Vehicle Routing Problem Using Genetic Algorithm with Multi Compartment on Vegetable Distribution

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Abstract. The problem that is often gained by the industries of managing and distributing vegetables is how to distribute vegetables so that the quality of the vegetables can be maintained properly. The problems encountered include optimal route selection and little travel time or so-called TSP (Traveling Salesman Problem). These problems can be modeled using the Vehicle Routing Problem (VRP) algorithm with rating ranking, a cross order based crossing, and also order based mutation mutations on selected chromosomes. This study uses limitations using only 20 market points, 2 point warehouse (multi compartment) and 5 vehicles. It is determined that for one distribution, one vehicle can only distribute to 4 market points only from 1 particular warehouse, and also one such vehicle can only accommodate 100 kg capacity.

1. Introduction
Almost all Indonesians (97.29 percent) consume vegetables [1]. To comply the needs of vegetable consumption, in addition to the required quality improvement. Consumers love the vegetables in a fresh and hygienic state, while itself and seasonally to damage (easily rotten). Vegetables are also usually imported from other places far from the perimeter. Vegetables must be consumed as soon as possible due to limited time before decay or decreased quality.

Given the facts about vegetables described above, vegetable suppliers have their own challenges in distributing their vegetable products to the rest of the country. The challenge is how to choose an effective travel route. Effectively referred to here is the selection of travel routes with short distances. In addition, if the supplier has more than one supply warehouse, then another constraint will arise. This causes the supplier to be able to determine from what warehouse and where the purpose of the distribution is more efficient by considering the different distance between one a warehouse with another warehouse to a particular consumer.

This research is a development of 2 (two) previous research that has been done. The first study conducted by (Slamet et al, 2014) is the vehicle routing problem (VRP) with the genetic algorithm on the distribution of highland vegetables. The study has only one supplier or one warehouse alone as the origin of the vegetable distribution route. The second study conducted by (Tanujaya et al, 2013) is the application of genetic algorithms for vehicle routing problem-solving in PT.MIF. This study determines the parameters in GA is stimulated not separately and does not use GA optimization so that the resulting output is not good, fast and optimal.
Therefore, the authors conducted research on Vehicle Routing Problem (VRP) with the settlement using genetic algorithms that implement multi-compartment on vegetable distribution. This study aims to distribute vegetables to various regions in Java Island by considering the optimal mileage. The results of this study will be used for industries that want to supply vegetables to urban areas and also remote areas to minimize the occurrence of damage (rotten or not fresh) that occurs in the vegetables it carries.

1.1. Genetic Algorithm (GA)
On the search for solutions that sometimes require complex mathematical formulations to provide a definite solution [4].
To overcome this then used the calculation by a heuristic method that called genetic algorithm. Genetic algorithm is a search method based on the mechanism of natural selection and genetics [5]. In a genetic algorithm to produce an optimal solution, the search process is performed among a number of alternative optimal points based on a probabilistic function [6].

1.2. Vehicle Routing Problem (VRP)
VRP can be defined as the problem of designing a shipping vehicle path known to its capacity, operating from one depot to provide supply to a set of customers with known location and demand with one or more definite commodities [2].
VRP belongs to the Nondeterministic Polynomial-Hard (NPH) class which means that the parameters that influence are very complex and the solution can not be solved by a linear algorithm only because it takes a very long time, which generally uses a heuristic approach to find the solution [2].
Just like TSP, on VRP each vehicle must depart from a depot with a specific route to meet the demand nodes in the route and return to the original depot [3]. Here is a simple overview of the VRP using 2 vehicles, there are 1 depot and 12 nodes after the solve two routes with the minimum total distance.

![Figure 1. Simple VRP with number of vehicle 2](image)

Each vehicle has a certain maximum operating time at which time is the maximum time for a vehicle to return to the depot [3].

2. RESEARCH METHOD
In this research method, will be discussed about research data, and also the formulation of a genetic algorithm to solve Vehicle Routing Problem (VRP).

2.1. Research Data
The first thing to do is determine the markets that will be used as a point of distribution of vegetables, and also the point of a warehouse that will be used. In this research will be used 20 point market for distribution and also 2 warehouses for vegetable storage. Then after determining the market points and also the point of the warehouse, the researcher takes the data of the distance between each market, the
distance from each market to the warehouse, and also the warehouse distance to the warehouse. Distance value data can be obtained from google maps with units of km (kilometers). After the distance data was obtained, the researchers began compiling the systematical distribution of vegetables from 2 warehouse points to 20 market points. The data used for vegetable distribution systematics is the dummy data obtained from the random function in the excel software.

