

## Optimization of Badarawa/Malali Water Distribution Network Using Genetics Algorithm

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**Abstract:** In this study EPANET, a widely used water distribution package was linked to OptiGa, a Visual Basic ActiveX control for implementation of genetic algorithm, through Visual Basic programming technique, to modify the computer software called OptiNetwork. OptiNetwork was applied to Badarawa / Malali distribution network consisting of 96 pipes of different materials, 75 junctions, two tanks, and a source reservoir (i.e treatment plant) from which water is pumped through a pumping main to the overhead reservoir and later distributed to the network by gravity. After several runs the cost obtained from this network using OptiNetwork software under the application of genetics algorithm is \$433,520.00 which is lower than \$435,118.00 obtained from OptiDesigner software. This difference is approximately 3% lower than the result obtained from OptiDesigner (a commercial software) with minimum pressure head of 3m and maximum of 100, Pressure penalty of 200,000 and probability of mutation equal to 0.03, also the commercial diameters of 4", 6", 8", 10", 12", 14", 16", 18", 20", 22" and 24"  $d_{min} = 4"$ ,  $d_{max} = 24"$  were used for the distribution network during the optimization process. The results obtained shows that the introduction of the modified software (OptiNetwork) is justified. This is because it has been able to improve the search method in terms of achieving the "least-cost" designed water distribution system that will supply sufficient water quantities at adequate pressure to the consumers.

**Keywords:** Water distribution systems, cost, optimization, genetic Algorithm.

## INTRODUCTION

A water distribution network is a system containing pipes, reservoir, pumps and valves of different types, (appurtenances) which are connected to each other to provide water to consumers. It is a vital component of the urban infrastructure and requires significant investment. Optimization, as it applies to water distribution system modeling, is the process of finding the best, or optimal solution to a water distribution system problem, it can also be referred to as mathematical techniques used to automatically adjust the details of the system performance (that is the best value of the objective functions).

The problem of optimal design of water distribution network has various aspects to be considered such as hydraulics, reliability, water quality, and infrastructure and demand pattern. Though, each of these factors has its own part of the planning, design and management of the system despite the inherent dependence.

## LITERATURE

### What is Genetic Algorithm?

Genetic algorithms (GAs) are optimization techniques based on the concepts of natural selection and genetics. Genetic algorithms are inspired by Darwin's theory of evolution. In this approach, the variables are represented as genes on a chromosome. Solution to a problem solved by genetic algorithms uses an evolutionary process (it is evolved). GAs features a group of candidate solutions (population) on the response surface. Through natural selection and the genetic operators, mutation and recombination, chromosomes with better fitness are found. Natural selection guarantees that chromosomes with the best fitness will propagate in future populations. Using the recombination operator, the GA combines genes from two parent chromosomes to form two new chromosomes (children) that have a high probability of having better fitness than their parents. Mutation allows new areas of the response surface to be explored. This is repeated until some condition (for example number of populations or improvement of the best solution) is satisfied

**Simple Genetic Algorithm**

The mechanics of a simple genetic algorithm are surprisingly simple, involving nothing more complex than copying strings and swapping partial strings [1]. Basic components of simple genetic algorithm are as follows [2]:

**Encoding a chromosome**

A chromosome should in some way contain information about solution that it represents. The most used way of encoding is a binary string. A chromosome then could look like this

**Table-1: Encoding a chromosome**

Chromosome1	1 11011   00100110110
Chromosome2	2 1101  111000011110

Each chromosome is represented by a binary string. Each bit in the string can represent some characteristics of the solution. Another possibility is that the whole string can represent a number. Of course, there are many other ways of encoding. The encoding depends mainly on the solved problem. For example, one can encode directly integer or real numbers; sometimes it is useful to encode some permutations and so on. *Reproduction* during reproduction, recombination (or crossover) first occurs. Genes from parents combine to form a whole new chromosome. The newly created offspring can then be mutated. Mutation means that the elements of DNA are a bit changed. These changes are mainly caused by errors in copying genes from parents. The fitness of an organism is measured by success of the organism in its life (survival).

