

**DEVELOPEMENT OF ANT COLONY OPTIMIZATION SOFTWARE AS A
SOLID WASTE MANAGEMENT SYSTEM.**

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. Additionally, an Evolutionary Algorithm in Microsoft Excel 2013 was applied to the University of Port Harcourt four campus segments and the results were compared with those of the Proposed model. The percentage error margin between Evolutionary Algorithm and the Proposed model prediction ranges from -0.34 to 11.27. The Proposed models was able to achieve optimum value with minimum number of iterations in all cases and this is an advantage.

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.

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

45 From researches [6, 7, 8, 9, 10], the development of a decision support system to
46 optimize the collection of solid waste which gulps about 60 - 95% of the total
47 finance budgeted by waste management agencies will aid management in making
48 cost effective decisions and plans.

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

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

55 **2.1 Floyd-Warshall's Algorithm (Dynamic Programming)**

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

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

- 72 a) Characterize the structure of an optimal solution;
- 73 b) Recursively define the value of the Optimal solution;
- 74 c) Compute the value of the optimal solution, usually in a bottom-up
75 approach; and
- 76 d) Construct an optimal solution from computed information.

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

83 In the model development of this research, the node represents solid waste
84 collection points and dumpsites while the weighted function for the edges which

85 connects the nodes represents the relative distance between the solid waste
86 collection points and dumpsites.

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88 2.1.1 Developing a Dynamic Program for Shortest-Route Problem using Flyod- 89 Warshall's Algorithm

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

92 Step 1- Structure Characterization:

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

94 $V = \{1, 2, 3, \dots, n\}$.

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

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

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

- 104 i. If k is not an intermediate node of path p , then all intermediate nodes of
105 path p are elements of the set $\{1, 2, 3, \dots, k-1\}$. Thus, a shortest path
106 from nodes i to j with all intermediate nodes in the set $\{1, 2, 3, \dots, k-1\}$
107 is also a shortest path from i to j with intermediate nodes in the set
108 $\{1, 2, 3, \dots, k\}$.
- 109 ii. If k is an intermediate node of path p , then the path p is broken down or
110 say decomposed into two path p_1 and p_2 , where $p_1 = i \rightsquigarrow k$ and $p_2 = k$
111 $\rightsquigarrow j$. That is path p will then be:

$$112 \quad p = p_1 + p_2 = i \rightsquigarrow k \rightsquigarrow j$$

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

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

117 From nodes i to j for which all intermediate nodes are elements of the set $\{1,$
118 $2, 3, \dots, k\}$, let $d_{ij}^{(k)}$ be the weight factor. When $k=0$, the path from nodes i to j
119 has no intermediate nodes numbered higher than 0. It implies that such path
120 has at most one edge and hence, $d_{ij}^{(0)} = w_{ij}$, where: w_{ij} is the value of the weight
121 factor with respect to the edge between nodes i & j .

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

$$123 \quad d_{ij}^{(k)} = \begin{cases} w_{ij} & \text{if } k = 0. \\ \min(d_{ij}^{(k-1)}, d_{ik}^{(k-1)} + d_{kj}^{(k-1)}) & \text{if } k \geq 1. \end{cases} \quad (1)$$

124 Note: For any path, all intermediate nodes are elements in the set $\{1, 2,$
 125 $3, \dots, n\}$, hence the matrix $D^{(n)} = (d_{ij}^{(n)})$ gives the final solution:

$$126 \quad d_{ij}^{(k)} = \delta(i, j) \text{ for all } i, j \in V.$$

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

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

$$131 \quad w_{ij} = \begin{cases} 0 & \text{if } i = j, \\ \text{the weight of directed edge } (i, j) & \text{if } i \neq j \text{ and } (i, j) \in E, \\ \infty & \text{if } i \neq j \text{ and } (i, j) \notin E. \end{cases} \quad (2)$$

132 Note: From Equation (2) it follows that if there is no direct path
 133 connecting nodes i to j the weight of the edge between the nodes
 134 $= \infty$ (or say NIL).

135 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).

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

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

140 Table 2: Pseudo code for Optimal Solution Construction

141 Start

142 for $i = 1$ to N

143 for $j = 1$ to N

144 if there is an edge from i to j

145 $d_{ij}^{(0)} = w_{ij}$

146 else

147 $d_{ij}^{(0)} = \infty$

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148         for k = 1 to N
149         for i = 1 to N
150         for j = 1 to N
151              $d_{ij}^{(k)} = \min(d_{ij}^{(k-1)}, d_{ik}^{(k-1)} + d_{kj}^{(k-1)})$ 
152         End

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153 2.2 Swarm Intelligence (SI)

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

164 2.2.1 Ant Colony Optimization (ACO)

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

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

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

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

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

189 The program commences with the specification of the various variables (α , β , ρ , n).
190 α & β are positive parameters assigned values 1 & 2 respectively to control the
191 relative weight of *pheromone* information T_{ij} . ρ is the *pheromone* evaporation
192 parameter which usually ranges between 0 to 1 but for the case of the developed
193 decision support system was assigned the value of 0.5. n represents the number of
194 waste collection points (nodes).

