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Determining Distribution Vehicle Routes to Reduce Distribution Costs Using Sequential Insertion Method at PT. XYZ

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ABSTRACT

VRP is concerned with determining routes for problems involving more than one vehicle with a certain capacity to serve consumers with their respective requests. Route determination is one of the important factors in delivering products to consumers. Determining the optimal distribution route can minimize distance, shorten product delivery time and save transportation costs. PT. XYZ is a company engaged in the distribution of consumer goods. Problems that are happening at PT. XYZ is a product distribution problem where the number of vehicles is limited. The number of customers and the distance from the depot to the customer and from one customer to another is far away. Therefore, it is necessary to determine distribution routes, especially in transportation problems, to save time, distance, and distribution costs. The objectives to be achieved from research at PT. XYZ is to determine the product distribution route using the Sequential Insertion method. Based on the data processing results, the route Sequential Insertion method can serve customers in 5 routes with a total distance of 227.8 km, a total travel time of 15.9 hours, and a total distribution cost of IDR 145,792/week. The travel distance savings are 28.20 km, and the percentage of distribution cost savings is 11%, or the distribution cost savings are IDR 866,304/year. So, the Sequential Insertion method can be applied to determine the optimal distribution route to produce a minimum distribution cost.

Keywords: Vehicle Routing Problem (VRP), sequential insertion, distribution costs, distribution routes.

Introduction

In business processes, distribution is an important part that cannot be separated, especially in product distribution (Pattiasina et al., 2018). VRP is concerned with determining routes for problems involving more than one vehicle with a certain capacity to serve consumers with their respective requests (Arvianto et al., 2016). Route determination is one of the important factors in delivering products to consumers. In determining the distribution route, it is necessary to know the customer's order to be visited (Hignasari & Mahira, 2018). Determining the optimal distribution route can minimize distance, shorten product delivery time and save transportation costs.

PT. XYZ is a company engaged in the distribution of consumer goods. Problems that are happening at PT. XYZ is a product distribution problem where the number of vehicles is limited. The number of customers and the distance from the depot to the customer and from one customer to another is far away. Therefore, it is necessary to determine distribution routes, especially in transportation problems, to save time, distance, and distribution costs.

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Product delivery at PT. XYZ starts and ends at the same warehouse. The first customer to visit usually depends on the driver considering the shortest distance from the depot. The problem at PT. XYZ is how to determine the vehicle routes with the Vehicle Routing Problem (VRP) characteristics, namely single depot, and single trip. It is said to be a single depot because the company only has 1 warehouse and a single trip. After all, the vehicle departs from the depot with some vehicle capacities and then returns to the depot after all vehicle capacities are empty (Nurhidayat & Purwani, 2018). Determination of this route aims to minimize the total time, distance, and distribution costs. The objectives to be achieved from research at PT. XYZ is to determine the product distribution route using the Sequential Insertion method. With the background of the problem above, this research will use the Sequential Insertion method in finding the optimum solution. Sequential insertion was chosen because this method is fast in providing solutions and easy to implement (Paillin & Wattimena, 2015). The sequential Insertion method finds the next customer location by inserting each customer that has not been assigned to a route to be formed (Hariati et al., 2021).

Literature Review

Vehicle Routing Problem

Vehicle Routing Problem (VRP) is a problem in the distribution system that aims to create an optimal route (Auliani et al., 2021) for a group of vehicles of known capacity to meet customer demand known locations and number of requests. An optimal route is a route that meets various operational constraints, namely having the shortest total distance and time in meeting customer demand and using a limited number of vehicles (Nugroho et al., 2020). The following are the characteristics of problems in VRP, namely (Lukmandono et al., 2019) :

1. Each route will start and end at one depot.
2. Each customer will only be visited by one vehicle
3. If the vehicle capacity has been used and cannot serve the next place, the vehicle can return to the depot to fill the vehicle capacity and serve the next place.

The purpose of this problem is to minimize the total distance traveled by the vehicle by arranging the order of places that must be visited and when the vehicle returns to fill its capacity again (Rahman et al., 2020).

