Improvement Route for Distribution Solutions MDVRP (Multi Depot Vehicle Routing Problem) using Genetic Algorithm

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Abstract. The Supply Chain Management Division (SCM) of KM Rubber Company is responsible for delivering the sole product, crumb rubber, from its various factories in Sumatera to the destination ports for further delivery to customers or export destinations. The aim of this study is to provide the improved route for the depot distribution to each destination ports with the shortest time and distance. Writing stage begins with preliminary studies, followed by the identification of the problem, determine the purpose of research, data collection, data processing that contains the initial distribution system optimization solved by methods of transportation and distribution of a new route that is resolved by Genetic Algorithm, and closed by the analysis and conclusions. The manual calculation method to obtain the optimal route gives a total transport distance of 8832.12 km; while the distribution of the proposed route using Genetic Algorithms generate total distance routes as far as 5188.06 km. As the distance is shorter the new route will generate minimal costs and shorter travel time.

Keywords: Multi Depot Vehicle Routing Problem, Genetic Algorithm, Transportation.

1. Introduction
PT. KM Factory Operation department is the department that responsible for managing the operations of production, SCM (Supply Chain Management) and planned production needs. This study focused on the part of SCM companies. The main product produced in the form of crumb rubber (rubber crumb) with quality standards based on SIR (Standard Indonesian Rubber). Factories are the focus in this thesis is the entire plant KM group located on the island of Sumatra.

The factory which is located on the island of Sumatera Indonesia, there are 12 factories, PT. N in Medan, PT. PS in Simelungun, PT. TSS in Riau, PT DJ 1 in Jambi, PT. KM in Bangka, PT. KS Padang, PT. DS 2 in Jujuhan, PT. ALB in Muara Bungo, PT. KW in Windu, PT KMP in Sekayu, PT. KP in Prabumulih, and PT. KJP in Tulang Bawang.

The whole factory in Sumatra sends the result of the products to 6 different port is the port of Jambi, the port of Belawan, the port of Padang, the post of Palembang, the port of Perawang, and the port of Tanjung Priok. Distribution costs incurred by the company for each plant is very diverse and depend on the destination port. In this research will model the distribution of the most optimal route for each plant on the island of Sumatra.

Problems Appears PT KM distribution system is the produce includes distribution costs are very diverse and have a route that is ineffective. It initials caused because distribution system the previously
used process less efficient currently where hearts one plant can send prayers or more to ports. Mileage and travel time distribution is very dependent to port the destination, travel time different in each ports as well as the distance from factory to ports that also different.

One way is to determine the most efficient distribution of the products of time and distance as well as the maximum in transportation. Here is the distribution that is used today by the company. The table below shows the factory which will deliver the products to the ports available.

Table 1. Distribution System Company Now

| No. | Factory | Port   | No. | Factory | Port   |
|-----|---------|--------|-----|---------|--------|
| 1   | ABL1    | Belawan| 10  | KPT1    | Palembang|
| 2   | ABL1    | Padang | 11  | KSP1    | Belawan |
| 3   | DWJ1    | Jambi  | 12  | KUT1    | Jakarta |
| 4   | DWJ1    | Palembang| 13  | KWI1    | Jambi  |
| 5   | DWJ2    | Belawan| 14  | KWI1    | Palembang|
| 6   | DWJ2    | Padang | 15  | NSI1    | Belawan |
| 7   | KJP1    | Palembang| 16  | PSUI1   | Belawan |
| 8   | KMP1    | Palembang| 17  | TSS1    | Belawan |
| 9   | KPT1    | Jakarta | 18  | TSS1    | Perawang |

The aim of this study is to provide the proposed improvements to the depot distribution of each destination and determine the distribution of the depot to the most optimal destination resulting in distance and time most efficiently.

There many research about vehicle routing problem. Okude proposed an approximate solution calculation method for vehicle routing problems (VRPs) that obtains a better solution in a shorter time. The proposed method generates an approximate solution by using a hierarchical traffic network composed on the basis of a vehicle's behavior, which is the frequency of using roads [1].

At MDVRP, number and location of the depot has been determined in advance. Each depot has certainly large enough to accommodate orders from customers. Every vehicle departs and returns to the depot respectively. Location and demand of each customer are also known in advance and every customer will be served exactly once. Customers are served from the same depot will be allocated passes through several routes with methods of saving [2]. The goal of routing is to minimize the number of lanes without neglecting the capacity. The better the process of routing and scheduling , it will be closer spacing will be pursued vehicle , the shorter the time of customer service , more efficient , and more affordable price of its delivery. Generally MDVRP used to shorten the distance and shorten the time of service to all customers. The less the vehicle will make the operating costs are also getting cheaper, can be said MDVRP also an effort to reduce vehicle.

