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Optimization of Fast Moving Consumer Goods Distribution Routes Using Vehicle Routing Problem at PT Cahaya Mahakam Samarinda

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ABSTRACT

PT Cahaya Mahakam Samarinda, as one of the companies engaged in the distribution of fast-moving consumer goods, serves a variety of customers, including wholesalers, small shops, and food businesses. Based on the initial observations that have been made, the determination of distribution routes is carried out by the warehouse manager, who subjectively determines the route based on personal observations before the driver delivers consumer products because the company does not yet have the appropriate tools or methods to determine the route. This sometimes forces drivers to search for customer locations directly in the field if they have never delivered to that customer before, and sometimes there are inaccuracies in selecting the delivery route to the next customer. In this problem, it falls under the Vehicle Routing Problem, which is solved using the cluster first, route second approach with the Sweep method to create clusters and Nearest Neighbor with manual calculations, as well as Branch and Bound with calculations using the WinQSB software to determine the route for each created cluster. The results of both route creation methods were compared with the initial route. Based on the research results, the Sweep method produced 9 fewer clusters compared to the initial route of 11 clusters. In route determination, the Nearest Neighbor method resulted in a distance savings of 55.4 km (20.11%) and a cost savings of IDR 74,190.43. The Branch and Bound method resulted in savings of 64.6 km (23.47%) and cost savings of IDR 93,144.07.

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1. INTRODUCTION

The number of Fast Moving Consumer Goods (FMCG) industries is increasing. This is because consumer products have become one of the necessities for humans to carry out their daily lives, so the demand for these products is always increasing (Barata et al., 2022). The success factor for companies in meeting consumer demand for fast-moving consumer goods is the logistics system efficiently established by the company by enhancing the necessary facilities to support product management and distribution, storage conditions, transportation capacity, and the use of technology (Wang et al., 2021). Distribution refers to the process of transferring goods or materials from suppliers to end consumers through intermediaries such as distributors, retailers, or sales outlets (Waise, 2023) .

The shorter the distance traveled in the distribution process, the less fuel consumption is required, which will impact the efficiency of operational costs. The design of an optimal route needs to consider the selection of paths with the shortest total distance without neglecting vehicle capacity constraints.

Based on the initial observations that have been made, the determination of the distribution route is carried out by the warehouse manager, who subjectively determines the route based on personal observations before the driver delivers consumer products because the company does not yet have the appropriate tools or methods to determine the route. This sometimes forces drivers to search for customer locations directly in the field if they have never delivered to that customer before, and sometimes there are inaccuracies in selecting the delivery route to the next customer.

Although there has been a decrease in costs over the past two months, this does not solve the problem because fuel costs remain volatile and still require a solution, namely the need for an appropriate tool or method to determine the optimal route. With more optimal route planning before the distribution process to customers, fluctuations can be minimized so that there will not be significant differences each month, even though situational differences will occur.

Vehicle Routing Problem (VRP) is a problem of determining the optimal route for each vehicle to start its journey from one depot, then visit several locations only once in one route while considering various operational constraints and then return to the depot (Toth & Vigo, 2002). However, in reality, the vehicles owned by PT Cahaya Mahakam Samarinda have different capacities. In its planning, the difference in capacity of each vehicle must be considered and calculated in the creation of the delivery route.

Based on the problems experienced by PT Cahaya Mahakam Samarinda, it is necessary to use the appropriate method to select the optimal distribution route and determine the road paths that can be traversed by PT Cahaya Mahakam Samarinda's vehicles. The Cluster First Route Second approach using the sweep method for cluster creation followed by the Nearest Neighbor and Branch and Bound methods for route creation can be the right choice to solve the problem efficiently and optimally. Cluster First Route Second approach using the sweep method for cluster creation followed by the Nearest Neighbor and Branch and Bound methods for route creation can be an appropriate choice to solve the problem efficiently and optimally.

The Sweep Method divides the delivery area based on geographical proximity by grouping delivery points into several clusters based on polar angles. The next stage is determining the route for each cluster obtained using the Nearest Neighbor method and Branch and Bound as a comparison method to achieve optimal route results. In addition, in the creation of the distance matrix, it is not necessary to include all possible distances between customers. Just calculate the distance between customers within a single cluster that has been formed, so the calculation process is more efficient without having to consider all possible routes. This can reduce the complexity of calculations and speed up the route optimization process.

