COMPLETION VEHICLE ROUTING PROBLEM (VRP) IN DETERMINING ROUTE AND DETERMINING THE NUMBER OF VEHICLES IN MINIMIZING TRANSPORTATION COSTS IN PT XYZ WITH USING GENETIC ALGORITHM

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Abstract— In the transportation process is closely related to the route, the route is the path through which a mode / vehicle to arrive at a destination. The route is related to the number of vehicles and the location where it goes. PT XYZ is a company engaged in fast moving consumer goods (FMCG), with the field makes the flow of goods speed will be high until the goods distribution process becomes fast and often. In the process of distribution is done by using 1 fleet in each customer. Currently in the process of distributing goods, the company still ignores the utility of the vehicles used, so the availability of empty space in capacity is still occurring and this makes the cost of transportation is high. Consolidation of multiple customers becomes possible, keeping in mind the time window, capacity and multiple products. This study designs a route by considering the limits to get the route, the number of vehicles, the utility increase of each vehicle and the optimal distance so that it can minimize transportation costs. The use of a genetic algorithm preceded by the nearest neighbor algorithm is used to solve this problem. Later the route will be formed and get the number of vehicles, the increase in vehicle utility and the optimal distance. This resulted in average vehicle utility improvement of 35,317%, vehicle repairs amounted to 34.05%, and distance of 10.075% so as to reduce transportation costs by 26.56% from initial conditions.

Keywords— Transportation, FMCG, Vehicle Routing Problem, Time Window, Heterogeneous Fleet, Utility, Vehicle Number Determination.

I. INTRODUCTION

PT XYZ is a fast moving customer good (FMCG) company. The company's FMCG products consist of several categories: fresh, consisting of fruits, vegetables and eggs, then S & M category consisting of food and non-food items, and the last is an extra category or other item. In the distribution process, each DC item ships goods to each branch based on the number of requests from that branch without any forecasting request. In October 2016, average demand or requests requested by customers ranged between 6,0142 m3. Figure 1 explains the average demand for each Customer of the period of October 2016.

Fig. 1 The Average Demand For Each Customer Of The Period Of October 2016

In the condition of the company, in the distribution to each customer using 47 vehicles, with each vehicle responsible for each customer, or can be said that one vehicle is responsible for one customer. The use of the vehicle will be effective if the delivery time of goods capacity or utility of the box of the vehicle is maximal or to the limit received by the company by 90% of the actual capacity. But the current condition is still very far from the accepted conditions, because the capacity in use is still around 50% of the capacity that can be used.
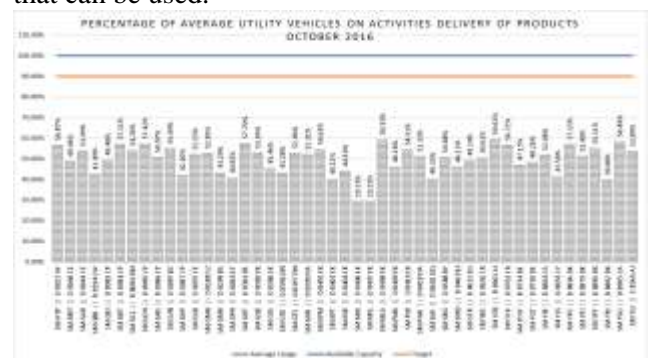

Fig. 2 Graph of Vehicle Utility Percentage During Product Delivery Process October 2016

The data in Figure 2 shows that the current capacity is still low. Ineffective from the utility of the vehicle will also impact on the transportation costs are quite expensive every day. This is because every vehicle is used to deliver goods to the customer. The following table is the total cost of transportation per branch per day.
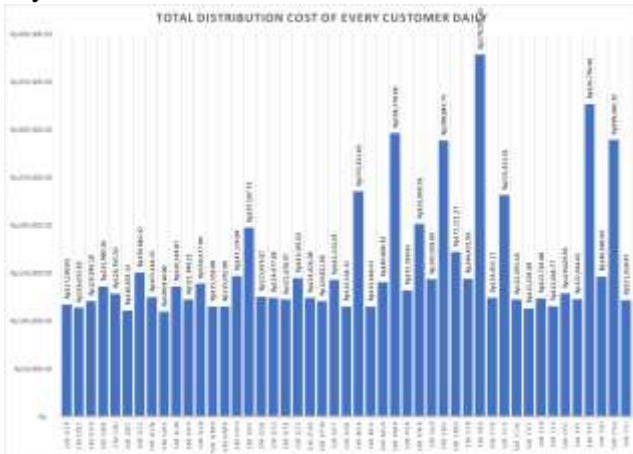