Figure 1. The decision making process on MDVRP
Formulation for MDVRP with the objective of modeling the customer order contained in the path of the vehicle. In this model it is assumed that all vehicles have a capacity of uniforms, and each vehicle will depart and return to their respective depots. Notation is used for mathematical models as follows [3]:

\( I \): set the whole depot  
\( J \): set the whole consumer  
\( K \): set the entire vehicle  
\( j \): indexes consumer  
\( k \): indexes track  

Parameter :  
\( N \): number of vehicles  
\( C_{ij} \): distance of points \( i \) to \( j \)  
\( V_i \): The maximum number of products on the depot \( i \)  
\( d_{ij} \): demand consumer \( j \)

Decision variable :  
\( X_{ijk} = \begin{cases} 1, & \text{if } i \text{ immediately proceeds } j \text{ on route } k \\ 0, & \text{otherwise} \end{cases} \)

\( Z_{ij} = \begin{cases} 1, & \text{if customer } j \text{ is allotted to depot } i \\ 0, & \text{otherwise} \end{cases} \)

\( U_{ik} \) = auxiliary variable to subtour elimination constrain in route \( k \).

Mathematical model:

The function objective to minimize the total distance of all vehicles

\[ \text{Min} \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} C_{ij} X_{ijk} \]  

(1)

Every consumer should be allocated to a track.

\[ \sum_{k \in K} \sum_{i \in I} X_{ijk} = 1, j \in J \]  

(2)

Every track will be served one time.

\[ \sum_{i \in I} \sum_{j \in J} X_{ijk} \leq 1, k \in K \]  

(3)

Below is the capacity for each depot.

\[ \sum_{j \in J} d_{ij} \leq V_i, i \in I \]  

(4)

Below is the equation that specifies that a consumer can be allocated to a depot only if there is a path from the depot to the consumer.

\[ -Z_{ij} \sum_{u \in U} (X_{iu} + X_{uj}) \leq 1, i \in I, j \in J, k \in K \]  

(5)

Equationn (6) dan (7) give binary requirements to decision variable.

\[ X_{iu} \in \{0,1\}, i \in I, j \in J, k \in K \]  

(6)

\[ Z_{id} \in \{0,1\}, i \in I, j \in J \]  

(7)

Variable score auxiliary has to be positive.

\[ U_{ik} \geq 0, i \in I, j \in J, k \in K \]  

(8)

**Genetic Algorithm**

Genetic Algorithm (GA) work based on parallel mechanisms, and therefore more efficient than other optimization techniques such as branch and bound, tabu search and simulated annealing. Basically GA will keep the population of the solutions involved based on existing boundaries. By using GA (genetic operators, crossover, dan mutation) will prevent the processing of data trapped in a local optimum solution. Because it is possible to produce global optimization, then genetic algorithm is suitable to apply to the MDVRP. GA applying natural selection work like genetics [3]. Research about determination of base-stock levels in a ten member serial supply chain with multiple products produced by factories using Uniform Crossover Genetic Algorithms. The complexity of the problem increases when more distribution centers and agents and multiple products were involved. These considerations leading to very complex inventory management process has been resolved in this work[4]. Research about Genetic algorithm developed a mathematical model for a distribution network in a three echelon supply chain.
that minimizes the system-wide costs and delays on delivery of products. The mathematical model is designed as a multi-objective optimization problem taking into account the two conflicting objective functions[5]. Research about Node duplication Genetic Algorithm (NGA) based technique by comparing against some of the existing deterministic scheduling techniques for minimizing inter processor traffic communication. A comparative study of the results obtained from simulations shows that genetic algorithm can be used to schedule tasks to meet deadlines, in turn to obtain high processor utilization[6]. Research about a method for optimizing software testing efficiency by identifying the most critical path clusters in a program had done by developing variable length Genetic Algorithms that optimize and select the software path clusters which are weighted in accordance with the criticality of the path[8].

