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Research

Web-Based Monitoring System for Optimal Collection and Disposal of Solid Waste Using Geographic Information System (GIS)

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Abstract: This research developed a Web-based Monitoring System for Optimal collection and Disposal of Solid Waste using Geographic Information System (GIS) with the aim of improving an effective waste management system and also providing a geographical view of waste collection bins and their locations in the study area. The rationale of this research was to provide a geo-spatial view of solid waste bins by allowing the public lodge complaints about filled waste bins in the covered region and also reducing the transit time it takes for garbage truck drivers to dispose waste at the major dump-site. This work adopted the Y-model web-GIS Development Methodology (YWDM) in developing the system. Also, object oriented analysis and design methods were used in developing the logical aspect of the system. On the analysis, development and implementation, the system uses Geographic Information System (GIS) combined with web technologies. While evaluating the system, as a proof of concept, dynamic tests were carried out during the validation process to test the functionalities of the system. Finding shows that the system can receive information dynamically at real time about waste bin situations within the study area and proactively take an action to evacuate wastes from storage locations. Transportation route was also optimized based on analysis of waste collection bin locations which results in ensuring that minimal time is spent on disposing wastes into the landfill. In conclusion, the work has shown that automating the waste management process by the use of a web-based monitoring system for optimal collection and disposal of solid wastes will improve waste management in Nigeria and beyond.

1 INTRODUCTION

Over the years, one major environmental difficulty experienced by indigenous denizens, States and Federal governments as well as the world at large has been problem associated with trash collection and clearance. Garbage or trash collection is a component in an integrated waste management system which consist of hipping of waste , collection points, garbage vehicles moving around the neighborhood, as well as moving the waste to a landfill, (Gaurav, Kunal & Shashank, 2014). Research has shown that monitoring of waste bins in developing countries such as Nigeria is not fully taken into consideration. This is because the public is not fully involved. Imam (2008) reported that the attitude to handling of waste by the public indicated poor awareness which has affected the management process of solid waste. However, the consequences of inappropriate waste disposal have been emphasized but residents rather feel that it is the responsibility of the government and fail to understand that it is by individual effort. Urban centers are major attractions for the location of private and public facilities such as waste bins which require strategic spatial decision support to enhance practicable maximum service. According to Farahani and Hekmatfer (2009), the science of locating a facility otherwise referred to as a facility location problem has attracted much attention over the last five decades. Although waste bins are kept at strategic places to reduce the exposure of waste but these bins always get filled quickly on timely basis because there is little or no existing technology to display the location of these bins to be monitored and evacuated. As a community's tolerance for dump-sites decreases, they are moved farther from densely populated areas, requiring garbage trucks to drive farther distances to dispose wastes. Also, the complexity of collection routes increases the cost of managing waste collection and disposal. Therefore, any improvement in the monitoring of waste bins and routing system of waste collection and disposal can improve the efficiency of solid waste management.

The development of Geographic Information System (GIS) and its use throughout the world has imparted a lot in ameliorating waste management systems (Essays, 2013). According to the report of Chalkias and Lasaridi (2009), “GIS helps to manipulate data in the computer to simulate alternatives and to take the most effective decisions. GIS can add value to waste management applications by providing outputs for decision support and analysis in a wide spectrum of projects such as route planning for waste collection, site selection exercises for transfer stations, landfills or waste collection points. GIS provides a flexible platform which integrates and analyses maps and waste management databases. GIS integrated with spatial modeling tools for collection and transportation optimization can provide economic gains by reducing travel time, distances, fuel consumption, and pollutant emissions" (p. 640).

Optimizations of transportation routes are essential for effective disposal of waste. Transport networks are represented in form of road maps and modeled using graphs. A graph is a collection of two sets V and E where V is the collection of vertices V0, V1,……Vn-1 also called nodes and E is the collection of edges e1, e2,…..en where an edge is an arc which connects two nodes [6]. This can be represented as

G = (V, E) where;

V (G) = (V0, V1,……Vn-1); or set of vertices

E (G) = (e1, e2, en) or set of edges.

In a graph theory, the shortest path problem is used to determine the path between source vertices and destination vertices (or nodes) such that the sum of the weights of its constituent edges is minimized.

