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CAPACITATED MULTI DEPOT MULTI VEHICLE ROUTING PROBLEM USING GENETIC ALGORITHM (CASE STUDY: WATERING THE MEDAN CITY PARK)

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ABSTRACT

Watering a city park is one of the steps taken to treat city parks in the city of Medan so that plants remain alive and fresh so they can reduce air pollution. The water capacity needed to water the plants in each location is adjusted to the area of the site to be watered. Therefore, the city park watering vehicle must be able to adjust the route to be passed with the capacity of water that can be carried. To determine the route that must be traversed in quite complex problems like this, Genetic Algorithms can be used to obtain an approach solution to the optimization problem in this case. The genetic algorithm will generate chromosomes that represent the route to be followed, then the chromosomes will go through the process of evaluation, selection, crossover, and mutation so that new chromosomes are produced by many generations. After several trials in the case of the Capacitated Vehicle Routing Problem using the Genetic Algorithm for determining the park watering route in Medan, the route was found to be the closest to optimal for depot A in the 173rd generation with a fitness value of 0.00292227 and the route for depot B at 148th generation with a fitness value of 0.00261028. From several trials, it can be concluded that the chance of finding the best route is influenced by the size of the population and the maximum number of generations used. The greater the population size and the maximum number of generations used, the more optimal the best route found.

Keywords: *Capacitated Vehicle Routing Problem, Heuristic, Genetic, Route.*

1. INTRODUCTION

Watering a city park is one step is taken to care for city parks in the city of Medan, as well as routines undertaken to anticipate drought in plants, especially during the dry season, and to keep plants alive and fresh which can reduce pollution from vehicle fumes.

The Medan City Sanitation and Landscaping Service is the executing element of the Medan City Government which has the task of carrying out affairs in the field of city landscaping and beauty. By considering the distance between the existing park locations and the number of depots as a limited water source, an optimal travel route is needed in the process of watering the park in Medan. The concept of watering that is carried out by the Medan City Sanitation and Gardening Office is still based on the experience of the foreman as the person in charge of the field in charge of monitoring the process of watering the park. Therefore, graph theory is needed to optimize the route to be taken by each watering car.

Vehicle Routing Problem (VRP) is a problem in the sending or taking of goods that require an optimal route but still takes into account obstacles in the demand for several locations. Capacitated Vehicle Routing Problem (CVRP) is an extension of VRP due to constraints in the form of limited vehicle capacity [1].

Many optimization problems occur in the Vehicle Routing Problem, one of which is the Multi Depot Multi-Vehicle Routing Problem. Called Multi Depot Multi-Vehicle, because of the location as a source of inventory and the number of vehicles in charge of delivering more than one.

In problems that often occur in the real world, optimization problems are often complemented by constraints that must be met. This causes this problem is very complex, so difficult if only solved using conventional methods [2].

The heuristic search technique is one of the strategies in selectively searching for the state of a problem and the search process along the path is

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carried out by choosing the solution that has the highest likelihood of success [3].

In a previous study that discussed "Plant Watering Route Problem Solving Using Artificial Immune System (AIS) Algorithm in Yogyakarta City", the results showed that the problem of plant watering routes can be solved by the AIS algorithm with a total distance of 38.53 km with a time of 1304 minutes [4].

A genetic algorithm is a heuristic search method that produces many solutions based on natural selection and genetic processes. Genetic algorithms begin with the formation of populations containing chromosomes that represent the problem at hand. This chromosome will then undergo a process of evolution through an iteration called generation. From this iteration, we will get the best chromosome that approaches the optimal solution to the problem at hand.

Genetic algorithms are usually used to obtain approach solutions to optimization problems, both minimization, and maximization. This algorithm has been tested for one or multi-variable optimization problems such as Traveling Salesman Problem (TSP), Scheduling, Vehicle Routing, Group Technology, Facility Layout, Location Allocation and proven to be able to provide solutions that are near to optimal [2].

2. VEHICLE ROUTING PROBLEM

Vehicle Routing Problem is one of the problems that can occur in the search for one or more routes that will be passed by vehicles originating from one depot and will end up in the same depot. The vehicle is tasked with delivering from a depot to several locations that are scattered and with different numbers of requests.

The solution to the Vehicle Routing Problem problem is the route the vehicle will take to deliver all customer requests, where the route starts and ends at the same depot [5].

An example illustration of a Vehicle Routing Problem case represented on a graph can be seen in Figure 1.

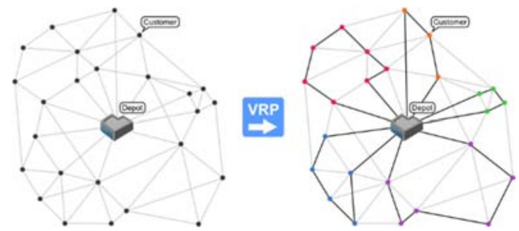

Figure 1. Graph Example for Vehicle Routing Problems

http://neo.lcc.uma.es/vrp/wp-content/uploads/vrp.png

3. CAPACITATED VEHICLE ROUTING PROBLEM

Capacitated Vehicle Routing Problem is one variation of the Vehicle Routing Problem where there are constraints in the form of the vehicle carrying capacity. This optimization problem solving is done to find a route with a minimum cost for many vehicles with a certain capacity of the same size. This vehicle is tasked to serve several agents following the number of requests that have been known before the distribution process takes place [1].

One example of the problem Capacitated Vehicle Routing Problem in the case of delivering drinking water in gallon refill packs. Determination of vehicle routes is expected to minimize the distance that must be traveled while taking into account the capacity of the vehicle [6].

4. MULTI DEPOT MULTI VEHICLE ROUTING PROBLEM

Multiple Depot Vehicle Routing Problem (MDVRP) is a variation of the Vehicle Routing Problem with a condition where there is more than one depot to supply customer needs. In MDVRP, the number and location of depots have been predetermined. Each depot is large enough to store all products ordered by the customer. Each vehicle starts and ends at the same depot. The location and request of each customer are also known in advance and each customer is visited by the vehicle exactly once [7]. An example illustration of a Multiple Depot Vehicle Routing Problem case that is represented on a graph can be seen in Figure 2.

