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Distribution Truck Route Optimisation at UDMB Using The Clarke and Wright Savings and Cluster First Route Second

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Abstract

UDMB is a distributor company of frozen food products in East Kalimantan and North Kalimantan. Time and distance are the biggest obstacles felt by companies in the distribution process. It is because the product must be at a minimum temperature of -18o Celsius so that the product remains in good condition. Meanwhile, the cooling machine on a distribution truck can only maximize working temperature for 6 hours. These travel time and distance problems have occurred more than 12 times a year in out-of-town distribution. Therefore, this research aims to produce an optimal distribution routes with consideration of the fastest time and shortest distance. This problem is solved using the Clarke and Wright Savings Method with the Head and Tail concept and the Cluster First Route Second Method with Sweep Algorithm and Nearest Neighbor. Then, the total distribution time and distance between the results of the two methods are compared. Based on the first results, the total trucks used are 3 units with a total distribution time of 847 minutes and a total distribution distance of 475.8 km. Based on the second results, the total trucks used are 3 units with a total distribution time of 875 minutes and a total distribution distance of 483.8 km. This shows that the Clarke and Wright Savings Method with the Head and Tail concept is the method that produces the most optimal route with the fastest total distribution time and shortest total distribution distance.

1. INTRODUCTION

Problems related to distribution are the biggest obstacle for companies, especially in Supply Chain Management because they are dealing with partners that can affect the sustainability of the supply chain (Saragih, 2024). Distribution is defined as an activity that includes planning, implementing and monitoring the flow of materials to obtain the final product from the place of production by obtaining profits using transportation. Usually, transport problems can be in the form of varying amounts of goods transported which will result in different profits and costs so that the solution to the problem is to determine the number of units of goods that must be transported (Sekarningtyas et al., 2023). That way, the distribution and transport network needs to be done optimally because it is one of the important factors that affect the amount of expenses and income in a company. One of the steps that can be taken to make the process more efficient is to make proper distribution and transportation planning so that products can reach customers on time (Wulandari and Mulyanto, 2024).

Optimal route planning can be done when the organisation experiences a problem that arises in the distribution and transportation department. These problems are generally related to the value of place and time obtained based on the varied products distributed. These values can be analysed to find solutions to the causes and effects. Thus, the company managing the distribution system can take the necessary actions to optimise the use of its transportation resources.

Distribution and transport route planning can be solved using the Vehicle Routing Problem (VRP). The Vehicle Routing Problem (VRP) was first introduced by Dantzig and Ramser in 1959 and is a development of the Traveling Salesman Problem. In the VRP problem there is more than one vehicle that visits each customer

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and the customer can only be visited once (Widyastiti and Sumarsa, 2023). There are four general objectives in the Vehicle Routing Problem (VRP), namely minimising transportation costs related to distance and fixed costs associated with vehicles, minimising the number of vehicles (or drivers) needed to serve all consumers, balancing routes for travel time and vehicle load, and minimising complaints from consumers due to unsatisfactory service (Wulandari, 2020). There are several variations of the Vehicle Routing Problem (VRP), namely VRP with multiple trips, VRP with capacitated, VRP with time window, VRP with split deliveries, VRP with multiple products, Periodic VRP, VRP with multiple depots, VRP with heterogeneous fleet of vehicles, Stochastic VRP, and Dynamic VRP (Pertiwi et al., 2020). The types of VRP in this research are VRP with capacitated, VRP with time window, and VRP with multiple products.

The examples of research using these methods are research by Setiawan and Suseno (2024) using the Clarke And Wright Savings and Sequential Insertion Methods, Afriana et al. (2023) using the Clarke And Wright Savings and Nearest Neighbor Methods, Yusuf and Sukoyo (2023) using the Clarke And Wright Savings Method, Solihin et al. (2023) using the Cluster First Route Second Method, and research by Putri et al. (2021) using the Genetic Algorithm Method with Cluster First Route Second. Whereas in this study, the Vehicle Routing Problem (VRP) approach used is Clarke And Wright Savings developed using the Head and Tail concept, and Cluster First Route Second using Sweep Algorithms and Nearest Neighbor. This research compares the two types of Vehicle Routing Problem (VRP) approaches with methods that have been developed to see which approach has the most optimal results.

