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Route Optimization of Oil Country Tubular Goods Distribution Using Sweep and Savings Algorithm

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***Abstract*—In the oil and gas industry, one of the key activities is the drilling process where the oil or natural gas are extracted. The process requires the supply of rolled products known as the Oil Country Tubular Goods (OCTG). As an important drilling component, OCTG has a high demand, which in some case it is not balanced with the optimal distribution route and cost that may affect the industry's profit. In order to obtain the optimal distribution routes, this research compares transport routes generated by Sweep and Savings Algorithm to solve the Capacitated Vehicle Routing Problem, by taking an oil and gas company with inefficient OCTG distribution in Sumatera as the object of the study case. Additionally, the total transportation cost is calculated to further compare the results. The research concludes that Sweep Algorithm produces the most efficient routes with the lowest total transportation cost of Rp.18,890,875,000 per year, or 24% less than total cost derived from Savings Algorithm route.**

***Keywords*—Sweep Algorithm, Nearest Neighbor, Savings Algorithm, Capacitated Vehicle Routing Problem, Oil Country Tubular Goods.**

I. INTRODUCTION

THROUGH the recent developments of drilling technology, drilling activity requires extensive amount of Oil Country Tubular Goods (OCTG) to meet its operational objectives as one of the main activities performed in the oil and gas industry [1, 2]. OCTG refers to a classification of seamless rolled products consisting of drill pipe, casing and tubing, and they are used in the extraction of oil or natural gas [3]. Nevertheless, failures of these materials may happen, and the requirement of superior quality of OCTG materials replacement and the increasing prices for oil and natural gas, contribute to the high number of OCTG demand [4]. To accommodate the high demand and maximizing the industry's profits at the same time, an efficient supply chain has to be managed [5]. One of the strategy is by reducing the distribution cost for OCTG supply by utilizing the vehicle fleet effectively and building new more rational distribution routes [6].

PT XYZ is an industry engaged in the oil and gas sector, regularly distributing OCTG from a location to supply their oil fields. These oil fields are spread across Indonesia, including in Sumatra, Java and Borneo Island. Based on data gathered by authors in Table 1, Sumatra is the region where most of the oil fields and OCTG demands come from, if compared to Java and Borneo. Hence, OCTG distribution to oil fields owned by PT. XYZ in the Sumatra region is taken as the object of this research. However, based on initial observation, the existing supply condition of PT XYZ has been considered as inefficient. The company does not have a Distribution Center (DC) near the locations of their fields, so whenever the OCTG are needed in a certain oil field, it will be distributed from another oil field which have extra supplies. The pattern of this distribution route has been causing rising transportation cost for PT XYZ, therefore a prior study by Fadhil *et al*. (2020) [7] determined the DC location selection for PT XYZ, the same company used in this research, to support OCTG distribution. The selected location of DC in Sumatra from that study is Ramba. As a continuation to this previous study, this research applies Ramba as the single DC location to be the main starting and end shipment point to distribute the OCTG to seven different oil fields across Sumatra. Each field has different numbers of demands in a year as presented in Table 1, and the data of distances to Ramba DC and from a field to another was collected and presented in Table 2. Due to these various demands and shipment points, the optimal routes with minimum transportation cost for OCTG distribution are the desired result of this research.

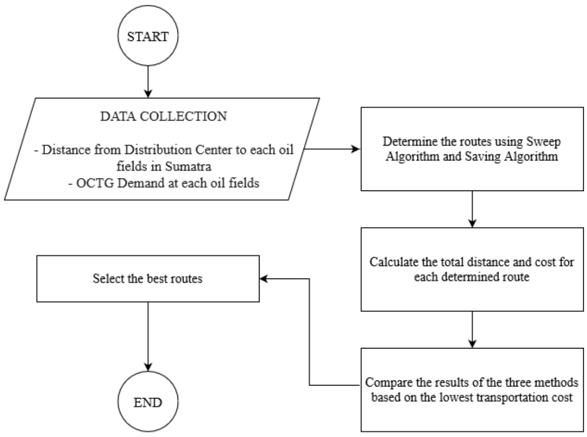

Figure 1. Research Methodology.