**Selection**

Parents are selected according to their fitness. The better the chromosomes are, the more chances to be selected they have. Imagine a roulette wheel where all the chromosomes in the population are placed. The size of the section in the roulette wheel is proportional to the value of the fitness function of every chromosome – the bigger the value is, the larger the section is.

**Crossover**

After we have decided what encoding we will use, we can proceed to crossover operation. Crossover operates on selected genes from parent chromosomes and creates new offspring. The simplest way how to do that is to choose randomly some crossover point and copy everything before this point from the first parent and then copy everything after the crossover point from the other parent. Crossover can be illustrated as follows: (is the crossover point):

**Table-2: Crossover**

Chromosome1	11011   00100110110
Chromosome2	11011   11000011110
Offspring 1	11011  11000011110
Offspring 2	11011  00100110110

There are other ways how to make crossover, for example we can choose more crossover points. Crossover can be quite complicated and depends mainly on the encoding of chromosomes. Specific crossover made for a specific problem can improve performance of the genetic algorithm.

**Mutation**

After a crossover is performed, mutation takes place. Mutation is intended to prevent falling of all solutions in the population into a local optimum of the solved problem. Mutation operation randomly changes the offspring resulted from crossover. In case of binary encoding we can switch a few randomly chosen bits from 1 to 0 or from 0 to 1. Mutation can be then illustrated as follows:

**Table-3: Mutation**

Originaloffspring1	1101111000011110
Originaloffspring2	1101100100110110
Mutatedoffspring1	1100111000011110
Mutatedoffspring2	1101101100110110

The technique of mutation (as well as crossover) depends mainly on the encoding of chromosomes. For example when we are encoding permutations, mutation could be performed as an exchange of two genes.

**Elitism**

The idea of the elitism has been already introduced. When creating a new population by crossover and mutation, we have a big chance, that we will lose the best chromosome. Elitism is the name

of the method that first copies the best chromosome (or few best chromosomes) to the new population. The rest of the population is constructed in ways described above. Elitism can rapidly increase the performance of GA, because it prevents a loss of the best found solution.

### Steps in Using Genetic Algorithms for Network Optimization

The following steps summarize an implementation of a genetic algorithm for optimizing the design of a water distribution network system (based on Simpson, Murphy and Dandy [3]; Simpson, Dandy and Murphy [4])

- Develop a coding scheme to represent the decision variables to be optimized and the corresponding lookup tables for the choices for the design variables.
- Choose the form of the genetic algorithm operators; e.g. population size (say  $N=100$  or  $500$ ); selection scheme-tournament selection or biased Roulette wheel; crossover type-one-point, two-point or uniform; and mutation type - bit-wise or creeping.
- Choose values for the genetic algorithm parameters (e.g. crossover probability -  $pc$ ; mutation probability -  $pm$ ; penalty cost factor  $K$ ).
- Select a seed for the random number generator
- Randomly generate the initial population of WDS network designs.
- Decode each string in the population by dividing into its sub-strings and then determining the corresponding decision variable choices (using the lookup tables).
- For the decoded strings, compute the network cost of each of the designs in the population.
- Analyze each network design with a hydraulic solver for each demand loading case to compute network flows, pressures and pressure deficits (if any).
- Compute a penalty cost for each network where design constraints are violated.
- Compute the fitness of each string based on the costs in steps 7 and 9; often taken as the inverse of the total cost (network cost plus penalty cost).
- Create a mating pool for the next generation using the selection operator that is driven by the "survival of the fittest."
- Generate a new population of designs from the mating pool using the genetic algorithm operators of crossover and mutation.
- Record the lowest cost solutions from the new generation.
- Repeat steps 6 to 13 to produce successive generations of populations of designs stop if all members of the population are the same.
- Select the lowest cost design and any other similarly low cost designs of different configuration.

- Check if any of the decision variables have been selected at the upper bound of the possible choices in the lookup table. If so, expand the range of choices and re-run of genetic algorithm.
- Repeat steps 4 to 16 for say, ten different starting random number seeds.
- Repeat steps 4 to 17 for successively larger and larger population sizes. Some of the main steps in the genetic algorithm process are now described in more detail.