2.2. Initial Modelling
In the initial modeling of vehicle routing problem solving using a genetic algorithm, the following are formulated:

2.2.1. Identify Constrains.
In the vehicle routing problem, there are some limitations that must be fulfilled so that a solution can be considered as a viable solution. The boundaries that cause a solution to become unfeasible are called constraints. In order for a genetic algorithm to be executed to produce a viable solution, it is necessary to identify what factors make a solution improper.

2.2.2. Formulation of Objective Function and Fitness Function.
The objective function serves to measure the value of a solution. The result of this objective function is then converted into a fitness value that determines the quality of a solution by using the fitness function.

2.3. Model Optimization (Genetic Algorithm)
At this stage, model optimization is done to obtain optimal results. Optimization is done by changing parameters that determine how genetic algorithms work. The parameters in question are the initial population, population size, probability of crossing, and the probability of mutation. The genetic algorithm begins with the formation of the initial population of chromosomes formed by using random permutation algorithm. The next step in the genetic algorithm is the process of natural evolution that occurs continuously, namely selection, crossing, and mutation.

2.4. Ranking Selection
The first stage of natural evolution is selection, choosing which individuals will survive in the new population. The type of selection used in this study is rank selection, which is a stage of population selection that will live to the next generation by ordering the fitness value of each individual. Individuals to be selected as mothers are the individuals who have the highest fitness scores. Individuals who have the worst fitness score will die and be replaced by the crossed individuals.

2.5. Position Based Crossover
The second stage of natural evolution is a crossover, crossing the individual genes to produce new individuals who inherit the nature of the two parent. In this study, the type of crossing used is Position Based Crossover, which is a crossing stage applied to chromosomes that have the characteristics of permutation genes. The crossing is done by selecting several genes to cross, then the selected genes will be exchanged with their partner in the same positioning gene. Then another non-selected gene will adjust its sequence based on the same sequence of genes on the chromosome. In this study, the genes that will be selected for crossover are just destination genes only.

2.6. Binary Mutation dan Position Based Mutation
The third stage of natural evolution is the mutation, the sudden change of genes in the population and occurs randomly. In this study, the type of mutation used there are two, namely Binary Mutation and Position Based Mutation. Binary Mutation is a mutation stage used to convert a gene into another random gene. In this study, a binary mutation will be applied to the gene compartment. While Position Based Mutation is the stage applied to chromosomes that have the characteristics of permutation genes.
Mutations are made by exchanging selected gene positions to other random genes on the same chromosome. In this study, a position based mutation will be applied to the destination genes.

2.7. Model Analysis dan Evaluation
At this stage analysis and evaluation of the model applied to obtain the optimal model. If the model is still not optimal then it will be done changing the parameters of the genetic algorithm.

3. RESULT AND DISCUSSION
The results and discussion in this study include VRP modeling and also the process of formulating a genetic algorithm to solve Vehicle Routing Problem (VRP).

3.1. Research Data

3.1.1. Warehouse.
This research applies multi-compartment, that is source point that provides goods there is more than one point. Source point used in this study there are two, namely the warehouse located in (A) Boyolali and warehouse located in (B) Magelang.

3.1.2. Market.
Vegetables will be distributed to the markets spread in the area of Yogyakarta and surrounding areas. These markets will be the destination points in the model created. There are 20 destination points used in this research: (1) Pakem Market, (2) Prambanan Market, (3) Turi Market (Sleman), (4) Tempel Market, (5) Cebongan Market, (6) Colombo Market, (7) Kutu Market, (8) Condong Catur Market, (9) Srago Market, (10) Basin Market, (11) Pingit Market, (12) Klewer Market, (13) Jambon Market, (14) Muntilan Market, (15) PuluhWatu Market, (16) Godean Market, (17) Sentul Market Yogyakarta, (18) Ngasem Market, (19) Demangan Market, and (20) Jangkang Market.

3.1.3. Demand.
The amount of vegetable demand from the market will be considered to be the number of vegetables to be distributed to the destination points. In this study, all markets were uninformed and had the same amount of demand, 25 kg of vegetables for each market. This number of requests is a fixed number of requests.

3.1.4. Distance.
In this study, the distance to be taken from one point to another is obtained from the Google Maps map application. If there are several alternative paths to take, the path that occupies the top position in Google Maps. From here formed distance matrix that maps the distance of each point to another point.

3.1.5. Vehicle.
In this study, all vehicles have the same type and the same capacity, which is 100 kg per vehicle. The number of vehicles available for distribution of goods there are 5 vehicles, with the total capacity of the entire fleet is 500 kg of vegetables.