To solve the problem of this research, one of the approach of Vehicle Routing Problem (VRP) classification is implemented, namely Capacitated Vehicle Routing Problem (CVRP). CVRP is the VRP where the vehicle used in the problem has limited capacity in picking up or delivering goods to various

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Table 1.
List of oil fields and OCTG demands per year

Sumatra Oil Fields	Demand (MT)	Java Oil Field	Demand (MT)	Borneo Oil Field	Demand (MT)
Rantau	1021	Jatibarang	1811	Sangatta	984
Pangkalan Susu	1605	Cepu	940	Sangasanga	2835
Lirik	445	Poleng	285	Tanjung	659
Ramba	1087			Bunyu	3188
Jambi	2672			Tarakan	3684
Prabumulih	3561				
Pendopo	1194				
Adera	1161				
Total	12746	Total	3036	Total	11350

Table 2.
Distance between fields and DC (km)

Oil Fields	Rantau	Pangkalan Susu	Lirik	Ramba DC	Jambi	Prabumulih	Pendopo	Adera
Rantau	0	27	697	1029	904	1101	1057	1080
Pangkalan Susu	27	0	671	1003	878	1075	1031	1054
Lirik	697	671	0	333	208	409	369	387
Ramba DC	1029	1003	333	0	129	84	71	63
Jambi	904	878	208	129	0	211	181	189
Prabumulih	1101	1075	409	84	211	0	50	20
Pendopo	1057	1031	369	71	181	50	0	37
Adera	1080	1054	387	63	189	20	37	0

Table 3.
Calculation of Polar Coordinates

Oil Field	Demand (MT)	Demand / 264 days (MT)	Latitude	Longitude	r	θ
Rantau	1021	4	4.33304	98.10006	425.071484	0.044140905
Pangkalan Susu	1605	6	4.1212	98.21079	404.7463077	0.041938198
Lirik	445	2	-0.31158	102.30558	31.87637262	-0.003045572
Ramba	1087	4	-2.69613	104.11494	280.7074132	-0.025889921
Jambi	2672	10	-1.65262	103.60352	171.2172492	-0.015950036
Prabumulih	3561	13	-3.44077	104.234	358.6452202	-0.032998072
Pendopo	1194	5	-3.26306	103.82254	338.7791774	-0.031418864
Adera	1161	4	-3.2627	104.15676	339.8322609	-0.031314659

(a) (b)

Figure 2. (a) Clustering Results for Cluster 1; (b) Clustering Results for Cluster 2.

shipment points [8]. The capacity itself is based on the volume of the quantity of the goods, and the maximum capacity of the vehicle. The intended result of implementing this CVRP is the utilization of vehicle with minimized distance without exceeding its capacity. CVRP is chosen in this research, because there are two vehicles with each capacity of 30 Metric Tons (MT) taken as the study objects also as the limitation which complies with the CVRP. To obtain the best routes, Sweep Algorithm and Savings Algorithm are implemented. The expected results from the calculation is the minimized distribution routes, and the best routes with minimum costs to distribute OCTG from Ramba DC to oil fields will be selected. The results of this study also provide an overview of the initial route solutions to PT XYZ, which can be further developed if additional constraints are added to this model such as time, fuel costs, and others.

Additionally, obtaining the optimal distribution routes and costs are expected to give several benefits to the oil company, such as: (1) increased customer satisfaction of the oil company, due to the drilling activities that run smoothly because of the continuous OCTG supply, (2) increased revenue and profits of the oil company, due to the increasing number of loyal customers, which produces stable income to the company, and the distribution costs that are saved can be transferred to the other departments to improve the quality of the oil production activities, and (3) the size of the company may expand, because companies who obtains profits from the distribution process usually grow stronger financially [9].

Table 4.
Savings Values Based on Coordinates

	Rantau	Pangkalan Susu	Lirik	Ramba DC	Jambi	Prabumulih	Pendopo	Adera
Rantau	0	2005	665		254	12	43	12
Pangkalan Susu		0	665		254	12	43	12
Lirik			0		254	8	35	9
Ramba DC				0				
Jambi					0	2	19	3
Prabumulih						0	105	125
Pendopo							0	97
Adera								0

