

DEVELOPEMENT OF ANT COLONY COMPUTER-AIDED OPTIMIZATION
SOFTWARE AS A DECISION SUPPORT SYSTEM USING VISUAL BASIC
STUDIO.

ABSTRACT

In this paper a Decision Support System named *W8st colSoft* is developed by employing dynamic programming and swarm intelligence model encoded in Visual Basic Studio 10.0. Solved solutions from literatures were used to validate the developed decision support system. The results obtained from these validation presented an average error margin of 2.58% when compared with that from literature. Also, in order to present the scalability of the swarm intelligence model employed in the developed decision support system, it was used as a decision tool to analyze the collection of solid waste of the University of Port Harcourt three campuses as a whole, unlike recent publication where it was analyzed Campus-wise. The resultant optimal path from the analysis presented a total distance of 15,682m saving a total distance of 17.15m when compared with other route options.

Key Words: Decision Support System, W8st colSoft, Swarm Intelligence, Dynamic Programming.

1. INTRODUCTION

Decision support systems are exclusive class of computerized information system that registers valuable information from primary data, documents personal knowledge and models used as a tool to identify, solve problems and suggest appropriate decisions in a structured and logical way based on scientific facts [1]. Decision Support Systems also referred to as '*system analysis platforms*'[2] can be considered as computer-based systems developed to assist decision makers in problem solving by employing combination of simulation models (SMs), expert systems(ESs) and geographic information systems (GIS)[3].

Chang and Wang [4] made the first attempt to introduce decision support system as a tool to aid management in planning of solid waste collection, recycling and incineration system. Abeliotis and Others [5] grouped Decision Support Systems (DSS) developed for solid waste management into two main categories:

- i. DSS based on applied mathematics, emphasizes application of statistical, optimisation or simulation modelling; and
- ii. DSS that provides specific problem solving expertise stored as facts, rules, and procedures.

Abeliotis and Others [5] further recognised that there are other DSS that use hybrid approaches in providing insights toward efficient solid waste management system.

From researches [6, 7, 8, 9, 10], the development of a decision support system to optimize the collection of solid waste which gulps about 60 - 95% of the total

42 finance budgeted by waste management agencies will aid management in making
43 cost effective decisions and plans.

44

45 2. DEVELOPMENT OF DECISION SUPPORT TOOL (*W8st colSoft*)

46 The development of the decision support tool (*W8st colSoft*) involved the
47 application of Floyd-Warshall's Algorithm (a dynamic programming model) and Ant
48 Colony Optimization Algorithm (a swarm intelligence model).

49 2.1 Floyd-Warshall's Algorithm (Dynamic Programming)

50 Dynamic programming is a numerical programming method commonly used in
51 solving complex problems optimally piece-wise. It combines knowledge of
52 immediate penalty of a decision at hand with knowledge of the future penalties
53 resulting from the immediate decision. It is both a mathematical optimization
54 method and a computer programming method [11]. This numerical technique can be
55 applied to any problem that requires decisions to be made in stages with the
56 objective of finding a minimal penalty decision pathway [12].

57 A problem must possess an optimal substructure; and overlapping sub-problems for
58 it to be solved using dynamic programming algorithm. An optimal substructure
59 entails that the solution to the optimization problem can be obtained by the
60 combination of the optimal solution of its sub-problems. Overlapping sub-problems
61 means that any recursive algorithm solving a sub-problem should be able to solve
62 the other sub-problems instead of generating another new algorithm for the other
63 sub-problems. Dynamic programming has two basic approaches for its
64 implementation; the "*top-down approach*" and the "*bottom-up approach*" [13]. The
65 basic steps in developing a dynamic programming algorithm are:

- 66 a) Characterize the structure of an optimal solution;
- 67 b) Recursively define the value of the Optimal solution;
- 68 c) Compute the value of the optimal solution, usually in a bottom-up
- 69 approach; and
- 70 d) Construct an optimal solution from computed information.

71 Flyod-Warshall's algorithm is a dynamic programming method and it is an algorithm
72 that usually operates on graphs [13]. Its penalty function is the distance between
73 pairs of nodes in a given weighted graph $G = f(V, E)$. The optimal solution of the
74 sub-problems is to obtain the shortest distance between pair of nodes in the given
75 weighted graph. The associated distance between the nodes in the graph represents
76 the weighted function for the edges.

77 In the model development of this research, the node represents solid waste
78 collection points and dumpsites while the weighted function for the edges which
79 connects the nodes represents the relative distance between the solid waste
80 collection points and dumpsites.

81

2.1.1 Developing a Dynamic Program for Shortest-Route Problem using Floyd-Warshall's Algorithm

The various steps involved in developing a dynamic program for shortest –route problem using Floyd-Warshall's Algorithm includes:

Step 1- Structure Characterization:

Assume that the nodes of a given weighted graph $G = f(V, E)$ are

$V = \{1, 2, 3, \dots, n\}$.

Let a subset of some nodes say $K = \{1, 2, 3, \dots, k\}$.

For any pair of nodes $i, j \in V$, consider all paths from i to j with intermediate nodes belonging to the subset $\{1, 2, 3, \dots, k\}$ and let the minimum weight path among these nodes be p .

Floyd-Warshall's algorithm works in a way that it exploits the relationship that exist between the minimum weighted path p and the shortest paths from i to j with all the intermediate nodes in the subset $\{1, 2, 3, \dots, k\}$. The relationship constraint is on the condition of k being an intermediate node of the path p or not:

- i. If k is not an intermediate node of path p , then all intermediate nodes of path p are elements of the set $\{1, 2, 3, \dots, k-1\}$. Thus, a shortest path from nodes i to j with all intermediate nodes in the set $\{1, 2, 3, \dots, k-1\}$ is also a shortest path from i to j with intermediate nodes in the set $\{1, 2, 3, \dots, k\}$.
- ii. If k is an intermediate node of path p , then the path p is broken down or say decomposed into two path p_1 and p_2 , where $p_1 = i \rightsquigarrow k$ and $p_2 = k \rightsquigarrow j$. That is path p will then be:

$$p = p_1 + p_2 = i \rightsquigarrow k \rightsquigarrow j$$

It follows that p_1 is the shortest path from i to k having all intermediate nodes as elements of the set $\{1, 2, 3, \dots, k-1\}$, also p_2 is the shortest path from k to j with all intermediate nodes in the set $\{1, 2, 3, \dots, k-1\}$.

Step 2 – Definition of the value of the optimal solution recursively:

From nodes i to j for which all intermediate nodes are elements of the set $\{1, 2, 3, \dots, k\}$, let $d_{ij}^{(k)}$ be the weight factor. When $k=0$, the path from nodes i to j has no intermediate nodes numbered higher than 0. It implies that such path has at most one edge and hence, $d_{ij}^{(0)} = w_{ij}$, where: w_{ij} is the value of the weight factor with respect to the edge between nodes i & j .

Defining $d_{ij}^{(k)}$ recursively with respect to the above statements will be:

$$d_{ij}^{(k)} = \begin{cases} w_{ij} & \text{if } k = 0. \\ \min(d_{ij}^{(k-1)}, d_{ik}^{(k-1)} + d_{kj}^{(k-1)}) & \text{if } k \geq 1. \end{cases} \quad (1)$$

118 Note: For any path, all intermediate nodes are elements in the set $\{1, 2,$
 119 $3, \dots, n\}$, hence the matrix $D^{(n)} = (d_{ij}^{(n)})$ gives the final solution:
 120 $d_{ij}^{(k)} = \delta(i, j)$ for all $i, j \in V$.