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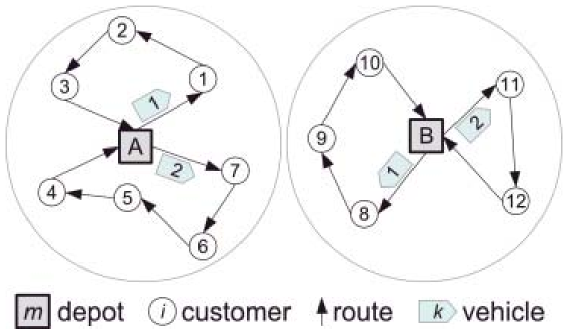

Figure 2. Example of MDMVRP Graph https://ars.els-cdn.com/content/image/1-s2.0-S0957417415005771-gr1.jpg

5. GENETIC ALGORITHM

A genetic algorithm is a search method based on the mechanism of natural selection and genetics to determine high-quality individuals naturally. This algorithm was inspired by Darwin's theory of evolution which states that the strongest rule is the one who will win [8].

How the genetic algorithm works are as follows:

1. Initial population generation
   The population consists of n chromosomes which each represent an individual. The initial value of each gene on the chromosome is randomly assigned as long as it is still within the set limits.
2. Chromosomes Evaluation
   Each chromosome is calculated its fitness value, then the value is stored as a parameter that will be used in the selection process.
3. Chromosomes Selection
   Several selection methods can be used in genetic algorithms, one of which is roulette-wheel selection. The work methods of this method are:
   1. Calculate the fitness value of each chromosome and its total fitness
   2. Calculate the probability (P) of each chromosome
   3. Calculating the cumulative probability value (C) of each chromosome
   4. Generating random numbers (R) in the range 0-1
      a. If R [k] <C [1], the 1st chromosome is selected as the parent
      b. If C [k-1] <R <C [k], the k-chromosome is selected as the parent
4. Crossover
   Two chromosomes are chosen randomly to become the parent, then the parents exchange one another.
5. Mutation
   In the mutation process, one gene from several randomly selected chromosomes will be replaced by a new value that is randomly obtained.
6. Repeat step 2 until the termination conditions are met.

6. USING THE GENETIC ALGORITHM IN CAPACITATED MULTI DEPOT MULTI VEHICLE ROUTING PROBLEM

In this case, the genetic algorithm is used to determine the watering route of Medan City Park where there are a total of 80 park locations in Medan City and 2 locations as water sources (depots) located in the Model Park and the river in Titi Bobrok.

Genetic algorithm parameters used in this study are population size of 10 populations, crossover rate of 0.35, the mutation rate of 0.25, and maximum generation size of 500 generations.

Data on 80 park locations in Medan can be seen in table 1.

Table 1. Park Location Data In Medan City

No	Location	Distance to Depot A	Distance to Depot B
1	Ahmad Yani	3	5,2
2	Air Mancur Teladan	0	8,1
3	Air Mancur Jl. Sudirman	3,3	4,6
4	Batas Kota Tjg. Morawa	8,3	15
5	Batas Kota Tuntungan	8,1	7,7
6	Beringin Jalan Sudirman	3,5	4,1
7	Bundaran Polonia	9,5	5,3
8	Dekranas Jl. Listrik	9,7	5,7
9	Depan Kantor Dinas Pertamanan	11	4,5
10	Depan Kantor Lonsum	3,4	6,4
11	Depan Wisma Kodam Jl. Sudirman	3,3	3,7
12	Desa Nelayan Indah	35	24
13	Dibawah Jembatan Layang P.Brayan	8,1	9,1
14	Guru Patimpus Petisah	5,2	6,2
15	Istana Maimun	2	6,1
16	Jl. A.H Nasution	6	11
17	Jl. Danau Limboto	7,8	4,5

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18	Jl. Danau Singkarak/Jl. D. Marsabut	7,9	4,1
19	Jl. Dc Barito	4,7	7,7
20	Jl. Djamin Ginting Rs. Jiwa	12	5,4
21	Jl. Gudang Arang Belawan	29	26
22	Jl. H. Misbah	2,5	5,4
23	Jl. Letda Sudjono	6,6	11
24	Jl. Listrik	5	5,7
25	Jl. Masdulhak	3,4	4,4
26	Jl. Mongonsidi/Simp. Jl. Dr. Cipto	5,1	4,1
27	Jl. Pelabuhan I Belawan	31	28
28	Jl. Pelabuhan Ii Belawan	37	26
29	Jl. Rifai	3,5	4,3
30	Jl. Rotan Depan Puskesmas Petisah	5,6	3,6
31	Jl. Sei Batang Serangan	5,8	2,1
32	Jl. Serdang Ujung/ Jl. Soekarno Hatta	10	17
33	Jl. Seruwai/Labuhan	22	22
34	Jl. Sidodame	8,1	9,9
35	Jl. Sinabung	1,7	6,4
36	Jl. Sunggal/Simp. Jl. Tb. Simatupang	11	4,4
37	Jl. Uskup Agung	3,7	4,2
38	L. Walikota	3,1	4,1
39	Jl. Pandu/Mahkamah	3	6,8
40	Kampung Lalang	13	5,7
41	Kantor Dharma Wanita	4	4,4
42	Kantor Dinas Walikota Medan	5,3	4,9
43	Kantor DPRD Kota Medan	5	4,6
44	Kantor Perpustakaan Kota Medan	6,7	3,6
45	Kantor Pramuka Jl. Kapt. Maulana Lubis	5	4,6
46	Karang Berombak	8,4	6,7
47	Koni Jl. Gajah Mada	5,6	2,4
48	Lapangan Merdeka	3,6	6,1
49	Majestik (Air Mancur Petisah)	5,7	4,5
50	Marendal Simp. S. M. Raja	3	9,9
51	Puskesmas Darussalam	6,7	1,9
52	Puskesmas Glugur	5,6	7,1
53	Rumas Dinas Walikota	3,4	5,5
54	Sei Serapuh	5,9	2,5
55	Sei Tuntung	5,9	2,2
56	Simp. Empat Gabion Belawan	30	27
57	Simp. Jl. Hanafiah Belawan	31	27
58	Simpang Limun	1,6	8,5
59	Simpang Pos	7,4	8,3
60	Simpang Selayang	13	7,7
61	Sri Deli	1,5	6,4
62	Sriwijaya/ Jl. Nibung	4,8	3,2
63	Sudut Jl. Mangubumi	5,6	5,5
64	Taman Exponen 66	3,7	5,4
65	Taman Jl. Gaperta	9,9	4,1
66	Taman Jl. Gurillah/ Samanhudi	5,9	7,9
67	Teladan (Jogging Track)	0,5	7,2
68	Terminal Amplas	5,2	12
69	Terminal Pinang Baris	12	4,7
70	Toll Simp. Amplas	14	18
71	Tugu Adipura	6,2	6,1
72	Tugu Apollo Jl. Sutomo	5,7	4,5
73	Tugu Gapensi	9,6	2,9
74	Tugu Juang 45	5,2	7,7
75	Tugu Kb. Jl. Sutomo	3,7	7
76	Tugu Perintis Kemerdekaan	5,2	7,7
77	Kantor Dispenda	6,7	10
78	Stan Medan Fair	6	4,2
79	Smu Negeri 4	8,1	3,1
80	Smp Negeri 1	10	4,9