Table 5.
Savings Value Calculation

Savings Calculation: s(i,j) = c(d,i)+c(d,j)-c(i,j)	Km	Savings Calculation: s(i,j) = c(d,i)+c(d,j)-c(i,j)	Km
s(1,2) = c(0,1)+c(0,2)-c(1,2) =	2005	s(3,4) = c(0,3)+c(0,4)-c(3,4) =	DC
s(1,3) = c(0,1)+c(0,3)-c(1,3) =	665	s(3,5) = c(0,3)+c(0,5)-c(3,5) =	254
s(1,4) = c(0,1)+c(0,4)-c(1,4) =	DC	s(3,6) = c(0,3)+c(0,6)-c(3,6) =	8
s(1,5) = c(0,1)+c(0,5)-c(1,5) =	254	s(3,7) = c(0,3)+c(0,7)-c(3,7) =	35
s(1,6) = c(0,1)+c(0,6)-c(1,6) =	12	s(3,8) = c(0,3)+c(0,8)-c(3,8) =	9
s(1,7) = c(0,1)+c(0,7)-c(1,7) =	43	s(5,6) = c(0,5)+c(0,6)-c(5,6) =	2
s(1,8) = c(0,1)+c(0,8)-c(1,8) =	12	s(5,7) = c(0,5)+c(0,7)-c(5,7) =	19
s(2,3) = c(0,2)+c(0,3)-c(2,3) =	665	s(5,8) = c(0,5)+c(0,8)-c(5,8) =	3
s(2,4) = c(0,2)+c(0,4)-c(2,4) =	DC	s(6,7) = c(0,6)+c(0,7)-c(6,7) =	105
s(2,5) = c(0,2)+c(0,5)-c(2,5) =	254	s(6,8) = c(0,6)+c(0,8)-c(6,8) =	125
s(2,6) = c(0,2)+c(0,6)-c(2,6) =	12	s(7,8) = c(0,7)+c(0,8)-c(7,8) =	97
s(2,7) = c(0,2)+c(0,7)-c(2,7) =	43		
s(2,8) = c(0,2)+c(0,8)-c(2,8) =	12		

II. METHODS

As a study case research, in depth study of a particular situation to select the best routes for OCTG distribution in Sumatra with the lowest cost for PT XYZ is carried out. The first step in the research design is by collecting several related data such as the distances from Ramba DC to each oil fields in Sumatra, and identifying each field's demand for OCTG. In this study, two algorithms will be used to complete the CVRP model to optimize the OCTG material distribution routes in Sumatra for PT XYZ, namely Sweep Algorithm and Savings Algorithm.

The Sweep Algorithm is used because the calculations for large amount of data using this algorithm can be simplified. This algorithm also provides an optimal solution, because at the clustering stage when the vehicle capacity is at its maximum, the clustering stage one will be completed and continued with the clustering stage two as the new cluster. The accuracy of the calculation in the Sweep Algorithm is 90%, so the percentage of errors in the Sweep Algorithm calculation is 10%, which is still within reasonable limits [10].

Moreover, the Savings Algorithm is used in this study because this algorithm method is a method that can combine two or more customers into one route, and consider the maximum vehicle capacity [11]. Savings Algorithm Method is a method used in determining the route of product distribution to customers by determining the path that must be traversed and the number of vehicles based on the capacity of the vehicle in order to obtain an efficient route and optimum transportation costs [12].

Those two methods will produce the proposed routes for two vehicles distributing OCTG. Then, each route will be calculated for its total distance and total transportation cost. The results will be compared, where the routes generated from a method will be selected, if those routes have the lowest transportation cost. The illustration of the research design is presented in Figure 1.

A. Developing the CVRP Model

The problem of route optimization for OCTG distribution at PT XYZ is solved using a mathematical model of CVRP with several assumptions such as, every request can be fulfilled by DC in Ramba, there are 2 vehicles operating every day with each of the vehicle capacity is 30 Metric Tons (MT), delivery is carried out every day for 1 year with assumption of 1 year is equal to 264 days, and each agent is connected to each other and the distance between agents is symmetrical, which means $C_{ij} = C_{ji}$. The input parameter for this CVRP calculation is as follows: C_{ij} is the distance between location i and j; K is the set of vehicles, where index $K = \{1, 2\}$ refers to vehicle 1 and vehicle 2, respectively; N is the set of oil fields $N = \{1,2,3,4,5,6,7,8\}$, where 0 refers to the Distribution Center; the demand of distribution center$-i$ is d_i; and maximum capacity of vehicle-k is D_k. The decision variable is symbolized as X_{ijk}, and if vehicle k transports OCTG from location i and j, then X_{ijk} is valued as 1, and otherwise it is valued as 0.

$$X_{ijk} = \begin{cases} 1, & if\ there\ is\ a\ trip\ from\ i\ to\ j\ by\ vehicle \\ 0, & otherwise \end{cases} \quad (1)$$

The objective function of this case is to minimize the distance of OCTG material distribution in Sumatra, as illustrated in equation 2.

