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ORIGINAL ARTICLE

Design of Feed Product Distribution System using Vehicle Routing Problem (VRP) and Simulated Annealing (SA) Methods at XYZ, L.P

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ABSTRACT – A good distribution system can give an impact on cost efficiency and delivery time. XYZ , L.P is an animal feed firm who faces problems of high cost and long time to carry out distribution activities. This happens after an increase in demand for animal feed which was not followed by significance of increase in cost and distribution time. The research aimed to design a distribution system and determine an optimum distribution route using efficient resources, in order to obtain a minimum vehicle mileage. The research consists of 8 stages. Vehicle Routing Problem (VRP) with Nearest Neighbor method was carried out, followed by optimizing the route solution obtained from the VRP calculation using the Simulated Annealing (SA) Algorithm. According to the route optimization using SA, the mileage, travel time, and distribution costs can be reduced by 40.04%, 75%, and 49.85%, respectively. It is, therefore, assumed that the firm can gain benefits, in terms of cost and time, by implementing the proposed distribution method.

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Vehicle Routing Problem, Nearest Neighbor, Simulated Annealing

INTRODUCTION

The need for livestock consumption in Indonesia, especially in Java Island, is increasing, leading to a rise in demand for animal feed. The high demand is in accordance with data submitted by [1], that Java Island recorded the largest consumption of beef and buffalo regionwise in 2020 at 517.43 thousand tons.

XYZ, L.P is a firm that produces ruminant feed in the form of flour and pellets for the Greater Jakarta area. The increasing demand for animal feed causes a surge of orders from consumers, resulting in an increase in shipment volume of feed products and raw materials. As a consequence, firm has always to be ready to produce and deliver goods in order to meet consumer needs. The problem that occurs in the distribution of feed products at XYZ, L.P is delays in arrival time, caused by unintegrated distribution, where routes of the delivery have not been determined with a clear system, and limited volume of production. This, definitely, can affect the next sales volume as the delays may lower consumer trust in the firm.

Based on results of interview with firm's employees, the current delivery route is only based on trials from drivers, a large number of requests for delivery and different distribution points. As a result, it is difficult for the drivers to meet consumer needs, especially in terms of delivery time, leading to high distribution costs. The objective of this research is to optimize distribution routes at XYZ, L.P by performing resource efficiency in order to obtain a minimum vehicle mileage and lower distribution costs.

The distribution of feed products is one of important aspects to be considered by the firm. This was conveyed by [2] that distribution and transportation networks are of important factors for a product distribution system. Good product distribution produces a distribution management system that can make products available according to consumer needs, both regarding punctuality of delivery and the number of product requests from consumers.

Selection of a distribution management system started with choosing an optimum distribution channel to minimize delays in product arrivals to consumers. The distribution route was determined by using a vehicle routing problem (VRP) with the nearest neighbor method. The VRP was chosen for optimization of distribution routes since it is able to solve distribution problems using heuristic methods to find out distribution routes [3] dan [4]. After the VRP results were obtained, the initial solution was used to enter into a Simulated Annealing (SA) algorithm. Simulated Annealing (SA) can be viewed as an enhanced version of an iterative (repetitive) improvement method in which the initial solution is improved repeatedly by making small changes until a better solution is found. The Simulated Annealing (SA) algorithm is an efficient approach to solve difficult combinatorial problems [5]. Another reason for choosing simulated annealing is because it is the closest solution to an optimum one [6].

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RESEARCH METHODOLOGY

This study was carried out in 8 stages. The first stage was identifying problems. The second stage included collecting data of transportation, demand, delivery location, distance traveled, initial route, initial costs spent by the firm and conducting interviews with drivers. The third stage was determining the distance between consumers and the storehouse, and the fourth stage was determining routes with the nearest neighbor. The fifth stage was identifying the travel time with the nearest neighbor. The sixth stage was calculating the distribution cost with the nearest neighbor. The seventh stage was performing route optimization with a simulated annealing algorithm. The eighth stage is determining routes with the Simulated Annealing Algorithm and comparing them to the route results based on the nearest neighbor. The complete stages of the research methodology can be seen in Figure 1