From table 1 above then, each location with the same water source will be grouped to determine the route through genetic algorithms. This location grouping can be seen in table 2 for depot A and table 3 for depot B.

Table 2. Location Of Parks With Water From Depot A

No	Location	Surface Area(m^2)
1	Ahmad Yani	15200
2	Air Mancur Teladan	11350
3	Air Mancur Jl. Sudirman	2650
4	Batas Kota Tjg Morawa	370
6	Beringin Jalan Sudirman	12219
10	Depan Kantor Lonsum	300

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11	Depan Wisma Kodam Jl. Sudirman	14600
13	Di Bawah Jembatan Layang P.Brayan	8625
14	Guru Patimpus Petisah	278
15	Istana Maimun	6100
16	Jl. A.H Nasution	490
19	Jl. Dc Barito	615
22	Jl. H. Misbah	2675
23	Jl. Letda Sujono	6181
24	Jl. Listrik	520
25	Jl. Masdulhak	1680
29	Jl. Rifai	640
32	Jl. Serdang Ujung/ Jl. Soekarno Hatta	65
33	Jl. Seruwai/ Labuhan	720
34	Jl. Sidodame	4200
35	Jl. Sinabung	240
37	Jl. Uskup Agung	980
38	Jl. Walikota	945
39	Jl. Pandu/ Mahkamah	650
41	Kantor Dharma Wanita	3800
48	Lapangan Merdeka	9500
50	Marendal Simp. S. M. Raja	200
52	Puskesmas Glugur	87
53	Rumah Dinas Walikota Medan	2500
58	Simpang Limun	254
61	Sri Deli	13159
64	Taman Exponen 66	568
66	Taman Jl. Gurillah/ Samahundi	613
67	Teladan (Jogging Track)	15500
68	Terminal Amplas	180
70	Tol Simp. Amplas	1544
74	Tugu Juang 45	2400
75	Tugu Kb. Jl. Sutomo	2351
76	Tugu Perintis Kemerdekaan	2300
77	Kantor Dispenda	434

From table 2 above, it can be seen that there are 40 locations of the park whose water needs are taken from the sprinkling water source of the Medan City Parks Department in the Model Park (depot A). And for the location of the park whose water needs are taken from depot B can be seen in table 3

Table 3. Location Of Parks With Water From Depot B

No	Location	Surface Area(m^2)
5	Batas Kota Tuntungan	249
7	Bundaran Polonia	490
8	Dekranas Jl. Listrik	60
9	Depan Kantor Dinas Pertamanan	650
12	Desa Nelayan Indah	490
17	Jl. Danau Limboto	428
18	Jl. Danau Singkarak/ Jl. D. Marsabut	250
20	Jl. Djamin Ginting Rs. Jiwa	265
21	Jl. Gudang Arang Belawan	504
26	Jl. Mongonsidi/ Simp. Jl. Dr. Cipto	90
27	Jl. Pelabuhan I Belawan	1017
28	Jl. Pelabuhan Ii Belawan	1837
30	Jl. Rotan Depan Puskesmas Petisah	430
31	Jl. Sei Batang Serangan	1800
36	Jl. Sunggal/ Simp. Jl. Tb. Simatupang	105
40	Kampung Lalang	700
42	Kantor Dinas Walikota Medan	2545
43	Kantor DPRD Kota Medan	650
44	Kantor Perpustakaan Kota Medan	451
45	Kantor Pramuka Jl. Kapt. Maulana Lubis	2978
46	Karang Berombak	3730
47	Koni Jl. Gajah Mada	11800
49	Majestik (Air Mancur Petisah)	562
51	Puskesmas Darussalam	135
54	Sei Serapuh	900
55	Sei Tuntung	812
56	Simp. Empat Gabion Belawan	4280
57	Simp. Jl. Hanafiah Belawan	825
59	Simpang Pos	458
60	Simpang Selayang	230
62	Sriwijaya/ Jl. Nibung	370
63	Sudut Jl. Mangubumi	485
65	Taman Jl. Gaperta	21800
69	Terminal Pinang Baris	250
71	Tugu Adipura	2483
72	Tugu Apollo Jl. Sutomo	600
73	Tugu Gapensi	992
78	Stan Medan Fair	145
79	Smu Negeri 4	160
80	Smp Negeri 1	85

From table 3 above, it can be seen that there are 40 park locations whose water needs are taken from the Medan City Parks Department watering water source in Titi Bobrok (depot B).

The genetic algorithm steps to determine the route of watering locations that take water from depot A, that is:

1. Formation of the initial population

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The initial chromosome is obtained by entering locations that take water in the same depot into one chromosome. First, locations that have a water demand greater than the maximum capacity of the vehicle are chosen, namely locations 1, 2, 6, 11, 13, 15, 23, 48, 61, and 67. Each chromosome will start at the depot location. then location 1 is checked, water needs at location 1 are 15200, because the maximum capacity of water that can be carried by vehicles is 5000 then location 1 is visited 3 times so that the current needs are less than 5000. The remaining water needs at location 1 of 200 will be met later after all water needs in all locations covering an area of more than 5000 are visited. This check is carried out until all locations with an area of> 5000 are visited and the remaining needs of each of these locations are currently <5000.