Cromosom Representation

Cromosom in MDVRP is a list of consumer that have been visited. There are 6 customer, customer 1-6. Route that representative is first route (02410) and second route (0650). In the first route move from depot to customer 2, then 4, 1, and back to the first place. In the second route is done the same thing. GA for MDVRP is done with three step: grouping, routing, and scheduling. Grouping- in this step customer will be connected into every n links. The purpose of it is costumer will be divided into depot that have small destination with this rules:

- If $D(ci,A) < D(ci,B)$, then customer $ci$ will be transferred from the depot A
- If $D(ci,A) > D(ci,B)$, then customer $ci$ will be transferred from the depot B
- If $D(ci,A) = D(ci,B)$, then customer $ci$ will be transferred from the depot A or B

From that cases, this is the distance between customer $ci$ and depot $k$ [3].

$$D(c_i,k)=\sqrt{(x_{ci}-x_k)^2+(y_{ci}-y_k)^2}$$  \hspace{1cm} (9)

Routing- customer in one link will be alocated into several route using saving matrix [2]. A saving matrix $S(c_i,c_j)$ divided into two customer $i$ and $j$ in the same link. At the end costomer that have the biggest saving will be join into one route without. Saving matrix formulated as follows.

$$S(c_i,c_j)=D(k,c_i)+D(k,c_j)-D(c_i,c_j)$$  \hspace{1cm} (10)

Scheduling- from the first costumer, delivery step by step until the distance of next customer is not too far from the previous consumer. This process will be done until all customer can get delivery line. In the final step, the most visible solution will be done.

Fitness Evaluation

One of the objective MDVRP is to minimize time that needed to process delivery. Process delivery is started at the same time, but can be finished at different time depend on how many costumer can be served.

Time to spend for delivery process is counted from vehicle that have longest time in finished his job to send their product to customer. $D_t$ is total time delivery that needed in depot $k$ and min($D_t$) is delivery time minimum that spent in all depot [3].

$$D_t=\sum_{k=1}^{n_k} d[c(m_s).c(0)]+\sum_{i=1}^{m_c} d[c(i-1), c(i)]$$ \hspace{1cm} (11)

Whish $d(a,b)$ is time travel a vehicle from customer a ke b, $V$ is the speed of vehicle, $c(i)$ is location from customer to i, $c(0)$ is from adalah point start or depot position, $m_s$ is customer number in r route, $m_c$ is route number for depot $k$. Equation function is define as $F = \sum_{p=1}^{P\text{Size}} \text{min}(Dt)$

Selection

A common method of selection that used is roulette-wheel. As the name, this methode copy games roulette-wheel where each cromosoms occupied circle pieces on roulette wheel proportionally according to fitness value. Cromosom that have the biggest fitness score occupying a larger circle than a chromosome value is low fitness chromosomes. This method is very easy to use. The first step is to make cumulative interval number (in interval [0,1]) from fitness score every cromosoms is divided by total nilai fitness score from every cromosom. The cromosom will be chosen if random number will be raised by in interval accumulation [7].

Crossover
Crossover technik Best Cost Route Crossover (BCRC) develop to solve route problem with time windows (VRPTW), now it can be used to solve problem route multi depot (MDVRP) with modification.  

**Mutation**  
Mutation is modification process of child cromosom randomly. [9]. In the TSP, mutation carriers typically implemented by exchanging genes with the other genes mutated randomly selected. For example, chromosome \{2, 3, 4, 1, 5\} can be mutated into a chromosome \{4, 3, 2, 1, 5\}. In this case the gene 1 and gene 3 can be exchanged. This mutation scheme is known as swapping mutation.

There are many research about MDVRP for instance like research about a new VRP solution based on a bi-directional road network, which aims to minimizing fuel consumption for gasoline powered delivery vehicle[10].

2. **Research Method**

![Flowchart Transportation Method](image1)

![Flowchart Genetic Algorithm](image2)

3. **Result And Discussion**

**Results Distribution Company Rute Optimization**  
Optimization of the distribution system applied by the company nowadays, can be settled with the transportation table and MODI. Here is the result of the calculation using the transport table is least cost way of charging cell that has the lowest price. Previously it had to known in advance the cost of distribution per unit which each unit is used pallet (Rp/Pallet).
The request data is also needed to determine the demand for each of the objectives and the capacity of the plant. By way of a column filled multiplied by the cost it will obtain the total cost of least cost for distribution of products for Rp 98,724,817,800.00 in one year.

After obtaining least cost charges can proceed to the stage of optimization using MODI. Basically MODI performed to optimize the results of the table transportation so can result the most optimal transport routes.

**Table 2. Table Description**

| Name of the Port                  | No | Code | No | Code |
|-----------------------------------|----|------|----|------|
| A Belawan Port                    | 1  | ABL1 | 7  | KSP1 |
| B Teluk Bayur Padang Port         | 2  | DWJ1 | 8  | KUT1 |
| C Talang Duku Jambi Port          | 3  | DWJ2 | 9  | KWI1 |
| D Boom Baru Palembang Port        | 4  | KJP1 | 10 | NSH1 |
| E Tanjung Priok Jakarta Port      | 5  | KMP1 | 11 | PSU1 |
| F Perawang Port                   | 6  | KPT1 | 12 | TSS1 |