2. LITERATURE REVIEW

2.1 Supply Chain Management

Supply Chain Management is the process of managing and overseeing the supply chain cycle that encompasses the entire flow from raw materials, payments, to the flow of information between suppliers, manufacturers, wholesalers, retailers, and finally to the hands of consumers. (Wijaya et al., 2021). SCM as the design, planning, execution and control of flows across networks of firms to satisfy customer needs and create value (Evangelista et al., 2023)

2.2 Determination of Vehicle Capacity and Priority

In determining which vehicle should be prioritized for use first in planning, a priority order is established by comparing the cost with the vehicle's carrying capacity.If the highest cost-saving ratio is obtained, it will be allocated for use first. Other vehicles will be used if the highest priority has been utilized (Rizal & Saidatuningtyas, 2024). It is important to take into account the dimensions of both the transported goods and the vehicle containers when defining the capacity constraints, as this helps to optimize the utilization of container space (Sitompul & Horas, 2021).

Fixed costs are a component of transportation costs that must be incurred every time a vehicle is used, regardless of other variables in the transportation process. Fixed costs consist of asset depreciation (vehicle wear and tear), labor costs, and vehicle maintenance costs. Meanwhile, variable costs are transportation costs whose amount depends on other factors in the delivery process. In the problem of determining the optimal route, variable costs are influenced by the distance traveled by each vehicle, where the main component is the fuel cost per kilometer travelled (Ramadhan et al., 2023).

2.3 Vehicle Routing Problem

The assumptions used in the VRP problem are that each vehicle has the same capacity, there is an unlimited number of vehicles, the demand for each customer is known, and no single demand exceeds the capacity of the vehicle (Sugiono, 2022).

2.4 Sweep

Sweep is a simple method for performing calculations, even though the problems to be solved are complex. The sweep method functions to produce solutions that align with field conditions, such as varying transport capacities among fleets. Sweep is divided into two types: forward sweep and backward sweep. Forward sweep is a sweep method with a forward clustering process, meaning it starts from the smallest polar angle to the largest polar angle, whereas backward sweep is a sweep method with a backward clustering process, meaning it starts from the largest polar angle to the smallest polar angle (Tjaja & Saiful, 2021).

The Sweep calculation for route creation can be practically performed using GeoGebra software to determine the value of polar coordinate points (Rahmadini et al., 2023).

2.5 Nearest Neighbor

The Nearest Neighbor method is used to solve vehicle routing problems. This method becomes a strategy used to determine the travel route by selecting the nearest distribution locations and the last point visited by the fleet. The process of this method begins by determining the starting point or terminal, then continues by selecting the area with the shortest distance. After that, the nearest location from the last visited branch is determined again, until all branches in the new group are visited (Siraj, 2024).

2.6 Branch and Bound

The Branch and Bound method is a technique used to solve optimization problems in order to achieve the most optimal results. There are advantages to using the Branch and Bound method, namely that it provides more optimal results compared to other methods and has a low error rate. However, there are drawbacks to this method, namely that it requires a relatively long time to execute and has a high level of difficulty in its implementation (Zupemungkas & Handayani, 2021).

In solving problems using Branch and Bound, it can also be done with the help of software, namely WinQSB, which is a software developed by Yih-Long Chang that can assist in solving problems in finding optimal routes (Nurjanah & Nabila, 2019).

2.7 Previous Research

From the comparison of these studies, it is evident that heuristics (Sweep and Nearest Neighbor) are efficient but prone to suboptimal results, while exact approaches (Branch and Bound) provide accuracy but struggle with scalability. Few studies explicitly combine these methods to balance efficiency and optimality within a Cluster First Route Second framework. This represents a research gap, especially in the context of heterogeneous vehicle capacities such as those faced by PT Cahaya Mahakam Samarinda. Addressing this gap, the present study integrates Sweep, Nearest Neighbor, and Branch and Bound to provide a more comprehensive solution to the Vehicle Routing Problem.

3. RESEARCH METHOD

The activity flowchart illustrates the stages that will be undertaken in conducting the research. Primary data is data obtained directly by the researcher from its original source for the specific purpose of the ongoing research. Secondary data is data obtained indirectly through various sources with the aim of supporting primary data. In this problem, customers are clustered based on their nature, characteristics, condition, etc., and visiting one customer in a cluster eliminates the need to visit other customers in that cluster (Jolfaei et al., 2023).

