Optimization of Multiple Depot Vehicle Routing Problem (MDVRP) on Perishable Product Distribution by Using Genetic Algorithm and Fuzzy Logic Controller (FLC)

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Abstract – Distribution has a large portion of the total cost of sales of goods or product. It cause high cost transport and risk to the quality of the goods which are distributed, especially perishable product. Perishable product quality is greatly influenced by distribution, thus when the distribution not optimal, it will risk very big deal of broken product. In connection with this matter, the distribution process needed to optimize especially to perishable product. Optimal distribution problem can be solved using Multiple Depot Vehicle Distribution Routing Problem (MDVRP) model, which was development of Vehicle Routing Problem (VRP). To get the optimal solution of MDVRP, genetic Algorithm (GA) was used. Using GA, more than one alternative solution with good fitness value were gained. Then Fuzzy Logic Controller (FLC) was used to control these parameter values in order not to trap into local optimum. After new pm and pc value were obtained, the GA process was conducted to get the shortest route. The result of this research showed that the value of the probability of crossover and mutation affected the fitness values. The higher fitness value, the smaller the distance which reached. It will reduce the risk of rot caused by travel time. Testing results showed some alternative solutions which is not much different in fitness value. Level of optimality increased when FLC process were conducted. From 10 times evaluation reached 89, 9%.

Keywords: *Multiple Vehicle Routing Problem (MDVRP), grouping, scheduling, genetic algorithms, Fuzzy Logic Controller (FLC).*

1. INTRODUCTION

The distribution is closely related to the fields of transport, where transport becomes an important role in the flow of products in a supply chain distributors. But in the activities, the distributions often have constraints on transport costs which have a large proportion of the total cost of sales of goods or product. Costs incurred for the transport process reached 50.8% of the total cost of a supply chain [2]. This is because of the distance between the distributor and the customer that cause high cost transport and risk to the quality of the goods which are distributed, especially perishable product.

Perishable product is a product that has a life span with short-term and sensitive high level such as fresh fruits, fresh vegetables, fresh milk and flowers alive. Perishable product quality is greatly influenced by distribution, therefore when the distribution not optimal, it will risk very big deal of broken product.

A perishable company product has several depots and customers spread across several regions. In each distribution, the quota goods have been assigned to its own fleet, in accordance to customer's demand which exist around the depot area. However, if customers and depots are not in a good arrangement then this will greatly disrupt the distribution of goods to the depot and fleet. Customer could be serviced by more than one depot. This will make the service and route of distribution at depot are not optimal.

In connection with this matter, the distribution process needed to optimize especially to perishable product. The optimal distribution process can minimize the cost of transportation and distribution and also the quality of perishable products can be maintained by organizing the time and route of transport. The optimal distribution problem can be solved Using Multiple Depot Vehicle Distribution Routing Problem (MDVRP) model, which was development of Vehicle Routing Problem (VRP), a method that usually used for shortest path problem. MDVRP is widely used in solving shortest route problem, distribution of products allows a fleet of some depots (more than one) to be distributed again to many customers.

Related research to this study which done before, was also using Genetic Algorithm and Fuzzy Logic Controller but difference in case used. It used Capacitated Vehicle Routing Problem [9]. In this study, Genetic Algorithm and Fuzzy Logic Controller is used in MDVRP.

In the process of optimizing, multiple depot vehicle routing problem (MDVRP) has three stages, namely, grouping, routing, and scheduling stages. In this stage, a genetic algorithm is used to obtain more than one solution or alternative solution with a good fitness value.

Therefore, in order to control the parameter values and to reduce the possible risk of genetic algorithm trapped in local optimum, Fuzzy Logic Controller (FLC) was used. Based on the research that has been done by previous researchers, the use of models FLC genetic algorithm can improve the quality of the solution is better than not through adaptive use of FLC.