Process completion using MODI is by giving the row and column values for all variables in the formula base with bi + kj = cij, where bi is a line to i, kj a is column to j, an cij is a charge on the cell. After all the columns and rows had filled, then calculated non-base variables with the formula:

\[ z_{ij} - c_{ij} = bi + kj - c_{ij} \]

where \( z_{ij} \leq 0 \) for the optimal result. The result calculation is as follows [11].

\[
\begin{align*}
  z_{12} & = 0 + 357840 - 379260 = -21420 \\
  z_{24} & = 157500 + 52920 - 359100 = 0 \\
  z_{44} & = 365400 + 201600 - 567000 = 0 \\
  z_{65} & = 45360 + 201600 - 246960 = 0 \\
\end{align*}
\]

The transport table is optimal for a total cost Rp 98,724,817,800.00, and the total distance of the route as far 8832.12 km.

**The result optimization route proposal with Genetika Algoritma**

**The making of cromosom**

The making of cromosom starts with grouping process is grouping or allocation of interest to the nearest depot. Furthermore, the routing process is making of these groups based on the allocation of the value of saving [10]. And then scheduling process namely the manufacture of a complete service to all destinations across the depot that allows for no change in population size. This is the result of the making cromosom proses.

**Table 3. Grouping Result**

| Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 7 |
|---------|---------|---------|---------|---------|---------|
| A       | B       | C       | D       | E       | F       |
| 11      | 3       | 2       | 5       | 8       | 1       |
| 10      | 9       | 6       | 4       | 12      | 7       |

**Fitness Evaluation**

Indication that a route had optimal distance route is to know time schedule in the travel route. And then will calculate using persamaan evaluation fitness from population [3].

**Selection**
Selection process can be done to choose population the most fit of the others based on their fitness values. From that selection had been chosen Parents and then will be crossover. This is the result of selection. From the selection had been choosen P1 dan P4 as a Parents.

Table 4. Selection

|     | Dt  | Sum of Dt | Score of Fitness | Sum of Fitness | Interval | Rn       | Chosen |
|-----|-----|-----------|------------------|----------------|----------|----------|--------|
| P1  | 2478| 9926      | 0.2496           | 0.2496         | 0.2269   | 0.2496   |        |
| P2  | 2481|          | 0.2499           | 1.0            | 0.2499   | 0.9909   | 0.2499 |
| P3  | 2485|          | 0.2503           | 0.2502         | 0.2546   | 0.2503   |        |
| P4  | 2482|          | 0.2500           | 0.2500         | 0.2290   | 0.2500   |        |

Crossover
Crossover process is done between two population parents and then resulting new generation. Change P1 and P4 into biner form before crossover with give score 1 if point i have passed point j, and 0 if not.

Mutation
This is the result from sum of biner score then it become weight and then resulting new allocation route.

Table 5. New Allocation Route

| Step | 10 | 11 | A  | 3  | B  | 2  | 9  | C  | 6  | 4  | 5  | D  | 8  | E  | 12 | 7  | 1  | F  |
|------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Allocation | A | 1  | 1  | A  | B  | 3  | B  | C  | 2  | 9  | C  | 6  | 4  | 5  | D  | 8  | E  | 12 | 7  | 1  | F  |
| Distan- | 3  | 1  | 2  | 2  | 2  | 5  | 2  | 2  | 1  | 2  | 28 | 1  | 70 | 70 | 20 | 51 | 62 | 4  |
| ce    | 5  | 0  | 5  | 3  | 3  | 7  | 2  | 4  | 5  | 4  | 3  | 7  | 4  | 4  | 8  | 3  | 0  | 8  |
|       | 6  | 9  | 9  | 5  | 6  | 7  | 5  | 5  |    |    |    |    |    |    |    |    |    |    |

The total distance route with that route is 5188.06 km.
From the above calculation with optimization of routes used by the company using the transport table and optimization MODI obtained total mileage is 8832.12 km. Where the distance is the total distance of all route from starting the vehicle departs from the place of origin to destination and back again to destination.
If compared with calculation using Algoritma Genetika, total mileage of the vehicle is shorter 5188.06 km. This can be happened because the repair service is opened all lanes of the depot to the destination that has the shortest distance to the depot, then the product distribution area may include the area around the depot area. Different with distribution route that used by the company now where in one delivery, vehicle only delivery to one place and then back to the first place.

4. Conclusion
1. The new more efficient distribution routes formed after making repairs are A-10-11-A, B-3-B, C-2-9-C, D-6-4-5-D, E-8-E, F-12-7-1-F.
2. These new distribution routes produce a shorter total distance of 5,188.06 km which gives a saving of 3,644.06 km from the initial distribution distance of 8,832.12 km.

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