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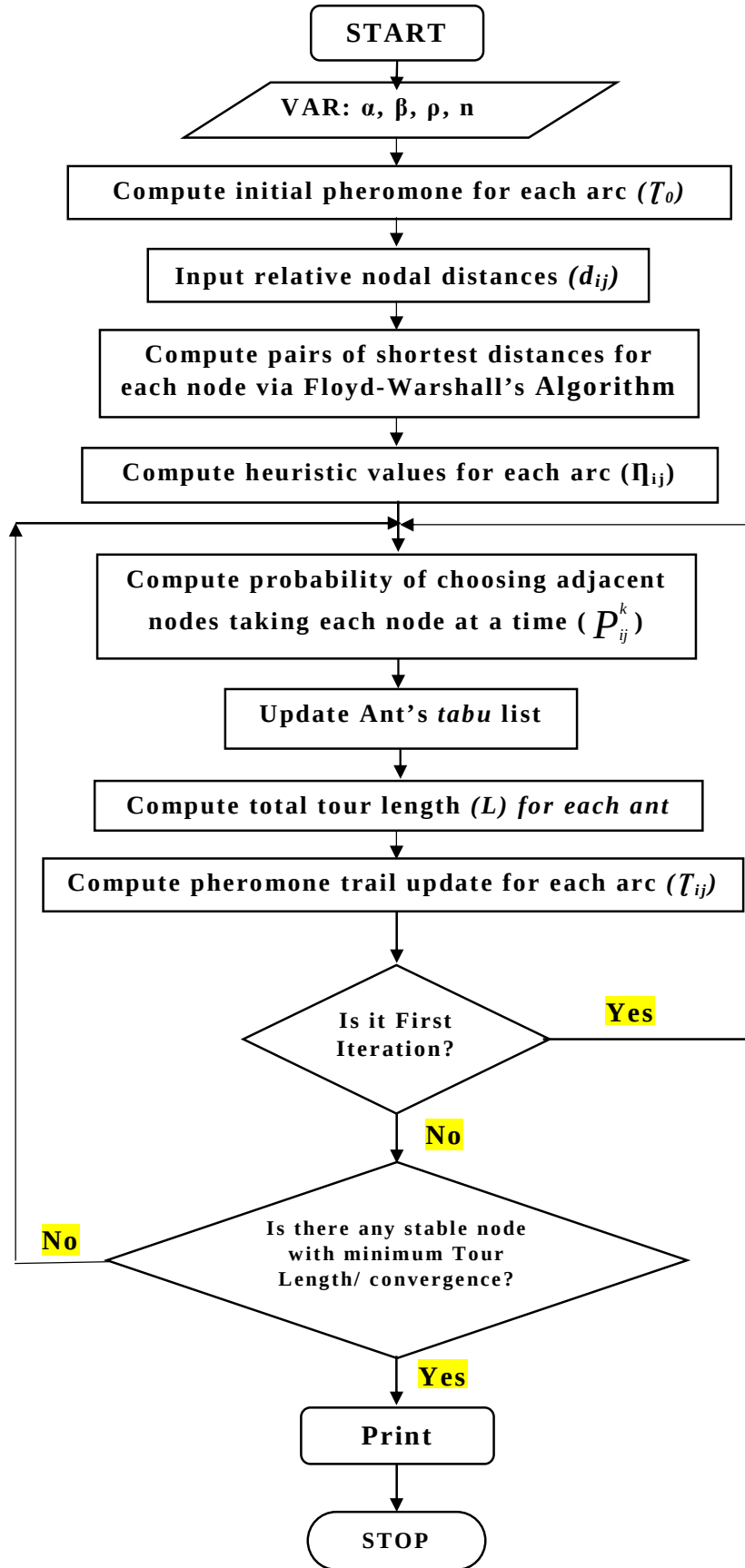


Figure 1: Flow Chart of ACO algorithm [17]

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. 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 2). 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)).

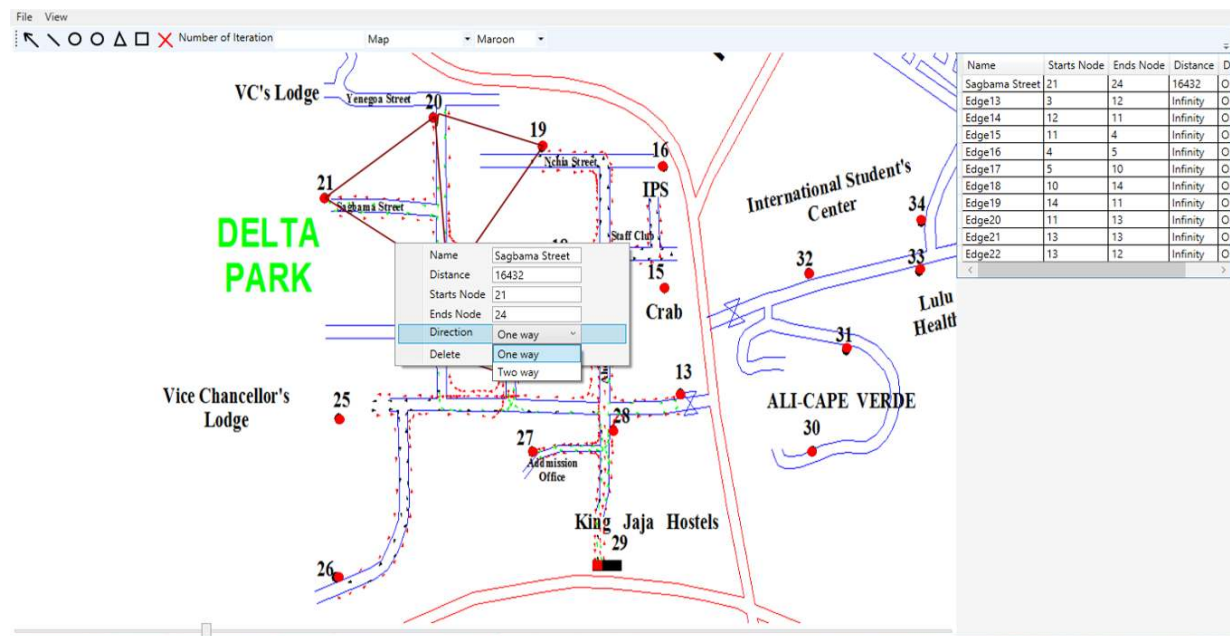


Figure 2: Display Screen of Decision Support System when performing an analysis

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 2).

3.1 Solving a Hypothetical Problem Using W8st colSoft

A sketch of the road network of an estate (Figure 3) 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

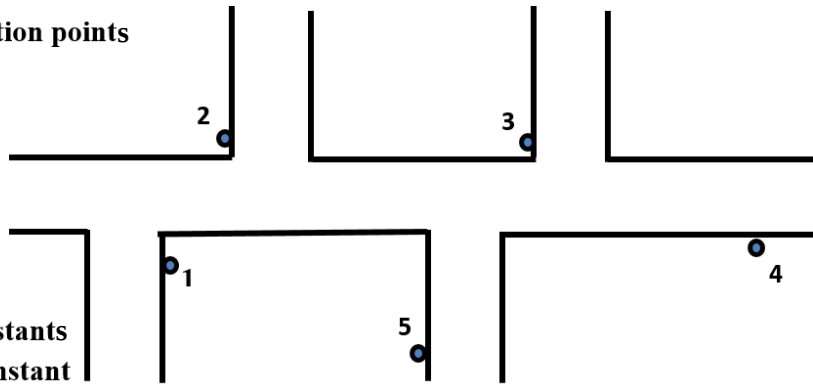


Figure 3: Road Network of Hypothetical Estate with waste collection points

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 4);