121 **Step 3** – Compute the value of the optimal solution (bottom-up approach):

122 Using Equation (1), compute the values of $d_{ij}^{(k)}$ in order of increasing values
 123 of k using the bottom up approach (Table 1). The input used by this approach
 124 is a $n \times n$ matrix W is presented as Equation (2):

$$125 \quad w_{ij} = \begin{cases} 0 & \text{if } i = j. \\ \text{the weight of directed edge } (i, j) & \text{if } i \neq j \text{ and } (i, j) \in E, \\ \infty & \text{if } i \neq j \text{ and } (i, j) \notin E. \end{cases} \quad (2)$$

126 Note: From Equation (2) it follows that if there is no direct path
 127 connecting nodes i to j the weight of the edge between the nodes
 128 $= \infty$ (or say NIL).

129 Table 1 Final computation of the value of the optimal solution.

Input initial $n \times n$ matrix W (see Equation (2))

$D^{(0)} = W$

for $k=1$ to n

let $D^{(k)} = (d_{ij}^{(k)})$ be a new $n \times n$ matrix

for $i=1$ to n

for $j=1$ to n

$$d_{ij}^{(k)} = \min(d_{ij}^{(k-1)}, d_{ik}^{(k-1)} + d_{kj}^{(k-1)})$$

Return $D^{(n)}$ (optimal solution i.e. Matrix of pairs of shortest path weight).

130 **Step 4** – Construction of Optimal Solution:

131 The optimal solution is constructed based on the computed information from
 132 step 3. The pseudo code for the construction of the optimal solution is
 133 presented in Table 2. The code assumes an input graph of N nodes.

134 Table 2: Pseudo code for Optimal Solution Construction

135 Start

136 for $i = 1$ to N

137 for $j = 1$ to N

138 if there is an edge from i to j

139 $d_{ij}^{(0)} = w_{ij}$

140 else

141 $d_{ij}^{(0)} = \infty$

142 for $k = 1$ to N

143 for $i = 1$ to N

144 for $j = 1$ to N

145 $d_{ij}^{(k)} = \min(d_{ij}^{(k-1)}, d_{ik}^{(k-1)} + d_{kj}^{(k-1)})$

146 End

147 2.2 Swarm Intelligence (SI)

148 Swarm Intelligence is a group of computational intelligence that represents
 149 algorithms developed or modeled from the study of swarming behaviors in nature
 150 such as the social behavior of organisms in swarm [14]. It uses group of simple
 151 individuals to solve complex problems through simple and binary interactions.
 152 Swarm Intelligence has a goal to design intelligent multi-agent systems by taking
 153 inspiration from the collective behavior of social insects, for example, the social
 154 and foraging behavior of ants in colonies; the bee colony; the graceful, but
 155 unpredictable, choreography of bird flocks; school of fish; and aggregating slime
 156 molds. Swarm Intelligence algorithms are most useful for problems that are dynamic
 157 in nature and are amendable to an agent based decomposition.

158 2.2.1 Ant Colony Optimization (ACO)

159 Biologists have proven that the self-organizing behavior of social insects can be
 160 presented through simple models using only *stigmergic* interaction [15]. Ant colony
 161 optimization involves a colony of artificial ants which are abstractions from the
 162 behavioral traits of real ants cooperating in finding better solutions to different
 163 discrete optimization problems. The similarities between real ants and artificial ants
 164 which is exploited in ACO [16] include:

- 165 i. The use of a colony of cooperate individual into finding a better global
 166 solution to the problem/task under consideration;
- 167 ii. The use of artificial pheromone trail for *stigmergic* interaction;
- 168 iii. The use of a local move to find the shortest path between the origin
 169 (nest) and the destination (food site); and
- 170 iv. The use of a probabilistic decision policy to move through adjacent
 171 nodes.

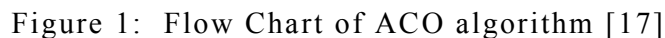
172 The Ant Colony Optimization algorithm has two basic components [17]:

- 173 i. Pheromone trail on arc $(i, j), \tau_{ij}$; and
- 174 ii. Heuristic value of arc $(i, j), \eta_{ij}$. This has to do with the desirability of
 175 the arc.

176 In ant colony optimization algorithm, every step in which all the ants involved in
 177 the problem solution achieves a feasible solution is referred to as an *iteration*. The
 178 flow chart for the Ant Colony Optimization algorithm used for the development of
 179 the decision support system (*W8st colSoft*) is presented in Figure 1. With reference
 180 to the developed decision support system, each node in the program represents waste
 181 collection point/dumpsite while the connecting arc represents the route connecting
 182 two collection points/dumpsites.

183 The program commences with the specification of the various variables (α, β, ρ, n) .
 184 α & β are positive parameters assigned values 1 & 2 respectively to control the
 185 relative weight of *pheromone* information T_{ij} . ρ is the *pheromone* evaporation
 186 parameter which usually ranges between 0 to 1 but for the case of the developed

187 decision support system was assigned the value of 0.5 . n represents the number of
188 waste collection points (nodes).



3. DESCRIPTION OF THE DEVELOPED DECISION SUPPORT SYSTEM

The input data used by the developed decision support system is mainly the distances/positions of solid waste collection points/dumpsites. The decision support system employs mainly two models (Dynamic programming model and Swarm intelligence model) encoded in Visual Basic Studio 2010. Figure 2 presents the splash screen from the developed decision support system (*W8st colSoft*). The developed decision support system has the property that supports the importation of files (usually maps of road network) with file extension of *jpg*, *jpeg*, *bmp*, and *png* which could be used as the background to aid the easy location of waste collection points/dumpsites. These collection points are connected with straight lines which when right clicked on opens a property table where the relative distance of the connecting route between the waste collection points are entered (see Figure 3). This property includes the route name (or street name), the relative distance (in metres) between collection points, the traffic flow direction through the route (that is, one way or two way traffic flow direction(s)).



Figure 2: Splash Screen of Developed Decision Support System (*W8st colSoft*)

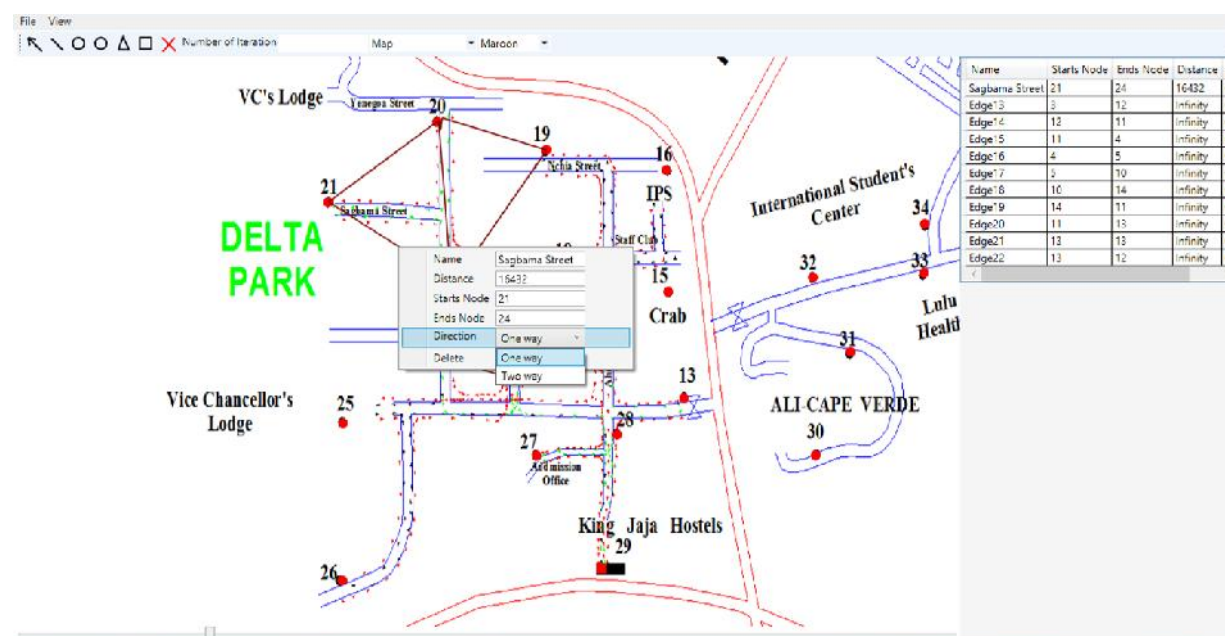


Figure 3: Display Screen of Decision Support System when performing an analysis

The tool bar consists of icons (from left to right) whose properties include, selection of elements, placement of collection points, deleting of elements, number of iterations and colour assignment for collection points, connecting arc and

background input properties. Also on the far end of the display screen is a table
being formed as the collection points are placed and assigned properties (see Figure
3).