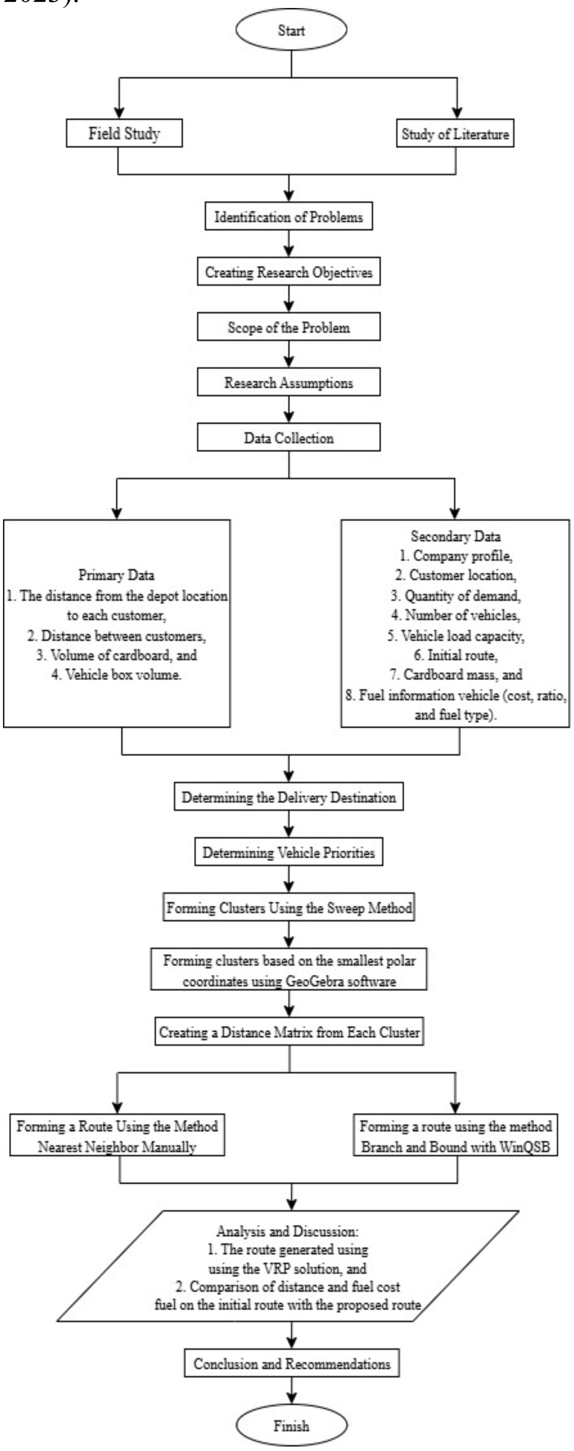

Figure 1. Flowchart analysis stages

The main limitations of using manual tools such as GeoGebra and WinQSB are the need for manual data input, which is time-consuming and prone to human error. Additionally, these tools cannot handle large-scale data and are unsuitable for real-time monitoring or optimization, as they are not directly connected to operational systems or automated databases.

4. RESULT AND DISCUSSION

4.1 Customer Data

The displayed customer names are only initials to maintain the company's privacy. The following are the initials of the customers names, delivery areas, codes, and requests from each customer of PT Cahaya Mahakam Samarinda.

Table 1. Customer demand data

Customer Name	Area	Code	Demand (crt)
MPR	Sambutan	X1	25
TZ	Sungai Kunjang	X2	100
WJT	Sungai Kunjang	X3	5
…	…	…	…
AG	Sungai Kunjang	X43	1 6 30

(Source: historical data PT CMS)

4.2 Mass and volume data of the cardboard boxes

Data on the volume and mass of the cardboard boxes are needed to adjust the boxes that can fit in the vehicle because the vehicle's load capacity does not have a fixed value. This is because each cardboard box has different volumes and masses.

Table 2. Customer demand data

Product	Mass (kg)	Volume (m^3)
Bimoli Klasik Jerigen 5 L	20	0.0309
Terigu Segitiga Biru Eco 1 kg	12	0.0299
Terigu Cakra Kembar Eco 1 kg	12	0.0299
…	…	…
Dore Meises Rainbow TC 12,5 kg	12,5	0.0213

(Source: historical data PT CMS)

4.3 Vehicle Information

PT Cahaya Mahakam Samarinda owns 10 vehicles with different specifications for delivering customer orders. Nine of the vehicles are equipped with enclosed boxes or covered cargo beds, each fitted with two doors for loading and unloading goods, while one vehicle has an open cargo bed.

Table 3. Vehicle information

Vehicle Type	Volume (m^3)	Payload Capacity (kg)	Lowest Road Class
Daihatsu Gran Max Pick Up	3,667	1500	IIIC
Toyota Dyna 115ST	7,367	3200	IIIB
Mitsubishi Colt L300	5,065	2500	IIIC
Toyota Dyna 110ET	13,191	4200	IIIA
Toyota Dyna 110ET	11,918	4200	IIIA
Toyota Dyna 110ET	12,079	4200	IIIA
Hino Dutro 110SD	8,912	3200	IIIB
Isuzu Elf NMR 71	12,358	4700	IIIA
Isuzu Elf NMR 71	11,827	4700	IIIA

(Source: historical data PT CMS)

In this study, most vehicles operated using Dexlite fuel, which was commonly used for distribution activities. However, the Daihatsu Gran Max Pick Up used Pertalite due to its different engine type and fuel requirements.