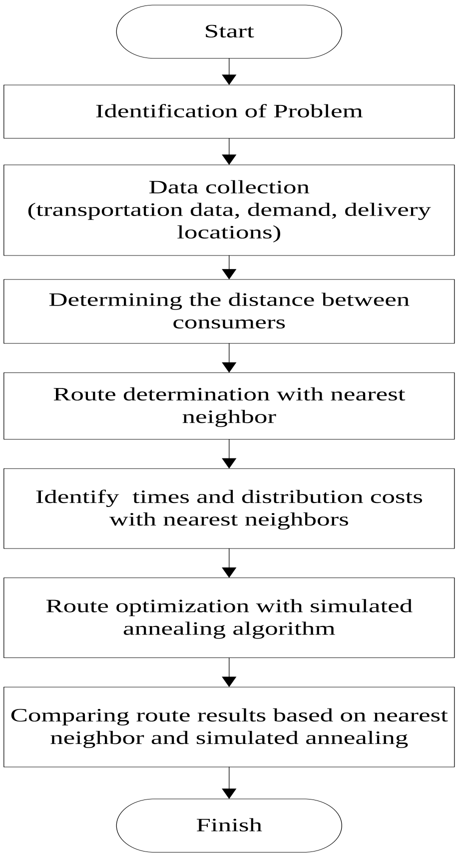

Figure 1. Stages of research methodology

RESULTS AND DISCUSSION

The first stage is problem identification

Results of problem identification showed that the emergence of problems is delays in feed product receiving in consumers and high distribution costs spent by companies due to poor scheduling system on delivery routes.

The second stage is data collection

Data collection method in this study was carried out by collecting primary data of transportation, requests, delivery locations, and conducting interviews with drivers.

Storehouse and Consumer Location Data Collection

Data was obtained by interviewing Nuansa Baru, L.P and using firm historical data. Storehouse location and consumers data were obtained directly from the firm. Location of the storehouse coded as A00 is in Parung-Bogor area. Consumer data taken in this study are from those who have the same delivery route with other consumers as well as consumers who make repeat orders, called as permanent consumers. Consumers were coded A01, A02, A03, A04 and so on. Based on the data obtained, there are 16 consumers who fit to the delivery criteria as seen in Table 1.

Table 1. Consumer data and delivery distance.

No.	Consumen code	Address	Distance (Km)
1	A01	Laladon	16.2
2	A02	Roh-Bubulak	13.3
3	A03	Cisarua	41.6
4	A04	Sawangan	14.1
5	A05	Citeurep	31.4
6	A06	Cibinong	18.9
7	A07	Gunung Sindur	15.8
8	A08	Sawangan	14.1
9	A09	Ciawi	31.8
10	A10	Gadog-Ciawi	33.6
11	A11	Tajur Halang	9.9
12	A12	Ciampea	14.3
13	A13	Balitnak	33.6
14	A14	Ciawi	33.1
15	A15	Bubulak	14.1
16	A16	Ciseeng	11

Data of Consumer Demand

Data of consumer demand consists of the number of orders for each product and raw materials, obtained directly from the firm. This data was used to determine daily demand of consumers for products and raw materials sold by the firm. The data can be seen in Table 2.

Table 2. Number of Customer Requests

No.	Consumen code	Demand (sack)	Demand (sack)
1	A01	6	31
2	A02	25	
3	A03	25	35
4	A04	10	
5	A05	10	20
6	A06	10	
7	A07	37	45
8	A08	8	
9	A09	6	35
10	A10	4	
11	A11	25	
12	A12	11	31
13	A13	15	
14	A14	5	
15	A15	16	38
16	A16	22	

Data of Consumer Demand

Products produced at Nuansa Baru, L.P include NBF 1, NBF 2, NBF 3 and NBF4 weighing 40 kg/sack.

Data of Number of Vehicles

Vehicles used in this study were only 4-wheeled vehicles with a capacity of 2 tons and passing through random travel routes. Initial distribution route data was obtained directly from interviews with the drivers. Distribution route data can be seen in Table 3.