Fig. 3 Graph of Total Distribution Cost of Every Branch Per Day

With reference to Figure 3 can be seen the cost of the company every day up to Rp7,327,313.19. With these components the cost comes from fixed costs and variable costs.
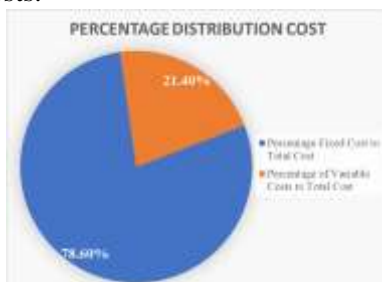

Fig. 4 Graph of Percentage of Fixed Costs and Variable Costs to Total Cost

The percentage indicates if the company currently has 47 vehicles then 47 vehicles are definitely have fixed costs. While for variable cost will be calculated based on the distance it passes.

Under current conditions, DC Fruit Stone at PT XYZ requires route planning in every vehicle, especially by consolidating or merging several customers in one route that will provide transportation cost savings, and also will get the optimal number of vehicles that must be owned by the company with Demand conditions during October 2016. The condition is of course still pay attention to the capacity of vehicles, opening hours of DC and branch cover, and service time. The end result of the research will be obtained the number of vehicles that must be owned by the company appropriately, so the reduction of fixed costs which then will affect the total transportation cost will decrease (minimize transportation cost) [1]. From the problems that have been described which further developed the solution, then the use of Genetic Algorithm can be made for the solution [2].

II. THEORETICAL BACKGROUND

2.1 Vehicle Routing Problem (VRP)

Vehicle Routing Problem (VRP) is a problem that is in the distribution system that has the goal to create an optimal route for a number of vehicles known capacity, in order to be able to meet every customer demand with the location and the number of requests that have been known explain that the goal to be achieved in VRP is [3]:

1. Minimize the overall cost of travel that is affected by the overall distance traveled and the number of vehicles used
2. Minimize the number of vehicles to be used to serve all consumers.
3. Balancing route for travel time and vehicle cargo
4. Minimize customer complaints

2.2 Nearest Neighbor Algorithm

Nearest neighbor algorithm is a simple and open technique for a variety of problems. How it works in this algorithm is very simple to find the nearest point that has not been visited by taking into account various limits. In this algorithm, a vehicle will start the journey from the distribution center (depot) then look for the closest point of the depot to be visited first. The next point determination is chosen based on the closest distance from the last location [4].

2.3 Genetic Algorithm

Genetic algorithm is an algorithm with metaheuristic approach is best known because this method has a good performance for various types of optimization problems [5].

The basic principle in this algorithm is on natural selection and genetics. The basic elements of genetic algorithm are reproduction, crossover, and mutation. Genetic algorithms are generally used to solve combinatorial problems such as TSP, VRP, and crew scheduling

In general the structure of the genetic algorithm consists of several steps such as [6]:

1. Initialization of population
2. Population evaluation
3. Population selection to be subjected to genetic operator
4. The process of crossing a particular chromosome pair (crossover)
5. Evaluation of the new population
6. The process of step 3 continues to be repeated as long as the stop condition has not been met