3.1 Solving a Hypothetical Problem Using *W8st colSoft*

A sketch of the road network of an estate (Figure 4) with solid waste collection
points labeled 1-5 is presented and the management of the estate wants to make the
best decision on how to effectively collect the solid waste generated within the
proposed estate.

Given: Distance between collection points

Point 1 - Point 2 = 65m

Point 2 - Point 3 = 45m

Point 3 - Point 4 = 50m

Point 1 - Point 5 = 80m

Point 4 - Point 5 = 65m

$\alpha = 1$; $\beta = 2$; and $\rho = 0.5$

where α and β = weighting constants

ρ = pheromone evaporation constant

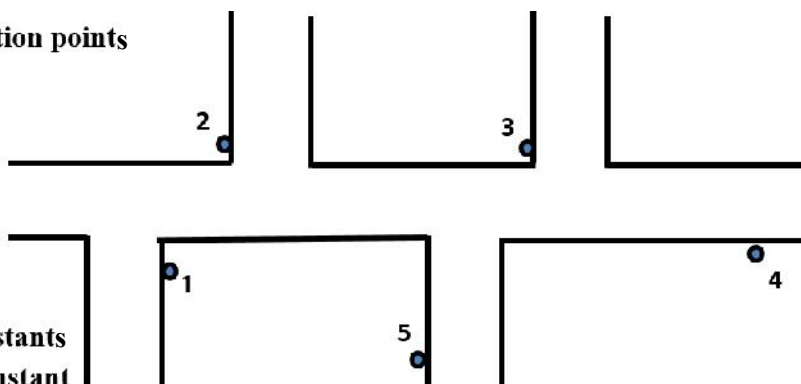


Figure 4: Road Network of Hypothetical Estate with waste collection points

The following step will take one through the basics in applying *W8st colSoft* in
solving a problem.

Step 1: Call up the Decision Support System from the installed program on your
computer desk top by double clicking;

Step 2: Import map of proposed problem area and insert the collection points (see
Figure 5);

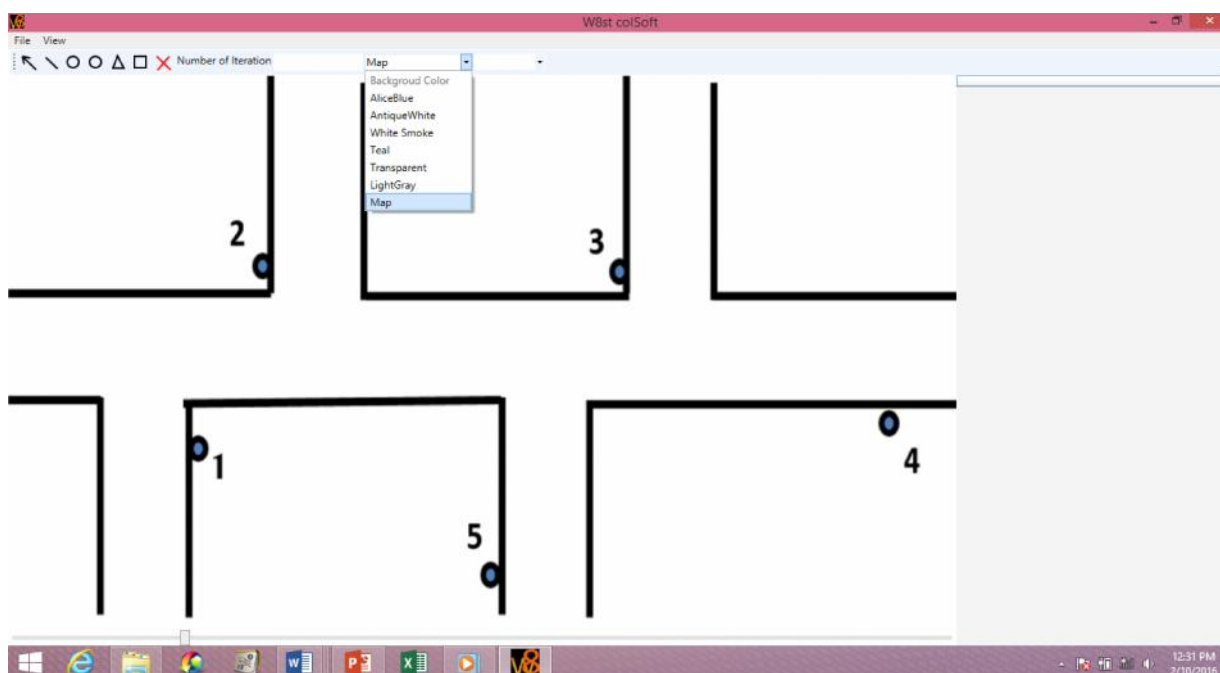


Figure 5: Screen shot of w8st colSoft with map being imported

Step 3: Insert the connecting arc to the collection points 1,2,...,5 and left click once and right click also on the connecting arc to open a property box where the details of the arc will be inserted in terms of distance, collection points at its end and beginning, the nature of the route if it is a one way traffic route or a two way(see Figure 6).Note for this analysis the direction of traffic flow is assumed to be two way; and

Step 4: Click on the View Tab on the Menu bar to view the results of the analysis with respect to the computed initial pheromone, input relative nodal distances, computed pairs of shortest distances, computed heuristic values for each arc, and the Computed tour path (see Figure 7).