After all locations with water requirements> 5000 are visited, the current chromosome contents are as follows:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 – A

Checking is done again from location 1 to meet water needs that have not been met. After all, locations have been visited, the formation of chromosome 1 has been completed and the route formed as chromosome 1 is as follows:

Chromosome 1:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 1 - 2 - 3 - 4 - A - 6 - 10 - A - 11 - A - 13 - 14 - A - 15 - 16 - 19 - 22 - A - 23 - 24 - 25 - 29 - 32 - 33 - A - 34 - 35 - A - 37 - 38 - 39 - A - 41 - A - 48 - 50 - 52 - A - 53 - 58 - A - 61 - 64 - 66 - 67 - A - 68 - 70 - 74 - A - 75 - 76 - A - 77 – A

For the 2nd to the 10th chromosomes, the value of the 1st chromosome is randomized using a random function.

Chromosome 2:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 15 - 1 - 70 - 58 - A - 23 - 50 - A - 10 - A - 29 - 14 - A - 76 - 74 - 67 - 77 - A - 68 - 52 - 3 - 16 - 35 - 2 - A - 33 - 34 - A - 22 - 38 - 66 - A - 53 - A - 11 - 64 - 48 - A - 4 - 6 - A - 32 - 19 - 25 - 75 - A - 39 - 13 - 24 - A - 41 - 61 - A - 37 – A

Chromosome 3:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 33 - 1 - 16 - 22 - A - 10 - 32 - A - 34 - A - 67 - 58 - A - 75 - 37 - 61 - 35 - A - 19 - 11 - 68 - 53 - 48 - 38 - A - 6 - 14 - A - 39 - 50 - 76 - A - 70 - A - 2 - 15 - 41 - A - 24 - 52 - A - 25 - 13 - 3 - 64 - A - 4 - 77 - 29 - A - 66 - 23 - A - 74 – A

Chromosome 4:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 61 - 15 - 29 - 16 - A - 76 - 70 - A - 33 - A - 39 - 52 - A - 37 - 3 - 2 - 35 - A - 24 - 34 - 77 - 10 - 13 - 48 - A - 23 - 75 - A - 14 - 22 - 53 - A - 38 - A - 4 - 41 - 25 - A - 64 - 74 - A - 66 - 67 - 32 - 11 - A - 1 - 58 - 19 - A - 68 - 50 - A - 6 - A

Chromosome 5:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 23 - 66 - 29 - 35 - A - 11 - 68 - A - 58 - A - 67 - 15 - A - 53 - 6 - 3 - 77 - A - 10 - 75 - 19 - 16 - 50 - 4 - A - 14 - 34 - A - 74 - 70 - 32 - A - 22 - A - 25 - 24 - 37 - A - 38 - 13 - A - 1 - 39 - 52 - 76 - A - 33 - 48 - 41 - A - 61 - 64 - A - 2 – A

Chromosome 6:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 2 - 1 - 24 - 74 - A - 33 - 29 - A - 67 - A - 14 - 3 - A - 22 - 48 - 39 - 10 - A - 6 - 38 - 76 - 77 - 15 - 75 - A - 19 - 34 - A - 32 - 53 - 70 - A - 68 - A - 11 - 16 - 61 - A - 52 - 37 - A - 41 - 35 - 58 - 50 - A - 4 - 64 - 66 - A - 13 - 23 - A - 25 – A

Chromosome 7:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 3 - 48 - 37 - 1 - A - 75 - 58 - A - 23 - A - 11 - 64 - A - 24 - 53 - 50 - 15 - A - 41 - 70 - 68 - 14 - 16 - 22 - A - 74 - 25 - A - 52 - 2 - 77 - A - 66 - A - 13 - 32 - 6 - A - 67 - 29 - A - 10 - 19 - 4 - 76 - A - 39 - 61 - 35 - A - 33 - 34 - A - 38 – A

Chromosome 8:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 67 - 16 - 70 - 35 - A - 33 - 25 - A - 10 - A - 50 - 29 - A - 38 - 34 - 6 - 23 - A - 1 - 32 - 68 - 14 - 11 - 41 - A - 58 - 75 - A - 77 - 61 - 64 - A - 76 - A - 74 - 3 - 22 - A - 2 - 53 - A - 13 - 15 - 24 - 52 - A - 4 - 48 - 19 - A - 39 - 66 - A - 37 - A

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Chromosome 9:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 68 - 19 - 48 - 16 - A - 6 - 14 - A - 35 - A - 77 - 10 - A - 52 - 23 - 58 - 34 - A - 61 - 25 - 13 - 38 - 1 - 11 - A - 32 - 2 - A - 66 - 41 - 24 - A - 3 - A - 74 - 70 - 50 - A - 53 - 37 - A - 39 - 33 - 76 - 4 - A - 22 - 15 - 64 - A - 29 - 75 - A - 67 - A

Chromosome 10:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - 58 - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - 24 - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 – A

2. Calculate the fitness value for each chromosome (Fitness = 1 / Total Distance)
The distance of each location to other locations is taken from the database that has been provided.
To overcome this, a distance value of 100 is added every time there is a need for water in a location that is not met so that the value of this chromosome fitness is getting smaller and the chances of appearing in the next generation are getting smaller.
Fitness chromosome 1 = 1/371,4 = 0,00269251
Fitness chromosome 2 = 1/898,4 = 0,00111297
Fitness chromosome 3 = 1/1519,5 = 0,00065807
Fitness chromosome 4 = 1/1320,4 = 0,00075729
Fitness chromosome 5 = 1/744,9 = 0,00134246
Fitness chromosome 6 = 1/1310,3 = 0,00076313
Fitness chromosome 7 = 1/1432 = 0,00069832
Fitness chromosome 8 = 1/1410,2 = 0,00070907
Fitness chromosome 9 = 1/1082,2 = 0,00092396
Fitness chromosome 10 = 1/1094 = 0,00091341

3. Calculate the probability value of each chromosome (fitness value / total fitness).
P[1] = 0,00269251 / 0,01057119 = 0,25470264
P[2] = 0,00111297 / 0,01057119 = 0,10528332
P[3] = 0,00065807 / 0,01057119 = 0,06225127
P[4] = 0,00075729 / 0,01057119 = 0,71633716
P[5] = 0,00134246 / 0,01057119 = 0,12699233
P[6] = 0,00076313 / 0,01057119 = 0,07218960
P[7]= 0,00069832 / 0,01057119 = 0,06605879
P[8] = 0,00070907 / 0,01057119 = 0,06707570
P[9]= 0,00092396 / 0,01057119 = 0,08740359
P[10] = 0,00091341 / 0,01057119 = 0,0864050

