Genetic Algorithm for Waste Transportation Route in Eastern Bandung (Case Study: PD. Kebersihan Kota Bandung)

Y Yogaswara¹ and L S M D Saputra

Department of Industrial Engineering, Faculty of Engineering Universitas Pasundan, Bandung, Indonesia
¹yogiyyoga@unpas.ac.id, larasshintamega@yahoo.com

Abstract. VRP highly close related with distance and cost minimization. PD. Kebersihan Kota Bandung has been facing one of the problem related with vehicle routing since this company has not have a fixed route for waste transportation because of their limited vehicle used and it will cost them a lot more if they have to add more vehicle to handle this. Therefore, research on VRP for this case has been done especially in West Bandung Region to find a better solution to reduce total distances and cost in which the company have to pay out. Method used to solve this problem is Genetic Algorithm with Clarke and Wright Saving used first to find initial solution. Genetic Algorithm is problem independent, it means that it can solve a lot of problems in a different field and still have probability to keep continuing to find the best solution including global search. Based on research that has been done, there are three route with three trucks created with total volume for each vehicle on those route which are 7,053 m³, 6,753 m³, and 6,903 m³ with total distance 65,33 km.

Keywords: Waste transportation, VRP, Clarke and Wright Saving, Genetic Algorithm

1. Introduction

PD. Kebersihan Kota Bandung has been facing one of the problem related with vehicle routing. This company has not have a fixed route for waste transportation because of their limited vehicle used and it will cost them a lot more if they have to add more vehicle to handle this. PD. Kebersihan Kota Bandung for East Bandung region scheduled for pick up a day per week for each TPS. However, the accumulation of trash in a few TPS in most case has reach more than the capacity in only two days. This caused the company to pick it up more than a day per week. There is often that the vehicle which is dump truck with 6 m³ capacity do the loading right after they unload the trash in SPA without going back to the pool. The company have a lot of consideration to add more vehicle considering for additional cost on maintenance and crew.

VRP (Vehicle Routing Problem) close related with distance and cost minimization. VRP has been applied to a lot of problem related with transportation and logistics. For example, school bus route, trashbin pick up route, retail distribution, expedition service, etc. The shorter the distance is gone through by the dump truck, the bigger the cost which can be reduce therefore operational cost each day can be more thrift. With this model, determining a route for waste transportation vehicle can be more closer to its real situation and a better solution can be proposed to reduce unnecessary cost.

Genetic algorithm is included on a group of metaheuristic problem solving method that could be able to solve a different type of optimization problem such as nonlinear programming, knapsack, TSP, VRP, flowshop sequence, jobshop scheduling, to facility layout design [1]. The data is processed with Genetic Algorithm with initial solution is solve first by heuristic method which is Clarke and Wright. After tour
and total distance has been found, a number of population is created to be optimized by Genetic Algorithm [1].

The data used from waste transportation trucks survey in April to May 2018. The data survey was completed with 22 TPS (temporary waste area) in Eastern Bandung.

Based on the background of the problem which has been explained, therefore question research are how is the better waste transportation route based on distance and total amount of waste which is being picked up and how much waste transportation route created in Eastern Bandung?

2. Literature Review

2.1. Vehicle Routing Problem (VRP)

In 1959, Dantzig and Ramser for the first time introduce a theory about Truck Dispatching Problem which has become a basis of Vehicle Routing Problem (VRP) to define fuel delivery route from one terminal to serve a number of gas station.

VRP is one of optimization problem that is related with distribution network in which there are depot with a few vehicles with a certain capacity to serve a number of customer. VRP is not only applied in goods distribution field but also in a lot of field such as trashbin pick up, road clean up route, school bus route, salesmen route, or even maintenance unit route.