Minimize:

$$Z = \sum_{k=1}^{2} \sum_{i=0}^{N} \sum_{j=0}^{N} c_{ij} X_{ijk} \quad (2)$$

Table 6.
Highest Savings Value Order

Highest Savings Value Order					
No	Coordinate	Savings Value	No	Coordinate	Savings Value
1	1,2	2005	12	3,7	35
2	1,3	665	13	5,7	19
3	2,3	665	14	1,6	12
4	1,5	254	15	1,8	12
5	2,5	254	16	2,6	12
6	3,5	254	17	2,8	12
7	6,8	125	18	3,8	9
8	6,7	105	19	3,6	8
9	7,8	97	20	5,8	3
10	1,7	43	21	5,6	2
11	2,7	43			

Table 7.
Savings Algorithm Routes Result

Routes Determination:		
1.	0-1-2-0 (4+6 = 10)	Route 1
2.	0-1-2-3-0 (4+6+2 = 12)	
3.	0-1-2-3-5-0 (4+6+2+10 = 22)	
4.	0-6-8-0 (13+4 = 17)	Route 2
5.	0-6-8-7-0 (13+4+5 = 22)	

Table 8.
OCTG Transportation Cost per Metric Ton (in Thousand Rupiah)

	Rantau	Pangkalan Susu	Lirik	Ramba DC	Jambi	Prabumulih	Pendopo	Adera
Rantau	-	725	2,080	3,700	3,600	3,990	4,000	4,180
Pangkalan Susu	725	-	1,790	3,785	2,700	3,500	3,480	3,990
Lirik	2,080	1,790	-	3,200	3,000	3,190	3,200	3,080
Ramba DC	3,700	3,785	3,200	-	1,900	2,000	1,990	2,000
Jambi	3,600	2,700	3,000	1,900	-	2,000	2,180	1,870
Prabumulih	3,990	3,500	3,190	2,000	2,000	-	1,100	1,300
Pendopo	4,000	3,480	3,200	1,990	2,180	1,100	-	2,200
Adera	4,180	3,990	3,080	2,000	1,870	1,300	2,200	-

Table 9.
Comparison of Transportation Costs

Tools	Routes	Mileage (km)	Total Mileage (km)	Cost in a Year (Thousand Rp)	Total Cost in a Year (Thousand Rp)
Sweep Algorithm	Ramba – Adera – Pendopo – Prabumulih – Ramba	234	2298	8,865,900	18,890,875
	Ramba – Jambi – Lirik – Pangkalan Susu – Rantau – Ramba	2064		10,024,975	
Savings Algorithm	Ramba – Rantau – Pangkalan Susu – Lirik – Jambi – Ramba	2064	2298	13,753,875	24,743,475
	Ramba – Prabumulih – Pendopo – Adera – Ramba	234		10,989,600	

The constraints are illustrated as follows:
Equation 3 and 4 set that each destination can only be visited exactly once by 1 vehicle.

$$\sum_{k=1}^{2}\sum_{j=1}^{N} X_{ijk} = 1, \qquad \forall i \in \{1,..8\} \tag{3}$$

$$\sum_{k=1}^{2}\sum_{i=1}^{N} X_{ijk} = 1, \qquad \forall j \in \{1,..8\} \tag{4}$$

Equation 5 ensures that the vehicle's capacity does not exceed, which is 30 MT for each vehicle.

$$\sum_{i=1}^{N}\sum_{j=1}^{N} d_i X_{ijk} \le D_k \,, \quad \forall k = \{1,2\} \tag{5}$$

Equation 6 ensures that each vehicle arriving at a customer will leave that customer.

$$\sum_{i=1}^{N} X_{ijk} - \sum_{j=1}^{N} X_{ijk} = 0\,, \qquad \forall k = \{1,2\}, i, j = \{1,\dots,8\} \tag{6}$$

Equation 7 limits that each route starts from the Distribution Center and must end at the origin Distribution Center.

$$\sum_{i=1}^{N} X_{i0k} - \sum_{j=1}^{N} X_{0jk} = 0\,, \qquad \forall k = \{1,2\}, i, j = \{1,\dots,8\} \tag{7}$$

B. Sweep Algorithm

Sweep Algorithm is an algorithmic paradigm that uses conceptual sweep lines to solve various problems in Euclidean space. Sweep algorithm itself is one method that is used in determining the shortest route to minimize distance, cost, and time [13]. The system used in this method is a grouping of regions used to calculate distances with the capacity of the vehicle used as the limitation. In this study case, some clusters are obtained and different routes will be passed by different vehicles, and the scope of the vehicle capacity limit is based on the demand of the area to be visited by as many as one cluster.