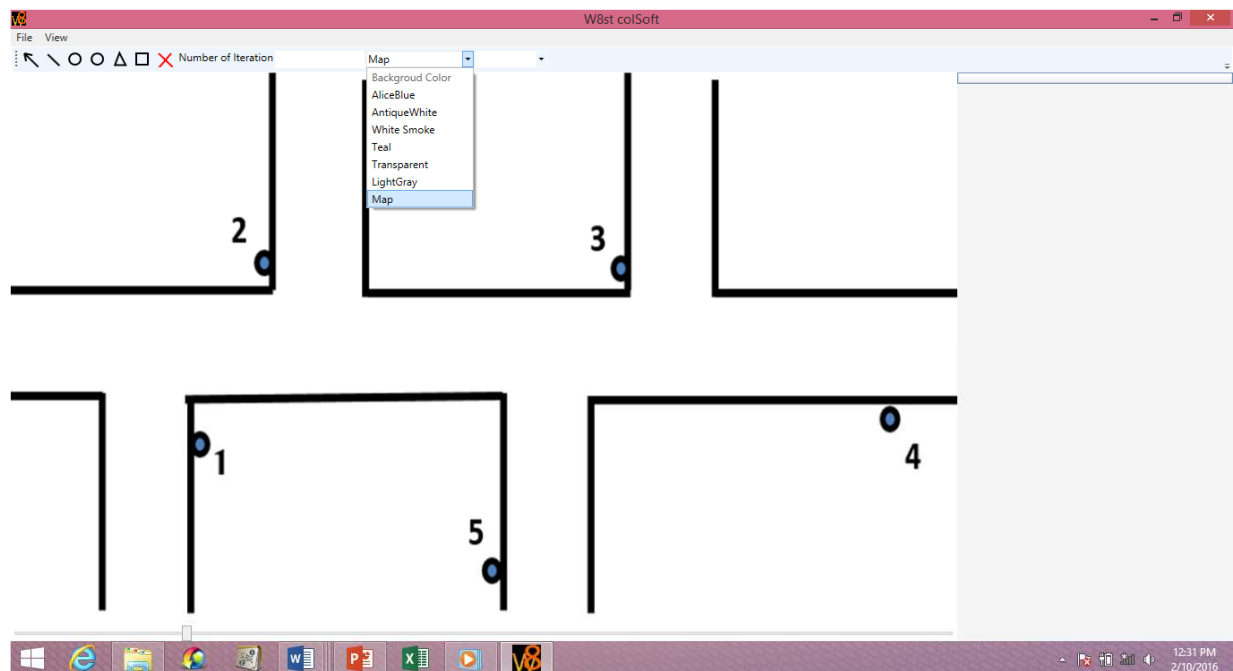
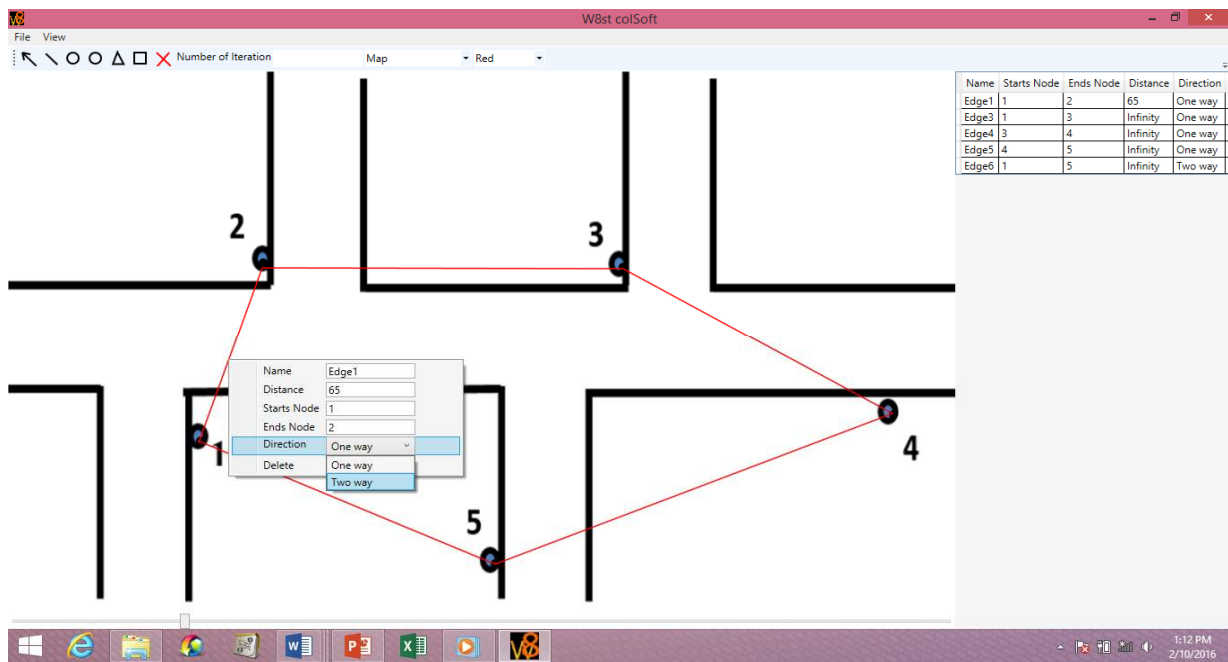


Figure 4: Screen shot of *w8st colSoft* with map being imported

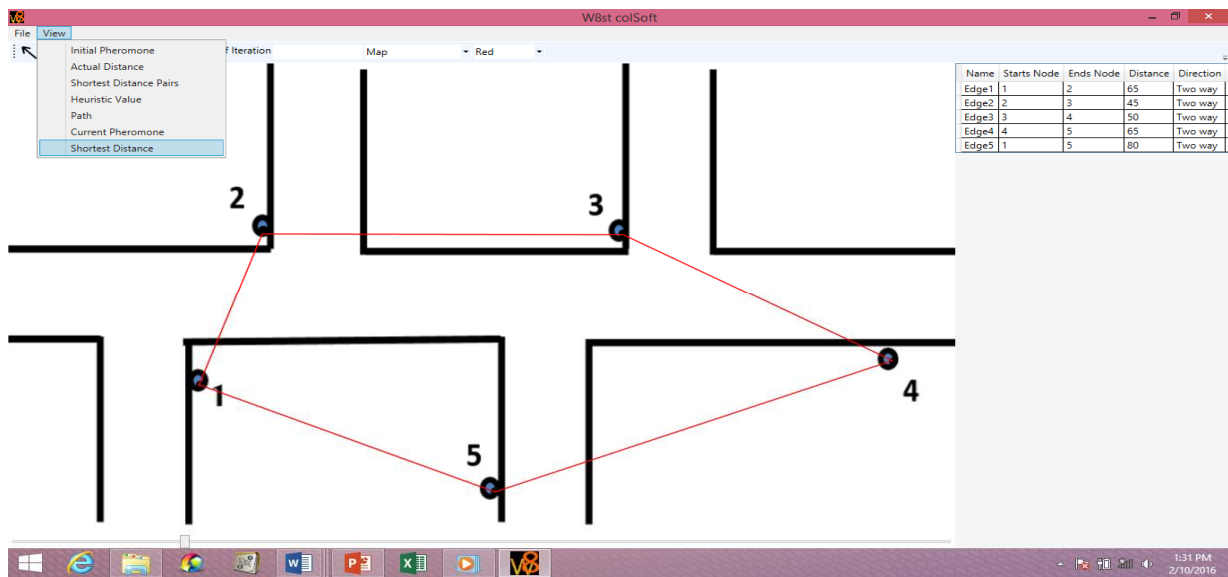
Step 3: Insert the connecting arc to the collection points 1,2,...,5 and left click once and right click also on the connecting arc to open a property box where the details of the arc will be inserted in terms of distance, collection points at its end and beginning, the nature of the route if it is a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