Table 3 Distribution route data can be seen in Table 3.

Table 3. Number of Customer Request

No.	Route	Demand (sack)	Distance (Km)	Total time (Minute)	Delivery Cost (IDR)	Distribution cost (IDR)	Total of Distribution cost (IDR)
1	A00-A01-A02-A00	31	33.4	86.37	125,000	125,000	250,000
2	A00-A03-A04-A00	35	117.9	217.80	150,000	100,000	250,000
3	A00-A05-A06-A00	20	58.4	111.00	150,000	100,000	250,000
4	A00-A07-A08-A00	45	43.2	117.45	100,000	120,000	220,000
5	A00-A09-A10-A11-A00	35	91.5	178.20	125,000	290,000	415,000
6	A00-A14-A12-A13-A00	31	122.2	148.32	150,000	240,000	390,000
7	A00-A15-A16-A00	38	47.7	116.01	100,000	75,000	175,000
	Total	235	514.3	975.15	900,000	1,050,000	1,950,000

Maximum Vehicle Capacity

Vehicles can be used at full capacity or 100% and given a leniency of 10%. The leniency value is given based on possibility of different products resulting in possibility of remaining space. Calculation for the maximum capacity of vehicles is as follows.

Example :
Product Volume = 40 Kg/Sack
Vehicle Volume = 2000 Kg
Leniency = 10 %

$$Maximum\ vehicle\ capacity\ = \frac{Vehicle\ Volume\ x\ \text{leniency}}{Product\ Volume} \quad (1)$$

$$Maximum\ vehicle\ capacity = \frac{(2000\ Kg\ x\ 0.9)}{40Kg/Karung} = 45\ \text{Sack}$$

The third stage was determining the distance between consumers and the storehouse. Determination of the distance between consumers and the storehouse was carried out based on searching results on google maps during working hours in normal road conditions. Data of the distance between consumers and the storehouse can be seen in Table 4.

Table 4. Matrix of distance between consumers and the storehouse

Code	A00	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11	A12	A13	A14	A15	A16
A00	0																
A01	16.2	0															
A02	13.3	3.9	0														
A03	41.6	31.5	33	0													
A04	14.1	27.8	24	62.2	0												
A05	31.4	26.1	22.8	34.1	30.4	0											
A06	18.9	24.2	20.9	34	18.8	8.1	0										
A07	15.8	29.1	25.8	56.3	14	59.7	27.2	0									
A08	14.1	27.8	24	61.5	1.3	30.4	17.1	13.3	0								
A09	31.8	21.6	23.2	18.7	43.4	21.6	21.8	46.6	43.4	0							
A10	33.6	23.5	25.1	11.5	45.3	23.4	23.7	48.5	45.3	4.8	0						
A11	9.9	23.1	19.8	48.4	8.4	21.5	15.6	15.4	8.4	41.3	45	0					
A12	14.3	9.2	9.4	40.4	28.3	28.8	24.6	25.2	28.3	33.5	32.8	22.1	0				
A13	33.6	23.1	24.6	11.7	44.8	23	23.6	48.1	44.9	2.7	3.7	36.2	32.5	0			
A14	25.8	22.5	12.2	42.7	20.9	21.1	46	42.7	5.4	6	36	30.4	30.3	2.1	0		
A15	14.5	5.1	2.8	34.1	25.7	22.2	18	29	25.8	32.9	26.1	17.2	9.1	25.8	25.4	0	
A16	11	24.2	20.9	49.5	12.4	37.6	33.5	9.2	12.4	42.4	41.6	13	16	41.3	40.8	22.2	0

Note :
An assumption used in this distance selection was that the distance from A01 to A02 will be the same as the distance from A02 to A01.

The fourth stage is determining the route with the nearest neighbor. The nearest neighbor method is a method of determining a distribution route starting with the closest location to the storehouse and followed with visiting the nearest location thereafter, until all destinations are visited and vehicles return to the storehouse. The following is an example of the nearest neighbor settlement steps on the 5th travel route:

Iteration 1

Table 5. Distance between consumers and the storehouse

No.	Code	Distance from A00 (storehouse)
1	A10	33.6
2	A12	14.3
3	A13	33.6

The first step in the nearest neighbor method was to determine the distance from the storehouse to a firstly visited consumer's place. To begin with A10, A12 and A13; according to the nearest neighbor, the first consumer to be visited was A12 with a distance of 14.3 km.