The fuel ratio used in this study was obtained through interviews with company personnel directly involved in distribution operations. This value reflects the actual operating conditions of the vehicles, including variations in load, road conditions, and engine performance. Therefore, this empirical approach provides a more realistic estimation of fuel consumption than relying solely on theoretical engine specifications.

Table 4. Fuel cost data

Vehicle Type	Fuel Cost/liter	Fuel Ratio	Fuel Cost/km
Daihatsu Gran Max Pick Up	IDR10.000,00	1:10	IDR1.000,00
Toyota Dyna 115ST	IDR13.900,00	1:7	IDR1.985,71
Mitsubishi Colt L300	IDR13.900,00	1:8	IDR1.737,50
Toyota Dyna 110ET	IDR13.900,00	1:5	IDR2.780,00
Toyota Dyna 110ET	IDR13.900,00	1:5	IDR2.780,00
Toyota Dyna 110ET	IDR13.900,00	1:5	IDR2.780,00
Hino Dutro 110SD	IDR13.900,00	1:7	IDR1.985,71
Isuzu Elf NMR 71	IDR13.900,00	1:4	IDR3.475,00
Isuzu Elf NMR 71	IDR13.900,00	1:4	IDR3.475,00
Isuzu Elf NMR 71	IDR13.900,00	1:4	IDR3.475,00

(Source: historical data PT CMS)

4.4 Initial Route

The initial distribution route data currently obtained represents a delivery cycle that is usually carried out 2-3 times a month at PT Cahaya Mahakam Samarinda, obtained through an interview with the company's warehouse manager.This data will be used as a comparison with the proposed route.

Table 5. Initial route

C	Route	Vehicle Type	Fuel ratio	Total Distance (km)	Total Fuel Cost
1	G → X26 → X17 → X4 → G	Toyota Dyna 115ST	1:7	30,3	IDR 60,167.14
2	G → X28 → X22 → G	Toyota Dyna 110ET	1:5	17,8	IDR 49,484.00

C	Route	Vehicle Type	Fuel ratio	Total Distance (km)	Total Fuel Cost
3	G → X40 → G	Isuzu Elf NMR	1:4	18	IDR 62,550.00
4	G → X30 → X19 → X8 → X18 → G	Toyota Dyna 110ET	1:5	22,5	IDR 62,550.00
5	G → X23 → X39 → X12 → X35 → X37 → G	Isuzu Elf NMR	1:4	28,5	IDR 99,037.50
6	G → X3 → X43 → X38 → X41→ X15 → X24 → X33 → X14 → X13 → G	Hino Dutro 110SD	1:7	29,2	IDR 57,982.86
7	G → X31 → X11 → X10 → X1 → X32 → G	Daihatsu Gran Max Pick Up	1:10	35	IDR 35,000.00
8	G → X36 → X5 → X42 → G	Daihatsu Gran Max Pick Up	1:10	18,4	IDR 18,400.00
9	G → X7 → X2 → X16 → X21 → X9 → X6 → G	Isuzu Elf NMR	1:4	30,7	IDR 106,682.50
10	G → X27 → X29 → G	Toyota Dyna 110ET	1:5	16,6	IDR 46,148.00
11	G → X25 → X20 → X34 → G	Mitsubishi Colt L300	1:8	28,3	IDR 49,171.25
Total				275,3	IDR 647,173.25

(Source: historical data PT CMS)

4.5 Vehicle Priority

The maximum capacity based on the vehicle's box volume can be determined by calculating the box volume and then adjusting it according to the volume or weight of the goods (Faturohman et al., 2021).

Table 6. Fuel cost data

Vehicle Type	Variable Cost		Fuel Cost/km	Capacity (100 kg)	Total Cost (Rp/cap)	P
	Fuel Cost/Liter	Ratio (km)				
Daihatsu Gran Max Pick Up	IDR 10,000.00	1:10	IDR 1,000.00	15	IDR 15,000.00	1
Toyota Dyna 115ST	IDR 13,900.00	1:7	IDR 1,985.71	32	IDR 63,542.86	3
Mitsubishi Colt L300	IDR 13,900.00	1:8	IDR 1,737.50	25	IDR 43,437.50	2
Toyota Dyna 110ET	IDR 13,900.00	1:5	IDR 2,780.00	42	IDR 116,760,00	7
Toyota Dyna 110ET	IDR 13,900.00	1:5	IDR 2,780.00	42	IDR 116,760,00	5
Toyota Dyna 110ET	IDR 13,900.00	1:5	IDR 2,780.00	42	IDR 116,760,00	6
Hino Dutro 110SD	IDR 13,900.00	1:7	IDR 1,985.71	32	IDR 63,542.86	4
Isuzu Elf NMR 71	IDR 13,900.00	1:4	IDR 3,475.00	47	IDR 163,325.00	9
Isuzu Elf NMR 71	IDR 13,900.00	1:4	IDR 3,475.00	47	IDR 163,325.00	8
Isuzu Elf NMR 71	IDR 13,900.00	1:4	IDR 3,475.00	47	IDR 163,325.00	10

(Source: historical data PT CMS)

4.6 Creating Cartesian Coordinates with Geogebra

In the creation of these Cartesian coordinates, the Geogebra software will be used by adding images of the depot and customer locations that have been created, then position point G exactly at (0,0) to become the center point of the Cartesian coordinates.