The literature review shows that the use of optimization is widespread in simple water distribution systems. Few literatures reviewed in the study includes: [5], used GA to find the optimal pump operation of water distribution system. The paper presents a new management model, H2O NET scheduler, for optimal control and operation of water distribution systems. The proposed model makes use of the latest advances in Genetic Algorithm (GA) optimization to automatically determine the least-cost pump scheduling/operation policy for each pump station in the water distribution system, while satisfying target hydraulic performance requirements. Quasi-dynamic (extended period simulation). Hydraulic network simulator [6], was directly embedded into the optimization model. Starting with an initial feasible set of design parameters and rehabilitation actions, it is passed to the network solver for use in explicitly satisfying the implicit system constraints and in evaluating the implicit bound constraints.

The results obtained indicate that the developed model can effectively reduce the cost of energy consumed for pumping in a complex water distribution system while maintaining satisfactory level of services [7]. Applied a combination of Tabusearch (TS) and Genetic Algorithm (GA) to solve a problem of split-pipe design of water distribution network.

The first, is the two-loop network which was first introduced by [8]. The system is to supply water to meet the required demand and to satisfy minimum pressure head at each node. Three different values of  $\alpha$  are adopted in the study which consist of the maximum and minimum values. The unit of the "Q" (flow rate) and "D" (diameters) maintained in the study are  $m^3/h$  and centimeter "C". The results obtained using  $\alpha = 10.5088$  and  $\alpha = 10.6792$ , produced a cost of \$400, 337.97 and \$403, 751.22, lower than that of simulated Annealing (SA) with a cost of \$408,035.00.

The second network is the New York City water supply network. The data of the New York City water supply tunnels are taken from [9, 10]. The challenge in the third network is to construct additional gravity flow tunnels parallel to the existing system to satisfy the increased demands at the required pressures.

The results obtained from the TS-GA are \$36.87 and \$38.05 when compared to the work of [7], with a cost of \$40.04, after satisfying the demand pressure requirements at all nodes, the result shows that a combination algorithm is better than the SA for the design problem of water distribution network. A number of good solutions are obtained by the TS-GA more than the SA.

## **METHODOLOGY**

### **Materials**

The materials used includes: topographical map, EPANET, OPTIDESIGNER, and Modified OPITNETWORK Optimization software.

### **Method of data Collection**

The topographical map of Badarawa / Malali study area, was produced using GIS software at Integrated Engineering Consultancy Kaduna, after obtaining the map, the existing water network for the study area was drawn on the map, togetherwith the junctions and their elevations. This was done with the help of experienced water board personnel, after proper editing, the full water supply network of the area was produced on the recent topographical map, and later transferred into the Epanet software work space using a process called map transport.

The demand was obtain after surveying the network in the area, average of 25 to 30 houses were connected to each individual model/Junction also the study area falls under the category of urban settlement, as a result of this development, the standard from the Federal Ministry of Water Resources manual on water demand was used, for this research 180 L/C/D

was considered with an average of nine (9) persons in each house. We obtain a demand at particular junction by multiplying (number of houses at junction by number of people in the house by 180L/C/D).

A computer software called optiNetwork was modified by linking EPANET to Optiga, a visual basic ActiveX control for implementation of genetics algorithm, through visual basic programming techniques.

### **Steps for Optinetwork Software**

The following steps are to be taken for the use of OptiNetwork software:

- Draw the system using EPANET and set system properties.
- Export the network from EPANET as an INP file to OptiNetwork software directory.
- Edit the text file called cost. Text with appropriate commercial diameters pipes with corresponding cost.
- Start the program by clicking OPEN, to select the imported file you want to work with and key in the correct number of pipes and nodes in the network.
- Set constraint that is the design parameters i.e. pressures, velocities and diameters.
- Set optimization parameters (standard genetic properties), you can change the defaults setting of advanced genetic properties by enabling it.
- Set the termination mode.
- Run the simulation. View results using EPANET software.