III. RESULT AND DISCUSSION
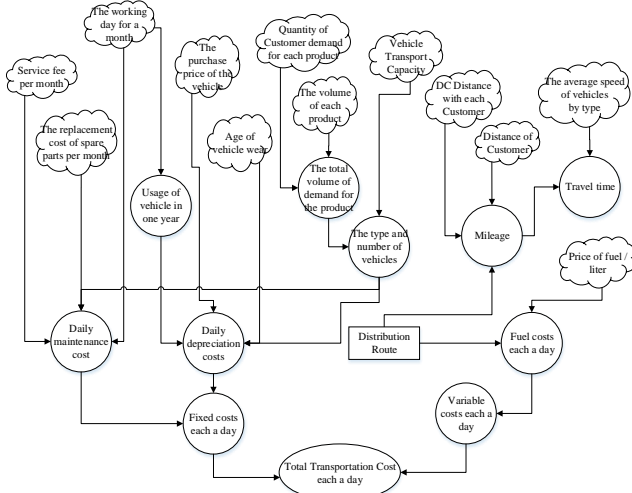
3.1 Influence Diagram

Fig. 5 Influence Diagram

3.2 Matematical Model

This stage is the stage of formulating transportation problems in the initial condition of PT XYZ into a mathematical model with the objective function of minimizing total transportation costs [7]. The formulation of mathematical models for problems in PT XYZ is as follows.

i : the customer index   i=1,2,3,….,N
j : the customer index   j=1,2,3,….,N
$i \neq j$
k : the index type of vehicles used   k=1,2,3,…K
p : the product type index   p=1,2,3,….p

Parameters:

f_k = Fixed vehicle cost k
y_k = Decision variable of each vehicle type usage
N   = Number of stores, Customer 0 is depot
C_{ijk} = Variable cost from i to j using vehicle k
d_{ij} = Distance from point i to j
Q_k = Maximum vehicle capacity k
Mj = Total volume requested by customer j
B_p = Product volume p
Hpj =Quantity of product p to be sent to customer j
e_i = Lower limit of customer time window i
l_i = Upper limit of customer time window i
t_{ijk} = Delivery time from i to j by vehicle k
b_i = Departure time of vehicle from i
a_i = Time arrives at vehicle point i
S_i = Unloading time at point i
T = Time limit horizon

Function Objective: Minimize total transportation costs

$$min \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{k=1}^{K} C_{ijk} X_{ijk} + \sum_{k=1}^{K} f_k\, y_k$$

Constraints:

1. Each store can only be visited exactly once in a single travel route.

$$\sum_{k=1}^{K} Xijk = 1 \quad Untuk\ i = 0,1,2,….,N \quad j = 0,1,2,…..,N$$

2. Every vehicle visiting customer i will visit customer i + 1.

$$\sum_{i=1}^{N} X_{ihk} - \sum_{j=1}^{N} X_{hjk} = 0 \quad di\ mana\ \forall h \in N$$

3. Each delivery in a single route must not exceed the capacity of the vehicle.

$$\sum_{i=1}^{N} \sum_{j=1}^{N} Mj X_{ijk} \leq Qk \quad untuk\ k = 1,2,…..,K$$

4. The volume of customer demand j is the product of the number between each product in the message with the volume of each product

$$\sum_{p=1}^{p} B_p H_{pj} = Mj \quad untuk\ j = 1,2,….N$$

5. The arrival time of vehicle at point j should be more than time depart from point i + travel time.

$$b_i + t_{ijk} - M(1 - X_{ijk}) \leq a_j$$
$$untuk\ i = 0,1,…N;\ j = 1,2,….N\ dan\ k = 1,2,…N$$

6. The departure time of point i is the sum of the arrival time at that point with the service time

$$b_i = a_i + S_i$$

7. The arrival time of the vehicle must be within the specified time window range.

$$e_i \leq a_i \leq l_i$$

8. Service time + travel time for each visited store should be less than the planning horizon time

$$\sum_{i=1}^{N} \sum_{j=1}^{N} (S_i + t_{ijk}) X_{ijk} \leq T \quad untuk\ k = 1,2,…..,N$$

9. Indicates that the value of the decision variable is 1 or 0. It is worth 1 if there is a route from point i to j selected and vice versa.

$$X_{ijk} \in \{0,1\}$$
$$y_k \in \{0,1\}$$

3.3 Calculation of Initial Route Determination Using Nearest Neighbor Algorithm

In the first process of solving problems that exist in the company that is by using the method nearest neighbor [8]. From this method will be found the initial solution of the distribution process conducted by PT XYZ. The main component of the nearest neighbor method is to find the closest customer that can be visited from the last position of the vehicle with regard to time window and capacity of the vehicle. In conducting the process of nearest neighbor algorithm in need of some input parameters such as distance between DC with customer, distance between customer, travel time of vehicle, demand of each customer, vehicle capacity used and service time required in each customer.