Table 7. Cartesian coordinates

Customer Name	Code	x	y
PT CMS	G	0	0
MPR	X1	15,295	0,229
TZ	X2	2,076	3,143
WJT	X3	-1,735	1,787
…	…	…	…
AG	X43	-2,289	-1,469

4.7 Convert and Sort Polar Coordinates

The next step before performing clustering on the delivery route is to convert the obtained Cartesian coordinates into polar coordinates.This is done to group or arrange customers based on specific areas to facilitate the clustering process, so that within one cluster, there are customers with adjacent areas.The following is the result of converting Cartesian coordinates to polar coordinates using Geogebra, then sorted based on a forward sweep from the smallest angle to the largest angle.

Table 8. Polar coordinates

Customer Name	Code	r	θ (°)
PT CMS	G	0	0
MPR	X1	15,297	0,856
GMM	X10	8,241	1,218
TAW	X26	7,614	18,344
…	…	…	…
ML	X31	5,987	343,198

4.8 Clustering Delivery Routes

After obtaining the polar coordinates of each customer and sorting them.The next step taken is clustering the delivery routes.The clustering process begins by grouping customers based on the angular order from the sweep method results, then placing them one by one into the vehicle while considering the vehicle's maximum capacity limit.

Table 9. Delivery route cluster

C	Vehicle Type	Customer Name	Product Name	Demand	Total Volume Cardboard (m^3)	Total Mass Cardboard (kg)
1	Toyota Dyna 115ST	MPR	Terigu Segitiga Biru Eco 1 kg	25	0.7480	300
		GMM	Terigu Segitiga Biru Eco 1 kg	1	0.7779	312
			Royco Bumbu Pelezat Rasa Ayam Mars 1 kg	15	0.9277	402
		TAW	Terigu Segitiga Biru Eco 1 kg	100	3.9197	1602
		JFCB	Royco Bumbu Pelezat Rasa Ayam Mars 1 kg	20	4.1194	1722
			Bimoli Klasik Pouch 2 L	1	4.1398	1734
		HHS	Knorr Beef Powder ID 1 kg	2	4.1795	1746
			Knorr Chicken Powder Refill 1 kg	8	4.2594	1794
		AJ	Terigu Segitiga Biru Eco 1 kg	60	6.0546	2514
			Terigu Segitiga Biru Eco 0,5 kg	2	6.1041	2534
		TB	Terigu Segitiga Biru Eco 1 kg	24	6.8221	2822
		CYL	Miwon 250 g	5	6.9963	2922
			Terigu Segitiga Biru Eco 1 kg	1	7.0262	2934
		LS	Simas White Fat Shortening 15 kg	10	7.2407	3084
			Terigu Segitiga Biru Eco 1 kg	1	7.2706	3096
2	Isuzu Elf NMR	SB	Mother Choice Margarine 15 kg	95	1.7389	1425
			Terigu Segitiga Biru Eco 1 kg	100	4.7309	2625
			Butir K10 Polos 12 kg	60	6.0288	3345
		HBS	Terigu Segitiga Biru Eco 1 kg	15	6.4776	3525
			Mother Choice Margarine 15 kg	70	7.7589	4575
3	**…**	…	….	…	…	…

4.9 Distance Matrix

The distance matrix is a table that shows the distance between each point in a location.In the creation of this distance matrix, it will be done for each cluster that has been formed using the Google Maps application. In this distance matrix, one-way street instructions and restrictions on U-turns are also followed according to real conditions, so the distance matrix created using Google Maps shows that the distance from point A to B is not always the same as the distance from point B to A.

In cluster 1, a group of customers consisting of 9 customers was formed.