The purpose of VRP is to minimize total cost on transportation by cutting total distance travelled by the vehicle and number of vehicle used by the company to serve the customer. This way, total cost that the company need to pay out can be reduced. Therefore, objective function for this problem is [1]:

\[
\text{minimize } z = \sum_{i \in V} \sum_{j \in V} c_{ij} \sum_{k=1}^{K} x_{ijk} 
\]

constraint subject to:

\[
\sum_{k=1}^{K} y_{ijk} = 1; i \in V \setminus \{0\} 
\]

\[
\sum_{k=1}^{K} y_{0k} = K 
\]

\[
\sum_{j \in V} x_{ijk} = \sum_{j \in V} x_{jik} = y_{ik}; \forall i \in V, k = 1, 2, 3, ..., K 
\]

\[
\sum_{i \in V} q_{i} y_{ik} \leq Q_{k}; k = 1, ..., K 
\]

\[
\sum_{i \in S} \sum_{j \in S} x_{ijk} \leq |S| - 1; \forall S \subseteq V \setminus \{0\}, |S| \geq 2, k = 1, 2, ..., K 
\]

\[
y_{ijk} \in \{0,1\} \forall i, j \in V, k = 1, ..., K 
\]

\[
x_{ijk} \in \{0,1\} \forall i, j \in V, k = 1, ..., K 
\]

Constraint (2) define that each customer is visited once, (3) define a number of K vehicle that leave the depot, constraint (4) define that the same vehicle will visit and leave the same customer, constraint (5) to (8) define that the load for each k vehicle is not overcapacity with \(|S|\) define cardinality of S don’t have subroute.

2.2. Problem Solving Method for VRP

VRP can be solved with heuristic or even metaheuristic. The difference between these two methods are that heuristic method depend on the type of problem so it only can be used for some certain case. Meanwhile metaheuristic method is not depend on what kind of problem that want to be solved so it can
be used for almost any type problems. A few examples on heuristic methods are Nearest Neighborhood (NN), Saving (Clarke and Wright), insertion method, Gillet-Miller algorithm, and 2-opt method. While on metaheuristic there are Genetic Algorithm (GA), Ant Colony Optimization (ACO), and Tabu Search.

2.2.1. Saving Method (Clarke and Wright)
This method first introduced by Clarke and Wright on 1964, that is why this method is also called as Clarke and Wright method. Saving method is based on saving concept which estimate cost reduction by serving two customer in sequence on the same route instead of different route [3]. This method start with a number of vehicle serving each customer individually in a separate route. There, all those separate route is clustered so that the vehicle can serve two or more customer on the same route considering maximum capacity of the vehicle.

This saving method can be modified in regards of waste transportation. Consider that a truck pool $D$, while $i$ and $j$ are two TPS’s that the waste need to be transported to SPA $S$, as shown on Figure 1a.

\[
s(D, S) = |d(D, i)+ d(i, S)+ d(D, j)+ d(j, S)+ 2d(j, S)|- [d(D, i)+ d(i, j)+ d(j, S)+ d(S, D)] = d(i, S)+ d(D, j)+ d(S, D)- d(i, j)
\]  

(9)

The difference of this modified is after collecting waste on $i$, the truck will not travel back to the pool instead of travel to $j$ to collect the waste and transporting the waste to SPA and after unload the waste in SPA, the vehicle will travel back to the truck pool.

2.2.2. Genetic Algorithm (GA) Operators
Genetic algorithm is a random global search technique which used to solve problem by immitating the process on natural evolution [1]. Genetic algorithm is included on a group of metaheuristic problem solving method that could be able to solve a different type of optimization problem such as nonlinier programming, knapsack, TSP, VRP, flowshop sequence, jobshop schedulling, to facility layout design.

Data representation on genetic algorithm to solve the problem can use bin\_ar\_ry representation using number 0 and 1, permutation representation which is using integer number, and random keys representation which is using decimal number. The data is represented as a series of number that appoint individual which called chromosome.

Roulette Wheel is one of the most used method in selection process. This method implemented with roulette wheel model [4]. Like a roulette wheel model, the size applied on the wheel of each individuals in a population is based on its fitness value proportion.