One of the companies that experience problems in the distribution and transportation section is UDMB. UDMB is the main distributor of frozen food products in East Kalimantan and North Kalimantan. The company distributes out of town and within the city based on incoming requests from the intended partners. Time and distance are the biggest obstacles felt by the company in the distribution process outside the city because the product must be at a minimum temperature of -18^{o} Celsius so that the product remains in good condition. Meanwhile, the cooling machine on the distribution truck can only maximise the temperature work for 6 hours and the temperature will start to drop as the distance and travel time increase to the last point. In addition, the company also needs to meet the minimum turnover value requirement of one hundred million rupiah in one out-of-town distribution trip. If the number in this requirement is not achieved, the company needs to add other partners as additional location points so that distribution can be carried out. Thus, the distribution system in this company is not included in the regular route type, which means that the company does not have a set route but the route depends on the changing demand conditions of each partner.

The problem of travelling time and distance has occurred more than 12 times a year. One of them occurs in 7 out-of-town partners. The company conducts the distribution process once a month with a six-wheeled truck. Each partner gets a supply of frozen food products in the form of processed meat distributed directly by the company. In the distribution process, the company always tries to maximise the volume of cargo, which is 9 m^3 to meet all requests to achieve the specified turnover value requirements. In fact, the company has an allowance volume that needs to be considered at 25% of the truck load volume. This is because frozen food products require good cold air circulation from the cooling machine on the truck box so that the product remains in good condition. This causes a decrease in truck performance, namely truck speed that becomes not optimal and causes the product to experience open vaccum seal damage so that the company experiences losses in the form of unsalable products. The distribution process is known to take approximately 9 hours with the destination of the farthest point (A7) which has exceeded the time limit of the cooling machine on the distribution truck.

Therefore, in an effort to minimise the losses caused by this problem, it is necessary to optimise the distribution truck routes. Route optimisation for distribution trucks to each point is carried out by taking into account the volume of cargo, the weight of the cargo, and the time to complete the distribution. The route results will consider the fastest time and shortest distance using the Clarke and Wright Savings Method with the Head and Tail concept and the Cluster First Route Second Method with Sweep Algorithms and Nearest

Neighbor. The results of this study are expected to help companies as input and evaluation material in achieving the desired goals.

2. METHODS

This research begins with a preliminary study to gather information of the company. Then, it continued with problem identification through observation and initial interviews in order to formulate and determine objectives. In solving the problem, data collection is carried out consisting of initial loading time data, unloading time for each stop, demand data, distance and time data between points, coordinate data for each point, product prices, truck capacity, truck box dimensions, and product box dimensions. The data collection was carried out by direct observation and interviews with the company. In addition, data related to distance and time was obtained using the help of google maps. The data is used to represent the real condition of the company into a mathematical model. Then, data processing is carried out using the data analysis techniques performed that can be described as follows.

2.1 Turnover Value

Turnover value is an important metric in management that describes the turnover value or total sales or total revenue generated by the company. Total turnover value can be obtained using Equation (1) below.

$$\text{Turnover value} = \Sigma\ (\text{Number of units} \times \text{Selling price}) \quad (1)$$

Where the number of units is the total units per product according to the demand data and the selling price is the price per product.

2.2 Clarke and Wright Savings

The Clarke and Wright Savings Method is a step discovered by Clarke and Wright in 1964 (Marpaung et al., 2022). This method serves to minimise time, cost, or distance by taking into account existing constraints. The Clarke and Wright Savings Method is the optimal solution because the Clarke and Wright Savings Method is the most widely used heuristic method for constructing routes and the total distance obtained is small (Munir et al., 2023). According to Engraini et al. (2020), the steps in the calculation process in the clarke and wright savings method are as follows.