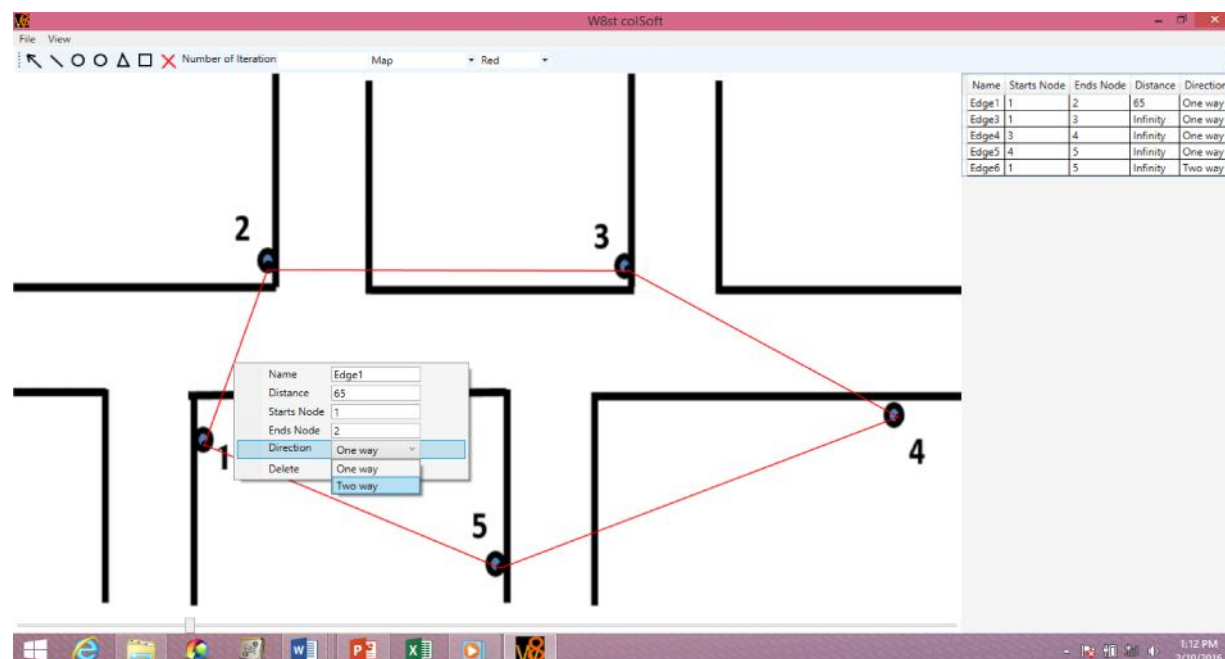


Figure 6: Screen shot with collection points being connected and assigned properties with respect to the connecting road network.

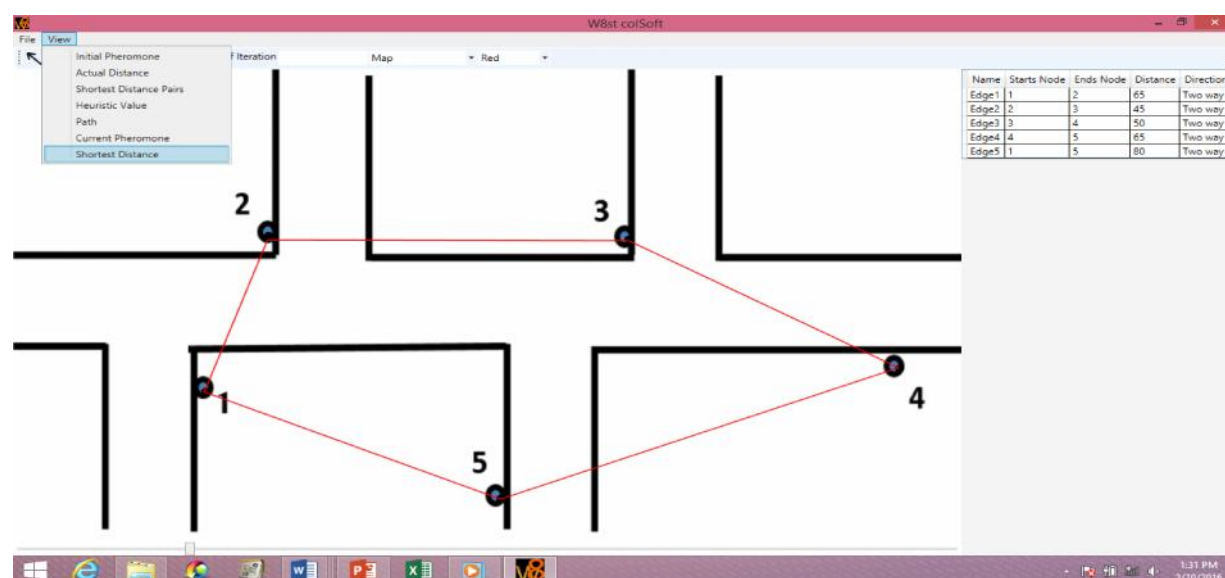


Figure 7: Screen shot with a drop down menu on resultant outputs from analysis.

The resultant outputs from the developed decision support system (*W8st colSoft*) for the hypothetical problem is presented along with the manual calculation for the problem in *Appendixes A1 & A2*

4. DECISION SUPPORT TOOL EVALUATION AND VERIFICATION

Solved example problem from a Textbook [18] was used to validate the accuracy of the developed decision support system (*W8st colSoft*) (see Figure 8). The resultant output with regards to the application of Flyod-Warshall's algorithm (dynamic programming) is presented in *Table 3*. Also in validating the DST (Decision Support Tool) as regards decision to aid the optimization of solid waste collection, a solved example problem (see Figure 9) from a research publication [19] was used and the result is presented in *Table 4*. Furthermore, the developed DST was applied to aid decision to optimize the solid waste route for the University of Port Harcourt [17] and a plot of the resultant output is presented in Figure 10.

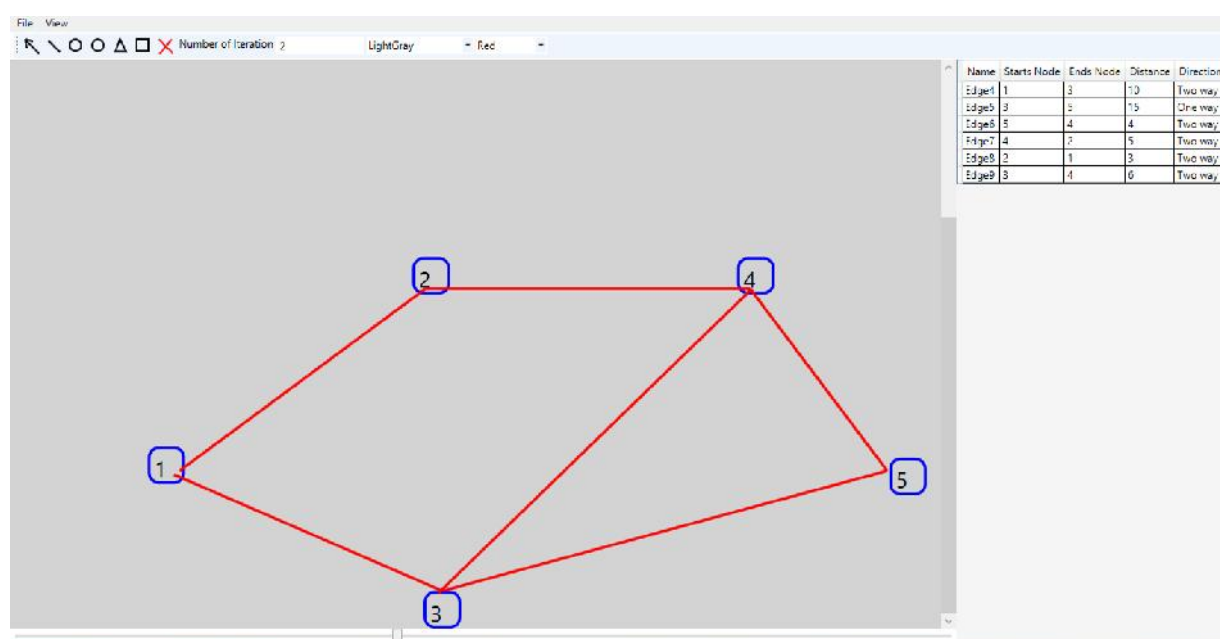


Figure 8: Screen shot of Developed Decision System showing the analysis for the validation using solved example from Textbook with regards to Dynamic Programming model.

Table 3: Output from *W8st colSoft* using data from Textbook exercise [17].

