD. Tabarak (45) → UB. Al-Mukmin (37) → 14.231.450 (1) → Idola Remaja (20) → PT Amalia Yusri (0)	257		6700 + 4000 + 2700 + 1600 + 500 + 8300 = 23800	

3.4 Fuel Consumption Cost Based on CGVRP Model Route

The fuel consumption of the total travel distance of both vehicles will be calculated to determine the optimum route with the assumption that the vehicle used had the same fuel capacity ratio which 9 Km/litre using Pertalite gasoline 7,650 IDR as the vehicle fuel without considering traffic light, vehicle full load capacity weight. Then, from table 4 the rate of fuel consumption is as follows; the sum of vehicle 1 travel is 75.8 km with fuel consumption of 8.43 litre that cost 64,490 IDR. Sum vehicle 2 travel is 79.7 km with fuel consumption of 8.86 litres that cost 67,779 IDR. Thus, the average fuel cost for two days delivering 3KG LPG is 66,135 IDR.

4. Conclusion

The route obtained from this research results of the CGVRP model and the Dijkstra Algorithm will serve as a guideline for the drivers while delivering the goods of PT Amalia Yusri which LPG 3 Kg. Based on the number of requests and vehicle capacity, the grouping and clustering of the CGVRP model and the Dijkstra Algorithm are divided into two days and then divided more into five groups with the results of calculating the total distance of 25.58 km (group 1), 24.65 km (group 2), 39.35 km (group 3), 27.5 km (group 4), and 38.5 km (group 5). It is concluded that vehicles 1 and 2 consumed 8.43 and 8.86 litres of Pertalite gasoline that cost around 66,135 IDR.

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