Sequential insertion method

Based on Cattaruzza et al. (2017), there are two ways to form a VRP solution: combining existing routes using the savings criterion and sequentially including customers in vehicle routes using the cost insertion criteria. According to Sydneyta and Komarudin (2017), the second method has proven to be popular to solve route and vehicle scheduling problems. The heuristic insertion algorithm is very popular because this method is very fast in providing solutions, easy to implement, and easy to develop to handle difficult constraints (Arvianto et al., 2019). The sequential insertion algorithm's basic principle is to try inserting a customer between all the edges on the current route (Fitriani et al., 2021). This edge is defined as a path that directly connects one location to another. In Figure 1, the next customer is trying to insert on edge 1 and edge 2 on the current route.

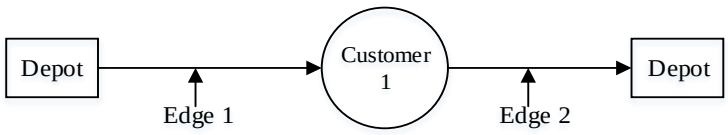

Figure 1. Customer insertion on current route

Material and Methods

This study examines the determination of the optimal product distribution route to minimize the total distribution costs of the company. Qualitative research is used in this research. Data is

needed to solve the problem by conducting direct interviews with the authorities in the delivery area and collecting secondary data from the company's documents. The steps in the Sequential Insertion method can be described as follows (Nugrahani et al., 2018):

a. Step 1: Determining customer data, amount of request, vehicle capacities, and matrix apart as required input.
b. Step 2: Determination of the first route started from depot go to the consumer and then return to the depot, selected nearest consumer with depot.
c. Step 3: Counting request and a total of traveled distance of customer at the route.
d. Step 4: Select a customer with the smallest traveled distance with the depot to be selected to be assigned into the route. If the number of requests is less than vehicle capacities hence continued to step 5. If the amount of requests is more than vehicle capacities hence continued to step 6.
e. Step 5: Customer then assigned into route and route t formed. Go back to step 4.
f. Step 6: If all customers have chosen hence the process of the algorithm of Sequential Insertion have. If customer which there is still not yet chosen hence continuing to step 7.
g. Step 7: Forming of the new route $t=t+1$, continue to step 8.
h. Step 8: Including customers which not chosen to be assigned into the route to be formed, continue to step 4.
i. Step 9: All delivered material requisition to the customer has been fulfilled, stop this procedure.

Then the last step is to calculate the total distance, the total time for each existing route, and the total cost of distribution.

Result and Discussion

Data collection

Data collection is carried out by direct research and reviewing the company's historical data. The data collected are initial distribution route, customer location, transport vehicle capacity, distribution costs, product demand, distance, travel time, and loading-unloading time. Delivery is carried out using truck transportation (Colt Diesel Ankle), totaling 2 trucks. Transportation data used for distribution from the warehouse to the customer is using a truck with a capacity of 1980 kg/truck. The price of solar fuel is IDR 9,600.00/liter, and 1 liter of solar fuel can cover a 15 km type Truck (Colt Diesel Ankle). PT. XYZ distributes 5 types of products on every delivery distribution. The products are instant noodles, mineral water, wheat flour, large and small tissues.

Furthermore, after the data has been collected, the data processing is carried out. Table 1 is the company's initial distribution route data. Table 4 is data on service times and requests for one-time deliveries that have totaled all products in one month.