In this method, there is choosen a number of position of gene randomly from the first parent, thereafter all those genes that has been choosen in the same position is become part of gene on its offspring. Meanwhile, the rest of position that is still empty on the offspring is filled with genes from the second parent sequentially from left to right [5].

Based on a comparative study about performance of a number of crossover operator in genetic algorithm to solve TSP problem which has been researched by [6], POS has become on of few method
that give a good solution after Exchange Recombination Crossover (EX) and Order Crossover (OX) compare to another eight crossover operator.

Reciprocal Exchange Mutation is mutation method in which choose two position of gene randomly and then exchange the position of these two genes.

3. Methods
Research started with literature study that is continued with data collection. Distance matrix is created from existing route. The data is processed with Genetic Algorithm with initial solution is solve first by heuristic method which is Clarke and Wright. After tour and total distance has been found, a number of population is created to be optimized by Genetic Algorithm.

Each steps for Clarke and Wright methods are as mentioned below:

- List volume of demand for each node including vehicle allocated and its maximum capacity to serve the customer.
- Joint the depot/pool to each node which will be visited.
- Create distance matrix.
- Calculate saving that has been made with \( s_{ij} = c_{i0} + c_{0j} - c_{ij} \), with:
  - \( s_{ij} \) = value of saving,
  - \( c_{i0} \) = distance between node \( i \) to depot,
  - \( c_{0j} \) = distance between depot to node \( j \),
  - \( c_{ij} \) = distance between node \( i \) to node \( j \).
- List the result of saving from the bigger to the smaller value.
- Create route from a node which have a bigger saving value and the load meet with the capacity in that node.

If the total load is smaller than capacity, therefore widen the route by adding node that have a bigger saving value after the previous node. If the total load meet the capacity, a new route can be created. If all the demands has been loaded, feasible solution has been made.

In general, step by step on genetic algorithm are as mentioned below:

- **Initialization first population**, which is the process of creating a number of individual randomly with a certain chromosome composition.
- **Evaluation** is used to calculate fitness value from each chromosome. The bigger the fitness value obtained, the bigger also the probability of its chromosome to be a better solution. Fitness value usually obtained from objective function. Since VRP is a minimization problem, therefore formulation used for the fitness value \( = \frac{1}{f(x)} \).
- **Selection**, the purpose of this step is to choose individual from a population which will be choosen to stay to the next generation. Probability function is used to choose individual. Individual with a better fitness value have a higher probability to be choosen [4].
- **Crossover**, the purpose of this step is to create offspring from individuals which has been choosen from the population and cross them between two parents.
- **Mutation**, the purpose of this step is to create a new individual by modifying its gene. The step is looping until a few generation. Usually, a better solution will be shown by a constant fitness value even though iteration has been done for a few more time.

4. Result and Discussion
To keep the problem from being explained far too wide on a different field according to the purpose of this research, there are a few constraints which is applied for this problem. Those constraints are as mentioned below:

- Research focus on Eastern Bandung.
- Existing route which is being observed based on route that is used by dump truck with capacity equal to 6 m³.
Research only focus on pool to TPS to SPA.

In this research, maintenance cost is not considered.

A few assumption used in this research are:
1. All vehicle used is in a good condition
2. The road travelled by the vehicle is not in a traffic condition
3. All road can be travelled by dump truck with capacity equal to 6 m³
4. All dump truck do the pick up everyday
5. There is a compaction factor for about 20% which affects on maximum capacity to 7.2 m³ for dump truck with capacity equal to 6 m³.