Iteration 2

Table 6. Distance from A12 to other consumen

No.	Code	Distance from A12 (storehouse)
1	A10	32.8
2	A12	0
3	A13	32.5

The next step was to determine the distance of the shortest route from A12. It can be seen that A13 has a shorter distance of 32.5 km than A10 with a distance of 32.8 km. Hence, the next point is A13.

Iteration 3

Table 7. Distance from A13 to other consumen

No.	Code	Distance from A13
1	A10	3.7
2	A12	32.5
3	A13	0

The result of the nearest neighbor method on this route is A00-A12-A13-A10-A00 with a total distance of 84.1 km.

The fifth stage is to identify the total distribution time. The total distribution time required for each distribution route is different from one to another. The loading time for 1 sack is 0,5 minutes, while the unloading time for 1 sack is 0,67 minutes. According to [4] there are 6 steps to determine the total distribution time as follows.

Step 1

Consumer demand data (Di) = 0, distance (km) loading time at the storehouse (LT) and unloading time at consumers (UT) was inputted. This data had been prepared during the data collection process.

Step 2

The route started from the storehouse, with a loading time (LT_1) = 22.05 minutes for a capacity (Q_1) = 45 which is the maximum vehicle capacity. The total loading time was calculated by multiplying the number of sacks by the loading time of 1 sack which is 0,5 minutes.

$$Loading\ time = Amount\ of\ sack\ x\ 0{,}5 \tag{2}$$

Step 3

Vehicle travel time was identified by multiplying vehicle mileage with vehicle speed (40km/hour).

$$Travelling\ time\ (Wij) = \frac{Distance}{40km/hour}\ x\ 60 \quad (3)$$

Step 4

After arriving at the destination, an unloading process will be carried out. Calculation of the unloading time can be seen in the formula below. The total unloading time was measured by multiplying the number of sacks by the unloading time of 1 sack, which is 0,67 minutes

$$Unloading\ time = Amount\ of\ sack\ \ x\ 0{,}67 \quad (4)$$

Step 5

The remaining value of Q was calculated by

$$Q = Q_1 - Di \quad (5)$$

Step 6

Total distribution time was calculated by adding loading time, unloading time and vehicle travel time

$$CT = LT\ + UT\ + Travelling\ time \quad (6)$$

Results of the total travel time on route 6 can be seen in Table 9.

Table 9. Total time on the 6th distribution route

No.	Destination		Distance	Demand (Sack)	Amount of sack	Time (minutes)		Traveling time	Total time (Minutes)
	From	to				*Loading*	*Unloading*		
	-	-	0	0	31	15.5	0	0	15.5
	A00	A12	14.3	11	20	0	7.33	21.45	28.78
6	A12	A13	32.5	15	5	0	10	48.75	58.75
	A13	A10	3.7	5	0	0	3.33	5.55	8.88
	A10	A00	33.6	0	0	0	0	50.4	50.4

The sixth stage is calculation of distribution costs with the nearest neighbor. According to [5] total costs can be determined by calculating all costs spent during distribution, which are in this research including fuel costs and travel costs (driver's meal costs, toll fees, and those for unexpected needs). Travel costs were obtained directly based on firm decisions. Fuel costs were obtained from the distance of routes multiplied by the amount of fuel consumed and by the fuel price. The ratio of fuel used for Mitsubishi L300 is 1:9, 1 litre of diesel can be used up to 9 km. Therefore, the fuel cost was calculated as follows.

$$Fuel\ Cost = Rp. 5.150\ x \frac{1}{9}\ x\ distance$$

Table 10 presents output of the total cost on all travel routes based on the nearest neighbor method.