4. Calculate the cumulative probability value of each chromosome.
C[1] = 0,25470264.
C[2] = 0,25470264 + 0,10528332 = 0,36
C[3] = 0,36 + 0,06225127 = 0,4222
C[4] = 0,4222 + 0,06225127 = 0,4393
C[5] = 0,4393 + 0,12699233 = 0,6209
C[6] = 0,6209 + 0,07218960 = 0,6931
C[7] = 0,6931 + 0,06605879 = 0,7591
C[8] = 0,7591 + 0,06707570 = 0,8262
C[9] = 0,8262 + 0,08740359 = 0,9136
C[10] = 0,9136 + 0,0864050 = 1

5. Chromosome selection by the roulette-wheel method.
Generate random numbers in the range 0-1

- If R [k] <C [1], then select chromosome 1 as the parent.
- If C [k-1] <R <C [k], then select the k-chromosome as parent. Then:

1. Random = 0,3131. Chromosome 2 selected.
2. Random = 0,9754. Chromosome 10 selected.
3. Random = 0,994. Chromosome 10 selected.
4. Random = 0,9953. Chromosome 10 selected.
5. Random = 0,7931. Chromosome 8 selected.
6. Random = 0,924. Chromosome 10 selected.
7. Random = 0,4902. Chromosome 4 selected.
8. Random = 0,1966. Chromosome 1 selected.
9. Random = 0,2757. Chromosome 2 selected.
10. Random = 0,7534. Chromosome 7 selected.

6. Then the new population selected is:
Chromosome 1 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 15 - 1 - 70 - 58 - A - 23 - 50 - A - 10 - A - 29 - 14 - A - 76 - 74 - 67 - 77 - A - 68 - 52 - 3 - 16 - 35 - 2 - A - 33 - 34 - A - 22 - 38 - 66 - A - 53 - A - 11 - 64 - 48 - A - 4 - 6 - A - 32 - 19 - 25 - 75 - A - 39 - 13 - 24 - A - 41 - 61 - A - 37 – A
Chromosome 2 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - 58 - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - 24 - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 - A
Chromosome 3 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - 58 - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A -

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11 - 23 - A - 14 - 22 - 24 - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 - A

Chromosome 4 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - 58 - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - 24 - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 - A

Chromosome 5 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 67 - 16 - 70 - 35 - A - 33 - 25 - A - 10 - A - 50 - 29 - A - 38 - 34 - 6 - 23 - A - 1 - 32 - 68 - 14 - 11 - 41 - A - 58 - 75 - A - 77 - 61 - 64 - A - 76 - A - 74 - 3 - 22 - A - 2 - 53 - A - 13 - 15 - 24 - 52 - A - 4 - 48 - 19 - A - 39 - 66 - A - 37 - A

Chromosome 6 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - 58 - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - 24 - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 - A

Chromosome 7 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 61 - 15 - 29 - 16 - A - 76 - 70 - A - 33 - A - 39 - 52 - A - 37 - 3 - 2 - 35 - A - 24 - 34 - 77 - 10 - 13 - 48 - A - 23 - 75 - A - 14 - 22 - 53 - A - 38 - A - 4 - 41 - 25 - A - 64 - 74 - A - 66 - 67 - 32 - 11 - A - 1 - 58 - 19 - A - 68 - 50 - A - 6 - A

Chromosome 8 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 1 - 2 - 3 - 4 - A - 6 - 10 - A - 11 - A - 13 - 14 - A - 15 - 16 - 19 - 22 - A - 23 - 24 - 25 - 29 - 32 - 33 - A - 34 - 35 - A - 37 - 38 - 39 - A - 41 - A - 48 - 50 - 52 - A - 53 - 58 - A - 61 - 64 - 66 - 67 - A - 68 - 70 - 74 - A - 75 - 76 - A - 77 – A

Chromosome 9 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 15 - 1 - 70 - 58 - A - 23 - 50 - A - 10 - A - 29 - 14 - A - 76 - 74 - 67 - 77 - A - 68 - 52 - 3 - 16 - 35 - 2 - A - 33 - 34 - A - 22 - 38 - 66 - A - 53 - A - 11 - 64 - 48 - A - 4 - 6 - A - 32 - 19 - 25 - 75 - A - 39 - 13 - 24 - A - 41 - 61 - A - 37 – A

Chromosome 10 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 3 - 48 - 37 - 1 - A - 75 - 58 - A - 23 - A - 11 - 64 - A - 24 - 53 - 50 - 15 - A - 41 - 70 - 68 - 14 - 16 - 22 - A - 74 - 25 - A - 52 - 2 - 77 - A - 66 - A - 13 - 32 - 6 - A - 67 - 29 - A - 10 - 19 - 4 - 76 - A - 39 - 61 - 35 - A - 33 - 34 - A - 38 – A

7. Crossover

Generate random numbers in the range 0-1

If the random number generated is less than the value of the crossover rate entered by the user, then select the chromosome as the parent.

1. Random = 0,797668575214999
2. Random = 0,717135253230638
3. Random = 0,94458753845868
4. Random = 0,427685670288133
5. Random = 0,0371803506450636
6. Random = 0,387527171702835
7. Random = 0,0039172424021723
8. Random = 0,966974479596584
9. Random = 0,0039172424021723
10. Random = 0,215535719048016

From the random numbers above, the chromosomes selected to undergo the crossover process are chromosomes 5, 8, 9, and 10.

Then generate Random numbers again to determine the cut-point position.

1. Chromosome 5 >< Chromosome 8. Random = 59

The intersection point is in the 59th gene, therefore the first child chromosome is filled with the 1st to 58th genes of the first parent, that is chromosome 5.