Table 1. Company distribution initial routes

No	Route	Distance (Km)
1	X-Q-J-O-X	64.9
2	X-N-K-P-D-X	60.9
3	X-R-I-H-A-C-B-X	97.2
4	X-M-L-E-F-G-X	33
	Total	**256**

Table 2. Distance matrix (KM)

From/To	X	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
X	0	3.2	6.7	1.4	0.6	1.8	2.7	1.8	22	26	14	2.9	7.9	12	21	2.9	6.4	16	11
A	3.2	0	8.8	3.2	3.1	1.4	3.2	2.3	23	27	15	3.4	11	15	22	2.2	9.2	18	13
B	6.7	8.8	0	6.7	6.6	7.5	6.3	8	24	28	16	6.3	2.2	8.3	21	8.3	8.3	16	12
C	1.4	3.2	6.7	0	1.4	3.2	3.7	1.6	21	25	15	4	8	12	20	4.1	4.9	17	12
D	0.6	3.1	6.6	1.4	0	1.8	4.7	1.7	22	26	14	3	7.8	12	21	2.9	6.3	15	11
E	1.8	1.4	7.5	3.2	1.8	0	1.9	2.4	24	28	16	2.1	9	14	23	4	8.2	16	12
F	2.7	3.2	6.3	3.7	4.7	1.9	0	4.1	25	28	16	0.3	8.6	13	23	2	8.6	15	11
G	1.8	2.3	8	1.6	1.7	2.4	4.1	0	25	29	17	3.9	9.7	14	24	4.7	8.8	17	13
H	22	23	24	21	22	24	25	25	0	9.6	9.1	25	26	30	25	25	16	37	33
I	26	27	28	25	26	28	28	29	9.6	0	12	29	29	34	29	29	20	41	37
J	14	15	16	15	14	16	16	17	9.1	12	0	17	18	22	17	17	7.8	29	25
K	2.9	3.4	6.3	4	3	2.1	0.3	3.9	25	29	17	0	9	13	24	2	9	16	11
L	7.9	11	2.2	8	7.8	9	8.6	9.7	26	29	18	9	0	4.2	16	11	10	20	16
M	12	15	8.3	12	12	14	13	14	30	34	22	13	4.2	0	16	15	14	23	18
N	21	22	21	20	21	23	23	24	25	29	17	24	16	16	0	24	16.3	37	33
O	2.9	2.2	8.3	4.1	2.9	4	2	4.7	25	29	17	2	11	15	24	0	9.4	17	13
P	6.4	9.2	8.3	4.9	6.3	8.2	8.6	8.8	16	20	7.8	9	10	14	16.3	9.4	0	21	17
Q	16	18	16	17	15	16	15	17	37	41	29	16	20	23	37	17	21	0	4.3
R	11	13	12	12	11	12	11	13	33	37	25	11	16	18	33	13	17	4.3	0

Table 3. Travel time matrix (Minutes)

From/To	X	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
X	0	7	15	4	2	5	6	5	37	38	20	0	8	4	9	6	0	3	8
A	7	0	18	6	8	3	8	5	39	40	25	1	2	9	1	5	5	8	3
B	15	18	0	15	13	15	11	17	45	47	22	2	4	6	8	6	9	1	6
C	4	6	15	0	3	5	9	4	33	36	23	0	6	4	6	0	7	5	1
D	2	8	13	3	0	4	9	4	37	40	24	8	6	3	0	7	1	4	9
E	5	3	15	5	4	0	6	7	40	44	28	7	20	6	4	9	5	6	1
F	6	8	11	9	9	6	0	10	42	46	29	3	17	3	6	5	7	4	8
G	5	5	17	4	4	7	10	0	42	45	29	11	23	0	6	7	6	0	5

To be continued

From/To	X	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
H	37	39	45	33	37	40	42	42	0	25	15	44	48	53	47	42	26	58	53
I	38	40	47	36	40	44	46	45	25	0	16	48	53	58	51	46	30	62	57
J	20	25	32	23	24	28	29	29	15	16	0	30	34	41	34	29	13	45	40
K	10	11	12	10	8	7	3	11	44	48	30	0	19	24	48	5	15	24	19
L	18	22	4	16	16	20	17	23	48	53	34	19	0	7	32	22	21	26	21
M	24	29	16	24	23	26	23	30	53	58	41	24	7	0	20	25	27	29	24
N	39	41	38	36	40	44	46	46	47	51	34	48	32	20	0	44	28	56	52
O	6	5	16	10	7	9	5	7	42	46	29	5	22	25	44	0	16	27	22
P	10	15	19	7	11	15	17	16	26	30	13	15	21	27	28	16	0	33	28
Q	23	28	21	25	24	26	24	30	58	62	45	24	26	29	56	27	33	0	5
R	18	23	16	21	19	21	18	25	53	57	40	19	21	24	52	22	28	5	0