TABLE 1
INITIAL SOLUTION USING NEAREST NEIGHBOR

Route	Vehicle	Sequence				
1	Type 1 01	DC	9	41	DC	
2	Type 1 02	DC	4	28	DC	
3	Type 1 03	DC	6	39	13	DC
4	Type 1 04	DC	2	5	DC	
5	Type 1 05	DC	31	18	33	DC
6	Type 1 06	DC	24	DC		
7	Type 1 07	DC	23	DC		
8	Type 1 08	DC	14	26	3	DC
9	Type 1 09	DC	1	DC		
10	Type 1 10	DC	45	DC		
11	Type 1 11	DC	22	8	DC	
12	Type 1 12	DC	15	DC		
13	Type 1 13	DC	43	34	DC	
14	Type 1 14	DC	11	DC		
15	Type 1 15	DC	47	25	DC	
16	Type 1 16	DC	29	DC		
17	Type 1 17	DC	21	19	DC	
18	Type 1 18	DC	40	16	DC	
19	Type 1 19	DC	38	DC		
20	Type 1 20	DC	36	DC		
21	Type 1 21	DC	17	DC		
22	Type 1 22	DC	42	37	DC	
23	Type 1 23	DC	10	DC		
24	Type 1 24	DC	12	DC		
25	Type 1 25	DC	27	DC		
26	Type 1 26	DC	20	DC		
27	Type 1 27	DC	7	DC		
28	Type 1 28	DC	30	32	DC	
29	Type 1 29	DC	46	DC		
30	Type 1 30	DC	44	DC		
31	Type 2 01	DC	35	DC		

3.4 Calculation of Best Solution Determination Using Genetic Algorithm

The process of this phase is to search the optimization solution from the initial solution using Genetic Algorithm.

TABLE 2
RESULT OF GENETIC ALGORITHM

Route	Vehicle	Sequence				
1	Type 1 01	DC	SM GHS	SM YLS	DC	
2	Type 1 02	DC	SM PMK	SM GBB	DC	
3	Type 1 03	DC	SM GBT	SM YGT	SM GMH	DC
4	Type 1 04	DC	SM DNT	SM GBJ	DC	
5	Type 1 05	DC	SM GSS	SM S60	SM SMD	DC
6	Type 1 06	DC	SM KSB	DC		
7	Type 1 07	DC	SM KPT	DC		
8	Type 1 08	DC	SM GMR	SM MJL	SM GAR	DC
9	Type 1 09	DC	SM ATP	DC		
10	Type 1 10	DC	SM YRI	DC		
11	Type 1 11	DC	SM GCN	SM KPM	DC	
12	Type 1 12	DC	SM GPH	DC		
13	Type 1 13	DC	SM YPJ	SM STR	DC	
14	Type 1 14	DC	SM GKP	DC		
15	Type 1 15	DC	SM YSJ	SM MJK	DC	
16	Type 1 16	DC	SM PSR	DC		
17	Type 1 17	DC	SM GTK	SM GUB	DC	
18	Type 1 18	DC	SM GRT	SM YJ8	DC	
19	Type 1 19	DC	SM YCW	DC		
20	Type 1 20	DC	SM YCB	DC		
21	Type 1 21	DC	SM GSB	DC		
22	Type 1 22	DC	SM YCK	SM YPC	DC	
23	Type 1 23	DC	SM GJN	DC		
24	Type 1 24	DC	SM GLB	DC		

25	Type 1 25	DC	SM MLA	DC		
26	Type 1 26	DC	SM GTS	DC		
27	Type 1 27	DC	SM GCL	DC		
28	Type 1 28	DC	SM PWK	SM SBG	DC	
29	Type 1 29	DC	SM YSG	DC		
30	Type 1 30	DC	SM YPT	DC		
31	Type 2 01	DC	SM YBS	DC		

3.5 Comparison Analysis of the Number of Vehicle

TABLE 3
COMPARISON OF NUMBER OF VEHICLES

	Number of Vehicle Recommendations	Number of Vehicles Existing
Single Engkel	30	42
Double Engkel	1	5
Amount of Vehicle	31	47

Based on Table 3 it can be seen that the number of vehicles used after the optimization process using nearest neighbor method and genetic algorithm there is a considerable difference. Where the initial conditions used 47 vehicles consisting of 42 single-axle vehicles and 5 double-kg vehicles while for proposed conditions only use 31 vehicles, with the vehicle consisting of 30 single-axle vehicles and 1 vehicle double ankle. Therefore, the company can save up to 16 vehicles.