273 distances, computed pairs of shortest distances, computed heuristic values
274 for each arc, and the Computed tour path (see Figure 6).



275
276 Figure 5: Screen shot with collection points being connected and assigned
277 properties with respect to the connecting road network.



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279 Figure 6: Screen shot with a drop down menu on resultant outputs from analysis.

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

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4. RESULTS AND DISCUSSION

4.1 Results

In order to validate the accuracy of the developed model (*w8st colSoft*), it was necessary to employed illustrative example problems from textbook, case study from literature (University of Port Harcourt example), and a typical example taken from Microsoft Excel 2013. The first example problem exemplified the application of dynamic programming in finding the shortest distance between two or more nodes [18]; whereas the case study problem was adopted to compare simulated result and manually computed result based on the same principle. However, an Evolutionary Algorithm in Microsoft Excel 2013 was applied to the University of Port Harcourt four campus segments and the results were compared with those of the Proposed model (*w8st colSoft*). The simulated results from both models are as presented later in the discussion section.

The first illustrative example problem taken from a textbook [18] was used to validate the accuracy of the developed decision support system (*W8st colSoft*) (see Figure 7). 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 second solved example problem (see Figure 8) from a research publication [19] was used and the results are as 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 as illustrative example 3 [17] and a plot of the resultant output is presented in Figure 9. The simulated results using evolutionary algorithm and the proposed model for University of Port Harcourt four campus segments are as presented in Table 4 and Figures 11a-d.

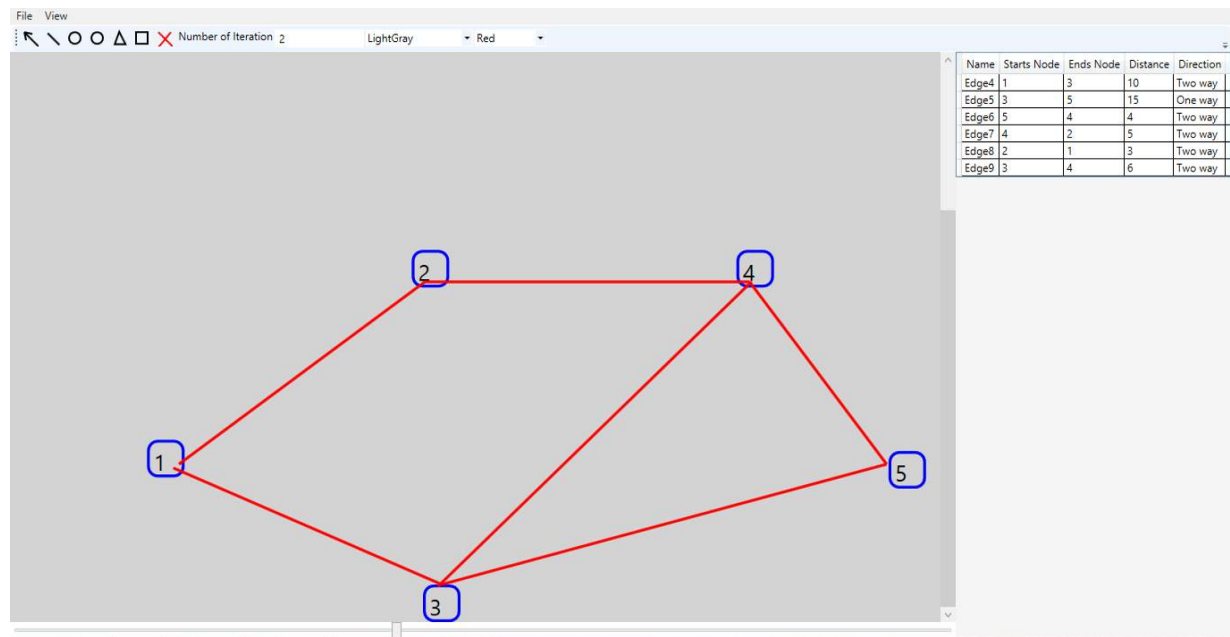
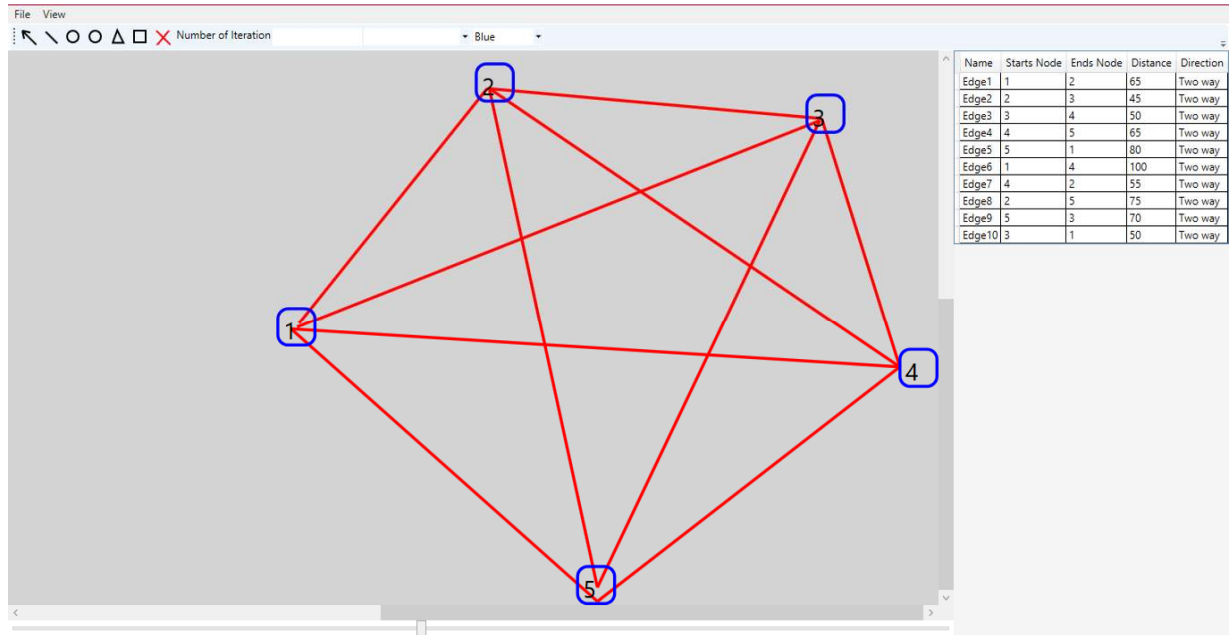