Table 10. Distance matrix cluster 1

	G	X10	X1	X26	X42	X7	X18	X32	X5	X36
G		9,6	12,9	7,3	8,9	1,9	8,4	5,5	8	7,7
X10	6,5		7,8	1,7	8,1	7,7	8,7	3,9	10,1	10,5
X1	13,1	6,6		8.2	4	11,6	4,6	10,1	6	6
X26	5,9	2,1	7,9		8,7	4,4	9,2	2,9	10,5	10,3
X42	9,1	7,4	4	9,1		7,6	0,5	10	1,9	2,6
X7	1,7	5,5	11,9	6,3	7,9		7,4	4,5	7	6,7
X18	8,6	7,9	4,6	9,3	0,5	7,1		9,5	1,4	1,4
X32	4,3	3,5	9,7	1,8	8,9	1.9	8,4		8	7,8
X5	8	8,6	5.2	10,5	1,2	6,5	0,7	8,8		1
X36	7,9	8,7	5,3	10,3	1,9	6,4	0,8	8,8	0,4	

In cluster 2, a group of customers consisting of 2 customers was formed.

Table 11. Distance matrix cluster 2

	G	X27	X34
G		8	7,2
X27	8,2		1,1
X34	7,4	0,9	

In cluster 3, a group of customers consisting of 3 customers was formed.

Table 12. Distance matrix cluster 3

	G	X29	X19	X8
G		7,1	9,7	9,7
X29	7,5		2,4	2,7
X19	9,5	2,6		0,09
X8	9,6	2,4	0,09	

In cluster 4, a group of customers consisting of 5 customers was formed.

Table 13. Distance matrix cluster 4

	G	X16	X6	X9	X30	X21
G		8,5	14,5	13,6	7,7	9
X16	8,5		6,1	5,2	1,5	0,9
X6	14,3	5,8		0,9	6,6	5,5
X9	14,6	6,2	0,9		7	5,7
X30	7,7	1,6	7,6	6,7		2,1
X21	9	0,9	5,3	4,7	1,4	

In cluster 5, a group of customers consisting of 2 customers was formed.

Table 14. Distance matrix cluster 5

	G	X28	X22
G		8,7	9,3
X28	8,6		0,4
X22	8,7	0,4	

In cluster 6, a group of customers consisting of 2 customers was formed.

Table 15. Distance matrix cluster 6

	G	X40
G		9,3
X40	8,7	

In cluster 7, a group of customers consisting of 6 customers was formed.

Table 16. Distance matrix cluster 7

	G	X39	X15	X24	X37	X23	X2
G		9,4	4,6	4,9	10,8	8,7	3
X39	9,4		4,8	5,1	2,1	0,95	7,2
X15	4,5	5,7		2,2	7	5,8	2,3
X24	5	4,5	0,4		5,9	3,6	2,4
X37	10,8	2	6,3	6,6		2,4	8,6
X23	9,2	0,9	4,7	5	2,3		7
X2	3,2	6,7	2	2,2	8,1	5,8	

In cluster 8, a group of customers consisting of 5 customers was formed.

Table 17. Distance matrix cluster 8

	G	X12	X35	X13	X14	X33
G		12,4	13	8,5	9	6,7
X12	12,4		0,6	4,7	5,9	6,7
X35	13	0,6		5,3	6,5	7,3
X13	8,5	4,5	5,1		1,5	2,3
X14	9	5,9	6,5	1,4		2,3
X33	6,7	6,7	7,5	2,2	2,3	

In cluster 9, a group of customers consisting of 10 customers was formed.

Table 18. Distance matrix cluster 9

	G	X41	X38	X43	X3	X17	X4	X20	X11	X25	X31
G		4,3	3,5	3	2,6	9,3	9,8	7,8	7,6	7,1	6,5
X41	5,1		1,7	2,3	2,5	8,4	8,9	11,6	11,4	10,9	10,3
X38	3,4	0,9		0,7	0,9	6,8	7,1	10	9,8	9,2	8,6
X43	3	1,5	0,7		0,4	6,9	7,3	9,5	9,3	8,8	8,2
X3	2,6	1,8	1	0,4		6,9	7,2	9,1	8,9	8,4	7,8
X17	9,3	7,5	6,7	6,9	6,9		0,5	4,7	6,8	7,2	9,1
X4	9,7	7,9	7,1	7,3	7,2	0,5		5,2	7,2	8,8	9,5
X20	6,2	9,2	8,5	7,9	7,5	4,7	5,2		3,3	4,8	5,6
X11	6,3	9,4	8,6	8,1	7,6	8,8	9,2	5,3		1,6	2,3
X25	6,8	9,9	9,1	8,6	8,1	8,3	7,7	3,7	0,5		2,8
X31	4,8	7,9	7,1	6,5	6,1	8,6	9	5,1	1,9	1,3	

4.10 Route Determination with Nearest Neighbor

At this stage, route determination will be carried out using the Nearest Neighbor method to determine the travel route in each cluster.This method will be used to arrange the sequence of customer visits based on the proximity between locations according to the distance matrix that has been created.

The following is an example of route determination using the Nearest Neighbor method on one of the clusters.