3.2. VRP Modelling
The VRP model created the model of transportation and distribution from the source points (warehouses) to the point of destination (the market) and back to the source point. In order to model VRP, it is necessary to identify constraints and problem limits and formulate objective functions and fitness functions.

3.3. Identify Constraints and Limitations
The VRP model created several constraints that must be a solution for a viable solution. There are some of the constraints and limitations applied to this research, among others ar each destination point is
visited exactly once, each vehicle departs from one of the specified source points, no vehicles distribute the goods beyond their capacity.

3.4. Formulation of Objective Functions and Fitness Functions

The objective function is a function used to measure the value of a solution. In this study, the objective function aims to calculate the total distance traveled by all vehicles. Here is the formula for calculating the total distance traveled by all vehicles in one individual problem solving:

\[
\text{sum } d = \sum_{i=1}^{5} \left( \sum_{j=1}^{4} d_{ij} + d_{i0} \right)
\]  \hspace{1cm} \text{... ... ... ... ... ... ... ... ... ... (1)}

The above formula, \( \text{sum } d \) means that the total distance is the number of the mileage of the \( i \) vehicle, and passes through four destination points (according to the capacity of the vehicle), then back again to the source point.

While the fitness function is used to calculate fitness that is the quality value of an individual problem-solving. Because the optimization will be done is minimization optimization (the smaller the distance the better), then the fitness function applied will change the small value into a great value fitness. Therefore, the fitness function uses a fairly simple formula:

\[
f(d) = \frac{1}{d}
\]  \hspace{1cm} \text{... ... ... ... ... ... ... ... ... ... (2)}

With \( d \) is the distance from the vehicle.

In this case, the number of possible solutions (including infeasible solution) in the search space \( (N_t) \) for this VRP problem is by looking at the genes that are on the chromosome. A chromosome has 25 genes which is divided into 5 genes representing the warehouses and 20 genes representing the markets. To calculate all possible solutions can uses the formula as below:

\[
N_c = w^n * v! \hspace{1cm} \text{... ... ... ... ... ... ... ... ... ... (3)}
\]

With \( w \) is a number of warehouse, \( n \) is a number of genes which represents warehouse and \( v \) is a number of visited points.

\[
N_s = i * k \hspace{1cm} \text{... ... ... ... ... ... ... ... ... ... (4)}
\]

Ns is the number of solutions generated from the calculation of the program to be run. With \( i \) is the number of iterations representing the number of generations to be generated and \( k \) is total solution per generation. The percentage of prospective search for a solution by genetic algorithm in the search space \( (P_{search}) \) uses the formula as below:

\[
P_{search} = \frac{N_s}{N_t} * 100\% \hspace{1cm} \text{... ... ... ... ... ... ... ... ... ... (5)}
\]

3.5. VRP Completion with Genetic Algorithm

The genetic algorithm is a searching technique and optimization technique based on evolutionary processes and changes in the genetic structure of living things [7]. In nature, chromosomes store the genetic information of an individual and consist of a set of genes. The characteristics and characteristics of an individual are determined by the genes, and these genes will be inherited to their offspring when breeding occurs. Individuals with good genes will survive over time, and individuals with bad genes will die. That means that the individual carrying the best genes and chromosomes will live and pass on the good characteristics of the offspring so that the average characteristic value of a population will continue to increase. Departing from this concept, genetic algorithms were developed with the aim of finding the optimal solution by crossing out existing solutions. Processes that occur in genetic algorithms can generally be seen in the following flow diagrams:
The genetic algorithm consists of several stages, starting from the encoding stage, initial population initialization, selection, crossing, and mutation. After the algorithm is complete, it will also do the process of translation of the solution (decoding). Selection is used to determine which individual will survive, the cross producing new individuals that will replace the dead individuals so that the size of the population remains, and the mutation allows the emergence of new individuals unexpectedly. After the solution search is completed, then do the decoding, which translates the solution that has been coded into a form that can be understood by humans as the answer to the problems encountered.

3.6. Chromosome Representation
In the genetic algorithm, each individual represents every possible solution of the problem at hand. The solutions brought by each individual are encoded in the form of chromosomes, consisting of genes. In this study, the chromosome representation used is a chromosome representation of strings. In this chromosome, the source point is represented by a gene containing the letters of the alphabet, and the destination point is denoted by a gene containing numbers. The sequence and location of the source gene and the destination gene determine the origin and the points to be visited by each vehicle.