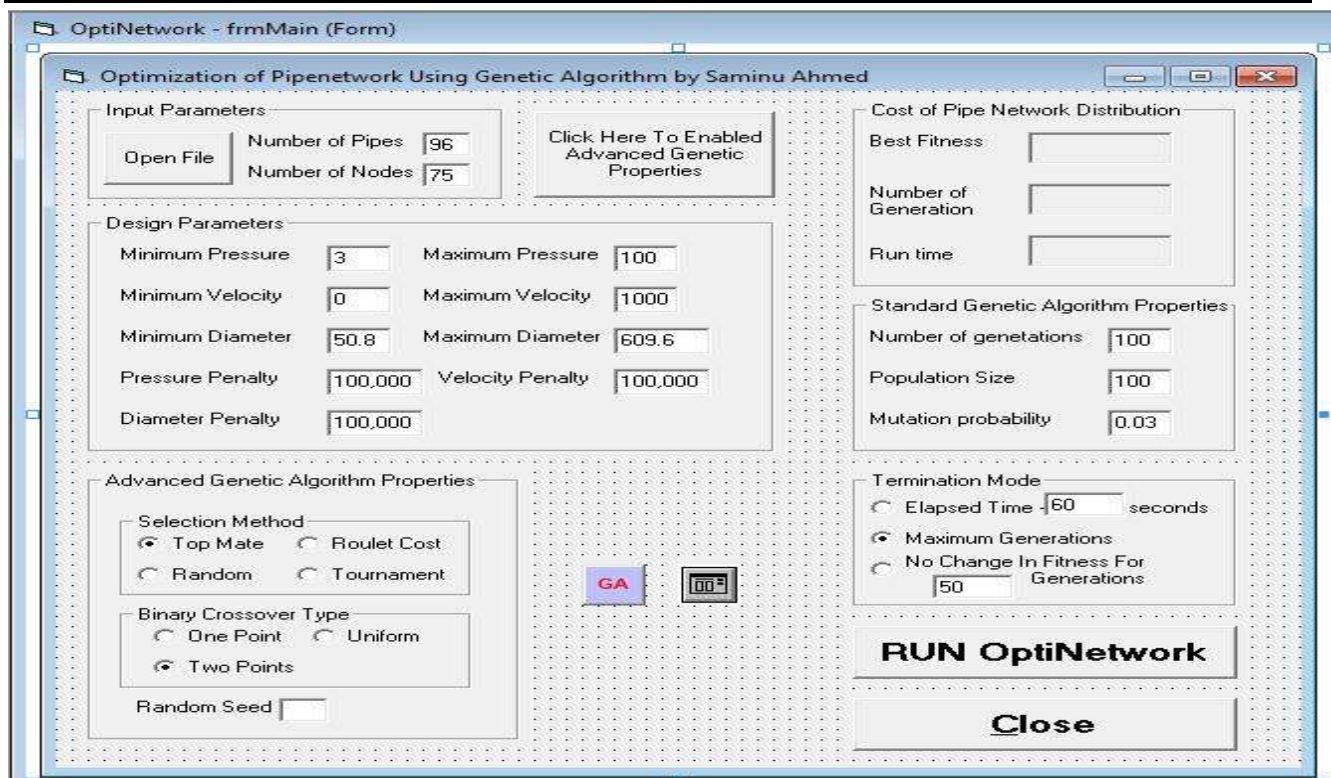


Fig-1: The modified software OptiNetwork

**RESULTS**

The existing distribution network of Badarawa/ Malali was studied and analyzed. It consists of 96 pipes of different materials, 75junctions, twotanks, and a source reservoir (i.e treatment plant) from which water is pumped through a pumping main to the overhead reservoir and later distributed to the network by gravity, as shown in (figure-4.1).

OptiNetwork software was applied to Badarawa/ Malali networks distribution designs. The optimum result of \$433,520.00 was obtained, which is lower than \$435,118.00 obtained from OptiDesigner (a commercial software).The commercial available diameters used for the network are given in table 4.1.Other hydraulic results that satisfied the constraints requirements are given in table-4.2.