1. Create a distance matrix, namely the distance matrix between depots and nodes and between nodes.
2. Calculate the savings value (Sij) in the form of mileage from a vehicle to serve nodes i and j combined using Equation (2) below.

   $$S_{ij} = C_{oi} + C_{oj} - C_{ij} \quad (2)$$

   Where Coi is the distance from the depot to node i, Coj is the distance from the depot to node j, Cij is the distance from node i to node j, and Sij is the distance saving value from node i to node j.
3. Create a savings matrix, where the general form of the savings matrix.
4. Select the combination of nodes with the largest to smallest saving value to be included in the route.
5. Conducting route feasibility tests by calculating constraints such as the total demand volume of the selected node combinations and the total completion time. If the total demand volume is ≤ the vehicle capacity and the total completion time is ≤ the time capacity then go to step 6, but if the total demand volume is > vehicle capacity and the total completion time is > time capacity then create a new route and return to step 4 by selecting the customer combination that has the next largest savings value.

   $$\text{Total demand volume} = \Sigma\ (\text{Number of units} \times (\text{Length} \times \text{Width} \times \text{Height}))_{(i)} \quad (3)$$
   $$\text{Total demand weight} = \Sigma\ (\text{Number of units} \times \text{Product weight})_{(i)} \quad (4)$$
   $$\text{Total completion time} = \text{Travelling time} + \text{Initial loading time} + \text{Unloading time}_{(i)} \quad (5)$$

Where i is the 1st,2nd,3rd product,... and so on.

6. Insert the selected nodes into the route.
7. Check whether all nodes have been assigned, if so then the distribution route is formed, if not then return to step 4 to select the combination of nodes with the next largest savings value.

2.2.1 Head and Tail Concept

The Head and Tail concept is used in the development of the Clarke and Wright Savings Method. The Head and Tail concept is used to change the route determination process by considering the savings value of the points that have been included in the temporary route. The steps in applying the Head and Tail concept to the Clarke and Wright Savings Method are as follows.

1. The initial head and tail are the point pairs that have the largest saving value. However, if there are pairs of points that have the same saving value, the pair of points that has the closest distance is taken.
2. Delete the selected point to continue the step.
3. Determine the next point by comparing the saving value between the point with the head and the point with the tail to determine the new point replacement. If the saving value of the point with the head is greater than the saving value of the point with the tail, then the head is replaced with a new point and vice versa.
4. Delete the selected point again to continue the step.
5. If there are still saving values with unselected points then the iteration is continued by determining the new head and tail. However, if there is no saving value left then iteration is done by restarting from determining the initial head and tail on the next vehicle route ($k = k + 1$).

2.3 Cluster First Route Second

Cluster First Route Second is a problem solving that involves two stages (Putri et al., 2021). The first stage is to group customer location points by considering capacity and distance first. Then the second stage is to determine the order of delivery within each group of customers that have been formed in order to get the optimal vehicle assignment and route. The Cluster First Route Second Method is useful for simplifying the problem by forming groups to get the optimal solution.

2.3.1 Sweep Algorithm

The Sweep Algorithm was first introduced by Gillet and Miller in 1974, which is a simple solution method used in creating clusters (Fauzi et al., 2023). Basically, this algorithm collects agents with the same direction from the distributor into one vehicle route using geographic coordinates. The steps in performing the Sweep Algorithm are as follows.

1. Create cartesian coordinates at each point,
2. Calculate the polar coordinates at each point, the calculation can be done using software such as Geo Gebra or Microsoft Excel. Polar coordinates can be done using Equation (6) below.

$$\theta_i = \arctan(\text{relative } y, \text{relative } x) \quad (6)$$

Where θ is the polar coordinate, and i is the 1st,2nd,3rd point,... and so on.