This paper is organized as follows: chapter I is described about introduction and motivation about research. Chapter II is describe about research method. Problem analysis is in chapter IV and followed by result and discussion in chapter V. Last chapter is about conclusion and future research.

II. RESEARCH METHOD

The research method describes how the steps or stages will be carried out in research to be able to answer the problem formulation of the research. Stages of research which was conducted in this study are shown in Figure 1.

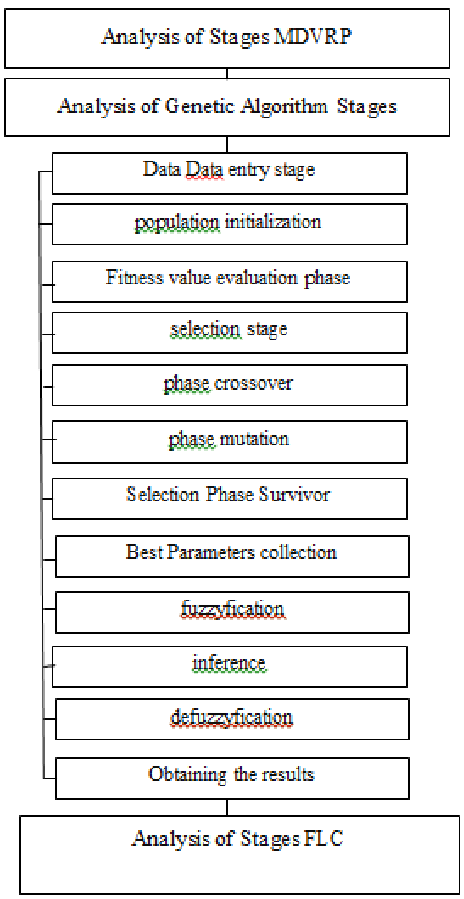

Figure 1. Research Flowchart

MDVRP analysis, including grouping the problem, routing (solution finding) and scheduling (route ordering). After MDVRP Analysis, a series of GA stages was done here. In this stage, initial population is generated randomly. For selection and crossover stage, roulette-wheel and order crossover method were used. After mutation stage, survivor selection was done. This stage's objective was to optimize solution which gained from previous process. After that the best parameters from the best solution were collected for FLC optimizing.

Fuzzy Logic Controller Optimizing was conducted to control running parameters in GA process. Here in this stage, crossover parameter (pc), mutation parameter (pm), number of generation, sampling rate, and fitness value were needed in this process. The stage of fuzzification, rule evaluation and defuzzification were done to gain new value for pc and pm. This new value then used in new GA calculation to get the output. Output from this FLC optimizing is optimal solution (shortest path).

Observation was done to a large-scale perishable product distributor to gain customers address and depots address. These data were needed to calculate the distance among customers and depots. Then a grouping process will be done to cluster customer with nearest depot.

III. ANALYSIS

A. Genetic Algorithm (GA) Analysis

The GA parameters which used were:

1. The population size is the number of chromosomes that will be proceed by using genetic algorithm
2. Probability of and crossover (pc) is a parameter used for the crossover process. There are three pc value used: (0.6), (0.7), (0.9).
3. Probabilities mutation (pm) is a parameter used for mutation process. There are three pm value used: (0,3), (0,4), (0,5) .

B. MDVRP using Genetic Algorithm

MDVRP optimization using a genetic algorithm are described below:

a. Initialization, in this stage customers and depots address were initialized (Table 1). Next stage is MDVRP grouping.

b. MDVRP grouping process, the objective was to generate groups of customer-depot which are nearly located.
The results of the process of grouping customers for depot A depot is CDEJ and B is FGHIK, Then 6 pieces populations can be established without violating the fleet capacity. The group of population can be seen in table 3.

c. Fitness value of each generated chromosome is calculated. Table 4 and 5 are shown the result of calculation.

d. The genetic algorithms processes
In genetic algorithms there are some processes to produce solution with the best fitness value, which are a process of selection, crossover and mutation with individual probability. Result of whole GA process can be seen in table 6. It showed that the best fitness value was gained from GA process with pc = 0,9, pm = 0,4, and fitness value = 0,0295.