Table 10. Total distribution costs for nearest neighbor routes

No	Travelling route	Cost of delivery (IDR)	Cost of fuel (IDR)	Total cost (IDR)
1	A00-A01-A02-A00	125,000	19,112	144,112
2	A00-A03-A04-A00	150,000	67,465	217,465
3	A00-A05-A06-A00	150,000	33,418	183,418
4	A00-A07-A08-A00	100,000	24,720	124,720
5	A00-A09-A10-A11-A00	125,000	51,271	176,271
6	A00-A14-A12-A13-A00	150,000	45,949	195,949
7	A00-A15-A16-A00	100,000	27,295	127,295

The seventh stage was performing route optimization with a simulated annealing algorithm**.** Data of the initial product delivery route and initial costs from Nuansa Baru, L.P were processed using the nearest neighbor method with the following results.

Table 11. Route results based on the nearest neighbor

No	Route	Demand (Sack)	Distance (Km)	Total time (minutes)	Cost of dclivery (IDR)	Fuel Cost (IDR)	Total cost (IDR)
1	A00-A02-A01-A00	31	33.4	86.37	125,000	19,,12	144,112
2	A00-A04-A03-A00	35	117.9	217.80	150,000	67,465	217,465
3	A00-A06-A05-A00	20	58.4	111.00	150,000	33,418	183,418
4	A00-A08-A07-A00	45	43.2	117.45	150,000	24,720	174,720
5	A00-A11-A09-A10-A00	35	89.6	175.35	225,000	51,271	276,271
6	A00-A12-A14-A13-A00	31	80.3	148.32	225,000	45,949	270,949
7	A00-A16-A15-A00	38	47.7	116.01	125,000	27.295	152,295
Total		235	470.5	972.30	1,150,000	269,231	1,419,231

The eighth stage was determining the route with Simulated Annealing Algorithm. Some of parameters used in simulated annealing include

a. Initial temperature, To
   An initial temperature is an initial condition for starting the iteration.
b. Cooling rate,
   Cooling rate is used to determine how fast the final solution can be achieved.
c. Number of iterations at each temperature level, NThe number of iterations carried out at each temperature level is obtained with random exchange of 2 points for 5 times.
d. d. Final temperature, Tt
e. The final temperature value is the point at which the iteration will be stopped.

Route Results with Simulated Annealing

The initial solution from the nearest neighbor was then used to find out an optimum solution using a simulated annealing algorithm. The investigation for this optimum solution employed Phyton application and language as a programming language for the simulated annealing algorithm. The assumption in this algorithm is that product demand occurs all the time. The ninth stage was comparing route results based on nearest neighbor and simulated annealing. Results of the simulated annealing algorithm were calculated manually by ensuring that over capacity of car in 1 delivery was avoided. Recapitulation of the simulated annealing algorithm can be seen in Table 12

Table 12. Results of the total cost calculation on simulated annealing

No	Route	Demand (sack)	Distance (Km)	Total time (Minutes)	Delivery cost (IDR)	Fuel Cost (IDR)	Total cost (IDR)
1	A00-A07-A00	37	31.6	93.69	125,000	18,082	143,082
2	A00-A01-A09-A10-A03-A00	41	95.7	184.55	150,000	54,762	204,762
3	A00-A14-A13-A05-A06-A00	40	77.9	156.85	150,000	44,576	194,576
4	-	-	-	0	0	0	0
5	A00-A02-A15-A00	41	30.6	86.9	125,000	17,510	142,510
6	A00-A16-A12-A00	33	41.3	94.95	150,000	23,633	173,633
7	A00-A11-A08-A04-A00	43	33.7	93.55	100,000	19,284	119,284
Total		235	310.8	710.49	800	177,847	977,847

Optimization Results Analysis

Analysis of the optimization results was carried out by verification and validation of the simulated annealing algorithm that has been created.

1. Verification

   Verification in this algorithm was conducted to find out if the algorithm that had been made could solve problem of the distribution route. Verification in the algorithm that had been made was carried out by showing that there were no errors in computation with python software.

2. Validation

   Validation in this algorithm was done by seeing whether the results that had been made were able to present problem solving in the simulated annealing algorithm. Validation in this algorithm aimed to ensure that there were no travel routes that carry loads exceeding the maximum capacity of the vehicle.