2 RELATED WORKS

In a study on waste management trends in developing and developed countries, it was reported that for some cities in Nigeria, waste management agencies are functional and also waste cans for solid waste collection are available while in other cities, they still practiced illegal dumping [(LAWMA, 2011), (Sampson-Akpan, 2009), (Opara, 2009)]. Some of the major challenges faced were low participation of the public in solid waste management, prompt collection of solid waste, Ineffective use of technology and little or no management systems of organized information, Poswa (2001). Efforts have been made to address some of these challenges. Recent technologies such as waste bin monitoring technology, compact garbage collection trucks, underground collection system and web based GIS (Geographic Information System) technology have been put in place to address the above mentioned challenges of solid waste management (Nippon, 2017). Report has shown that GIS combined with Network Analysis (NA) tools can be used in optimizing and improving the efficiency of waste collection and transportation. A study carried out in the municipality of Tunisia showed that routes were optimized using ArcGIS NA tool to improve the efficiency of waste collection and transportation, (Amjad, Mohamed & Moncef, 2016). Dijkstra's algorithm was used extensively in optimizing solid waste collection routes in Malaysia (Norhafezah, Nurfadzliana and Megawati, 2017). Furthermore Norhafezah *et.al.*, used GIS to cite waste collection points which provides a better spatial coverage of waste tanks in an area. In Kenya, waste collection points using GIS provided spatial view of waste cans in Thika sub-country (Ntarangwi & Odera, 2017).

Generally, in developing countries, previous studies have shown that ineffective technologies and inadequate waste facilities have been another source of challenge to the management of waste. A major drawback is the misuse of technology. Previous documentations have shown that sophisticated, expensive technological recycling, composting plants and other waste management systems in developing countries have failed (Wajeeha, Ayesha, Muneeba, Fatima and Ghazala, 2016). Reasons being that the systems might be too complex to implement or the public and stakeholders are not adequately and extensively consulted before adopting such systems. It was also observed that in developing countries, there is the failure of inappropriate technology characterized by imported mechanical and electrical parts which are too expensive to replace or too difficult to manage these systems(Yousif & Scott, 2007). Techniques that have often proven effective in developed countries prove to be ineffective in many situations in developing countries that do not have the needed infrastructure, need, or know-how to properly implement these technologies (McAllister, 2015). With these limitations in existence, this research bridged the gap by developing a less complex system that would reduce waste at waste bin storage points, provide spatial view of the location of waste bins and help truck drivers dispose waste to the landfill in the shortest time possible. Also, Since GIS can be used in keeping transportation parameters, this study provides detailed information on solving the problem by reducing transit time based on the modified Dijkstra's Algorithm method for Garbage truck drivers to dispose waste at the landfill in the study area.

3 BRIEF DESCRIPTION OF STUDY AREA

Calabar Municipal is a Local Government Area of Cross River State, Nigeria. Its headquarters are in the city of Calabar. It has an area of 331.551 square kilometres and a population of 179,392 at the 2006 census. Calabar Municipality lies between latitude 04° 15' and 5° N and longitude 8° 25' E. in the North, the Municipality is bounded by Odukpani Local Government Area in the North-East by the great Kwa River as shown in *Fig 1*. Its Southern shores are bounded by the Calabar River and Calabar South Local Government Area. The city is divided into ten (10) wards. The focus of this research was centered on the Ward 2 area of the Calabar Municipal Local Government, Cross River State.

Fig. 1. Map of Study area

FIG. 1 shows the map view of Calabar Municipal Local Government Area.

4 METHODOLOGY

The specific data required for this study were collected from primary and secondary sources. The primary data of this study were field survey data with Global Positioning System (GPS) to obtain the locations of dustbins. Secondary data was obtained from Google Earth data source to obtain the Digitized Map of the study area and also the roads and transportation routes in the study area. These data collections formed our GIS. The Y-model web-GIS Development Methodology (YWDM) proposed by (Ananda, Kuria & Ngigi, 2016) was applied in designing and implementing the system because our proposed system is a web GIS product. Web GIS projects produce a hybrid product that has qualities of both traditional GIS and web applications. The collected data were represented within the database schema and the web pages were coded using Hypertext Markup Language (XHTML), Cascading Style Sheet (CSS), Hypertext Pre-processor scripting language (PHP), Java and Java Scripting language (JS). The software packages used for the development of this application were RJ Text Editor, Adobe Fireworks, Windows, Apache, MySQL and PHP (WAMP). The analysis of the network was implemented using Java Scripting Language. These tools were chosen because of their level of integration and suitable Graphical User Interface (GUI) which makes the use of the system easy to understand and manage. Unit testing was done on the web pages to check for errors at individual functional points.