G → X27 = 8 km

G → X34 = 7.2 km

The route taken is G → X34 with the shortest distance of 7.2 km. Next, from the location of customer X34, the nearest customer location to X34 is searched, which is at the last point X27 with a distance of 0.9 km.After all the requests in that cluster have been fulfilled, they will return to the depot with a total distance of 8.2 km.

Table 19. Vehicle routing with the nearest neighbor method

C	Route	Vehicle Type	Fuel Ratio	Total Distance (km)	Total Fuel Cost
1	G → X7 → X32 → X26 → X10 → X1 → X42 → X18 → X5 → X36 → G	Toyota Dyna 115ST	1:7	32.9	IDR 65,330.00
2	G → X34 → X27 → G	Isuzu Elf NMR 71	1:4	16.3	IDR 56,642.50
3	G → X29 → X19 → X8 → G	Isuzu Elf NMR 71	1:4	19.19	IDR 66,685.25
4	G → X30 → X16 → X21 → X9 → X6 → G	Hino Dutro 110SD	1:7	30.1	IDR59,690.57
5	G → X28 → X22 → G	Toyota Dyna 110ET	1:5	17.8	IDR 49,484.00
6	G → X40 → G	Isuzu Elf NMR 71	1:4	18	IDR 62,550.00
7	G → X2 → X15 → X24 → X23 → X39 → X37 → G	Mitsubishi Colt L300	1:8	24.6	IDR 42,742.50
8	G → X33 → X13 → X14 → X12 → X35 → G	Toyota Dyna 110ET	1:5	29.9	IDR 83,122.00
9	G → X3 → X43 → X38 → X41 → X17 → X4 → X20 → X11 → X25 → X31 → G	Toyota Dyna 110ET	1:5	31.2	IDR 86,736.00
	Total			**220**	**IDR 572,982.82**

4.11 Route Determination with Branch and Bound

Route determination using Branch and Bound is a method that systematically explores all possibilities by breaking the problem into subproblems and then calculating the lower bound of each problem.If the lower bound value is higher than the predetermined best solution, then this branch will be pruned. The WinQSB software is used to help solve the problem more quickly. Route creation will be carried out for each cluster by inputting the distance matrix that has been created into the WinQSB software.

03-15-2025	From Node	Connect To	Distance/Cost		From Node	Connect To	Distance/Cost
1	G	X36	7,7	6	X1	X10	6,6
2	X36	X5	0,4	7	X10	X26	1,7
3	X5	X18	0,7	8	X26	X32	2,9
4	X18	X42	0,5	9	X32	X7	1,9
5	X42	X1	4	10	X7	G	1,7
	Total	Minimal	Traveling	Distance	or Cost	=	28,10
	(Result	from	Branch	and	Bound	Method)	

Figure 2. Cluster 1 route branch and bound

Table 20. Vehicle routing with the branch and bound

C	Route	Vehicle Type	Fuel Ratio	Total Distance (km)	Total Fuel Cost
1	G → X36 → X5 → X18 → X42 → X1 → X10 → X26 → X32 → X7 → G	Toyota Dyna 115ST	1:7	28.1	IDR 55,798.57
2	G → X34 → X27 → G	Isuzu Elf NMR 71	1:5	16.3	IDR 56,642.50

C	Route	Vehicle Type	Fuel Ratio	Total Distance (km)	Total Fuel Cost
3	G → X29 → X19 → X8 → G	Isuzu Elf NMR 71	1:5	19.19	IDR 66,685.25
4	G → X16 → X9 → X6 → X21 → X30 → G	Hino Dutro 110SD	1:7	29.2	IDR 57,982.86
5	G → X28 → X23 → G	Toyota Dyna 110ET	1:5	17.8	IDR 49,484.00
6	G → X40 → G	Isuzu Elf NMR 71	1:5	18	IDR 62,550.00
7	G → X2 → X24 → X23 → X37 → X39 → X15 → G	Mitsubishi Colt L300	1:8	22.4	IDR 38,920.00
8	G → X33 → X14 → X13 → X35 → X12 → G	Toyota Dyna 110ET	1:5	28.5	IDR 79,230.00
9	G → X3 → X43 → X38 → X41 → X17 → X4 → X20 → X11 → X25 → X31 → G	Toyota Dyna 110ET	1:5	31.2	IDR 86,736.00
	Total			**210.7**	**IDR 554,029.18**

4.12 Comparison of Result Analysis

Based on the data processing that has been carried out in determining the distribution route from PT Cahaya Mahakam Samarinda, the results will be compared between the initial route, the proposed route using the Nearest Neighbor method, and the Branch and Bound method, with the comparison aspects to be considered being the travel distance and fuel cost.