1) Clustering Phase (Clustering)

In conducting calculations with Sweep Algorithm, the steps for grouping or clustering starts from drawing each request point on the Cartesian coordinates and set the Distribution Center location as the coordinate axis. Then, the Cartesian coordinates (x,y) is changed to polar coordinates (r, θ) as described in equation 8 and 9.

$$r = \sqrt{X^2 + Y^2} \quad (8)$$

$$\theta = arc\,tan\frac{y}{x} \quad (9)$$

After that, conduct clustering by starting from the point of demand which has the smallest polar angle and ensure that all request points are covered in the current cluster. When the route in the cluster has exceeded the vehicle, the clustering process will stop. Finally, create a new cluster with the same steps.

2) Route Determination Phase

A prior study by Oktavia (2019) stated that the use of Nearest Neighbor (NN) produces the optimal distribution path with reduced mileage, travel time and total distribution cost [14]. NN is a supervised learning algorithm where the results of the new sample are classified based on the majority of the nearest region. The purpose of using NN is to classify new objects based on attributes and samples. NN is used in the Sweep Algorithm to determine the distribution routes, by selecting the DC as a starting point, then looking for the closest distance from the DC and setting that point as the second point of the route. After that, do it repeatedly until all the request points are fulfilled.

C. Savings Algorithm

The Saving Heuristics method is also a method of VRP to help determining more efficient routes, hence to minimize the route travelled. The Savings Heuristics method constructs the shortest route based on the value of saving sorted from the largest then accumulated based on the demand for each vertex without exceeding the vehicle's capacity, denoted savings $s(i,j)$. The method starts by calculating the value of savings from city i to city j by adding the distance from DC to city i and the distance from DC to city j minus the distance from city i to city j for each vertex.

$$s(i,j) = c(d,i) + c(d,j) - c(i,j) \quad (10)$$

Then, create a ranking of savings calculations and make a list of the results of the largest to smallest savings. Accumulate each value of savings from the largest to the smallest based on the demand for each vertex. When the maximum capacity of the vehicle has been reached, then switch to the value of the second largest savings to start a new route with a different vehicle until the demand for each consumer is fulfilled.

III. RESULT AND DISCUSSION

A. CVRP Model Completion Using Sweep Algorithm

Clustering is done by changing the Cartesian coordinates into polar coordinates, as illustrated in Table 3. By using Google MyMaps, there are two clusters obtained (Figure 2). Cluster 1 consists of Prabumulih, Pendopo, and Adera oil fields, while Cluster 2 consists of Rantau, Pangkalan Susu, Lirik, and Jambi oil fields.
At the route determination phase using Nearest Neighbor, the vehicle route result for Cluster 1 is Ramba DC – Adera – Pendopo – Prabumulih – Ramba DC with a vehicle mileage of 234 km. Additionally, the route result for Cluster 2 is Ramba DC – Jambi – Lirik – Pangkalan Susu – Rantau – Ramba DC with a vehicle mileage of 2064 Km.

B. CVRP Model Completion Using Savings Algorithm

Savings Algorithm Testing is done using Microsoft Excel application. In using this algorithm, a savings value will be generated from the following formula $s(\mathrm{i},\mathrm{j}) = \mathrm{c}(\mathrm{d},\mathrm{i}) + \mathrm{c}(\mathrm{d},\mathrm{j}) - \mathrm{c}(\mathrm{i},\mathrm{j})$. The process of calculating the value of savings starts from determination of the value of saving using formula $\mathrm{s}(\mathrm{i},\mathrm{j}) = \mathrm{c}(\mathrm{d},\mathrm{i}) + \mathrm{c}(\mathrm{d},\mathrm{j}) - \mathrm{c}(\mathrm{i},\mathrm{j})$ from city i to city j by adding the distance from DC to city i and the distance from DC to city j minus the distance from city i to city j for each vertex. The amount of distance from the DC to the field, and between fields can be seen in Table 2. The results are obtained in the Table 4 and 5. An example of a calculation of the application of the savings algorithm is as follows: Example $s(1,2) = c(0,1) + c(0,2) - c(1,2)$ where $s(1,2)$ indicates the calculation of the value of savings from Rantau to Pangkalan Susu; $c(0,1)$ indicates the distance from Ramba DC to Rantau; $c(0,2)$ indicates the distance from Ramba DC to Pangkalan Susu; and $c(1,2)$ indicates the distance from Rantau to Pangkalan Susu. The calculation result will be $s(1,2) = 1029\,km + 1003\,km - 27\,km = 2005\,km$. The next step is to sort the value of savings from the largest to the smallest as presented in the following Table 6.