4.1 System Architecture

This shows the overall conceptual view of the entire system. It enables us to understand the main aspects of the system. This is shown in *Fig 2***.** In the figure, the overall system has three (3) modules which are the public, Garbage Truck Driver and the Administrator. It is expected that through web GIS application, the public should be able to lodge complaints about filled registered waste bins from a registered area, the administrator is expected to assign registered Garbage Truck Driver to an area containing filled bins while the Garbage truck driver is expected to view the location of the filled waste bins and also get the shortest time to dispose the waste at the landfill.

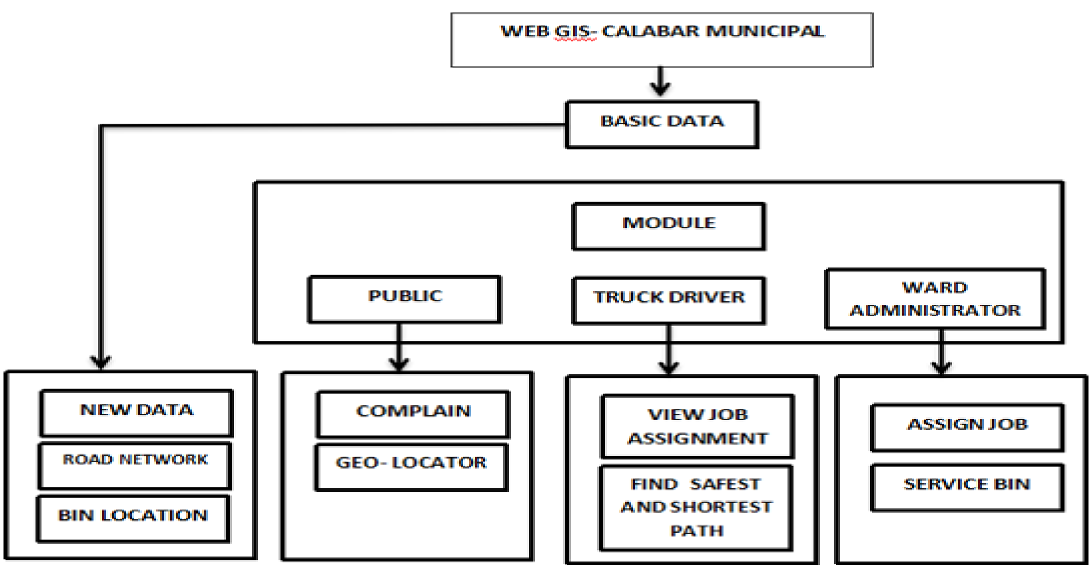

Fig. 2. System Architecture

Fig. 2 shows the Architectural conceptual view of the overall system showing the main modules of the system and their sub-functions.

4.2 Use Case Diagram

The use case diagram models the functionality of a system using actors and use cases. The use case diagram displays the system requirements that are used to show how the proposed system works in practice.

Fig 3 illustrates the use case of the overall system. From the illustration, there are three (3) actors which are the public, the admin and the truck driver. Through the web application, the public can lodge a complaint about filled waste bins which is seen by the admin. Based on these complaints, the admin can perform functions like managing the area where complaints were made and other functions as shown in *Fig. 3*. The truck driver can also perform functions like viewing the allocated area with filled waste bin assigned by the admin. Based on this information the truck driver finds the shortest route from the bin to the landfill.