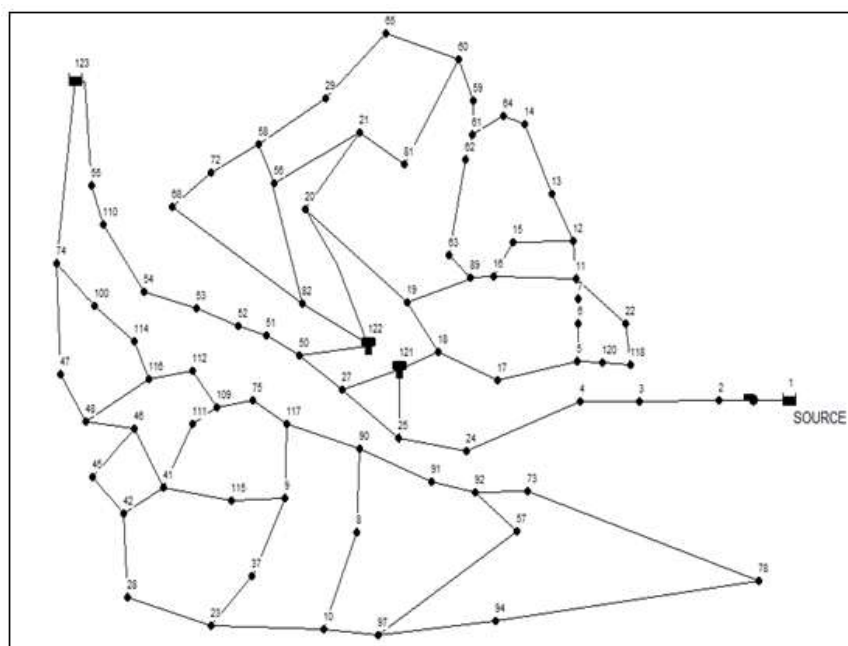


Fig-4.1: Badarawa/ Malali water distribution network

**Table-4.1: Cost of Commercial Available pipe Diameter for Badarawa/ Malali water distribution**

Diameter (mm)	Cost per Linear meter (\$)
152.40	16
203.20	23
254.00	32
304.80	50
355.60	60
406.40	90
457.20	130
508.00	170
558.80	300
609.60	550

**Table- 4.2: Network Data (pipes) for Badarawa/Malali Water Distribution Network with two Reservoirs. After Optimization (Using OptiNetwork)**

Link ID	Length m	Diameter mm	Roughness mm	Flow LPS	Velocity m/s	Unit Headloss m/km	Friction Factor
Pipe 3	218.88	609.6	0.005	-38.32	0.13	0.03	0.019
Pipe 11	323.23	254	0.005	-6.64	0.13	0.08	0.023
Pipe 12	120.65	508	0.005	-1.41	0.01	0	0
Pipe 13	250.34	101.6	0.005	-6.09	0.75	5.44	0.019
Pipe 14	350.21	406.4	0.005	2.13	0.02	0	0.038
Pipe 15	230.23	101.6	0.005	-0.67	0.08	0.11	0.033
Pipe 19	388.48	101.6	0.005	-12.55	1.55	20.1	0.017
Pipe 20	145.68	101.6	0.005	-16.43	2.03	32.84	0.016
Pipe 22	151.33	355.6	0.005	30.9	0.31	0.24	0.018
Pipe 23	540.56	101.6	0.005	-40.97	5.05	176.89	0.014
Pipe 24	230.56	508	0.005	-43.32	0.21	0.08	0.018
Pipe 26	202.41	101.6	0.005	-13.38	1.65	22.6	0.017
Pipe 43	170.88	355.6	0.005	-17.25	0.17	0.09	0.02
Pipe 8	123.54	101.6	0.005	-5.24	0.65	4.16	0.02
Pipe 46	535.74	152.4	0.005	-37.16	2.04	20.42	0.015
Pipe 47	118.59	406.4	0.005	-29.27	0.23	0.12	0.018
Pipe 48	175.18	101.6	0.005	-20.18	2.49	47.84	0.015
Pipe 57	240.12	101.6	0.005	10.11	1.25	13.59	0.017
Pipe 58	134.77	101.6	0.005	12.27	1.51	19.29	0.017
Pipe 62	125.76	457.2	0.005	-20.96	0.13	0.04	0.02
Pipe 63	75.43	101.6	0.005	-18.71	2.31	41.67	0.016
Pipe 64	240.25	355.6	0.005	-2.47	0.02	0	0.035
Pipe 66	101.45	101.6	0.005	0.18	0.02	0.01	0.031
Pipe 67	278.9	508	0.005	13.69	0.07	0.01	0.023
Pipe 68	102.33	457.2	0.005	-7.42	0.05	0.01	0.026
Pipe 74	230.79	609.6	0.005	-3.16	0.01	0	0.033
Pipe 75	160.23	508	0.005	-5.51	0.03	0	0.031
Pipe 76	1350.68	203.2	0.005	75.45	2.33	18.51	0.014
Pipe 84	90.22	101.6	0.005	-14.91	1.84	27.52	0.016
Pipe 87	42.84	152.4	0.005	-26.92	1.48	11.33	0.016
Pipe 94	200.12	508	0.005	2.83	0.01	0	0.038
Pipe 16	1400	101.6	0.005	-51.71	6.38	273.03	0.013
Pipe 1	220.23	203.2	0.005	-233.18	7.19	150.89	0.012
Pipe 60	450.43	558.8	0.005	50.37	0.21	0.07	0.017
Pipe 77	250.12	609.6	0.005	48.02	0.16	0.04	0.018
Pipe 95	280.12	152.4	0.005	45.67	2.5	29.82	0.014
Pipe 96	1000	254	0.005	23.79	0.47	0.77	0.017
Pipe 97	200.65	101.6	0.005	21.44	2.64	53.47	0.015
Pipe 98	240.65	406.4	0.005	25.12	0.19	0.09	0.019
Pipe 99	230.65	304.8	0.005	22.67	0.31	0.29	0.018