Table 4. Service time (Loading-unloading in minutes) & customer demand July-December

From/To	Loading	Unload-ing	Total	Demand /month (kg)	Demand /Week (kg)	From/To	Loading	Unloading	Total	Demand /month (kg)	Demand /Week (kg)
A	2	3	5	229	57	J	23	29	52	3072	768
B	2	2	4	180	45	K	27	35	62	2827	707
C	2	2	4	181	45	L	13	17	30	1704	426
D	2	3	5	248	62	M	20	25	45	1711	428
E	11	13	24	1225	306	N	24	31	55	2855	714
F	8	10	18	1028	257	O	18	23	41	1610	402
G	8	10	18	955	239	P	23	29	52	1889	472
H	13	17	30	1792	448	Q	22	28	50	3173	793
I	20	26	46	2678	670	R	15	19	34	2716	679

Data processing

The Sequential Insertion Algorithm is an algorithm to solve the Vehicle Routing Problem by selecting customers who have not entered any routes to be inserted and selecting the location of the customer insertion site with the smallest total time criteria. The calculation of the Sequential Insertion Algorithm in this study uses Ms. Excel as a tool to calculate and determine distribution routes. The results of calculations using the Sequential Insertion method obtained route results for each customer can be seen in Table 5.

Table 5. Calculations using sequential insertion method for each assigned customer

No Truck	Subtour	From	To	Node Insert	Demand (Kg)	Remaining Capacity (<1980)	Time (Minutes) Travel	Service	Total	Total (Hour)	Distance (Km)	Total Distance
1	X-D-C-G-A-E-F-K-B-X	D	X	D	62	1,918.00	2	5	7	0.1	0.6	0.6
		D	C	C	45.1	1,872.90	3	4	14	0.2	1.4	2
		C	G	G	238.7	1,634.20	4	18	36	0.6	1.6	3.6
		G	A	A	57.3	1,576.90	5	5	46	0.8	2.3	5.9
		A	E	E	306.3	1,270.70	3	24	73	1.2	1.4	7.3
		E	F	F	256.9	1,013.80	6	18	97	1.6	1.9	9.2
		F	K	K	706.7	307.1	3	62	162	2.7	0.3	9.5
		K	B	B	45	262.1	12	4	178	3	6.3	15.8
		B	X		-	262.1	15	-	193	3.2	6.7	22.5
2	X-O-P-J-X	O	X	O	402.5	1,577.50	6	41	240	4	2.9	2.9
		O	P	P	472.2	1,105.40	16	52	308	5.1	9.4	12.3
		P	J	J	768	337.3	13	52	373	6.2	7.8	20.1
		J	X		-	337.3	20	-	393	6.6	14	34.1
	X-L-R-Q-X	L	X	L	425.9	1,554.10	18	30	48	0.8	7.9	7.9
		L	R	R	679.1	875	21	34	103	1.7	16	23.9
		R	Q	Q	793.3	81.7	5	50	158	2.6	4.3	28.2
		Q	X		-	81.7	23	-	181	3	16	44.2
	X-M-N-H-X	M	X	M	427.7	1,552.30	24	45	250	4.2	12	12
		M	N	N	713.7	838.6	20	55	325	5.4	16	28
		N	H	H	448	390.6	47	30	402	6.7	25	53
		H	X		-	390.6	37	-	439	7.3	22	75
1	X-I-X	I	X	I	669.5	1,310.50	38	46	523	8.7	26	26
		I	X		-	1,310.50	38	-	561	9.4	26	52
						Total	379	575		Total Distance : 227.8 km		

The recapitulation of the route obtained from the calculation using the Sequential Insertion method and the initial route can be seen in Table 6 and Table 7.