Location	Node1	Node2	Node3	Node4	Node5
Node1	0	3	10	8	12
Node2	3	0	11	5	9
Node3	10	11	0	6	10
Node4	8	5	6	0	4
Node5	12	9	10	4	0

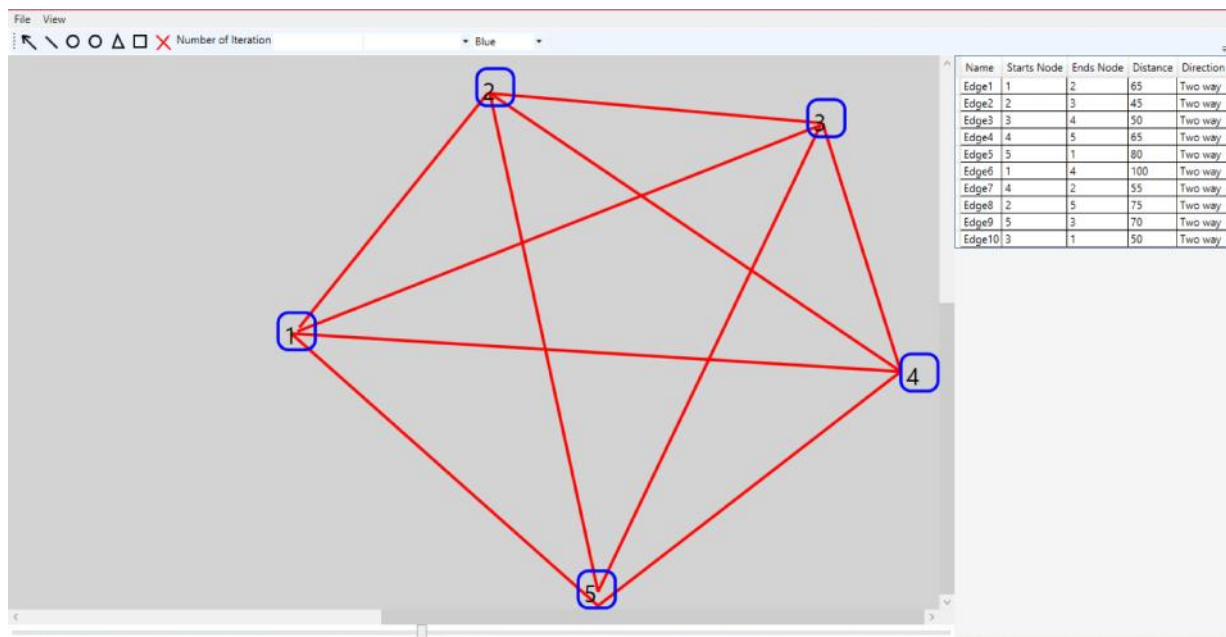


Figure 9: Screen shot of *W8st colSoft* showing the analysis for the validation using solved example from Publication [19] with regards to Ant Colony Optimization Algorithm

Table 4: *W8st colSoft* output using data from research publication [19] with regards to Ant Colony Optimization Algorithm as input data.

Output	Values	No. of iterations
Research Publication	215m	5
W8st colSoft	215m	2
Error	0	-

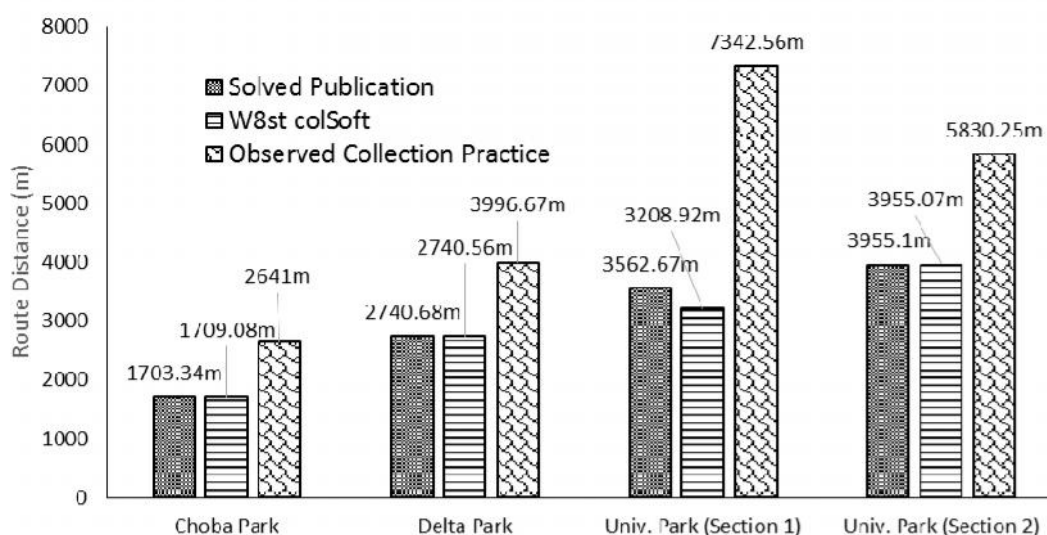
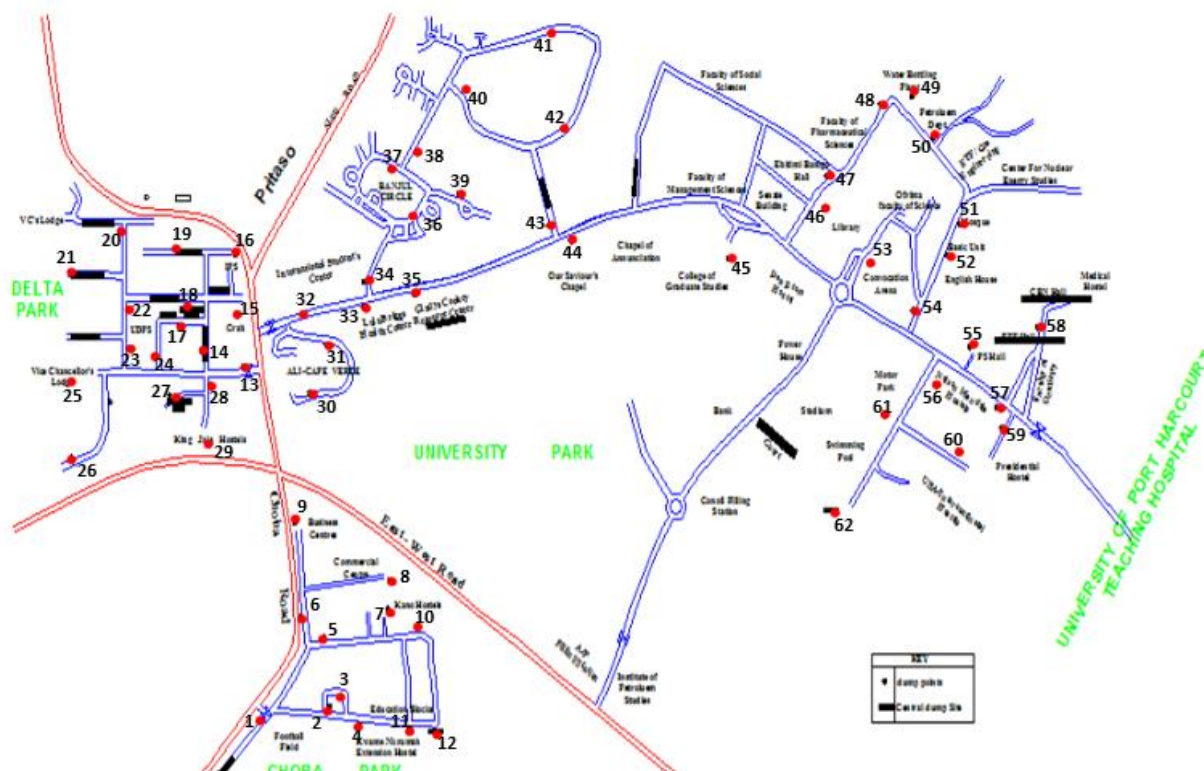


Figure 10: Plot of the Optimal route distance on University of Port Harcourt 3 campuses using *W8st colSoft* and results of analysis from published literature.