3. Sorting the smallest to largest polar coordinate value,
4. Making clustering based on the order of polar coordinates,
5. Followed by route sorting using a method that can solve the Travelling Sales Problem (TSP), for the example is Nearest Neighbor Method.

2.3.2 Nearest Neighbor

Mapping delivery routes, setting delivery schedules, and managing delivery fleets are some examples of using the Nearest Neighbor Method in distribution routes. The purpose of the Nearest Neighbor Method is to determine the closest route or nearest neighbor from a certain location or point to optimize the distance in the process of distributing goods or services (Azhar et al., 2023). Determination of the Nearest Neighbor can be done using Equation (7) below.

$$\Delta f = d_{0i} + d_{ij} + ... + d_{j0} \quad (7)$$

Where Δf is the total distance, d0i is the distance from the starting point (warehouse) to location i, dij is the distance from location i to location j (insert nearest location), and dj0 is the distance from location j to the starting point (Octaviarie et al., 2023). The steps to determine the route using the Nearest Neighbor Method are as follows.

1. Select the center point as the starting point for delivery or departure point.
2. Determine the point with the smallest distance from the starting point then merge between the two points.
3. The last visited point becomes the starting point, and then selects the next point with the closest distance from the starting point.
4. Repeat the process until the capacity reached is insufficient to select the next point.
5. Draw the point on a line, this point is called a travel route.
6. Perform the same process, in steps one through five until all existing points have their own routes.

3. RESULT AND DISCUSSION

This research aims to optimize distribution truck routes. The research uses data for one month in August 2024. Then, calculations are carried out using Equations (3), (4), and (1) on the demand data to produce data listed in Table 1. Meanwhile, Equation (5) is used after the formation of a route so that the distribution completion time does not exceed the time limit of the truck's cooling engine capability.

Table 1. Calculated demand data for each node.

Node	Demand		
	Total Volume (m^3)	Total Weight (Ton)	Total Price (IDR)
A1	2.714	0.740	79.896.418
A2	3.655	0.936	110.162.172
A3	1.062	0.343	42.262.917
A4	1.062	0.281	38.960.451
A5	3.887	0.995	106.846.935
A6	1.135	0.292	36.500.907
A7	1.630	0.376	37.186.887

Table 2. Truck capacity.

Truck Box Dimension	(m)	Box Volume (m^3)	*Allowence* (%)	Max Load Volume (m^3)	Max Load Weight (Ton)	Cooling Engine Capability (minute)
Length	3	9.18	25	6.885	5	360
Width	1.7					
Height	1.8					

The truck capacity in Table 2 is used as constraints in this research. There are three constraints used, which consist of the volume of cargo, the weight of the cargo, and the time to complete the distribution. The value of volume of cargo taken from the maximal load volume, which is 6.885 m^3. The value of weight of cargo taken from the maximal load weight, which is 5 Ton. The value of time to complete the distribution taken from the cooling engine capability, which is 360 minutes.

3.1 Turnover Value

Turnover value is the overall accumulation of the amount of revenue earned from the sale of a product or service that is calculated as a whole over a certain period of time (Wilujeng et al., 2024). Based on calculated demand data, it can be seen that the turnover value of each node using Equation (1) is IDR 451,816,687. This value can be said to have exceeded the minimum turnover value or minimum turnover value in one out-of-town distribution trip set by the company, which is IDR 100,000,000 so that the distribution problem solving can be continued.

3.2 Clarke and Wright Savings

This method is carried out to determine the number of trucks used and the group of locations to be targeted based on constraints, namely weight capacity, volume and truck cooling engine time limit. The first step is to create a distance matrix from one node to another based on distance data which can be seen in Table 3. Then, proceed with calculating the savings matrix using Equation (2) to produce data which listed in Table 4.

Table 3. The distance matrix.