Figure 7: Screen shot of Developed Decision System showing the analysis for the validation using solved example from Textbook with regards to Dynamic Programming model.

315 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

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318 Figure 8: Screen shot of *W8st colSoft* showing the analysis for the validation using
 319 solved example from Publication [19] with regards to Ant Colony Optimization
 320 Algorithm

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

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

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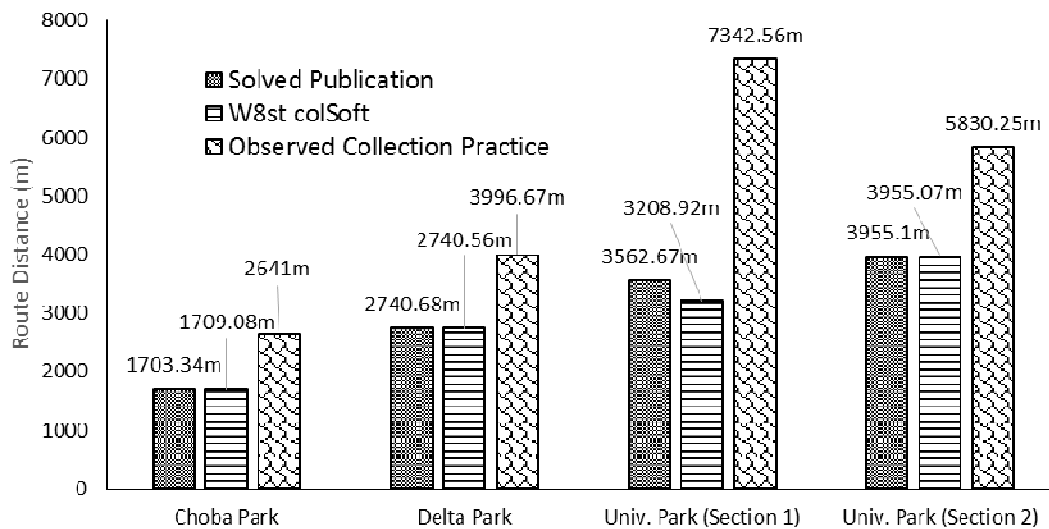
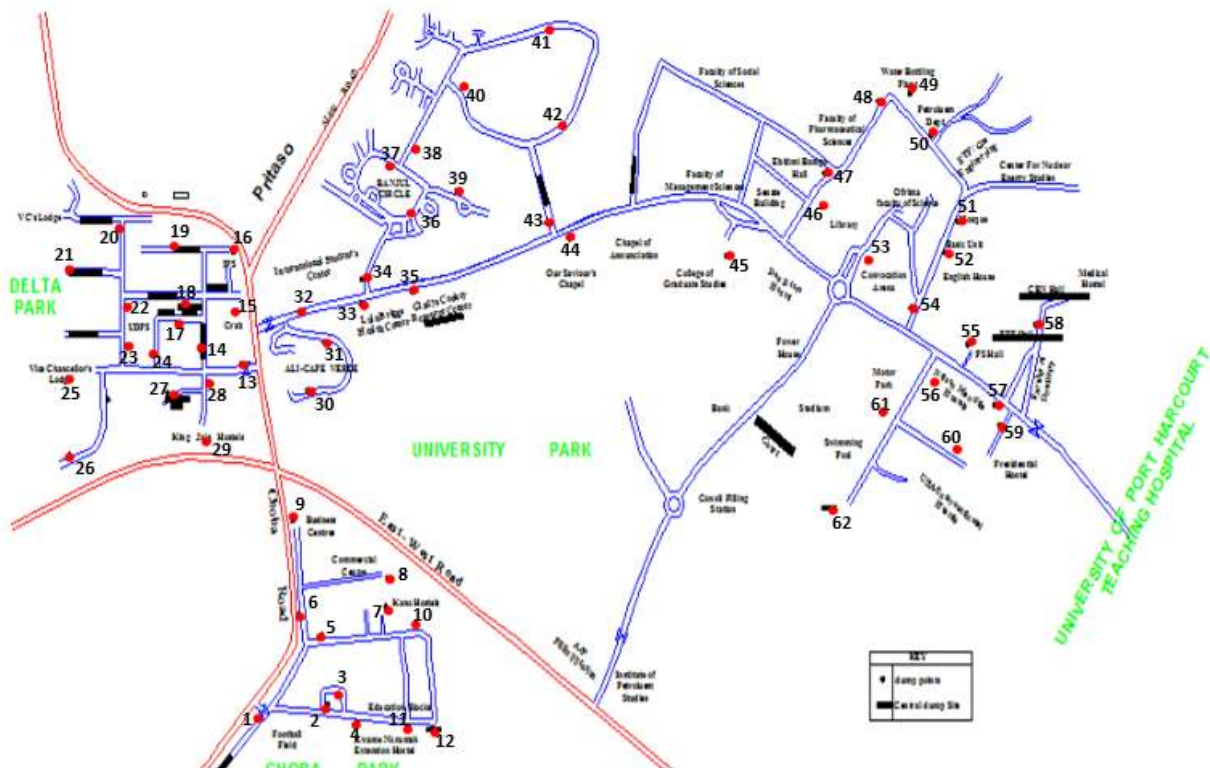


Figure 9: Plot of the Optimal route distance on University of Port Harcourt 3 campuses using *W8st colSoft* and results of analysis from published literature.

In an attempt to present the advantage of the developed decision support system (*W8st colSoft*) over the analysis made in earlier publication [17] the solid waste collection at the University of Port Harcourt three campuses clustered together is analyzed as a whole (instead of campus by campus)(see Figure 10).