4.1. Initial Solution with Saving Method

In this case, dump truck with capacity equal to 6 m³ will pick trash up from each TPS based on its route. Each TPS is represented with number from 1 to 22 with 0 represent the pool. The detail of each TPS is explained down below:

1 = Metro KFC & Superindo
2 = Pembakaran
3 = Santosa Asih RW 05 & 06
4 = Batu Karang
5 = Manisi
6 = Sindang Laya RW 01
7 = Cipadung Permai
8 = Cipadung RW 08
9 = Komp. Palasari
10 = Komp. Pasundan
11 = Cipagalo RW 07
12 = PT. Mepro
13 = Carrefour
14 = Buana Soetta
15 = Guruminda
16 = Bebedahan
17 = Rancameong
18 = Cisaranten Kidul RW 06 & 07
19 = Cipamokolan RW 02
20 = Apartemen The Suittes
21 = Kawaluyaan RW 04 dan 05
22 = Tanabe Abadi

Table 1. Route Created with Saving Method

| Dump Truck | Route                  | Amount of Volume Picked/Day | Distance |
|------------|------------------------|-----------------------------|----------|
| 1          | 0 – 13 – 20 – 21 – 1 – 2 – 3 – 4 – SPA | 7,053 m³                  | 25.78 km |
| 2          | 0 – 12 – 17 – 15 – 19 – 18 – 14 – 16 – SPA | 6,753 m³                  | 27.13 km |
| 3          | 0 – 7 – 8 – 5 – 9 – 22 – 6 – 10 – 11 – SPA | 6,903 m³                  | 28.44 km |
| Total      |                        | 20,708 m³                  | 81.35 km |

Based on the result shown on Table 1, total tour created for this case are three route in which first dump truck pick 7,053 m³ trash with distance travelled is 25.78 km, second dump truck pick 6,753 m³ trash with distance travelled is 27.13 km, and third dump truck pick 6,903 m³ trash with distance travelled is 28.44 km.

4.2. Optimization with Genetic Algorithm

First step on Genetic Algorithm is determining parameter and initialize first population. Parameter which is determine are as mentioned below:

- Population Size = 20
- Crossoover Probability = 0.6
- Mutation Probability = 0.1

First chromosome on the population is taken from the tour created with Saving method, meanwhile the rest nineteen chromosomes are determined randomly.

The next step is selection to choose which chromosome that will be chosen for crossover. Method used for this step is roulette wheel where chromosome will be chosen based on random number its get
from 0 to 1. If the random number on the said chromosome is less then or equal with fitness value cumulative probability, therefore the said chromosome is choosen for crossover.

After selection process, choosen chromosome will be crossed over with each other. The process of choosing chromosome for crossover will be determine with random number from 0 to 1. If the random number on the said chromosome is less then or equal with crossover probability, therefore the said chromosome will be choosen for the next step.

Method used for crossover is Position-Based Crossover (POS) which is a development from Order Crossover (OX). Example on how to do crossover with this method on the first generation is as shown on Figure 2.

Parent 1

| 13 | 20 | 21 | 1  | 2  | 3  | 4  |

Offspring

| 13 | 20 | 21 | 2  | 1  | 3  | 4  |

Parent 2

| 13 | 3  | 2  | 20 | 21 | 4  | 1  |

Figure 2. Crossover in POS with The First Generation

The result of crossover process from all chromosome on the first generation is shown on Table 2.

Table 2. Offspring Created with POS Method

| NO | OFFSPRING | DISTANCE |
|----|-----------|----------|
| 1  | 13 20 21 2 1 3 4 | 27.56    |
| 2  | 4 13 20 21 2 1 3 4 | 45.5     |
| 3  | 2 13 4 1 3 20 21 | 37.85    |
| 4  | 20 1 2 21 3 4 13 | 40.72    |
| 5  | 20 3 21 1 4 13 2 | 46.16    |

The next step after crossover is mutation. The process of choosing chromosome to applied mutation is quite similar with the other two genetic operator which is determined with random number from 0 to 1. If the random number on the said chromosome is less then or equal with mutation probability which is 0,1, therefore the said chromosome will be choosen for the next step. Example on how to determine the chromosome on the first generation is shown on Table 3.