	A1	A2	A3	A4	A5	A6	A7
A1	0	105	111.5	114	117	120	120
A2	105	0	18.5	23	25	27	27
A3	111.5	18.5	0	5.2	7.7	8.9	9.7
A4	114	23	5.2	0	5.7	5.1	5.1
A5	117	25	7.7	5.7	0	3.8	5.9
A6	120	27	8.9	5.1	3.8	0	2.5
A7	120	27	9.7	5.1	5.9	2.5	0

Table 4. The saving matrix.

	A1	A2	A3	A4	A5	A6	A7
A1	0	198	196	197	198	198	198
A2	198	0	220.3	220.8	222.6	221.8	215.5
A3	196	220.3	0	225.3	228.9	228.9	222
A4	197	220.8	225.3	0	233.2	231.1	227
A5	198	222.6	228.9	233.2	0	237.5	233
A6	198	221.8	228.9	231.1	237.5	0	231
A7	198	215.5	222	227	233	231	0

Based on the calculation results in Table 4, the distribution route results are formed for route 1 with nodes G-A5-A6-A4, route 2 with nodes G-A3-A7, and route 3 with nodes G-A1-A2. Detailed results can be seen in Table 5 below.

Table 5. The Clarke and Wright Savings results.

Truck	Route	Total Volume (m^3)	Total Weight (Ton)	Total Time (minute)	Total Distance (km)
1	G-A5-A6-A4	6.083	1.568	261	128.4
2	G-A3-A7	2.692	0.720	357	229
3	G-A1-A2	6.369	1.676	237	123.5

The Clarke and Wright Savings Method only determines the route sequence by considering the savings value of the pair of two customer points only and does not consider the savings value of other pairs of customer points that have been entered previously (Yusuf and Sukoyo, 2023). Therefore, the nodes for each route were arranged using the Head and Tail concept. The results of determining the route can be seen in the Table 6 below.

Table 6. The Head and Tail results.

Truck	Route	Total Volume (m^3)	Total Weight (Ton)	Total Time (minute)	Total Distance (km)
1	G-A4-A5-A6	6.083	1.568	253	123.3
2	G-A3-A7	2.692	0.720	357	229
3	G-A1-A2	6.369	1.676	237	123.5

Based on the calculation results in Table 6, the distribution route results are formed have changed for route 1 with nodes G-A4-A5-A6. While for other routes, there is no change in the order of nodes. This means that the previously formed nodes are optimal, except for the nodes on the first route.

3.3 Cluster First Route Second

This method is done by using a Sweep Algorithm to create clusters as an initial stage. This algorithm is used to determine the intended location group based on the constraints in the study, namely the weight capacity, volume and time limit of the truck cooling machine. The first step is to create a scatter diagram with the help of Microsoft Excel based on the coordinate data of each point.