Table 6. Recapitulation of the company's initial route

Route	Demand (Kg)	Time (Minutes) Travel	Service	Total	Total Time (Hours)	Total Distance (Km)
X-Q-J-O-X	1,963.8	103.0	143.0	246.0	4.1	64.9
X-N-K-P-D-X	1,954.5	115.0	174.0	289.0	4.8	60.9
X-R-I-H-A-C-B-X	1,944.0	175.0	123.0	298.0	5.0	97.2
X-M-L-E-F-G-X	1,655.4	72.0	135.0	207.0	3.5	33.0
Total	**7,517.7**	**465.0**	**575.0**	**1,040.0**	**17.3**	**256.0**

Table 7. Recapitulation of vehicle routes using sequential insertion method

Route	Demand (Kg)	Time (Minutes) Travel	Service	Total	Total Time (Hours)	Total Distance (Km)
X-D-C-G-A-E-F-K-B-X	1,717.9	53.0	140.0	193.0	3.2	22.5
X-O-P-J-X	1,642.7	55.0	145.0	200.0	3.3	34.1
X-L-R-Q-X	1,898.3	67.0	114.0	181.0	3.0	44.2
X-M-N-H-X	1,589.4	128.0	130.0	258.0	4.3	75.0
X-I-X	669.5	76.0	46.0	122.0	2.0	52.0
Total	**7,517.7**	**379.0**	**575.0**	**954.0**	**15.9**	**227.8**

The calculation of fuel costs per week for comparing the initial route with the Sequential Insertion route and the cost difference between each method used for the company route can be seen in Table 8.

Table 8. Calculation of distribution costs (Per week)

Component	Initial Route	Sequential Insertion Route	Saving
Total Time (Hours)	17.3	15.9	1.43
Number of Routes	4	5	
Total Distance (Km)	256	227.8	28.2
Fuel Cost (IDR)	163,840	145,792	
Total Cost	163,840	145,792	11.00%
Total Savings per month (IDR)		72,192	
Total Savings per year (IDR)		866,304	

Determining the effectiveness of the distributed capacity can be seen from how many trips maximize the capacity in the truck. The route is more effective if the route has trips that maximize more products in the truck. Determining the distance can be seen from how far the truck travels. In Table 6 and Table 7, the overall Sequential Insertion method gets the most minimal total distance compared to the company's initial route. Route Sequential Insertion method can serve customers in 5 routes and a total distance of 227.8 km. The distance is with a total travel time of 954 minutes or 15.9 hours, while the distance traveled by the company with a travel time of 1040 minutes or 17.3 hours. With the total distance traveled, the Sequential Insertion method's route is 28.2 km more effective than the company's initial route. After getting the order of the shortest route with the Sequential Insertion method, the fuel cost on the initial route was IDR 163.840/week, but after using the Sequential Insertion method, the fuel cost was IDR 145,792/week. The total cost of distribution to customers using the Sequential Insertion method can save costs of IDR 72,192/month or can save distribution costs of IDR 866,304/year which will benefit the company by reducing the company's variable costs. From Table 8 above, it can be seen that the percentage of the total cost using the Sequential Insertion method to the total cost of the company's initial route can save costs by 11%. Thus, it can be concluded that based on the total distance, route, and distribution cost savings using the Sequential Insertion method, the most effective route for completing product distribution to consumers is obtained. By comparing with the initial route, it is concluded that the sequential insertion method is a more effective route due to the capacity, distance, travel time, and distribution costs.

Conclusion

Based on the results of data processing, the shortest distribution route uses the Sequential Insertion method processing. Route 1: X-D-C-G-A-E-F-K-B-X, route 2: X-O-P-J-X, route 3: X-L-R-Q-X, route 4: X-M-N-H-X and route 5: X-I-X. With a total distance of 227.8 km, a total travel time of 15.9 hours, and a total distribution cost of IDR 145,792/week. The travel distance savings are 28.20 km, and the percentage of distribution cost savings is 11%, or the distribution cost savings are IDR 866,304/year. So, the Sequential Insertion method can be applied to determine the optimal distribution route to produce a minimum distribution cost.

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