305 In an attempt to present the advantage of the developed decision support system
306 (*W8st colSoft*) over the analysis made in earlier publication [17] the solid waste
307 collection at the University of Port Harcourt three campuses clustered together is
308 analyzed as a whole (instead of campus by campus)(see Figure 11).



Source: Bovwe and Nwaogazie [17]

Figure 11: Road Network of the University of Port Harcourt showing solid waste collection points.

The resultant final optimized route for the collection of the generated solid waste within the University takes path (see Appendix A):

53=>62=>60=>61=>56=>58=>59=>57=>55=>54=>52=>51=>50=>49=>48=>47=>46=>45=>44=>43=>42=>40=>38=>37=>36=>39=>41=>31=>32=>33=>34=>35=>30=>13=>28=>14=>17=>24=>23=>22=>18=>16=>19=>20=>21=>25=>26=>27=>29=>15=>1=>2=>3=>4=>11=>12=>10=>7=>5=>6=>9=>8

5. DISCUSSION

The application of *w8st colSoft* in solving the hypothetical problem when compared with the stress involved in doing the manual calculation (see Appendixes A1 & A2) presents a better approach in solving the problem with ease and a higher degree of precision especially when dealing with a more complex network of waste collection problem.

The result from the validation of the developed decision support system (*W8st colSoft*) using example from literature (see Table 4) yielded the same result (215m) at its 2nd iteration unlike the analysis from literature which converged on its 5th iteration. Also as presented in Figure 10, the decision support system (*W8st*

colSoft) was validated using another publication from literature on the optimization of solid waste collection from the University of Port Harcourt. The simulated output from the developed decision system when compared with those from the literature yielded error margins of 0.34, 0.04, 9.93, and 0.00076% for Choba Park, Delta Park and the University Park (sections 1 & 2) campuses, respectively.

The simulated output from the developed decision support system (*W8st colSoft*) when used as a tool to aid the choice for the optimal routing of solid waste collection within the University of Port Harcourt combining the three Campuses together instead of taking them individually presented an optimal path distance of 15,682m (Node 53) saving a total distance of 17.15m when compared with other route options (see Appendix B).

6. CONCLUSION

The results presented by the decision support system (*W8st colSoft*) make suggestions of various routes that could be taken with the path gained as a result of such choice. As a result one has the options of making aided decisions with practical/feasible field condition such traffic and road network conditions. The developed decision support system (*W8st colSoft*) is a very handy tool in the efficient management of solid waste using dynamic and swarm intelligence model. The comparison of the results from the developed decision system and that of literatures presents an average error margin of 2.58% making it a reliable tool that could be employed in efficient solid waste management system reducing the cost of solid waste collection. The graphical user interface GUI and the scalability of swarm intelligence model makes the developed decision support system user friendly with ease and be applied in route optimization of solid waste collection on a much larger scale.

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APPENDIX A

A1: MANUAL CALCULATION OF HYPOTHETICAL PROBLEM

The table of relative distance is formed using the given data on the distances between nodes (*see Table A1*).

Table A1: Initial relative distances between nodes/collection points

	1	2	3	4	5
1	0	65	infinity	infinity	80
2	65	0	45	infinity	infinity
3	infinity	45	0	50	infinity
4	infinity	infinity	50	0	65
5	80	infinity	infinity	65	0

417 Note: “*Nil*” is inputted into nodes where there is no direct connectivity. That is, it
 418 is assumed that there is a kind of obstruction between the nodes and as such there is
 419 no direct connection between them. Also, it is assumed that an ant is placed on each
 420 of the nodes. Therefore the initial pheromone $\tau_0 = \frac{1}{n}$, for each node

421 $n = 5$; $\tau_0 = \frac{1}{5} = 0.2$. Therefore forming a initial pheromone matrix (see Table A2):

422 Table A2: Initial Pheromone τ_0

	1	2	3	4	5
1	0.2	0.2	0.2	0.2	0.2
2	0.2	0.2	0.2	0.2	0.2
3	0.2	0.2	0.2	0.2	0.2
4	0.2	0.2	0.2	0.2	0.2
5	0.2	0.2	0.2	0.2	0.2

423 Applying Floyd Warshall’s algorithm to compute the pairs of shortest distances (
 424 d_{ij}) (see Table A3).

425 Table A3: Pairs of shortest distances between nodes

	1	2	3	4	5
1	0	65	110	145	80
2	65	0	45	95	145
3	110	45	0	50	115
4	145	95	50	0	65
5	80	145	115	65	0

426 The Heuristic information η_{ij} computed as presented in Table A4 is given by $\eta_{ij} = \frac{1}{d_{ij}}$

427 Table A4: Computed Heuristic information

	1	2	3	4	5
1	0	0.015	0.009	0.007	0.013
2	0.015	0	0.022	0.011	0.007
3	0.009	0.022	0	0.020	0.009
4	0.007	0.011	0.020	0	0.015
5	0.013	0.007	0.009	0.015	0

428

429 The probability of an ant making its choice on adjacent node to go is given by:

$$P_{ij}^k = \frac{\tau_{ij}^\alpha \eta_{ij}^\beta}{\sum_{i=N_i^k} \tau_{ij}^\alpha \eta_{ij}^\beta}$$

430

431 **Taking Ant 1:** Using the values from Tables 2 & 4, the probability for ant starting
 432 at node 1 is:

$$P_{12}^1 = \frac{(0.2)^1(0.015)^2}{[(0.2)^1(0.015)^2] + [(0.2)^1(0.009)^2] + [(0.2)^1(0.007)^2] + [(0.2)^1(0.013)^2]} = 0.429$$

$$P_{13}^1 = \frac{(0.2)^1(0.009)^2}{[(0.2)^1(0.015)^2] + [(0.2)^1(0.009)^2] + [(0.2)^1(0.007)^2] + [(0.2)^1(0.013)^2]} = 0.155$$

$$P_{14}^1 = \frac{(0.2)^1(0.007)^2}{[(0.2)^1(0.015)^2] + [(0.2)^1(0.009)^2] + [(0.2)^1(0.007)^2] + [(0.2)^1(0.013)^2]} = 0.094$$

$$P_{15}^1 = \frac{(0.2)^1(0.013)^2}{[(0.2)^1(0.015)^2] + [(0.2)^1(0.009)^2] + [(0.2)^1(0.007)^2] + [(0.2)^1(0.013)^2]} = 0.323$$

From the above solution the node with the highest probability (**node 2**) is obviously chosen by ant 1 as the adjacent node. From node 2, the probability of ant 1 to choose the next node is given by:

$$P_{23}^1 = \frac{(0.2)^1(0.022)^2}{[(0.2)^1(0.022)^2] + [(0.2)^1(0.011)^2] + [(0.2)^1(0.007)^2]} = 0.740$$

$$P_{24}^1 = \frac{(0.2)^1(0.011)^2}{[(0.2)^1(0.022)^2] + [(0.2)^1(0.011)^2] + [(0.2)^1(0.007)^2]} = 0.185$$

$$P_{25}^1 = \frac{(0.2)^1(0.001)^2}{[(0.2)^1(0.022)^2] + [(0.2)^1(0.011)^2] + [(0.2)^1(0.007)^2]} = 0.075$$

From the above solution the node with the highest probability (**node 3**) is obviously chosen by ant 1 as the adjacent node. From node 3, the probability of ant 1 to choose the next node is given by:

$$P_{34}^1 = \frac{(0.2)^1(0.020)^2}{[(0.2)^1(0.020)^2] + [(0.2)^1(0.009)^2]} = 0.832$$

$$P_{35}^1 = \frac{(0.2)^1(0.009)^2}{[(0.2)^1(0.020)^2] + [(0.2)^1(0.009)^2]} = 0.168$$

From the above result, **node 4** has the highest probability, thus Ant 1 moves from node 2 to node 3 and to node 4, then finally node 5 (being the only node left)

Tour path of Ant 1 = **1- 2-3 – 4- 5**

The above analysis is repeated for Ant 2, Ant 3, Ant 4 and Ant 5, respectively.