**Table-4.2: Network Data ( pipes) for Badarawa/Malali Water Distribution Network with two Reservoirs.After Optimization. (Using OptiNetwork, continued).**

Link ID	Length m	Diameter mm	Roughness mm	Flow LPS	Velocity m/s	Unit Headloss m/km	Friction Factor
Pipe100	150.77	152.4	0.005	21.94	1.2	7.81	0.016
Pipe101	200.99	406.4	0.005	12.65	0.1	0.03	0.022
Pipe102	200.12	254	0.005	10.3	0.2	0.17	0.021
Pipe103	230.43	254	0.005	4.55	0.09	0.04	0.025
Pipe123	100.54	101.6	0.005	-10.02	1.24	13.35	0.017
Pipe126	350.12	101.6	0.005	-46.76	5.77	226.25	0.014
Pipe127	400.12	101.6	0.005	-49.01	6.04	246.99	0.013
Pipe128	200	304.8	0.005	-6.23	0.09	0.03	0.024
Pipe129	280.79	254	0.005	-8.93	0.18	0.13	0.021
Pipe137	135.35	152.4	0.005	4.13	0.23	0.39	0.023
Pipe138	200.43	609.6	0.005	1.48	0.01	0	0.174
Pipe139	250.35	558.8	0.005	-1.22	0	0	0.131
Pipe140	120.32	254	0.005	3.62	0.07	0.03	0.027
Pipe141	110.11	101.6	0.005	1.07	0.13	0.25	0.029
Pipe142	100.32	101.6	0.005	-1.58	0.19	0.5	0.026
Pipe143	2600.54	203.2	0.005	-0.35	0.01	0	0.032
Pipe144	300.12	254	0.005	-3.05	0.06	0.02	0.028
Pipe 5	70.21	101.6	0.005	-25.03	3.09	71.09	0.015
Pipe 10	80.12	101.6	0.005	-36.16	4.46	140.23	0.014
Pipe 18	70.32	101.6	0.005	-38.86	4.79	160.3	0.014
Pipe 29	100.22	101.6	0.005	-41.66	5.14	182.44	0.014
Pipe 49	210.99	101.6	0.005	18.24	2.25	39.76	0.016
Pipe 51	100.43	558.8	0.005	15.99	0.07	0.01	0.021
Pipe 4	420	203.2	0.005	10.1	0.31	0.48	0.02
Pipe 6	400	406.4	0.005	3.2	0.02	0	0.029
Pipe 9	600	101.6	0.005	-44.11	5.44	202.93	0.014
Pipe 17	220	609.6	0.005	19.43	0.07	0.01	0.022
Pipe 50	220	101.6	0.005	8.47	1.05	9.86	0.018
Pipe 53	110	609.6	0.005	67.57	0.23	0.08	0.017
Pipe 55	110	254	0.005	34.42	0.68	1.5	0.016