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 67 - 16 - 70 - 35 - A - 33 - 25 - A - 10 - A - 50 - 29 - A - 38 - 34 - 6 - 23 - A - 1 - 32 - 68 - 14 - 11 - 41 - A - 58 - 75 - A - 77 - 61 - 64 - A - 76 - A - 74 - 3 - 22 - A - 2 - 53 - A - 13 - 15 - 24 - 52 - A - 4 - 48 - 19 - A - 39 - 66 - A - 37 - A

Then, refill the chromosome of the child with the value of the gene in the second parent, namely chromosome 8 which has not been present in the previous child chromosome. The following is a child chromosome that results from the crossover of chromosome 5 and chromosome 8:

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A -15- A – 23 - A - 48 - A - 61 - A - 61 - A - 67 - A – 67 - A - 67 A - 67 - 16 -

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70 - 35 - A - 33 - 25 - A - 10 - A - 50 - 29 - A - 38 - 34 - 6 -23 - A - 1 - 32 - 68 - 14 - **2 - 3 - A - 4 - 11 - A - 13 - 15 - 19 - A 22 A 24 - 37 - 39 - A - 41 - 48 - A - 52 - 53 - 58 - 61 - A - 64 - 66 - 74 - A - 75 - 76 - A - 77 - A**

2. Chromosome 8 >< Chromosome 9. Random = 46

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 1 - 2 - 3 - 4 - A - 6 - 10 - A - 11 - A - 15 - 70 - A - 58 - 23 - 50 – 29 - A - 14 - 76 - 74 - 67 - 77 - 68 - A - 52 – 16 - A - 35 - 33 - 34 - A - 22 - A - 38 - 66 - 53 - A - 64 - 48 - A - 32 - 19 - 25 - 75 - A - 39 - 13 - 24 A - 41 - 61 - A - 37 - A

3. Chromosome 9 >< Chromosome 10. Random = 68

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 15 - 1 - 70 - 58 - A - 23 - 50 - A - 10 - A - 29 - 14 - A - 76 - 74 - 67 - 77 - A - 68 - 52 - 3 - 16 - 35 - 2 - A - 33 - 34 - A - 22 - 38 - 66 - A - 48 - A - 37 - 75 - 11 - A - 64 - 24 - A - 53 - 41 - 25 - 13 - A - 32 - 6 - 19 - A - 4 - 39 - A - 61 – A

4. Chromosome 10 >< Chromosome 5. Random = 62

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 3 - 48 - 37 - 1 - A - 75 - 58 - A - 23 - A - 11 - 64 - A - 24 - 53 - 50 - 15 - A - 41 - 70 - 68 - 14 - 16 - 22 - A - 67 - 35 - A - 33 - 25 - 10 - A - 29 - A - 38 - 34 - 6 - A - 32 - 2 - A - 4 - 13 - 19 - 39 - A - 52 - 61 - 66 - A - 74 - 76 - A - 77 - A

8. Mutation

Generate random numbers in the range 0-1

If the random number generated is smaller than the mutation rate value entered by the user, then select the chromosome to do the mutation.

1. Random = 0,954858085585226
2. Random = 0,32443951597644
3. Random = 0,978255040933497
4. Random = 0,0987366913346279
   Chromosome 4 selected because the random value < mutation rate
5. Random = 0,681427048370907
6. Random = 0,542784679468155
7. Random = 0,829066979153579
8. Random = 0,312978260364839
9. Random = 0,919414971451934
10. Random = 0,432319257144034

From the Random numbers above chromosome 4 will mutate.

Generate 2 Random numbers to determine which genes will exchange values. Random 1 = 42 and Random 2 = 80.

Then the 42nd and 80th genes will exchange values.

Chromosome 4 :

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - **58** - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - **24** - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 - A

Results of chromosome 4 after mutation:

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - **24** - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 – 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - **58** - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 - A

9. The current population that will become the new population in the next generation are::

Chromosome 1 :

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 15 - 1 - 70 - 58 - A - 23 - 50 - A - 10 - A - 29 - 14 - A - 76 - 74 - 67 - 77 - A - 68 - 52 - 3 - 16 - 35 - 2 - A - 33 - 34 - A - 22 - 38 - 66 - A - 53 - A - 11 - 64 - 48 - A - 4 - 6 - A - 32 - 19 - 25 - 75 - A - 39 - 13 - 24 - A - 41 - 61 - A - 37 – A

Chromosome 2 :

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - 58 - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - 24 - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 - A

Chromosome 3 :

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - 58 - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - 24 - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 - A

Chromosome 4 :

A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A -

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61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - 24 - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - 58 - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41- A

Chromosome 5 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 16 - 70 - 35 - A - 33 - 25 - A - 10 - A - 50 - 29 - A - 38 - 34 - 6 - 23 - A - 1 - 32 - 68 - 14 - 2 - 3 - A - 4 - 11 - A - 13 - 15 - 19 - A - 22 - A - 24 - 37 - 39 - A - 41 - 48 - A - 52 - 53 - 58 - 61 - A - 64 - 66 - 74 - A - 75 - 76 - A - 77 - A

Chromosome 6 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 52 - 68 - 19 - 2 - A - 58 - 35 - A - 32 - A - 48 - 13 - A - 76 - 77 - 39 - 74 - A - 66 - 25 - 3 - 67 - 34 - 4 - A - 37 - 53 - A - 10 - 1 - 70 - A - 16 - A - 33 - 64 - 50 - A - 11 - 23 - A - 14 - 22 - 24 - 15 - A - 38 - 61 - 6 - A - 75 - 29 - A - 41 - A

Chromosome 7 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 61 - 15 - 29 - 16 - A - 76 - 70 - A - 33 - A - 39 - 52 - A - 37 - 3 - 2 - 35 - A - 24 - 34 - 77 - 10 - 13 - 48 - A - 23 - 75 - A - 14 - 22 - 53 - A - 38 - A - 4 - 41 - 25 - A - 64 - 74 - A - 66 - 67 - 32 - 11 - A - 1 - 58 - 19 - A - 68 - 50 - A - 6 - A

Chromosome 8 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 1 - 2 - 3 - 4 - A - 6 - 10 - A - 11 - A - 15 - 70 - A - 58 - 23 - 50 - 29 - A - 14 - 76 - 74 - 67 - 77 - 68 - A - 52 - 16 - A - 35 - 33 - 34 - A - 22 - A - 38 - 66 - 53 - A - 64 - 48 - A - 32 - 19 - 25 - 75 - A - 39 - 13 - 24 - A - 41 - 61 - A - 37 - A