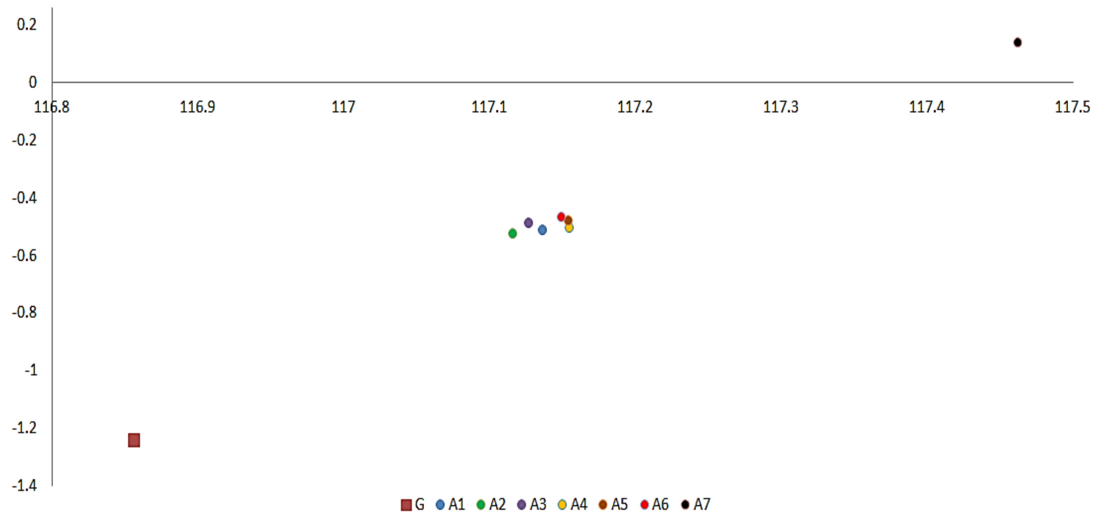

Figure 1. Scatter diagram of each nodes.

Based on the scatter diagram, it can be seen that the position of all nodes is to the right of the depot. Therefore, the polar coordinates of each point are calculated using Equation (6) sorted from the smallest to the largest value. Then, a straight line is drawn from one node to the next on the scatter diagram to see the clusters formed. This is done while still considering the three constraints.

Table 7. The Head and Tail results.

Node	θ
A3	0.342666767
A2	0.346119658
A6	0.359518442
A1	0.364152713
A5	0.370555893

A4	0.382750806
A7	0.412141791

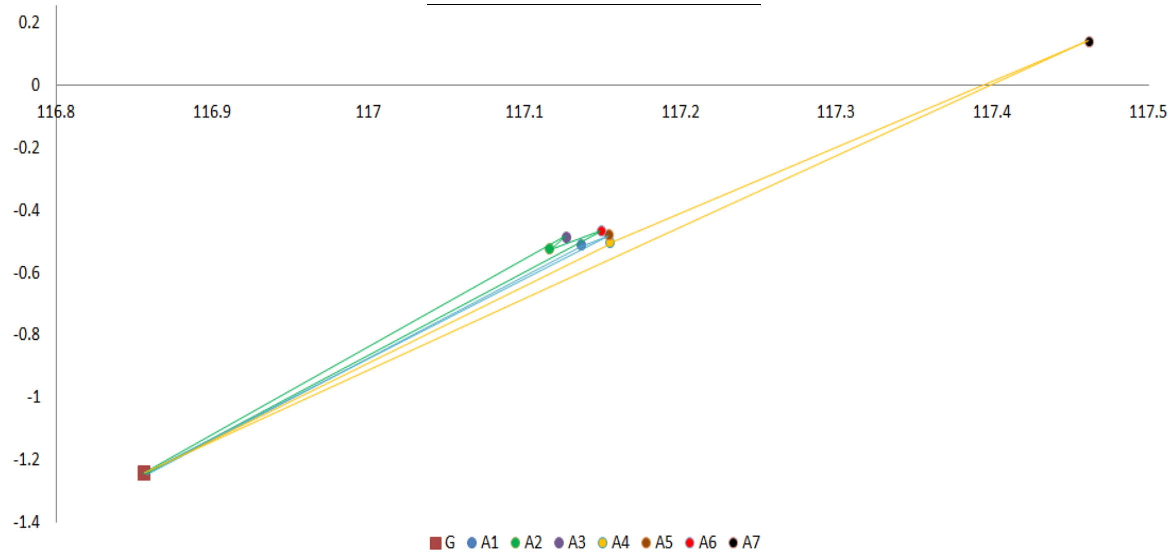

Figure 2. Clusters that are formed

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Based on the clusters result, the distribution route results are formed for route 1 with nodes G-A3-A2-A6, route 2 with nodes G-A1-A5, and route 3 with nodes G-A4-A7. Detailed results can be seen in Table 8 below.

Table 8. The cluster results.

Truck	Route	Total Volume (m^3)	Total Weight (Ton)	Total Time (minute)	Total Distance (km)
1	G-A3-A2-A6	5.852	1.572	273	128.9
2	G-A1-A5	6.600	1.734	258	132
3	G-A4-A7	2.691	0.658	358	230

After that, route determination is carried out as the second stage using the Traveling Salesman Problem such as the Nerarest Neighbor Method. The calculation is carried out using Equation (7) and the results can be seen below.