3.6 Comparison Analysis of the Utility Boxes in Each Vehicle

TABLE 4
PERCENTAGE OF UTILITY BOX COMPARISON ON EACH VEHICLE

Route	Vehicle Utility Percentage (Initial)	Vehicle Utility Percentage (Proposed)
1	69.120%	92.054%
2	74.310%	99.522%
3	31.454%	97.426%
4	51.699%	98.965%
5	14.759%	97.998%
6	29.741%	80.187%
7	60.249%	81.266%
8	31.167%	89.952%
9	68.895%	76.800%
10	72.004%	70.019%
11	69.564%	99.392%
12	69.340%	70.919%
13	25.362%	99.969%
14	23.584%	77.293%
15	42.654%	97.999%
16	34.670%	76.273%
17	58.458%	99.462%
18	15.741%	91.281%
19	45.094%	77.866%
20	52.194%	90.485%
21	44.422%	64.954%
22	58.285%	99.029%
23	48.877%	80.004%
24	72.169%	77.044%
25	28.679%	64.463%
26	25.920%	57.993%
27	58.017%	66.944%
28	12.209%	99.837%
29	68.645%	90.949%
30	46.984%	42.576%
31	35.412%	41.382%
32	42.869%	-
33	19.467%	-
34	45.935%	-
35	55.731%	-
36	81.436%	-
37	43.552%	-
38	70.080%	-
39	32.580%	-
40	47.482%	-
41	13.954%	-
42	45.574%	-
43	44.037%	-
44	38.319%	-
45	42.113%	-
46	81.854%	-
47	59.520%	-
Average Percent of Utilities	46.897%	82.268%

Based on Table 4 it can be seen that the proposed conditions for the average utility percentage in each vehicle reached effectiveness up to 82.26%, this is increased by 35.317% from the initial conditions.

3.7 Comparison Analysis of Distance

TABLE 5
COMPARISON OF ROUTE AND INITIAL ROUTES MILEAGE

Route	Distance (Initial)	Distance (Proposed)
1	12.499	10.201
2	7.981	261.927
3	17.577	17.659
4	2.538	35.691
5	28.426	107.114
6	3.516	9.797
7	59.033	10.41
8	23.443	21.172
9	2.2	12.499
10	38.864	13.835
11	20.171	40.664
12	43.318	14.689
13	9.795	37.651
14	9.376	20.171
15	14.689	190.132
16	124.555	33.539
17	23.864	42.237
18	22.527	140.199
19	19.988	20.037
20	51.306	22.49
21	22.455	23.864
22	17.427	172.411
23	10.41	38.864
24	9.797	43.318
25	177.472	45.437
26	9.498	51.306
27	45.437	59.033
28	262.947	247.662
29	33.539	252.737
30	130.419	304.768
31	11.164	377.389
32	251.875	-
33	89.132	-
34	50.398	-
35	377.389	-
36	22.49	-
37	172.295	-
38	20.037	-
39	6.795	-
40	21.531	-
41	10.202	-
42	28.879	-
43	20.346	-
44	304.768	-
45	13.835	-
46	252.737	-
47	18.956	-
Total Distance	2927.896	2678.903

Based on Table 5 it can be seen that the total distance traveled at the initial condition is 2927.896 km, while the total distance traveled at the proposed condition of 2678.903 km. This indicates the difference between the distance between the initial conditions conditions with the proposed condition of 294,993 km or if the percentage of 10.075% smaller than the initial conditions. In addition, by looking at the total mileage, will directly define the fulfillment of customer demand.