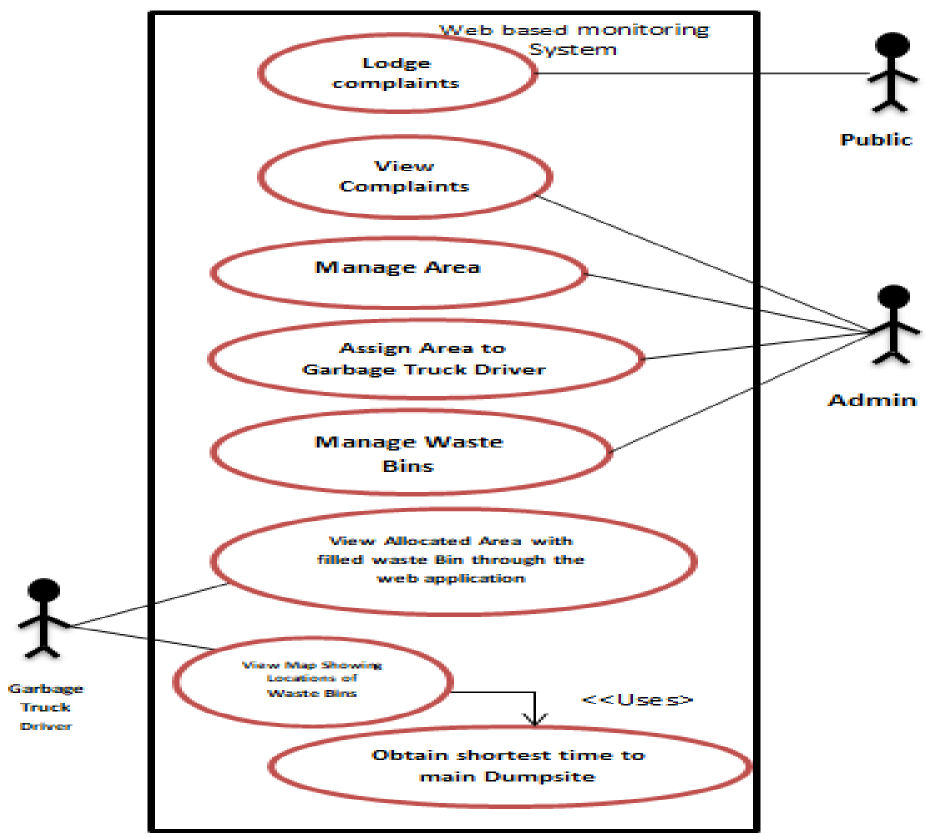

Fig. 3. Use case Diagram of the system

Fig. 3 shows the use case diagram displaying the functionalities of each module in the system.

4.3 Network Analysis

In this present study, the modified Dijkstra's Algorithm was used with a model known as the Comparism Additional Model in computing the shortest path between waste bins and the major dump site. This model was proposed by [19]. In achieving this, the shortest time for truck drivers to move from a bin location to the major dump-site would be obtained. Dijkstra's algorithm is one of the simplest path finding algorithms. The classic Dijkstra's algorithm solves the single-source, shortest-path problem on a weighted graph. It is simply a step-by-step procedure that results in some conclusion, like the least-cost path. Perhaps the most well-known algorithm is generally credited to Dijkstra (1959). Dijkstra's shortest path algorithm is the most appropriate for calculating shortest paths in real-road networks as it involves calculation of shortest path between single source single destination pair. But it needs to be modified to introduce several other factors in the real life scenario. From the brief description of the study area discussed earlier, a graph was generated based on the data collection obtained as shown in *Fig. 4*.

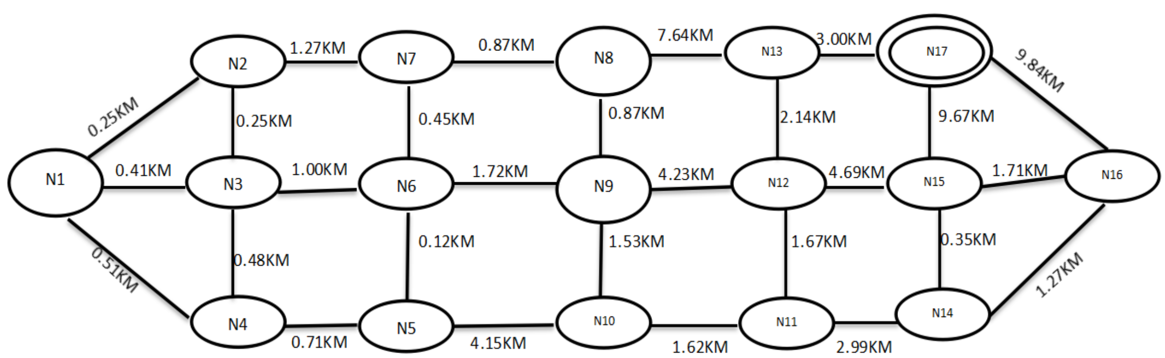

Fig. 4. Physical topology of the study area

Fig. 4 shows the physical topology of the network displaying the nodes and links that connects the nodes.

Because this research adopted the Comparism Additional Model, the following steps were carried out.