Chromosome 9 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 15 - 1 - 70 - 58 - A - 23 - 50 - A - 10 - A - 29 - 14 - A - 76 - 74 - 67 - 77 - A - 68 - 52 - 3 - 16 - 35 - 2 - A - 33 - 34 - A - 22 - 38 - 66 - A - 48 - A - 37 - 75 - 11 - A - 64 - 24 - A - 53 - 41 - 25 - 13 - A - 32 - 6 - 19 - A - 4 - 39 - A - 61 - A

Chromosome 10 :
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A - 67 - A - 3 - 48 - 37 - 1 - A - 75 - 58 - A - 23 - A - 11 - 64 - A - 24 - 53 - 50 - 15 - A - 41 - 70 - 68 - 14 - 16 - 22 - A - 67 - 35 - A - 33 - 25 - 10 - A - 29 - A - 38 - 34 - 6 - A - 32 - 2 - A - 4 - 13 - 19 - 39 - A - 52 - 61 - 66 - A - 74 - 76 - A - 77 – A

10. The fitness value of each chromosome after 1 generation::
Chromosome 1 = 0,00111297
Chromosome 2 = 0,00091341
Chromosome 3 = 0,00091341
Chromosome 4 = 0,00090917
Chromosome 5 = 0,00098804
Chromosome 6 = 0,00091341
Chromosome 7 = 0,00075729
Chromosome 8 = 0,00102807
Chromosome 9 = 0,0009982
Chromosome 10 = 0,00062139

11. The best fitness value after 1 generation is found in chromosome 1 with a fitness value of 0.00111297.
The best chromosome currently remains in the previous generation, because the value of the fitness chromosome 1 in the previous generation is greater than the value of the best fitness chromosome in the current generation.

12. The selection process is repeated as is the process of crossover and mutation to the maximum number of generations.

13. After testing up to 500 generations, the best chromosome is obtained in the 173rd generation with a fitness value of 0.0029, that is:
A - 1 - A - 1 - A - 1 - A - 2 - A - 2 - A - 6 - A - 6 - A - 11 - A - 11 - A - 13 - A - 15 - A - 23 - A - 48 - A - 61 - A - 61 - A - 67 - A - 67 - A -67 - A - 52 - 76 – 16 - 4 - A - 2 - 75 - A - 13 - A - 35 - 11 - A - 6 - 10 - 70 - 32 - A - 25 - 58 - 37 - 24 - 66 - 67 - A - 29 - 34 - A - 1 - 41 – 77 - A - 3 - A - 68 - 14 - 15 - A - 53 - 38 - A - 22 - 23 - 33 - 50 - A - 19 - 64 - 74 - A - 61 - 39 - A - 48 - A

The results of the route for locations that collect water at the "A" depot can be seen more clearly in Table 4.

Tabel 4. Routes for Locations with Depot Water Sources A

Route	Total Distance (km^2)	Water Purpose (L)	Vehicle to–
A – 1 – A	6	5000	1

A – 1 – A	6	5000	2
A – 1 – A	6	5000	3
A – 2 – A	0	5000	4
A – 2 – A	0	5000	5
A – 6 – A	7	5000	6
A – 6 – A	7	5000	7
A – 11 – A	6,6	5000	8
A – 11 – A	6,6	5000	9
A – 13 – A	16,2	5000	10
A – 15 – A	4	5000	11
A – 23 – A	12,2	5000	12
A – 48 – A	7,2	5000	13
A – 61 – A	3	5000	14
A – 61 – A	3	5000	15
A – 67 – A	1	5000	16
A – 67 – A	1	5000	17
A – 52 – 76 – 16 – 4 – A	38,4	3247	18
A – 2 – 75 – A	8,7	3701	19
A – 13 – A	16,2	3625	20
A – 35 – 11 – A	6,9	4840	21
A – 6 – 10 – 70 – 32 – A	35,6	4128	22
A – 25 – 58 – 37 – 24 – 66 – 67 – A	19,9	4547	23
A – 29 – 34 – A	18,8	4840	24
A – 1 – 41 – 77 – A	20,1	4434	25
A – 3 – A	6,6	2650	26
A – 68 – 14 – 15 – A	20,2	1558	27
A – 53 – 38 – A	8,5	3445	28
A – 22 – 23 – 33 – 50 – A	13,7	4776	29
A – 19 – 64 – 74 – A	21,3	3583	30
A – 61 – 39 – A	5,3	3809	31
A – 48 – A	7,2	4500	32
Total	**340,2**	**142683**	**32**

From table 4 it can be seen that to meet the water needs at each park location, 32 vehicles are needed with a total water requirement of 142683 Liters and the distance traveled by all vehicles is 340.2 km.

14. After the best route for locations that collect water in the "A" depot is found, then the same steps are taken also for locations in the "B" depot.

15. After testing for up to 500 generations, the best chromosome is obtained in the 148th generation with a fitness value of 0.00261, that is:

B - 47 - B - 47 - B – 65- B - 65 - B - 65 - B - 65 - B - 5 - 7 - 60 - 30 - 69 - 65 - 9 - 8 - 51 - 62 - 20 - B - 12 - 57 - 28 - 27 - 26 - B - 40 - 42 - 43 - B - 45 - B - 46 B - 47 - 18 - 73 - 80 - 31 - B - 56 - B - 36 - 55 - 21 - 59 - 79 - 49 - 54 - B - 44 - 78 - 72 - 17 - 63 - 71 - B

The results of the route for locations that collect water at the "B" depot can be seen more clearly in Table 5.

Tabel 5. Routes For Locations With Depot Water Sources B

Route	Total Distance (km^2)	Water Purpose (L)	Vehicle to–
B – 47 – B	4,8	5000	1
B – 47 – B	4,8	5000	2
B – 65 – B	8,2	5000	3
B – 65 – B	8,2	5000	4
B – 65 – B	8,2	5000	5
B – 65 – B	8,2	5000	6
B – 5 – 7 – 60 – 30 – 69 – 65 – 9 – 8 – 51 – 62 – 20 – B	89,5	4929	7
B – 12 – 57 – 28 – 27 – 26 – B	62,7	4259	8
B – 40 – 42 – 43 – B	22,6	3895	9
B – 45 – B	9,2	2978	10
B – 46 B	13,4	3730	11
B – 47 – 18 – 73 – 80 – 31 – B	25,6	4927	12
B – 56 – B	54	4280	13
B – 36 – 55 – 21 – 59 – 79 – 49 – 54 – B	39,6	3501	14
B – 44 – 78 – 72 – 17 – 63 – 71 – B	24,1	4592	15
Total	**383,1**	**67091**	**15**

From table 5 it can be seen that to meet the water needs at each park location, 15 vehicles are needed with a total water requirement of 67091 Liters and the distance traveled by all vehicles is 383.1 km.