Table 1. Distance value

	A	B	C	D	E	F	G	H	i	j	K
A	0										
B	160	0									
C	50	185	0								
D	70	157	38	0							
E	80	87	110	75	0						
F	165	100	160	125	51	0					
G	143	60	150	115	36	36	0				
H	154	75	193	176	119	140	100	0			
I	93	90	137	130	97	140	100	58	0		
J	60	195	10	48	120	170	160	203	147	0	
K	185	20	180	145	71	20	56	160	160	55	0

Table 2. Grouping Result

Depot A	C	D	E	J	
Depot B	F	G	G	I	K

Table 3 Grouping of population

Population of Depot A	Population of Depot A
C D E J	F-G-H | I-K
C E D J	G-K-H | F-I
C J D E	I-H-G | K-F
D E C J	F-I-G | H-K
D J E C	I-F-K | H-G
E C D J	K-F-H G | I

Table 4. Fitness Value of Depot A

No	Chromosome		Distance *(f)* $\sum^{N} Z_i$	Fitness Value *(Q[i])* $\frac{1}{f}$
K[1]	C-D-E | J	AC-CD-DE-EA | AJ-JA	363	0.002754821
K[2]	C-E-D | J	AC-CE-EC-CA | AJ-JA	425	0.002352941
K[3]	C-J-D | E	AC-CJ-JD-DA | AE-EA	338	0.00295858
K[4]	D-E-C | J	AD-DE-EC-CA | AJ-JA	425	0.002352941
K[5]	D-J-E | C	AD-DJ-JE-EA |AC-CA	418	0.002392344
K[6]	E-C-D | J	AE-EC-CD-DA | AJ-JA	418	0.002392344
Total				0.015203972

Table 5. Fitness Value of Depot B

Chromosome		Distance *(f)* $\sum_{i=1}^{N} Z_i$	Fitness Value *(Q[i])* $\frac{1}{f}$
F-G-H | I-K	BF+FG+GH+HB | BI+IK+KB	581	0.00172117
G-K-H | F-I	BG+GK+KH+HB | BF+FI+IB	681	0.001468429
I-H-G | K-F	BI+IH+HG+GB | BK+KF+FB	448	0.002232143
F-I-G | H-K	BF+FI+IG+GB | BH+HK+KB	655	0.001526718
I-F-K | H-G	BI+IF+FK+KB | BH+HG+GB	505	0.001980198
K-F-H-G | I	BK+KF+FH+HG+GB | BI+IB	520	0.001923077
Total			0.010851735

d. Optimization FLC Process

The parameters used in the optimization process FLC's is the number of generations of genetic processes previous process that is equal to 0.67 and Phenotype Diversity (PD) that is equal to 0.2684.

After process of fuzzification, rule evaluation and defuzification were conducted on each parameter, results probabilities value crossover and mutation are 0.8 and 0.297.

e. Scheduling

Pc and pm value from FLC process then became input on GA process on each depot. The shortest route of depot A is in table 7. The best route is AE-EJ-JC-CD-DA and takes over 7 hours. For depot B, the shortest route can be seen in table 8. The best route is BI-IH-HG-GF-FK-KB, and takes over 7 hours and 2 minutes.

IV. RESULT AND DISCUSSION

A. Result

Some testing were conducted in this research. The testing details are:

1. Evaluation of fitness value from GA process

   Figure 2 showed evaluation result before FLC was conducted. The best fitness value is from pc 0,9 and pm 0,4 with each fitness value 0,0041 for depot A and 0,0022 for depot B.
2. Evaluation of fitness value from FLC process

   Figure 2 showed that the best fitness value was obtained on pc 0,9 and pm 0,4 with value of 0,00295. While pm and pc which ran into FLC process has fitness value of 0, 00311.
3. Evaluation of optimality

   In this research, 10 testing were conducted to evaluate the optimality of the system. The average of optimality from 10 time evaluation reach 89,8%. The result of testing can be seen in Figure 3.