Table 9. The routes results.

Truck	Route	Total Volume (m^3)	Total Weight (Ton)	Total Time (minute)	Total Distance (km)
1	G-A2-A3-A6	5.852	1.572	259	121.8
2	G-A1-A5	6.600	1.734	258	132
3	G-A4-A7	2.691	0.658	358	230

Based on the calculation results in Table 9, the distribution route results are formed have changed for route 1 with nodes G-A2-A6-A6. While for other routes, there is no change in the order of nodes. This means that the previously formed nodes are optimal, except for the nodes on the first route.

3.4 Result Comparison

Based on the results of each method carried out above, namely the Clarke and Wright Savings Method and the First Route Second Cluster, a comparison is made to see which method is more optimal.

Table 10. Comparison of the two methods.

Method	Quantity of Truck	Truck	Route	Total Time (minute)	Total Distance (km)
Clarke and Wright Savings	3	1	G-A4-A5-A6	253	123.3
		2	G-A3-A7	357	229
		3	G-A1-A2	237	123.5
		Grand Total		847	475.8
Cluster First Route Second	3	1	G-A2-A3-A6	259	121.8
		2	G-A1-A5	258	132
		3	G-A4-A7	358	230
		Grand Total		875	483.8

Based on this comparison, it can be seen that the total trucks used with the Clarke and Wright Savings Method and the Cluster First Route Second Method have the same number of 3 units. The total travelling time with the Clarke and Wright Savings Method is 847 minutes which is smaller than the travelling time with the Cluster First Route Second Method of 877 minutes. The total travelling distance with the Clarke and Wright Savings Method is 475.8 km which is smaller than the travelling distance with the Cluster First Route Second Method of 483.8 km. The difference in total travel time between the two methods is 28 minutes and the difference in total distance is 8 km, so the method with the shortest total travel distance and the fastest total travel time is the Clarke and Wright Savings Method followed by the Head and Tail concept.

Thus, the route determination method using the Clarke and Wright Savings Method followed by the Head and Tail concept can be considered as the most optimal route determination method compared to the Cluster First Route Second Method carried out in solving the problem in this study. Then based on the problems experienced by the company, the travel time to distribute to the farthest point (A7) lasts for 9 hours or 540 minutes can be completed with a travel time of 237 minutes. This shows that with this method the company can minimise time by 56% or equivalent to saving 303 minutes which is faster than before.

4. CONCLUSIONS

Based on the results of the analysis and discussion, it can be concluded that the number of trucks used is 3 trucks with each having 1 route generated by the Clarke and Wright savings method followed by the Head and Tail concept. The first truck route has an optimal travel time of 253 minutes and an optimal distance of 123.3 km. The second truck route has an optimal travel time of 357 minutes and an optimal distance of 229 km. The third truck route has an optimal travel time of 237 minutes and an optimal distance of 123.5 km.

The results of this study recommend the company to consider the proposed application of the Clarke and Wright Savings Method developed with the Head and Tail concept to determine routes so that the distribution process becomes more optimal. That way, the company still prioritises large partners and can reduce losses. In addition, the company still has the opportunity to maximise the use of transportation resources by adding destination location points on trucks that have load volume, load weight, and distribution completion time with values that are still below the limit.

However, this research also has limitations in processing this case study. The limitations of the research are that the demand data used is only one month in August 2024, the distance and time data does not consider traffic congestion conditions, and it does not rule out the possibility of data bias in this research. Furthermore, suggestions for future research are to consider using other methods as route sorting such as Genetic Algorithm, Insertion Method, Ant Colony Optimisation, and Branch and Bound. In addition, consider the use of other software such as Arena and Cube IQ because they can produce more real load capacity simulations to optimise the use of truck capacity.

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