7. EXPERIMENTS AND DISCUSSIONS

The experiment was carried out on a Windows 8.1 Laptop with an Intel Core i3 processor, 64-bit architecture, and 4096 MB RAM. The Integrated Development Environment (IDE) used for coding is

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SharpDevelop 5.1 RC and the programming language used is C#.

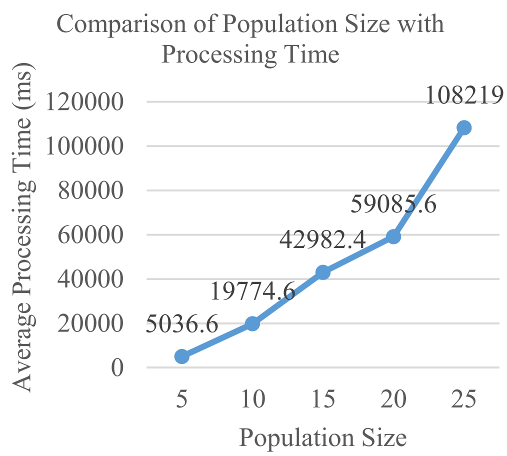

Figure 3. Graph Comparison of Population Size with Processing Time

In Figure 3 it can be seen that there is a relationship between population size and increasing processing time. This shows that the larger the population size, the longer the time spent running the program.

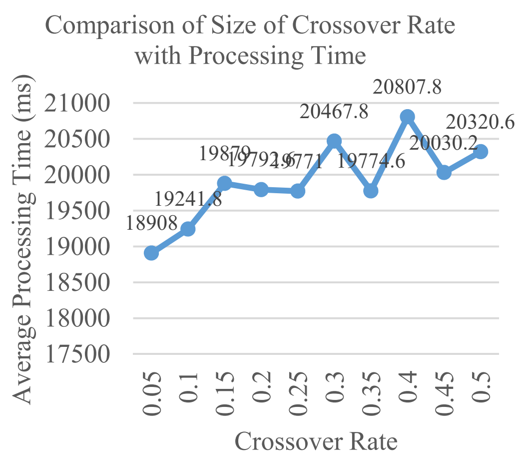

Figure 4. Graph Comparison of Crossover Rate with Time

Figure 4 shows a graph showing the relationship between the size of the crossover rate does not affect the processing time. This shows that the greater the size of the crossover rate, the time used to run the program is not always longer. Likewise, the smaller the size of the crossover rate, the time used to run the program is not always faster.

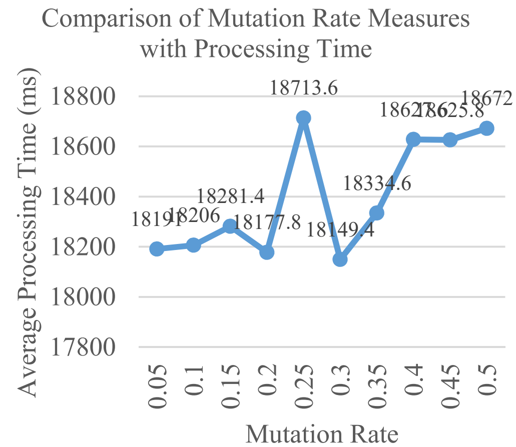

Figure 5. Graphic Comparison of Mutation rate and Processing Time

Figure 5 can be seen as a graph that shows the relationship between the size of the mutation rate does not always affect the processing time. This shows that the greater the size of the mutation rate, the time used to run the program is not always longer.

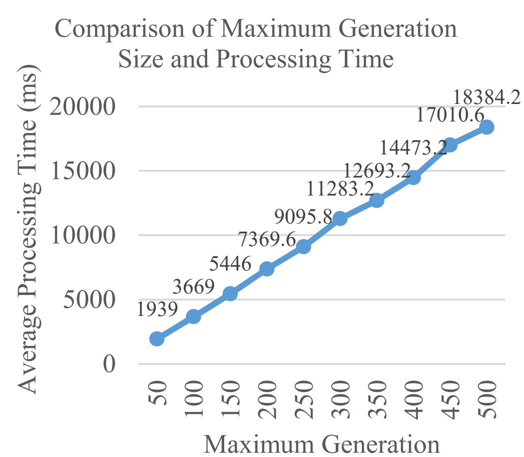

Figure 6. Graph Comparison of Maximum Generation with Time

In Figure 6 can be seen a graph that shows the relationship between the maximum size of the generation is directly proportional to the processing time. This shows that the greater the maximum size of the generation, the more time it takes to run the program.

8. CONCLUSIONS

Based on testing the determination of the route for the case of Capacitated Multi Depot Multi-Vehicle Routing Problem using genetic algorithms that have been done, we get several conclusions obtained by the author, namely as follows. Genetic algorithms can be used for route determination in the case of Capacitated Multi Depot Multi-Vehicle Routing Problems. To meet the water needs of all parks that take water from the exemplary depot, 142683 liters of water is needed with 32 vehicles required and the total distance traveled by all vehicles is 340 km and to meet the water needs of all parks that take water from the Titi Bobrok depot A amount of water is needed as much as 67091 Liters with the number of vehicles needed as many as 15 vehicles and the total distance traveled by all vehicles is 383.91 km. The processing time needed by the system to get the route with the optimal approach distance is influenced by population size, crossover rate, mutation rate, and the maximum number of generations used. The chance of finding a route with the closest total distance is influenced by the total population size and the maximum generation used. The greater the population size and the maximum number of generations, the greater the chance of finding the best route. Based on the measurement of the complexity of the genetic algorithm in determining the route for the case of Capacitated Multi Depot Multi-Vehicle Routing Problem, obtained T (n) = θ (n4). In the next research, the genetic algorithm can be applied in other cases with vary parameters.

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