Source: Bovwe and Nwaogazie [17]

Figure 10: Road Network of the University of Port Harcourt showing solid waste collection points.

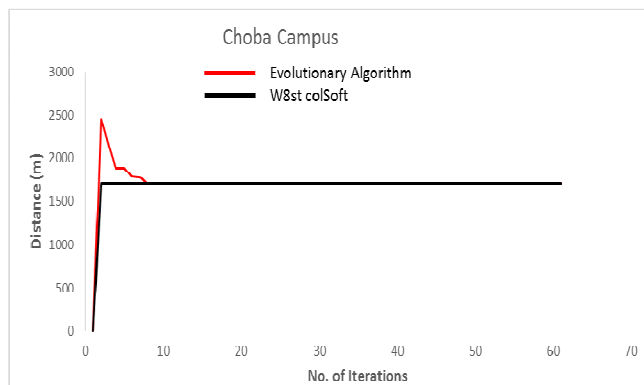
335 The resultant final optimized route for the collection of the generated solid waste
 336 within the University takes path (see Appendix A):

337 53=>62=>60=>61=>56=>58=>59=>57=>55=>54=>52=>51=>50=>49=>48=>4
 338 7=>46=>45=>44=>43=>42=>40=>38=>37=>36=>39=>41=>31=>32=>33=>34
 339 =>35=>30=>13=>28=>14=>17=>24=>23=>22=>18=>16=>19=>20=>21=>25
 340 =>26=>27=>29=>15=>1=>2=>3=>4=>11=>12=>10=>7 =>5=>6=>9=>8

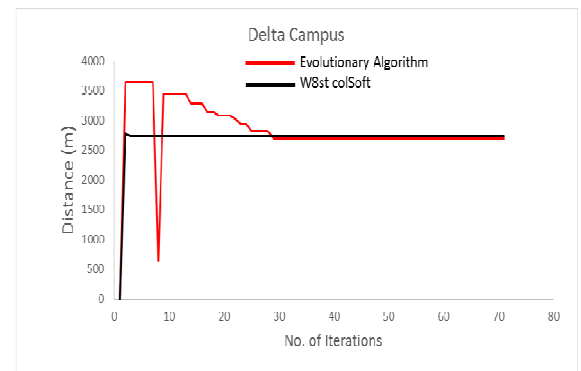
341 **Table 5: Simulated Outputs of Observed, Evolutionary Algorithm, Proposed**
 342 **smodel and Literatures**

(1) Campuses	(2) Observed Collection Practice	(3) Literature [±]	(4) W8st colSoft	(5) Evolutionary Algorithm [*]	% Error $\left(\frac{Col\ 5 - Col\ 4}{Col\ 5} \times 100\right)$
Choba Park	2641	1703.34	1709.08	1703.34	-0.337
Delta Park	3996.67	2740.68	2740.56	2702.64	-1.403
Univ. Park (Section 1)	7342.56	3562.67	3208.92	3019.03	-6.290
Univ. Park (Section 2)	5830.25	3955.1	3955.07	4457.18	11.265

343 * Microsoft Excel 2013; [±] Journal Article [17]

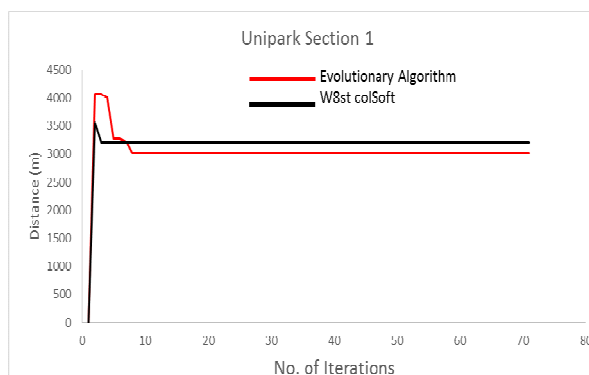


a). EA versus PM for Choba Campus

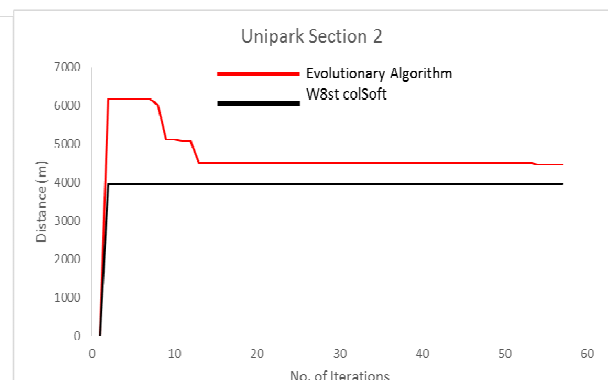


b). EA versus PM for Delta Campus

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c). EA[±] versus PM[±] for Unipark Campus Section 1



d). EA[±] versus PM[±] for Unipark Campus Section 2

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 348 [±]EA = Evolutionary Algorithm; [±]PM = Proposed Model (w8st colSoft)

349 Figure 11 Plots of No. of Iterations against Output for Evolutionary Algorithm and
 350 proposed model.

4.2 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).

To add value to the validation of the proposed model it was necessary to compare results from evolutionary algorithm applied to the University of Port Harcourt four campus segments. Both models were allowed to iterate up to 80No. iterations and from Figures 11a-d the evolutionary simulated results showed early fluctuations between first and thirty iterations before achieving stable and optimum values. However, the proposed model was more stable and achieved optimum solution in less than five iterations. Apparently, the proposed model has an advantage in stability and small number of iterations for optimum solution. At the optimum solution for each of the four campus segments the percentage error between evolutionary algorithm and proposed model is between -0.34 and 11.27. Table 5 equally confirms the close agreement between the results of the proposed model and those from literature [17]. The reference point in Table 5 is the observed data (collection practice) that is useful in comparing all the simulated options, their effectiveness and the principles in which the models are constructed.

5 CONCLUSION

Based on the study carried out the following conclusions can be drawn:

- i. The proposed model (*W8st colSoft*) makes suggestions of various routes that could be taken with the path gained as a result of each choice.
- ii. The developed model is a very handy tool in the efficient management of solid waste using dynamic and swarm intelligence model;

- iii. Comparison of simulated results using the field conditions of the University of Port Harcourt four campus segments using evolutionary algorithm, proposed model, observed field collection practice (reference values) and literature confirmed the proposed model as very stable with small number of iterations to achieve optimum values;
- iv. The evolutionary algorithm suffers early instability between the first and thirty iterations before achieving steady condition with optimum;
- v. The percent error in the simulated results with evolutionary algorithm and proposed model are between -0.34 and 11.27; and
- vi. The proposed model is a veritable tool for effective solid waste collection and it has shown comparative advantage over evolutionary algorithm in stability and speed of (small number of iterations) to achieve optimum values.