The last step is to determine the route by selecting the largest savings value that will be the starting point of the route and heading to the next coordinate point, until the vehicle capacity is no longer able to meet. The results are presented in Table 7. In conclusion, the orders of the routes obtained by Savings Algorithm are as follows, Vehicle Route 1: Ramba DC – Rantau – Pangkalan Susu – Lirik – Jambi – Ramba DC with a total mileage of 2064 km, and Vehicle Route 2: Ramba DC – Prabumulih – Pendopo – Adera – Ramba DC with a total mileage of 234 km.

C. Comparison of the Results Obtained Based on Transportation Cost

To further validate the resulted routes have the lowest transportation cost, a calculation is made to determine the transporation costs for each route obtained from Sweep and Savings Algorithm. The intended result is to identify which methods generate the routes for two vehicles with the lowest transportation cost. The collected data from PT

XYZ for transportation cost per Metric Ton to each field is illustrated in Table 8. These costs are calculated with the number of demands of each field, as presented in the following equation.

$$\sum(Transportation\ cost\ per\ MT \times demand\ per\ year) \quad (11)$$

By calculating the total transportation cost in a year for distributing OCTG from Ramba DC to each of the eight oil fields owned by PT XYZ, authors compare the results to identify which routes have the cheapest transportation costs. Additionally, the considerations that needs to be taken into account are, there are two vehicles, two routes, and each of the routes must cover the points of demand according to the clusters. The results from Table 9 show that both algorithm generates similar vehicle mileage, which is 234 km for Ramba, Prabumulih, Pendopo, and Adera cluster; and 2064 km for Ramba, Jambi, Lirik, Pangkalan Susu and Rantau cluster. However, both algorithms produce different order of the distribution routes, which determines the difference in transportation cost. Since the focus of this research is identifying the routes with the lowest transportation cost, it is identified that Sweep Algorithm generates the two routes with the lowest total transportation cost of Rp. 18,890,875,000 per year, while Savings Algorithm generates Rp. 24,743,475 per year. If compared to Savings Algorithm, the results generated from Sweep Algorithm may contribute to the company of having to pay 24% less for the total transportation cost in a year to distribute OCTG. Based on this result, this study proposes a solution for the optimal OCTG distribution routes for PT XYZ, from the routes generated by Sweep Algorithm. The distribution path for the first vehicle may start from Ramba DC – Adera – Pendopo – Prabumulih – Ramba DC, while the second vehicle begins from Ramba DC – Jambi – Lirik – Pangkalan Susu – Rantau – Ramba DC.

IV. CONCLUSION

As an oil and gas company, one of the key activities carried out by PT XYZ is the drilling process, which requires the availability of various materials including the Oil Country Tubular Goods (OCTG). In the present condition, the OCTG supply is distributed from other oil fields with extra supplies and there is no implementation of a DC. Refer to a previous study that proposed Ramba as a DC in Sumatra, this research focuses on selecting the most efficient routes to distribute OCTG from Ramba DC to eight Sumatra oil fields by implementing capacitated vehicle routing problem model. Comparing the routes by using Sweep Algorithm and Savings Algorithm, this research determines two best routes for two vehicles. This research concludes that by using Sweep Algorithm, a minimized total transportation cost for the routes covering OCTG demands is produced. The company pays Rp. 18,890,875,000 per year for the transportation cost for the two routes, which is 24% less if compared to the result from Savings Algorithm.

The results of the calculation also indicate that the OCTG transportation total cost relies on the distribution path from an oil field to another and the volume of cargo transported. Based on this, the company may arrange a distribution strategy to reduce their annual expenditure on OCTG supplies, with future hopes they can achieve customer’s satisfaction, gaining more revenue and profit, and grow to the larger scale. Further study on the economic analysis can be conducted to further assess the applicability of this research method to solve the OCTG distribution problem, because real life situations view more complex analysis on the economical aspects.

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