![Figure 2. Genetic Algorithm Flow Diagram](image)

Table 1. Chromosome Representation

| Vehicle. 1 | Vehicle. 2 | Vehicle. 3 | Vehicle. 4 | Vehicle. 5 |
|-----------|-----------|-----------|-----------|-----------|
| A 1 2 3 4 | B 5 6 7 8 | A 9 10 11 12 | B 13 14 15 16 | A 17 18 19 20 |

From the figure above, it can be seen that vehicle 3 travels from the source point A, then travels to the 9-10-11-12 destination and returns from the destination point 12 to the source point (A).

3.7. Selection
Selection technique used in this research is ranking selection technique, that is selection done by sorting population based on its fitness value. The highest fitness chromosome will rank first, and so on. Selection is chosen to reduce the possibility of an individual with a very large fitness dominating the population. By using the rankings, then the value of fitness is too large will not greatly affect the selection process is done randomly.

3.8. Crossover
The process of crossing is the process by which the chromosomes between two individuals are crossed to produce new individuals. The crossing process of two mains will result in two new individual
children. Crosses aim to produce a new population with a higher average fitness value compared to the previous population.

Some individuals from the selection process will be randomly selected to cross each other. The selection is done randomly with a predetermined probability, is the probability of crossover (Pc). The expected frequency of the number of individuals to be crossed is Pc x population size. The crossover process used is a position based crossover where the position of the selected genes on one parent will be exchanged with selected genes on the other parent, and then another gene will adjust the sequence. In this study, the genes chosen to be crossed are only destination point genes, because if crossing involves source point genes the number of vehicles will not be regular.

### Table 2. Parent 1 & Parent 2

| Vehicle. 1 | Vehicle. 2 | Vehicle. 3 | Vehicle. 4 | Vehicle. 5 |
|-----------|------------|------------|------------|------------|
| B         | 5 18 2 17  | B          | 10 20 1 9  | A 12 14 16 6  |
| B         | 14 13 6 19 | B          | 10 8 16 9  | B 3 11 7 20  |
|           |            | B          | 17 1 5 18  | B 15 4 2 12 |

### Table 3. Descendant 1 & Descendant 2 :

| Vehicle. 1 | Vehicle. 2 | Vehicle. 3 | Vehicle. 4 | Vehicle. 5 |
|-----------|------------|------------|------------|------------|
| B         | 5 2 6 17 A | 10 20 1 9  | B          | 12 14 16 4  |
| B         | 14 13 2 6  | A 10 8 16 9 | B 3 11 7 20 | B 17 1 5 19 |
|           |            | B          | 15 13 11 3  | A 18 15 4 12 |

3.9. Mutation

Of the population of selection and crossing, then carried out the process of mutation, which is a process of randomly converting genes. The selection of a mutated gene is randomly assigned to a predetermined probability, the mutation probability (Pm). The mutation process used is binary mutation and position based mutation.

Binary mutation is used in the source point gene, where the selected gene is replaced by another gene. In this study, binary mutation of the source point gene is done by converting the gene into (A) if previously (B), and vice versa.

Position based mutation is used in the destination point gene, where the gene that has been selected for the mutation will be exchanged for its position with another random destination point gene on the same chromosome.

3.10. Evaluation

Resolving the VRP problem resulted in the distribution of vegetable distribution routes from 2 warehouses to 20 markets with 5 vehicles. Details of the paths taken by each vehicle can be seen in Table 1. The algorithm is run with the following parameters: Population size is 100, Max generation is 1000, Probability of crossover is 25%, Probability of mutation is 1%.

These parameters is determined by experiment. Population size of 40 is determined by having a look at the number of gen in a chromosome. Having a too small size of a population will risk the occurrence of a convergence (A population heavily dominated by a single chromosome). Max generation of 1000 is to ensure that the algorithm will yield a near-to-optimal solution, given enough iteration (generation). Crossover probability of 25% is determined by limiting the amount of offspring (new solutions) to a quarter of the population, so that the best parents would not be replaced by its less optimal offspring. As for the probability of mutation, probability of 1% is enough mutation (sudden change of a chromosome/solution), as higher chance would make it a different kind of genetic algorithm approach.