**Table 4.2: Network Data (pipes) for Badarawa/Malali Water Distribution Network with two Reservoirs. After Optimization.(Using OptiNetwork)( continued).**

Link ID	Length m	Diameter mm	Roughness mm	Flow LPS	Velocity m/s	Unit Headloss m/km	Friction Factor
Pipe 56	380	101.6	0.005	15.64	1.93	30.03	0.016
Pipe 59	89	101.6	0.005	1.53	0.19	0.47	0.026
Pipe 70	150	152.4	0.005	32.49	1.78	15.96	0.015
Pipe 73	260	101.6	0.005	4.5	0.56	3.18	0.021
Pipe 79	200	406.4	0.005	22.43	0.17	0.07	0.019
Pipe 80	380	254	0.005	2	0.04	0.01	0.031
Pipe 81	300	152.4	0.005	0.55	0.03	0.01	0.041
Pipe 82	60	558.8	0.005	10.99	0.04	0	0.027
Pipe 83	270	457.2	0.005	8.54	0.05	0.01	0.025
Pipe 86	200	152.4	0.005	-3.92	0.22	0.36	0.023
Pipe 90	380	101.6	0.005	8.06	0.99	9.01	0.018
Pipe 91	250	101.6	0.005	-1.62	0.2	0.52	0.026
Pipe 92	300	101.6	0.005	4.03	0.5	2.61	0.021
Pipe 93	260	304.8	0.005	6.94	0.1	0.04	0.023
Pipe104	200	101.6	0.005	6.87	0.85	6.77	0.019
Pipe105	300	355.6	0.005	4.17	0.04	0.01	0.027
Pipe106	390	254	0.005	3.31	0.07	0.02	0.027
Pipe107	200	304.8	0.005	4.85	0.07	0.02	0.026
Pipe108	300	203.2	0.005	4.24	0.13	0.1	0.024
Pipe109	1000	101.6	0.005	1.68	0.21	0.56	0.026
Pipe110	280	508	0.005	10.86	0.05	0.01	0.024
Pipe111	200	558.8	0.005	8.21	0.03	0	0.029
Pipe 2	350	152.4	0.005	35.97	1.97	19.23	0.015
Pipe 7	120	101.6	0.005	12.87	1.59	21.06	0.017
Pipe 21	110	609.6	0.005	-10.22	0.04	0	0.026
Pipe 25	200	101.6	0.005	8.95	1.1	10.9	0.018
Pump52	#N/A	#N/A	#N/A	197.21	0	-33.23	0



**Table-4.3: Network Data (Junctions) for Badarawa/Malali Water Distribution Network with two Reservoirs. After Optimization (Using OptiNetwork)**

Node ID	Elevation m	Demand LPS	Head m	Pressure m
Junc 2	600	0	615.23	15.23
Junc 3	610	2.35	621.96	11.96
Junc 4	611	2.65	621.97	10.97
Junc 5	655	2.35	712.03	57.03
Junc 6	660	2.55	712.03	52.03
Junc 7	665	2.65	712	47
Junc 11	667	2.55	712.05	45.05
Junc 12	650	2.55	712.05	62.05
Junc 13	703	2.45	713.41	10.41
Junc 14	704	2.45	713.41	9.41
Junc 15	700	2.8	712.05	12.05
Junc 16	675	2.7	712.07	37.07
Junc 17	685	2.45	712.23	27.23
Junc 18	710	2.35	720.04	10.04
Junc 19	715	2.35	724.83	9.83
Junc 20	720	2.25	724.99	4.99
Junc 21	700	2.55	724.95	24.95
Junc 22	660	2.7	711.98	51.98
Junc 24	650	2.35	717.59	67.59
Junc 25	700	2.55	717.61	17.61
Junc 27	718	2.7	722.18	4.18
Junc 37	1351	2.35	1404.36	53.36
Junc 41	1351	2.7	1405.14	54.14
Junc 42	1352	2.8	1405.16	53.16
Junc 45	1353	2.35	1405.64	52.64
Junc 46	1355	2.65	1405.66	50.66
Junc 47	1360	2.25	1424.98	64.98
Junc 48	1353	2.45	1416.6	63.6
Junc 50	700	2.65	727.17	27.17
Junc 51	720	2.7	738.41	18.41
Junc 52	730	2.8	749.68	19.68
Junc 53	755	2.45	767.96	12.96
Junc 54	800	2.65	889.72	89.72
Junc 55	1000	2.7	1067.76	67.76
Junc 56	700	2.35	721.69	21.69
Junc 58	700	2.55	719.09	19.09