4.3.1 Number of Nodes in the Network

A network is a usually referred to a framework of routes within a system of locations which are identified as nodes. A route is a single link between two nodes that are part of the larger network. In this research, the Number of nodes that formed the network were extracted from the study area i.e. selected routes from the University of Calabar (UNICAL) area to the main dump-site located at Lemna. A total of seventeen (17) nodes were captured. This is summarized in *TABLE I*. The nodes were represented with locations where bins where kept while the routes were represented with roads that link the nodes.

Table 1: Table of Location Names and their Equivalent Node Numbers.

NAME OF LOCATION	NODE NUMBER
FEMALE HOSTEL	N1
UNION BANK	N2
MALABOR	N3
MAIN LIBRARY	N4
FACULTY OF MANAGEMENTSTUDIES	N5
UNICAL SEC SCHOOL	N6
COLLEGE	N7
DEPT OF ENGLISH	N8
SATELLITE TOWN	N9
ATIMBO R.B	N10
FED. GOVT. GIRLS COLLEGE	N11
IBB	N12
MCC R.B	N13
GARMENT FACRORY	N14
UJIMCO F.S	N15
UCTH	N16
LEMNA	N17

4.3.2 Distances Between Nodes

The distances between the nodes were measured and recorded. This is summarized in Table 2.

Table 2: Table showing the nodes and the distances between the nodes.

S/N	NODES	DISTANCE IN KILOMETRES (KM)
1	N1-N2	0.25
2	N1-N3	0.41
3	N1-N4	0.51
4	N2-N7	1.27
5	N2-N3	0.25
6	N3-N6	1.00
7	N3-N4	0.48
8	N4-N5	0.71
9	N7-N8	0.87
10	N7-N6	0.45

11	N6-N9	1.72
12	N6-N5	0.12
13	N5-N10	4.15
14	N8-N13	7.64
15	N8-N9	0.87
16	N9-N12	4.23
17	N9-N10	1.53
18	N10-N11	1.62
19	N13-N17	3.0
20	N13-N12	2.14
21	N12-N15	4.69
22	N12-N11	1.67
23	N11-N14	3.25
24	N17-N16	9.84
25	N17-N15	9.67
26	N15-N16	1.71
27	N15-N14	0.35
28	N14-N16	1.27

4.3.3 Physical Topology of the Network

The network topology is the arrangement and connectivity of nodes and links or routes in a network. In this research the network topology was derived as shown in *Fig. 4* after the nodes and distances between the nodes were obtained.

4.3.4 Analysis of the physical topology of the network

From *Fig. 4*, steps were carried out to analyze the network in other to obtain the shortest route from a chosen source to a chosen destination.

In this research, the chosen source was Node 1 and Node 17 was chosen as the destination. The following keynotes were also used to represent the parameters used in the analysis of the network.

TL- temporary label of a node

PL- permanent label of a node

□-permanent label of a node

○-temporary label of a node

*-permanent label of a node

n- anode in a network

d_{ij} –distance cost between node I and j.

The steps taken were as follows;

- **Step 1**

Make node 1 to have a permanent label (PL) = 0. While all its reachable neighbors have their temporary labels (TL) =dij and all its non-reachable neighbors have their TL=+∞. See *Fig. 5***.**

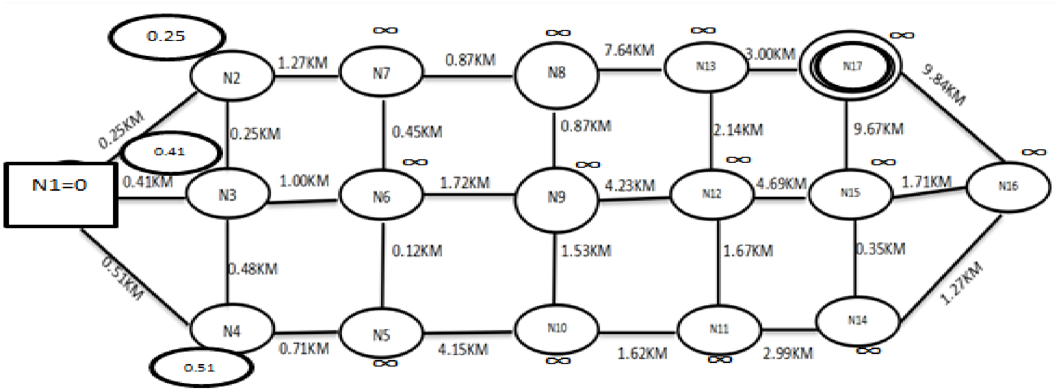

Fig. 5. At step 1, N1 is made a permanent label

- **Step 2**

Compare the TLs for all reachable neighbours of N1 and make the smallest a PL. If TL(N2)≤TL(N3) AND TL(N2)≤TL(N4), then PL = N2 = 0.25 otherwise PL≠N2 and subject for further comparison. See *Fig. 6***.** Update TL for the neigbours of N2 and compare with previous TL. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