### Table 4. The best solution of genetic algorithm

| Number | Capacity (kg) | Visited Point | Distance Estimation |
|--------|---------------|---------------|---------------------|
| 1      | 100           | 1. Magelang Warehouse | 4. Sentul Market Yogyakarta | 93.6 kilometers |
| 2 | 100 | 1. Magelang Warehouse | 4. Demangan Market | 94.8 kilometers |
|---|-----|----------------------|------------------|---------------|
|   |     | 2. Muntilan Market   | 5. Kuto Market    |               |
|   |     | 3. Condong Catur Market | 6. Magelang Warehouse |           |

| 3 | 100 | 1. Magelang Warehouse | 4. Pingit Market | 93.7 kilometers |
|---|-----|----------------------|------------------|---------------|
|   |     | 2. Turi (Sleman) Market | 5. Tempel Market |               |
|   |     | 3. Godean Market      | 6. Magelang Warehouse |           |

| 4 | 100 | 1. Boyolali Warehouse | 4. Klewer Market | 83.9 kilometers |
|---|-----|----------------------|------------------|---------------|
|   |     | 2. PuluhWatu Market  | 5. Srago Market  |               |
|   |     | 3. Basin Market      | 6. Boyolali Warehouse |           |

| 5 | 100 | 1. Magelang Warehouse | 4. Prambanan Market | 122.2 kilometers |
|---|-----|----------------------|------------------|---------------|
|   |     | 2. Colombo Market    | 5. Cebongan Market |               |
|   |     | 3. Jambon Market     | 6. Magelang Warehouse |           |

The best solution with these parameters resulted in a total distance of about 488.2 km and a fitness value of 0.00205, quite different when compared to the best solution in the first generation with a total distance of about 675.8 km and a fitness value of 0.0015.

The best solution the genetic algorithm came up with is a result of both the crossover method and the mutation method. By using position based crossover, the algorithm will search for a better path for each of the vehicle included. The crossover only affects gens that represents destination nodes, so that it won’t mess with the amount of load a single vehicle could carry, in case each vehicle has different capacity. On the other hand, the mutation will be able to change both gens that represents source nodes (compartments) and gens that represents destination nodes. The gens that represents source nodes will mutate by means of binary mutation, and the gens that represents destination nodes will mutate by means of position based mutation. This way, the algorithm will be able to find the optimal solution within the feasible solution space and won’t produce too much solutions that are infeasible.

The number of possible solutions (including infeasible solution) in the search space (Nt) for this VRP problem is about $2^5 \times 20!$. While the number of candidate solutions that have been evaluated by the genetic algorithm exists:

$$N_s = (1000 \text{ generations}) \times (40 \text{ solutions} / \text{ generation})$$
$$= 40,000 \text{ potential solutions}$$

The percentage of prospective search for a solution by genetic algorithm in the search space (Psearch) is:

$$P_{search} = (N_s / N_t) \times 100\%$$
$$= (40,000 / (2^5 \times 20!)) \times 100\%$$
$$= 5.1379 \times 10^{-14}\%$$

From that percentage, it appears that the genetic algorithm only searches for solutions on a very small portion of the overall probability of existing solutions, and has gained fairly optimal results.

### 4. CONCLUSION

From the tests that have been done, the population size of 100, max 1000 generation, the probability of crossover 25%, and the probability of the 1% mutation the best solution resulted in a total distance of 488.2 km and total fitness of 0.00205 which differed considerably from the first generation is the total distance around 675.8 km and fitness value 0.0015.

The authors conclude that the genetic algorithm only searches for solutions in a very small part of the overall probability of the existing solution, and has gained fairly optimal results with the total distance obtained less than the total distance obtained in the first generation and get a fitness value that is not much different from the fitness value of the first generation.

Suggestions for this research in the future is to add the optimal route calculation of travel time taking into account the congestion factor. So that the distribution of vegetables will be more optimal.
REFERENCES

[1] Nasional H G 2017 Konsumsi Buah Dan Sayur Susenas Maret 2016.

[2] Hermansyah B, Sains F, Teknologi D A N, Islam U, Sultan N, and Kasim S 2011 (VRP) Menggunakan Algoritma Genetika.

[3] Tanujaya W, Retno D, Dewi S, and Endah D 1976 Penerapan Algoritma Genetik Untuk Penyelesaian Masalah Vehicle Routing Di Pr. Mif pp 92–102.

[4] Hannawati A 2002 Pencarian Rute Optimum Menggunakan Algoritma Genetika 2(2) pp. 78–83.

[5] Paper C 2015 Optimasi Fungsi Tak Berkendala Menggunakan Algoritma Genetika Terdistribusi dengan Pengkoean Real Optimasi Fungsi Tak Berkendala Menggunakan Algoritma Genetika Terdistribusi dengan Pengkoean Real.

[6] Michalewicz Z et al 1996 Evolutionary algorithms for constrained engineering problems Computers & Industrial Eng. 30.4 pp 851-70.

[7] Slamet, Setiawan A, Siregar H H, and Kustiyo A 2014 Vehicle Routing Problem (VRP) dengan Algoritma Genetika pada Pendistribusian Sayuran Dataran Tinggi Jurnal Teknologi Industri Pertanian 24.1.