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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

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

482 $n = 5$; $\tau_0 = \frac{1}{5} = 0.2$. Therefore forming a initial pheromone matrix (see Table A2):

483

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

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

486

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

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

488

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

489

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

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

491

492 **Taking Ant 1:** Using the values from Tables 2 & 4, the probability for ant starting
 493 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.

514

515

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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

519

520 A2: OUTPUT OF HYPOTHETICAL PROBLEM FROM DEVELOPED 521 DECISION SUPPORT SYSTEM (W8st colSoft) SIMULATION

522 <-----Final Distance Matrix----->

523	Point	Nodes				
524	Node1	0.00	65.00	110.00	145.00	80.00
525	Node2	65.00	0.00	45.00	95.00	145.00
526	Node3	110.00	45.00	0.00	50.00	115.00
527	Node4	145.00	95.00	50.00	0.00	65.00
528	Node5	80.00	145.00	115.00	65.00	0.00
529						

530 Iteration 1

531 <-----Pheromone----->

532	Point	Nodes				
533	Node1	0.00	0.20	0.20	0.20	0.20
534	Node2	0.20	0.00	0.20	0.20	0.20
535	Node3	0.20	0.20	0.00	0.20	0.20
536	Node4	0.20	0.20	0.20	0.00	0.20
537	Node5	0.20	0.20	0.20	0.20	0.00

538 <-----Path Followed----->

539	Point	Nodes					Length	Path Gain
540	Node1	1	2	3	4	5	225.00	2.58
541	Node2	2	3	4	5	1	240.00	2.42
542	Node3	3	2	1	5	4	255.00	2.27
543	Node4	4	3	2	1	5	240.00	2.42
544	Node5	5	4	3	2	1	225.00	2.58

545 <-----Minimum Path----->

546	Point	Nodes					Length	Path Gain
547	Node1	1	2	3	4	5	225.00	2.58
548								

549 Iteration 2

550 <-----Pheromone----->

551	Point	Nodes				
552	Node1	0.00	9.95	0.10	0.10	7.21
553	Node2	9.95	0.00	12.36	0.10	0.10
554	Node3	0.10	12.36	0.00	10.09	0.10
555	Node4	0.10	0.10	10.09	0.00	9.95
556	Node5	7.21	0.10	0.10	9.95	0.00

557 <-----Path Followed----->

558	Point	Nodes					Length	Path Gain
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559	Node1	1	2	3	4	5	225.00	2.58
560	Node2	2	3	4	5	1	240.00	2.42
561	Node3	3	2	1	5	4	255.00	2.27
562	Node4	4	3	2	1	5	240.00	2.42
563	Node5	5	4	3	2	1	225.00	2.58
564	<-----Minimum Path----->							
565	Point					Nodes	Length	Path Gain
566	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

614		43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
615		41	31	17406.16		15.45															
616	Node11	11	4	3	2	1	5	6	9	8	7	10	12	13	28	14	17	24	23	22	18
617		16	19	20	21	25	26	27	29	15	30	32	33	34	35	36	39	38	37	40	42
618		43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
619		41	31	17527.00		15.35															
620	Node12	12	11	4	3	2	1	5	6	9	8	7	10	13	28	14	17	24	23	22	18
621		16	19	20	21	25	26	27	29	15	30	32	33	34	35	36	39	38	37	40	42
622		43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
623		41	31	17445.05		15.42															
624	Node13	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	30	32	33
625		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
626		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
627		9	8	16840.09		15.97															
628	Node14	14	28	13	30	32	33	34	35	36	39	38	37	40	42	43	44	45	46	47	48
629		49	50	51	52	54	55	57	59	58	56	61	60	62	53	41	31	15	29	27	26
630		25	21	20	19	16	18	22	23	24	17	1	2	3	4	11	12	10	7	5	6
631		9	8	17091.36		15.74															
632	Node15	15	29	27	28	14	17	24	23	22	18	16	19	20	21	25	26	13	30	32	33
633		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
634		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
635		9	8	16521.43		16.28															
636	Node16	16	19	20	21	25	26	27	29	15	17	14	28	13	30	32	33	34	35	36	39
637		38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56
638		61	60	62	53	41	31	24	23	22	18	1	2	3	4	11	12	10	7	5	6
639		9	8	17075.31		15.75															
640	Node17	17	14	28	13	30	32	33	34	35	36	39	38	37	40	42	43	44	45	46	47
641		48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41	31	15	29	27
642		26	25	21	20	19	16	18	22	23	24	1	2	3	4	11	12	10	7	5	6
643		9	8	17071.68		15.76															
644	Node18	18	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38	37	40	42	43
645		44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41
646		31	15	29	27	26	25	21	20	19	16	1	2	3	4	11	12	10	7	5	6
647		9	8	17203.42		15.64															
648	Node19	19	16	18	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38	37	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	31	15	29	27	26	25	21	20	1	2	3	4	11	12	10	7	5	6
651		9	8	17423.58		15.44															
652	Node20	20	19	16	18	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38	37
653		40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60
654		62	53	41	31	15	29	27	26	25	21	1	2	3	4	11	12	10	7	5	6
655		9	8	17436.05		15.43															
656	Node21	21	20	19	16	18	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38
657		37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61
658		60	62	53	41	31	15	29	27	26	25	1	2	3	4	11	12	10	7	5	6
659		9	8	17028.99		15.80															
660	Node22	22	23	24	17	14	28	13	30	32	33	34	35	36	39	38	37	40	42	43	44
661		45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41	31