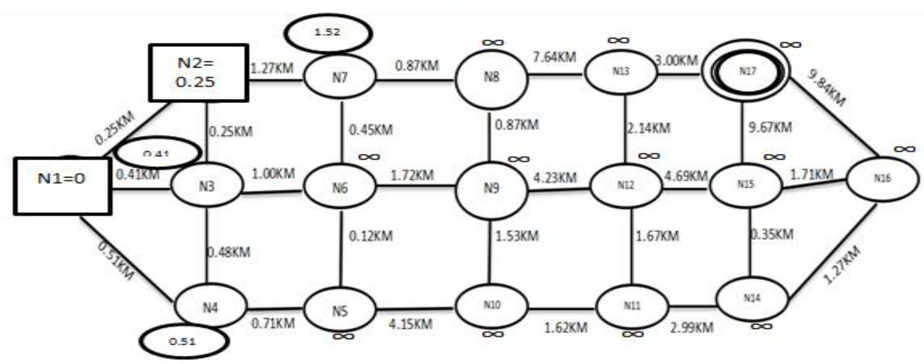

Fig. 6. At step 2, N2 is made a permanent label

- **Step 3**

  Compare the TLs for N3, N4, and N7 and make the smallest of them a PL. If TL(N3)≤TL(N4) AND TL(N3)≤TL(N7), then PL = N3 = 0.41 otherwise PL≠N3 and subject for further comparison test. Since the test condition is true, PL=N3 = 0.41. See *Fig. 7***.** If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

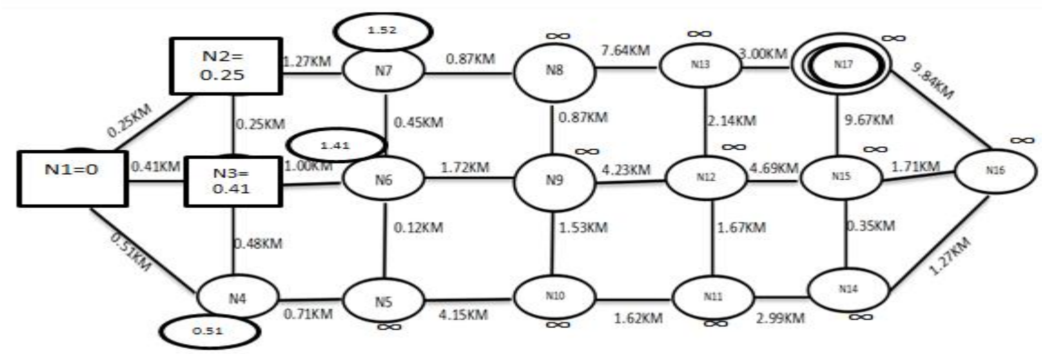

Fig. 7. At step 3, N3 is made a permanent label

- **Step 4**

  Compare the TLs for N4, N6 and N7 and make the smallest of them a PL. If TL(N4)≤TL(N6) AND TL(N4)≤TL(N7), then PL = N4 = 0.51 otherwise PL≠N4 and subject for further comparison test. Since the test condition is true, PL=N4 = 0.51. See *Fig. 8***.** If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