Table 6. Result of GA Process

No	Depot	Pc	Pm	R	Fitness Value	Chro moso me	Mean	Time $\frac{R}{v}$
1	A	0,6	0,3	318	0,00314	D J C E	0,002 25	7 hour
	B			481	0,00207	I F K G H		10 hour 6 minute
2	A		0,4	263	0,00380	C J D E	0,002 45	5 hours 8 minute
	B			474	0,00210	G F I H K		10 hours 5 minute
3	A		0,5	318	0,00314	E J C D	0,002 39	7 hours
	B			409	0,00244	G K F I H		9 hours
4	A	0,7	0,3	263	0,0038	E D C J	0,002 2	5 hours 8 minute
	B			470	0,00220	I G H F K		10 hours 4 me minute

5	A		0,4	246	0,00406	E C D J	0,0027	5 hours 4 minute
	B			469	0,00213	F G H I K		10 hours 4 minute
6	A		0,5	363	0,00380	C J D E	0,00278	8 hours
	B			424	0,00235	G K F H I		9 hours 4 minute
7	A	0,9	0,3	308	0,0033	D J C E	0,00235	6 hours 8 minute
	B			478	0,00209	I G H F K		10 hours 6 minute
8	A		0,4	243	0,0041	J C D E	0,00295	5 hours 4 minute
	B			455	0,00219	H G I F K		10 hours 1 minutes
9	A		0,5	263	0,0038	J C E D	0,00280	5 hours 8 minute
	B			401	0,00207	I K F G H		8 hours 9 minutes

Table 7. Shortest Route of Depot A

No	**Chromosome**		**R**	**Fitness Value**	**Travel Time**
1	D J C E	AD-DJ-JC-CE-EA	318	0,00314	7 hours
2	E J C D	AE-EJ-JC-CD-DA	318	0,00314	7 hours
3	D E J C	AD-DE-EJ-JC-CA	325	0,00307	7 hours 2 minutes
4	J E D C	AJ-JE-ED-DC-CA	343	0,00291	7 hours 6 minutes
5	J D E C	AJ-JD-DE-EC-CA	343	0,00291	7 hours 6 minutes
6	D J E C	AD-DJ-JE-EC-CA	398	0,00251	8 hours 8 minutes

Table 8. Shortest Route of Depot B

No	**Chromosome**		**R**	**Fitness Value**	**Travel Time**
1	I H G F K	BI-IH-HG-GF-FK-KB	324	0.00308	7 hours 2 minutes
2	H I G K F	BH-HI-IG-GK-KF-FB	409	0.00244	9 hours
3	I H G K F	BI-IH-HG-GK-KF-FB	424	0.00235	9 hours 4 minutes
4	F G K H I	BF-FG-FK-KH-HI-IB	464	0.00215	10 hours 3 minutes
5	G F I H K	BG-GF-FI-IH-HK-KB	474	0.00210	10 hours 5 minutes
6	I K G H F	BI-IK-KG-GH-HF-FB	646	0.00154	14 hours 3 minutes