Table 3. Random Number for Mutation Process

| NO | OFFSPRING | DISTANCE | RANDOM NUMBER |
|----|-----------|----------|--------------|
| 1  | 13 20 21 2 1 3 4 | 27.56    | 0.432        |
| 2  | 4 13 20 3 21 1 | 45.5     | 0.592        |
| 3  | 2 13 4 1 3 20 21 | 37.85    | 0.469        |
| 4  | 20 1 2 21 3 4 13 | 40.72    | 0.409        |
| 5  | 20 3 21 1 4 13 2 | 46.16    | 0.731        |

Random number on the first generation are all more than mutation probability as it shown on table 4.6 so the mutation is not applied in this generation. Thereafter, total offspring created on first generation is being put back to the population and the position of all individual will be ranked from the biggest fitness value to the smallest. Then, chromosome located on the twenty first position to the rest next chromosome which is left will be removed from the population and this new population will be used as initial population on the second generation.

The same step from selection to putting the offspring back to the population will be repeated until there is no change on fitness value. In this case, iteration has been done until thirtieth generation for each
route and fitness value has been in a constant condition in average on the twentieth generation. Final result on this VRP which is solved by Genetic Algorithm is as shown on Table 4.

**Table 4. Route Created with Genetic Algorithm**

| Dump Truck | Route                | Amount of Volume Picked/Day | Distance  |
|------------|----------------------|----------------------------|-----------|
| 1          | 0 – 4 – 3 – 2 – 1 – 13 – 20 – 21 – SPA | 7,053 m³                  | 24,30 km |
| 2          | 0 – 14 – 18 – 16 – 15 – 19 – 17 – 12 – SPA | 6,753 m³                  | 19,22 km |
| 3          | 0 – 11 – 10 – 6 – 22 – 9 – 8 – 7 – 5 – SPA | 6,903 m³                  | 21,81 km |
| Total      |                      | 20,708 m³                  | 65,33 km |

Based on Table 4, there is a few change on the position of TPS for each route. With the same amount of volume that is being picked each day, distance travelled by first dump truck reduce from 25,78 km to 24,30 km, distance travelled by second dump truck reduce from 27,13 km to 19,22 km, and distance travelled by the third dump truck reduce from 28,44 km to 21,81 km, therefore total distance travelled is 65,33 km.

**5. Conclusion and Further Research**

Based on data processing that has been done to determine the shortest path for trash bin pick up route in East Bandung Region, there are a few conclusion that can be made to answer problem formulation which previously has been determine. The conclusion of this research are Total route created are three in which each vehicle that will serve these route is constrained by maximum capacity equal to 7.2 m³. So that based on this constraint total amount of volume of trash that can be picked up for first route is 7,053 m³ with total number of TPS that is being visited are 7, on the second route is 6,753 m³ with total number of TPS that is being visited are 7, and on the third route is 6,903 m³ with total number of TPS that is being visited are 8.

In this case, metaheuristic method can give a better solution than heuristic method in which shown by the result created from Clarke and Wright Saving with total distance travelled is 81,53 km, meanwhile completion by Genetic Algorithm resulted a significantly total distance travelled which is 65,33 km. First route created is 0 – 4 – 3 – 2 – 1 – 13 – 20 – 21 – SPA with distance travelled 24,30 km, second route created is 0 – 14 – 18 – 16 – 15 – 19 – 17 – 12 – SPA with distance travelled 24,30 km, second route created is 0 – 11 – 10 – 6 – 22 – 9 – 8 – 7 – 5 – SPA with distance travelled 21,81 km.

Based on the conclusion that has been made, a few of recommendation that can be proposed for the next research are Traffic and maintenance cost can be considered for the next research. Hybrid Genetic Algorithm can be used so that a better solution can be found instead of using Standard Genetic Algorithm. A comparative study can be considered for genetic operator since each operator has a lot of method that can be applied, for example on crossover itself there are a few method such as PMX, OX, POS, One Cut Point, Heuristic Crossover, etc and each of them have different performance.

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