Table 21. Comparison of result analysis

C	Route	Total Distance (km)	Total Fuel Cost	
1	G → X26 → X17 → X4 → G	30.3	IDR 60,167.14	Initial Route
2	G → X28 → X22 → G	17.8	IDR 49,484.00	
3	G → X40 → G	18	IDR 62,550.00	
4	G → X30 → X19 → X8 → X18 → G	22.5	IDR 62,550.00	
5	G → X23 → X39 → X37 → X12 → X35 → G	28.5	IDR 99,037.50	
6	G → X3 → X43 → X38 → X41→ X15 → X24 → X33 → X14 → X13 → G	29.2	IDR 57,982.86	
7	G → X31 → X11 → X10 → X1 → X32 → G	35	IDR 35,000.00	
8	G → X36 → X5 → X42 → G	18.4	IDR 18,400.00	
9	G → X7 → X2 → X16 → X21 → X9 → X6 → G	30.7	IDR 106,682.50	
10	G → X27 → X29 → G	16.6	IDR 46,148.00	
11	G → X25 → X20 → X34 → G	28.3	IDR 49,171.25	
	Total	**275.3**	**IDR 647,173.25**	
C	Route	Total Distance (km)	Total Fuel Cost	Sweep-Nearest Neighbor
1	G → X7 → X32 → X26 → X10 → X1 → X42 → X18 → X5 → X36 → G	32.9	IDR 65,330.00	
2	G → X34 → X27 → G	16.3	IDR 56,642.50	
3	G → X29 → X19 → X8 → G	19.19	IDR 66,685.25	
4	G → X30 → X16 → X21 → X9 → X6 → G	30.1	IDR 59,690.57	
5	G → X28 → X22 → G	17.8	IDR 49,484.00	
6	G → X40 → G	18	IDR 62,550.00	

7	G → X2 → X15 → X24 → X23 → X39 → X37 → G	24.6	IDR 42,742.50	
8	G → X33 → X13 → X14 → X12 → X35 → G	29.9	IDR 83,122.00	
9	G → X3 → X43 → X38 → X41 → X17 → X4 → X20 → X11 → X25 → X31 → G	31.2	IDR 86,736.00	
	Total	**220**	**IDR 572,982.82**	
C	Route	Total Distance (km)	Total Fuel Cost	
1	G → X36 → X5 → X18 → X42 → X1 → X10 → X26 → X32 → X7 → G	28.1	IDR 55,798.57	
2	G → X34 → X27 → G	16.3	IDR 56,642.50	
3	G → X29 → X19 → X8 → G	19.19	IDR 66,685.25	
4	G → X16 → X9 → X6 → X21 → X30 → G	29.2	IDR 57,982.86	*Sweep-Branch and Bound*
5	G → X28 → X23 → G	17.8	IDR 49,484.00	
6	G → X40 → G	18	IDR 62,550.00	
7	G → X2 → X24 → X23 → X37 → X39 → X15 → G	22.4	IDR 38,920.00	
8	G → X33 → X14 → X13 → X35 → X12 → G	28.5	IDR 79,230.00	
9	G → X3 → X43 → X38 → X41 → X17 → X4 → X20 → X11 → X25 → X31 → G	31.2	IDR 86,736.00	
	Total	**210.7**	**IDR 554,029.18**	

4.13 Analysis of Comparative Results

The selected method is the Branch and Bound method with a total travel distance of 210.7 km and a fuel cost of IDR 554,029.18. A total of **9** clusters were formed using 9 vehicles, resulting in a distance savings of 64.6 km (23.47%) and a fuel cost savings of IDR 93,144.07 compared to the initial route.

These results indicate that the Branch and Bound method performs better than the Nearest Neighbor method because its algorithm is capable of exploring route combinations comprehensively (exhaustive search) to find truly optimal solutions, rather than relying only on the nearest local distance as in the Nearest Neighbor method. Thus, although it requires longer computation time, Branch and Bound is more effective in producing solutions with more efficient distance and cost.

5. CONCLUSION

The comparison of methods shows that the Branch and Bound method produces the most optimal total distance of 210.7 km with a fuel cost of IDR 554,029.18, achieving a distance savings of 64.6 km (23.47%) and a fuel cost reduction of IDR 93,144.07 compared to the initial route. These findings demonstrate that the Branch and Bound method is more effective than the Nearest Neighbor method in optimizing delivery routes, as it explores possible route combinations comprehensively to achieve a truly optimal solution. Implementing optimization algorithms like Branch and Bound can help companies design more systematic and cost-effective distribution systems, especially in sectors such as FMCG where delivery frequency and distance significantly impact profitability. For future research, integrating additional factors such as time windows**,** traffic conditions, or dynamic routing could enhance model applicability in real-time operations..

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