3.8 Comparison Analysis of Total Transportation Cost

Total transportation cost is the cost incurred by the company during the distribution process [8]. Total transportation cost consists of two cost components, namely fixed cost and variable cost. Based on the results of research using genetic algorithm in get total transportation cost in one day planning horizon that is as follows:

TABLE 6
COMPARISON OF TOTAL TRANSPORTATION COSTS

Condition	Fixed Cost	
	Single Engkel	Double Engkel
Initial	Rp4,550,000.00	Rp668,209.88
Proposed	Rp3,250,000.00	Rp133,641.98
Improvements	28.57%	80.00%
	Variable Cost	
	Single Engkel	Double Engkel
Initial	Rp2,061,397.78	Rp47,478.45
Proposed	Rp1,649,418.37	Rp347,737.01
Improvements	19.99%	-632.41%

TABLE 7
FINAL RESULT COMPARISON OF TOTAL TRANSPORT COSTS

Cost Component	Proposed	Initial	Improvements

Fixed Cost	Rp3,383,641.98	Rp5,218,209.88	35.16%
Variable Cost	Rp1,997,155.37	Rp2,108,876.23	5.30%
Total Cost	Rp5,380,797.35	Rp7,327,086.11	26.56%

Based on Table 7 shows the decrease of fixed cost of Rp1,834,567.90 or 35.16% from initial condition. As for variable costs there was a decrease of Rp111,720.86 or equivalent to 5.30% of the initial conditions. Furthermore, the final results obtained in the form of total transportation costs. For the proposed condition of Rp5,380,797.35 or decreased by Rp1,946,288.76 (26.56%) from the initial condition.

IV. CONCLUSION

Based on the results of research in designing routes and determining the number of vehicles in the product distribution process in PT XYZ, the conclusion is obtained that is:

1. Determination of the appropriate fleet route in order to minimize the distance, the number of vehicles and optimization of utility vehicles in the distribution process at PT XYZ can be done using the nearest neighbor method for the initial solution and followed by the method of genetic algorithm for optimal solution. The use of this method can result in better outcomes than the initial conditions seen from the increased percentage of utility boxes in the use of each vehicle, the reduced number of vehicles in a planning horizon and the minimization of the amount of transportation costs.

2. After route planning on PT XYZ using genetic algorithm it is known that the total transportation cost savings amounted to 25.62% or Rp1,946,288.65 from total cost of actual expenses, which is Rp7,327,086. The result was obtained due to the decrease of 8,504% distance or 248,933 km from actual mileage, the percentage decrease of vehicle usage amounted to 34.04% or 16 vehicles of total fleet used, and the increase in utility vehicle box percentage was 35.371% Utility vehicle box actually.

REFERENCES

[1] R. R. Anisa, "Perancangan Rute Pendistribusian Produk Obat Dengan Menggunakan Algoritma Tabu Search Pada Vehicle Routing Problem With Time Window di PT XYZ Bandung," Telkom University, Bandung, 2016.

[2] A. Desiana, "Penyelesaian Vehicle Routing (VRP) Untuk Meminimasi Total Biaya Transportasi Pada PT XYZ Dengan Metode Algoritma Genetika," Library Telkom University, Bandung, 2016.

[3] P. Toth and D. Vigo, "The Vehicle Routing Problem," Soc. for Industrial and Applied Math, Philadelphia, 2001.

[4] Kartikasari, "Perancangan Rute dan Penugasan Kendaraan pada Pendistribusian Produk di PT XYZ Untuk Meminimasi Total Biaya Transportasi Menggunakan Algoritma Genetika," Telkom University, Bandung, 2016.

[5] P. C. S. C. P. Z. I. L. a. C. C. Pop, " Int. J. of Computers, Communication & Control,," Heuristic Algorithms for Solving the Generalized Vehicle Routing Problem, pp. 158-165, 2011.

[6] Haupt, "Practical Genetic Algorithms," John Wiley&Sons Inc, America, 2004.

[7] M. W. Maulana, "Penentuan Rute Pendistribusian Produk di Regional Part Depo PT XYZ Bandung Untuk Meminimasi Biaya Transportasi Menggunakan Algoritma Harmony Search," Telkom University, Bandung, 2016.

[8] P. S. Muttaqin, " Penentuan Rute Armada di PT XYZ Menggunakan Algoritma Tabu Search Pada Heterogeneous Fleet Vehicle Routing Problem With Time Windows Untuk Meminimasi Jarak Dan Biaya Transportasi Berbasis Sistem Informasi Geografis," Universitas Telkom, Bandung, 2016.