**Table-4.3: Network Data (Junctions) for Badarawa/Malali Water Distribution Network with two Reservoirs. After Optimization.(Using OptiNetwork) Continued**

Node ID	Elevation m	Demand LPS	Head m	Pressure m
Junc 59	690	2.25	716.56	26.56
Junc 60	712	2.45	716.56	4.56
Junc 61	693	2.55	713.42	20.42
Junc 62	685	2.65	713.42	28.42
Junc 63	692	2.65	713.42	21.42
Junc 64	696	2.7	713.41	17.41
Junc 65	713	2.8	716.57	3.57
Junc 68	701	2.55	719.09	18.09
Junc 72	701	2.35	719.09	18.09
Junc 73	1353	2.55	1403.79	50.79
Junc 74	1400	2.65	1424.99	24.99
Junc 75	1354	2.45	1405.08	51.08
Junc 78	1351	2.35	1403.78	52.78
Junc 81	709	2.25	716.57	7.57
Junc 82	700	2.35	722.52	22.52
Junc 89	673	2.8	713.42	40.42
Junc100	1380	2.35	1424.96	44.96
Junc109	1349	2.55	1405.1	56.1
Junc110	880	2.25	968.93	88.93
Junc111	1355	2.7	1405.11	50.11
Junc112	1355	2.35	1415.83	60.83
Junc114	1360	2.35	1424.95	64.95
Junc115	1351	2.65	1405.14	54.14
Junc116	1353	2.45	1416.6	63.6
Junc117	1353	2.35	1405.01	52.01
Junc118	654	2.7	711.98	57.98
Junc120	655	2.65	711.98	56.98
Junc 90	1352	2.35	1403.83	51.83
Junc 91	1351	2.35	1403.83	52.83
Junc 92	1351	2.55	1403.79	52.79
Junc 94	1350	2.7	1403.78	53.78
Junc 97	1349	2.35	1403.79	54.79
Junc 57	1350	2.65	1403.79	53.79
Junc 8	1350	2.7	1403.83	53.83
Junc 9	1352	2.55	1405.14	53.14
Junc 10	1350	2.7	1403.79	53.79
Junc 23	1349	2.55	1403.8	54.8
Junc 28	1350	2.7	1403.81	53.81
Junc 29	703	2.65	716.57	13.57
Resvr123Resvr 1	1450	-127.16	1450	0
Resvr 1	582	35.97	582	0
Tank 22	715	-74.01	725	10

## DISCUSSION OF RESULTS

After several runs the cost obtained from this network using OptiNetwork software under the application of genetics algorithm is \$433,520.00 which is lower than \$435,118.00 obtained from OptiDesigner software. This difference is approximately 3% lower than the result obtained from OptiDesigner (a commercial software) with minimum pressure head of 3m and maximum of 100, Pressure penalty of 200,000 and probability of mutation equal to 0.03, also the commercial diameters of 4", 6", 8", 10", 12", 14", 16", 18", 20", 22" and 24"  $d_{min}=4"$ ,  $d_{max}=24"$ ,

were commercial diameters used for the distribution network during the optimization process.

## CONCLUSION

The performance of the OptiNetwork software was compared with OptiDesigner a commercial software package. The results obtained prove the introduction of the OptiNetwork is justified, as it has been able to improve the search in terms of achieving least cost of the distribution network.

## RECOMMENDATION

The use of OptiNetwork software should be encouraged in the design of water distribution network, as it has proved effective in obtaining optimal results satisfying the constraints requirements. Also the use of OptiNetwork software is recommended for solving similar problems in water distribution network,

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