Optimum Route Selection

An optimum route selection was determined by a comparative analysis of vehicle mileage, as well as the amount of costs spent and the time taken by the vehicle. The comparison can be seen in Table 13.

Table 13. Comparison of all routes

No.	Parameter	Rute Awal	*Nearest Neighbor*	*Simulated Annealing*
1	Distance (km)	514.3	470.5	310.8
2	Total time (minutes)	975.15	972.30	710.49
3	Total cost (IDR)	1950.000	1169.231	977.847

The analysis of mileage generated by the two methods showed differences in which the nearest neighbor method produced a mileage of 470,5 km while simulated annealing produces that of 310,8 km. Decreasing mileage will affect other variable costs such as decreasing fuel cost spent by the firm. This is supported by (Rahmadhini et al.[6]) that determination of the minimum cost is related to the minimum distance of the vehicle.

Analysis of the total travel time with the nearest neighbor method produced 942.30 minutes of travel time whereas that using the simulated annealing method produced 710,49 minutes of time. The decrease in travel time was due to the reduced distance traveled by the vehicle.

The total distribution cost generated by the nearest neighbor method was IDR 1,169,321, while that for the simulated annealing method was IDR 977,847.

Based on comparison of the methods that have been carried out, it is noticed that the solution with simulated annealing was able to produce a smaller distribution cost than that with the nearest neighbor method.

CONCLUSION

Based on results of the present research in designing product distribution routes at Nuansa Baru, L.P, it can be concluded that

1. Route results obtained from the nearest neighbor method were A00-A02-A01-A00, A00-A04-A03-A00, A00-A06-A05-A00, A00-A08-A07-A00, A00-A11-A09-A10-A00, A00-A12-A14-A13-A00 and A00-A16-A15-A00 and route results obtained from simulated annealing were A00-A07-A00, A00-A01-A09-A10-A03-A00, A00-A14-A13-A05 -A06-A00, A00-A02-A15-A00, A00-A16-A12-A00, A00-A11-A08-A04-A00.
2. The nearest neighbor was able to reduce distance by 8.52%. In comparison, simulated annealing was able to reduce distance by 39.57%. Reduction in distribution costs generated by the nearest neighbor and simulated annealing were 40.04% and 49.85%, respectively.
3. Implementation of the distribution route produced with the simulated annealing method is proposed for the firm for shorter distance traveled and smaller distribution costs than those with the nearest neighbor method.

REFERENCES

[1] Badan Pusat Statistik, "Peternakan dalam angka," 2020.

[2] W. Kosasih, I. K. Sriwana, and Y. Salim, "Evaluasi sistem distribusi industri kecil menengah menggunakan metode," *Jurnal Ilmiah Teknik Industri*, vol. 5, no. 3, pp. 139–147, 2017.

[3] A. S. Slamet, H. H. Siregar, and A. Kustiyo, "Vehicle Routing Problem (Vrp) Dengan Algoritma Genetika Pada Pendistribusian Sayuran Dataran Tinggi," *Journal of Agroindustrial Technology*, vol. 24, no. 1, 2014.

[4] B. Ju, M. Kim, and Ii. Moon, "Vehicle Routing Problem Considering Reconnaissance and Transportation," *Sustainability*, vol. 13, no. 3188, pp. 1–19, 2021.

[5] F. Cahyadi, J. O. Ong, and J. S. Kosasih, "Perancangan Algoritma Simulated Annealing Untuk Rute Kendaraan Yang Mempertimbangkan Backhaul Rute Majemuk dan Time Window," *Telematika*, vol. 7, no. 1–5, 2011.

[6] A. A. N. P. Redi and A. A. N. A. Redioka, "Algoritma Simulated Annealing untuk Optimasi Rute Kendaraan dan Pemindahan Lokasi Sepeda pada Sistem Public Bike Sharing," *Jurnal Sistem dan Manajemen Industri*, vol. 3, no. 1, p. 50, 2019.

[7] B. Santosa and P. Willy, *Metoda Metaheuristik Konsep dan Implentasi*, Edisi Pert. Penerbit Guna Widya, 2011.