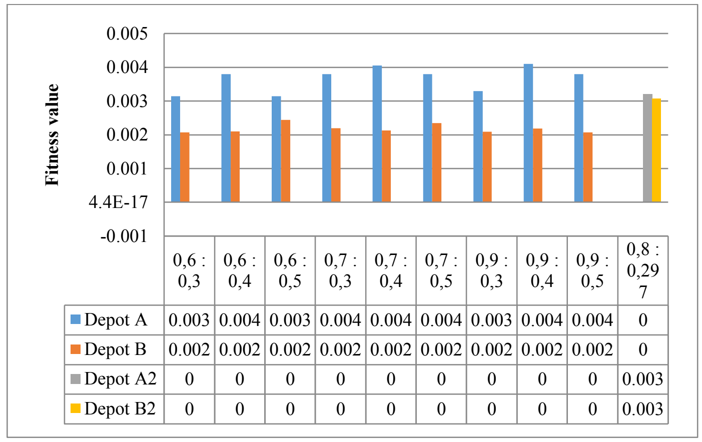

Figure 2. Evaluation of value from GA process

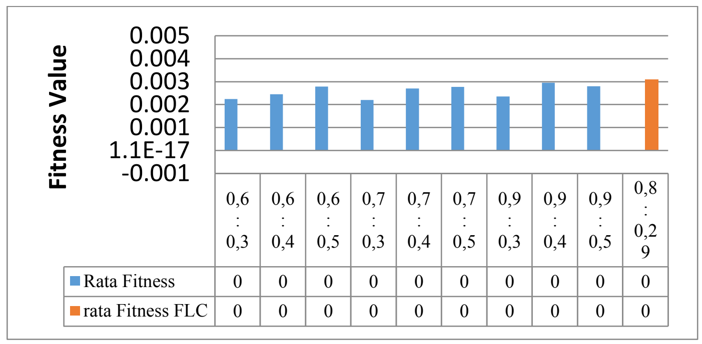

Figure 3. Evaluation of fitness value from FLC process

B. Discussion

Based on comparative testing, and the average fitness value fitness value it can be concluded that:

1. The value of the probability of crossover and mutation affected he fitness values. The higher fitness value, the smaller the distance which reached. It will reduce the risk of rot caused by travel time.
2. Testing results showed some alternative solutions which is not much different in fitness value.
3. Level of optimality increased when FLC process were conducted.
4. Optimality reached 89.8% in 10 times evaluation.

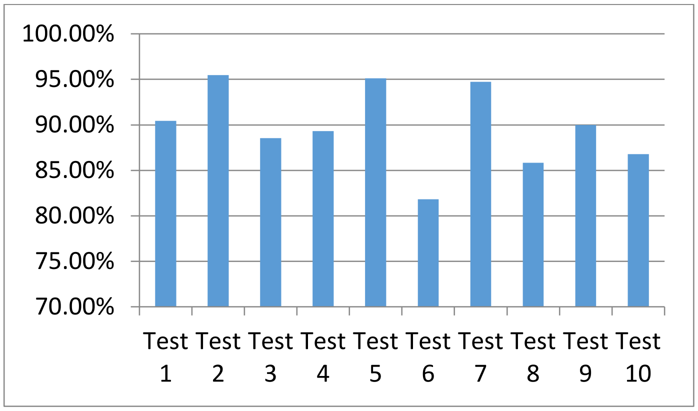

Figure 4. Optimality Testing

VI. CONCLUSION

Multiple Depot Vehicle Distribution Routing Problem (MDVRP) is a development model from Vehicle Routing Problem (VRP). In this research, genetic algorithm (GA) was used to get the optimal route for distribution of perishable product. Shortest route means reducing risk of rot. To optimize the parameter value which used in calculations, Fuzzy Logic Controller (FLC) was used. Shortest route as an output were obtained as a result of GA process using new parameter value resulted from FLC.

From this research, we can conclude that:

1. Probability of crossover and mutation affects the level optimization of solution obtained. The average value of the highest fitness value is 0,9 of pc and 0.4 of pm
2. Based on the testing that has been done before, it can be concluded that the optimization FLC genetic algorithm in case MDVRP (Multiple Depot Vehicle Routing Problem) can provide optimal service solutions for distribution of perishable products.

Some suggestion for future research of the optimization of fuzzy logic controller in case MDVRP (multiple Depot Vehicle Routing Problem) on the distribution of perishable product genetic algorithm are as follows:

1. The system can be expanded by adding other perishable materials for development
2. The system can be expanded by adding probability of crossover and mutation to test the level optimization.
3. The system can be developed by using case other vehicle routing problem.

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