Table A5 presents the resultant of the solution.

457

Table A5: Summary of Computation for Hypothetical Problem

Ant	Path Taken	L (m)	$\Delta\tau$
1	1-2-3-4-5	225	2.578
2	2-3-4-5-1	240	2.417
3	3-2-1-5-4	255	2.275
4	4-3-2-1-5	240	2.417
5	5-4-3-2-1	225	2.578

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459 **A2: OUTPUT OF HYPOTHETICAL PROBLEM FROM DEVELOPED**
 460 **DECISION SUPPORT SYSTEM (W8st colSoft) SIMULATION**

461 <-----Final Distance Matrix----->

462	Point	Nodes				
463	Node1	0.00	65.00	110.00	145.00	80.00
464	Node2	65.00	0.00	45.00	95.00	145.00
465	Node3	110.00	45.00	0.00	50.00	115.00
466	Node4	145.00	95.00	50.00	0.00	65.00
467	Node5	80.00	145.00	115.00	65.00	0.00
468						

469 Iteration 1

470 <-----Pheromone----->

471	Point	Nodes				
472	Node1	0.00	0.20	0.20	0.20	0.20
473	Node2	0.20	0.00	0.20	0.20	0.20
474	Node3	0.20	0.20	0.00	0.20	0.20
475	Node4	0.20	0.20	0.20	0.00	0.20
476	Node5	0.20	0.20	0.20	0.20	0.00

477 <-----Path Followed----->

478	Point	Nodes					Length	Path Gain
479	Node1	1	2	3	4	5	225.00	2.58
480	Node2	2	3	4	5	1	240.00	2.42
481	Node3	3	2	1	5	4	255.00	2.27
482	Node4	4	3	2	1	5	240.00	2.42
483	Node5	5	4	3	2	1	225.00	2.58

484 <-----Minimum Path----->

485	Point	Nodes					Length	Path Gain
486	Node1	1	2	3	4	5	225.00	2.58
487								

488 Iteration 2

489 <-----Pheromone----->

490	Point	Nodes				
491	Node1	0.00	9.95	0.10	0.10	7.21
492	Node2	9.95	0.00	12.36	0.10	0.10
493	Node3	0.10	12.36	0.00	10.09	0.10
494	Node4	0.10	0.10	10.09	0.00	9.95
495	Node5	7.21	0.10	0.10	9.95	0.00

496 <-----Path Followed----->

497	Point	Nodes					Length	Path Gain
-----	-------	-------	--	--	--	--	--------	-----------

498	Node1	1	2	3	4	5	225.00	2.58
499	Node2	2	3	4	5	1	240.00	2.42
500	Node3	3	2	1	5	4	255.00	2.27
501	Node4	4	3	2	1	5	240.00	2.42
502	Node5	5	4	3	2	1	225.00	2.58
503	<-----Minimum Path----->							
504	Point				Nodes		Length	Path Gain
505	Node1	1	2	3	4	5	225.00	2.58

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APPENDIX B:
OUTPUT FROM DEVELOPED DECISION SUPPORT SYSTEM FOR ANALYSIS OF UNIVERSITY OF PORT HARCOURT
SOLID WASTE COLLECTION

NODE		<-----PATH FOLLOWED----->																		
		NODES																		
		LENGTH		PATH GAIN																
Node1	1	2	3	4	11	12	10	7	5	6	9	8	39	36	34	33	35	32	31	30
	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	38	37	40
	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
	53	41	17646.33		15.24															
Node2	2	3	4	11	12	10	7	5	6	9	8	1	15	29	27	28	14	17	24	23
	22	18	16	19	20	21	25	26	13	30	32	33	34	35	36	39	38	37	40	42
	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
	41	31	17022.12		15.80															
Node3	3	2	1	5	6	9	8	7	10	12	11	4	13	28	14	17	24	23	22	18
	16	19	20	21	25	26	27	29	15	30	32	33	34	35	36	39	38	37	40	42
	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
	41	31	17339.31		15.51															
Node4	4	11	12	10	7	5	6	9	8	1	2	3	13	28	14	17	24	23	22	18
	16	19	20	21	25	26	27	29	15	30	32	33	34	35	36	39	38	37	40	42
	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
	41	31	17313.56		15.54															
Node5	5	6	9	8	1	2	3	4	11	12	10	7	13	28	14	17	24	23	22	18
	16	19	20	21	25	26	27	29	15	30	32	33	34	35	36	39	38	37	40	42
	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
	41	31	17403.77		15.46															
Node6	6	5	7	10	12	11	4	3	2	1	15	29	27	28	14	17	24	23	22	18
	16	19	20	21	25	26	13	30	32	33	34	35	36	39	38	37	40	42	43	44
	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41	31
	9	8	17972.34		14.97															
Node7	7	10	12	11	4	3	2	1	5	6	9	8	39	36	34	33	35	32	31	30
	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	38	37	40
	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
	53	41	17652.12		15.24															
Node8	8	9	6	5	7	10	12	11	4	3	2	1	15	29	27	28	14	17	24	23
	22	18	16	19	20	21	25	26	13	30	32	33	34	35	36	39	38	37	40	42
	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
	41	31	16621.35		16.18															
Node9	9	6	5	7	10	12	11	4	3	2	1	15	29	27	28	14	17	24	23	22
	18	16	19	20	21	25	26	13	30	32	33	34	35	36	39	38	37	40	42	43
	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41
	31	8	17979.30		14.96															
Node10	10	7	5	6	9	8	1	2	3	4	11	12	13	28	14	17	24	23	22	18
	16	19	20	21	25	26	27	29	15	30	32	33	34	35	36	39	38	37	40	42

553		43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
554		41	31	17406.16		15.45															
555	Node11	11	4	3	2	1	5	6	9	8	7	10	12	13	28	14	17	24	23	22	18
556		16	19	20	21	25	26	27	29	15	30	32	33	34	35	36	39	38	37	40	42
557		43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
558		41	31	17527.00		15.35															
559	Node12	12	11	4	3	2	1	5	6	9	8	7	10	13	28	14	17	24	23	22	18
560		16	19	20	21	25	26	27	29	15	30	32	33	34	35	36	39	38	37	40	42
561		43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
562		41	31	17445.05		15.42															
563	Node13	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	30	32	33
564		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
565		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
566		9	8	16840.09		15.97															
567	Node14	14	28	13	30	32	33	34	35	36	39	38	37	40	42	43	44	45	46	47	48
568		49	50	51	52	54	55	57	59	58	56	61	60	62	53	41	31	15	29	27	26
569		25	21	20	19	16	18	22	23	24	17	1	2	3	4	11	12	10	7	5	6
570		9	8	17091.36		15.74															
571	Node15	15	29	27	28	14	17	24	23	22	18	16	19	20	21	25	26	13	30	32	33
572		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
573		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
574		9	8	16521.43		16.28															
575	Node16	16	19	20	21	25	26	27	29	15	17	14	28	13	30	32	33	34	35	36	39
576		38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56
577		61	60	62	53	41	31	24	23	22	18	1	2	3	4	11	12	10	7	5	6
578		9	8	17075.31		15.75															
579	Node17	17	14	28	13	30	32	33	34	35	36	39	38	37	40	42	43	44	45	46	47
580		48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41	31	15	29	27
581		26	25	21	20	19	16	18	22	23	24	1	2	3	4	11	12	10	7	5	6
582		9	8	17071.68		15.76															
583	Node18	18	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38	37	40	42	43
584		44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41
585		31	15	29	27	26	25	21	20	19	16	1	2	3	4	11	12	10	7	5	6
586		9	8	17203.42		15.64															
587	Node19	19	16	18	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38	37	40
588		42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
589		53	41	31	15	29	27	26	25	21	20	1	2	3	4	11	12	10	7	5	6
590		9	8	17423.58		15.44															
591	Node20	20	19	16	18	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38	37
592		40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60
593		62	53	41	31	15	29	27	26	25	21	1	2	3	4	11	12	10	7	5	6
594		9	8	17436.05		15.43															
595	Node21	21	20	19	16	18	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38
596		37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61
597		60	62	53	41	31	15	29	27	26	25	1	2	3	4	11	12	10	7	5	6
598		9	8	17028.99		15.80															
599	Node22	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38	37	40	42	43	44
600		45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41	31