662		15	29	27	26	25	21	20	19	16	18	1	2	3	4	11	12	10	7	5	6
663		9	8	17244.85		15.60															
664	Node23	23	22	18	16	19	20	21	25	26	27	29	15	17	14	28	13	30	32	33	34
665		35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57
666		59	58	56	61	60	62	53	41	31	24	1	2	3	4	11	12	10	7	5	6
667		9	8	17072.81		15.76															
668	Node24	24	23	22	18	16	19	20	21	25	26	27	29	15	17	14	28	13	30	32	33
669		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
670		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
671		9	8	16526.14		16.28															
672	Node25	25	26	27	29	15	16	19	20	21	18	22	23	24	17	14	28	13	30	32	33
673		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
674		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
675		9	8	16404.06		16.40															
676	Node26	26	25	21	20	19	16	18	22	23	24	17	14	28	13	30	32	33	34	35	36
677		39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58
678		56	61	60	62	53	41	31	15	29	27	1	2	3	4	11	12	10	7	5	6
679		9	8	16638.73		16.17															
680	Node27	27	29	15	16	19	20	21	25	26	24	23	22	18	17	14	28	13	30	32	33
681		34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55
682		57	59	58	56	61	60	62	53	41	31	1	2	3	4	11	12	10	7	5	6
683		9	8	16271.32		16.53															
684	Node28	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	30	13	31	32
685		33	34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54
686		55	57	59	58	56	61	60	62	53	41	1	2	3	4	11	12	10	7	5	6
687		9	8	17016.60		15.81															
688	Node29	29	27	28	14	17	24	23	22	18	16	19	20	21	25	26	13	30	32	33	34
689		35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57
690		59	58	56	61	60	62	53	41	31	15	1	2	3	4	11	12	10	7	5	6
691		9	8	16841.47		15.97															
692	Node30	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	1	2
693		3	4	11	12	10	7	5	6	9	8	39	36	34	33	35	32	31	41	53	62
694		60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40
695		38	37	18379.90		14.64															
696	Node31	31	32	33	34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51
697		52	54	55	57	59	58	56	61	60	62	53	41	30	13	28	14	17	24	23	22
698		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
699		9	8	16621.35		16.18															
700	Node32	32	33	34	35	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52
701		54	55	57	59	58	56	61	60	62	53	41	31	30	13	28	14	17	24	23	22
702		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
703		9	8	16720.69		16.09															
704	Node33	33	34	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26
705		27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	39	36	37	38	40
706		42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
707		53	41	17368.45		15.49															
708	Node34	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26
709		27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	39	36	37	38	40

710		42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
711		53	41	17370.15		15.49															
712	Node35	35	34	33	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26
713		27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	39	36	37	38	40
714		42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
715		53	41	17289.31		15.56															
716	Node36	36	39	38	37	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59
717		58	56	61	60	62	53	41	31	32	33	34	35	30	13	28	14	17	24	23	22
718		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
719		9	8	16733.98		16.07															
720	Node37	37	38	40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56
721		61	60	62	53	41	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22
722		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
723		9	8	15966.36		16.85															
724	Node38	38	37	36	39	41	31	32	33	34	35	44	43	42	40	30	13	28	14	17	24
725		23	22	18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7
726		5	6	9	8	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60
727		62	53	18886.34		14.24															
728	Node39	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21
729		25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37	38	40
730		42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
731		53	41	17357.48		15.50															
732	Node40	40	38	37	36	39	41	31	32	33	34	35	44	43	42	45	46	47	48	49	50
733		51	52	54	55	57	59	58	56	61	60	62	53	13	28	14	17	24	23	22	18
734		16	19	20	21	25	26	27	29	15	30	1	2	3	4	11	12	10	7	5	6
735		9	8	18118.92		14.85															
736	Node41	41	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20
737		21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37	38
738		40	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60
739		62	53	16453.44		16.35															
740	Node42	42	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62
741		53	41	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19
742		20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37
743		38	40	17835.35		15.08															
744	Node43	43	44	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53
745		41	39	36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20
746		21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37	38
747		40	42	17928.00		15.00															
748	Node44	44	43	42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24
749		23	22	18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7
750		5	6	9	8	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60
751		62	53	17966.79		14.97															
752	Node45	45	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	41	39
753		36	34	33	35	32	31	30	13	28	14	17	24	23	22	18	16	19	20	21	25
754		26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	37	38	40	42
755		43	44	17589.95		15.29															
756	Node46	46	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	45	44	43
757		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22

758		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
759		9	8	15804.01		17.02															
760	Node47	47	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	45	46	44	43
761		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
762		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
763		9	8	16408.37		16.39															
764	Node48	48	49	50	51	52	54	55	57	59	58	56	61	60	62	53	45	46	47	43	44
765		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
766		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
767		9	8	16698.63		16.11															
768	Node49	49	48	47	46	45	44	43	42	40	38	37	36	39	41	31	32	33	34	35	30
769		13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15	1	2	3
770		4	11	12	10	7	5	6	9	8	50	51	52	54	55	57	59	58	56	61	60
771		62	53	19275.55		13.96															
772	Node50	50	51	52	54	55	57	59	58	56	61	60	62	53	45	46	47	48	49	44	43
773		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
774		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
775		9	8	16738.78		16.07															
776	Node51	51	52	54	55	57	59	58	56	61	60	62	53	45	46	47	48	49	50	44	43
777		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
778		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
779		9	8	16916.80		15.90															
780	Node52	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36	39	41	31	32	33
781		34	35	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29	15
782		1	2	3	4	11	12	10	7	5	6	9	8	53	62	60	61	56	58	59	57
783		55	54	18876.29		14.25															
784	Node53	53	62	60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43
785		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
786		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
787		9	8	15681.65		17.15															
788	Node54	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36	39	41	31	32
789		33	34	35	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26	27	29
790		15	1	2	3	4	11	12	10	7	5	6	9	8	53	62	60	61	56	58	59
791		57	55	18681.59		14.40															
792	Node55	55	57	59	58	56	61	60	62	53	54	52	51	50	49	48	47	46	45	44	43
793		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
794		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
795		9	8	15684.35		17.15															
796	Node56	56	61	60	62	53	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37
797		36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19	20
798		21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	55	57
799		59	58	19033.92		14.13															
800	Node57	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36	39	41
801		31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19	20	21	25	26
802		27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	53	62	60	61	56
803		58	59	18865.11		14.26															
804	Node58	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36
805		39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19	20	21

806		25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	53	62	60
807		61	56	18374.36		14.64															
808	Node59	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40	38	37	36	39
809		41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19	20	21	25
810		26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	53	62	60	61
811		56	58	18707.66		14.38															
812	Node60	60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40
813		38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16
814		19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8
815		53	62	18706.87		14.38															
816	Node61	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42	40	38
817		37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18	16	19
818		20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9	8	53
819		62	60	18856.94		14.26															
820	Node62	62	60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43	42
821		40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22	18
822		16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6	9
823		8	53	18284.60		14.71															
824																					
825																					
826	NODE																				
827																					
828																					
829																					
830	Node53	53	62	60	61	56	58	59	57	55	54	52	51	50	49	48	47	46	45	44	43
831		42	40	38	37	36	39	41	31	32	33	34	35	30	13	28	14	17	24	23	22
832		18	16	19	20	21	25	26	27	29	15	1	2	3	4	11	12	10	7	5	6
833		9	8	15681.65		17.15															

834