601		15	29	27	26	25	21	20	19	16	18	1	2	3	4	11	12	10	7	5	6
602		9	8	17244.85		15.60															
603	Node23	23	22	18	16	19	20	21	25	26	27	29	15	17	14	28	13	30	32	33	34
604		35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57
605		59	58	56	61	60	62	53	41	31	24	1	2	3	4	11	12	10	7	5	6
606		9	8	17072.81		15.76															
607	Node24	24	23	22	18	16	19	20	21	25	26	27	29	15	17	14	28	13	30	32	33
608		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
609		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
610		9	8	16526.14		16.28															
611	Node25	25	26	27	29	15	16	19	20	21	18	22	23	24	17	14	28	13	30	32	33
612		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
613		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
614		9	8	16404.06		16.40															
615	Node26	26	25	21	20	19	16	18	22	23	24	17	14	28	13	30	32	33	34	35	36
616		39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58
617		56	61	60	62	53	41	31	15	29	27	1	2	3	4	11	12	10	7	5	6
618		9	8	16638.73		16.17															
619	Node27	27	29	15	16	19	20	21	25	26	24	23	22	18	17	14	28	13	30	32	33
620		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
621		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
622		9	8	16271.32		16.53															
623	Node28	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	30	13	31	32
624		33	34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54
625		55	57	59	58	56	61	60	62	53	41	1	2	3	4	11	12	10	7	5	6
626		9	8	17016.60		15.81															
627	Node29	29	27	28	14	17	24	23	22	18	16	19	20	21	25	26	13	30	32	33	34
628		35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57
629		59	58	56	61	60	62	53	41	31	15	1	2	3	4	11	12	10	7	5	6
630		9	8	16841.47		15.97															
631	Node30	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	1	2
632		3	4	11	12	10	7	5	6	9	8	39	36	34	33	35	32	31	41	53	62
633		60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40
634		38	37	18379.90		14.64															
635	Node31	31	32	33	34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51
636		52	54	55	57	59	58	56	61	60	62	53	41	30	13	28	14	17	24	23	22
637		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
638		9	8	16621.35		16.18															
639	Node32	32	33	34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52
640		54	55	57	59	58	56	61	60	62	53	41	31	30	13	28	14	17	24	23	22
641		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
642		9	8	16720.69		16.09															
643	Node33	33	34	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26
644		27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	39	36	37	38	40
645		42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
646		53	41	17368.45		15.49															
647	Node34	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26
648		27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	39	36	37	38	40

649		42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
650		53	41	17370.15		15.49															
651	Node35	35	34	33	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26
652		27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	39	36	37	38	40
653		42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
654		53	41	17289.31		15.56															
655	Node36	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59
656		58	56	61	60	62	53	41	31	32	33	34	35	30	13	28	14	17	24	23	22
657		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
658		9	8	16733.98		16.07															
659	Node37	37	38	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56
660		61	60	62	53	41	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22
661		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
662		9	8	15966.36		16.85															
663	Node38	38	37	36	39	41	31	32	33	34	35	44	43	42	40	30	13	28	14	17	24
664		23	22	18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7
665		5	6	9	8	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60
666		62	53	18886.34		14.24															
667	Node39	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21
668		25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37	38	40
669		42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
670		53	41	17357.48		15.50															
671	Node40	40	38	37	36	39	41	31	32	33	34	35	44	43	42	45	46	47	48	49	50
672		51	52	54	55	57	59	58	56	61	60	62	53	13	28	14	17	24	23	22	18
673		16	19	20	21	25	26	27	29	15	30	1	2	3	4	11	12	10	7	5	6
674		9	8	18118.92		14.85															
675	Node41	41	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20
676		21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37	38
677		40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60
678		62	53	16453.44		16.35															
679	Node42	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
680		53	41	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19
681		20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37
682		38	40	17835.35		15.08															
683	Node43	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
684		41	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20
685		21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37	38
686		40	42	17928.00		15.00															
687	Node44	44	43	42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24
688		23	22	18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7
689		5	6	9	8	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60
690		62	53	17966.79		14.97															
691	Node45	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41	39
692		36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21	25
693		26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37	38	40	42
694		43	44	17589.95		15.29															
695	Node46	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	45	44	43
696		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22

697		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
698		9	8	15804.01		17.02															
699	Node47	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	45	46	44	43
700		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
701		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
702		9	8	16408.37		16.39															
703	Node48	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	45	46	47	43	44
704		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
705		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
706		9	8	16698.63		16.11															
707	Node49	49	48	47	46	45	44	43	42	40	38	37	36	39	41	31	32	33	34	35	30
708		13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	1	2	3
709		4	11	12	10	7	5	6	9	8	50	51	52	54	55	57	59	58	56	61	60
710		62	53	19275.55		13.96															
711	Node50	50	51	52	54	55	57	59	58	56	61	60	62	53	45	46	47	48	49	44	43
712		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
713		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
714		9	8	16738.78		16.07															
715	Node51	51	52	54	55	57	59	58	56	61	60	62	53	45	46	47	48	49	50	44	43
716		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
717		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
718		9	8	16916.80		15.90															
719	Node52	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36	39	41	31	32	33
720		34	35	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15
721		1	2	3	4	11	12	10	7	5	6	9	8	53	62	60	61	56	58	59	57
722		55	54	18876.29		14.25															
723	Node53	53	62	60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43
724		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
725		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
726		9	8	15681.65		17.15															
727	Node54	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36	39	41	31	32
728		33	34	35	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29
729		15	1	2	3	4	11	12	10	7	5	6	9	8	53	62	60	61	56	58	59
730		57	55	18681.59		14.40															
731	Node55	55	57	59	58	56	61	60	62	53	54	52	51	50	49	48	47	46	45	44	43
732		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
733		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
734		9	8	15684.35		17.15															
735	Node56	56	61	60	62	53	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37
736		36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19	20
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738		59	58	19033.92		14.13															
739	Node57	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36	39	41
740		31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26
741		27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	53	62	60	61	56
742		58	59	18865.11		14.26															
743	Node58	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36
744		39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19	20	21

745		25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	53	62	60
746		61	56	18374.36		14.64															
747	Node59	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36	39
748		41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19	20	21	25
749		26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	53	62	60	61
750		56	58	18707.66		14.38															
751	Node60	60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40
752		38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16
753		19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8
754		53	62	18706.87		14.38															
755	Node61	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40	38
756		37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19
757		20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	53
758		62	60	18856.94		14.26															
759	Node62	62	60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42
760		40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18
761		16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9
762		8	53	18284.60		14.71															
763																					
764																					
765	NODE																				
766																					
767																					
768																					
769	Node53	53	62	60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43
770		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
771		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
772		9	8	15681.65		17.15															

<-----MINIMUM PATH----->

NODES

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