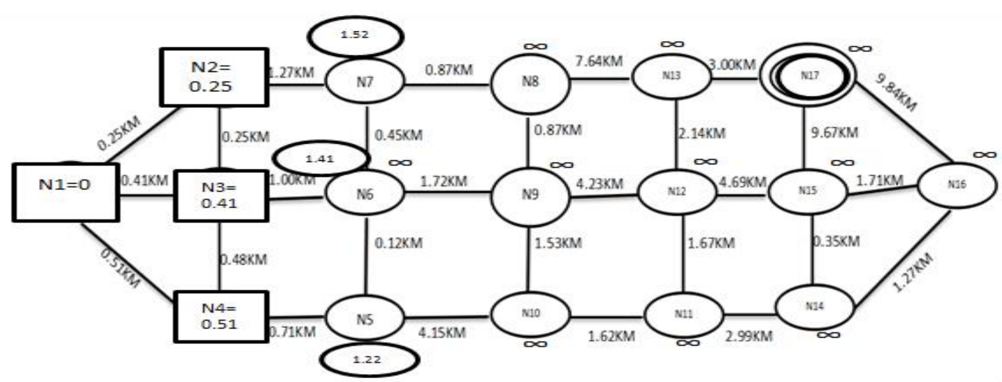

Fig. 8. At step 4, N4 is made a permanent label

- **Step 5**

Compare the TLs for N5, N6, and N7 and make the smallest of them a PL.

If TL(N5)≤TL(N6) AND TL(N5)≤TL(N7), then PL = N5 = 1.22 otherwise PL≠N5 and subject for further comparison test. Since the test condition is true, PL = N5 = 1.22. See *Fig. 9*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

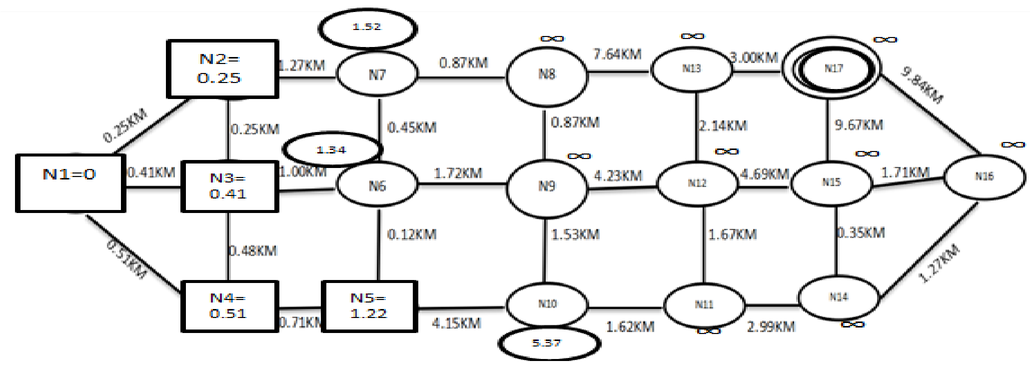

Fig. 9. At step 5, N5 is made a permanent label

- **Step 6**

Compare the TLs N6,N7 and N10 and make the smallest of them a PL. If TL(N6)≤TL(N7) AND TL(N6)≤TL(N10), then PL = N6 = 1.22 otherwise PL≠N6 and subject for further comparison test. Since the test condition is true, PL = N6 = 1.34. See *Fig. 10*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

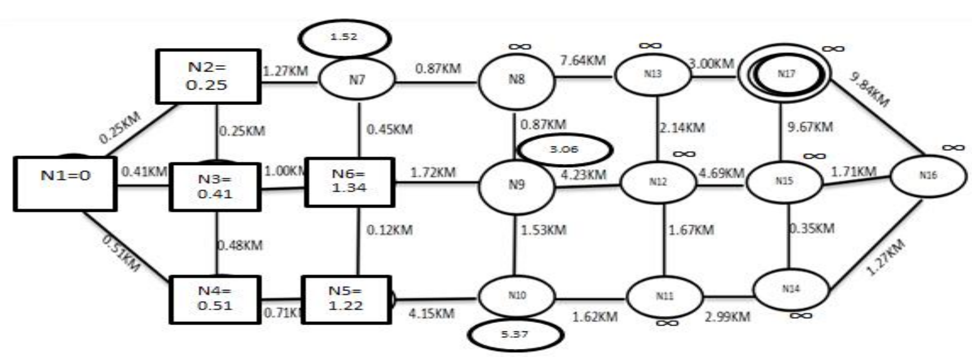

Fig. 10. At step 6, N6 is made a permanent label

- **Step 7**

  Compare the TLs for N7, N9 and N10 and make the smallest of them a PL. If TL(N7)≤TL(N9) AND TL(N7)≤TL(N10), then PL = N7 = 1.52 otherwise PL≠N7 and subject for further comparison test. Since the test condition is true, PL = N7 = 1.52. See *Fig. 11*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

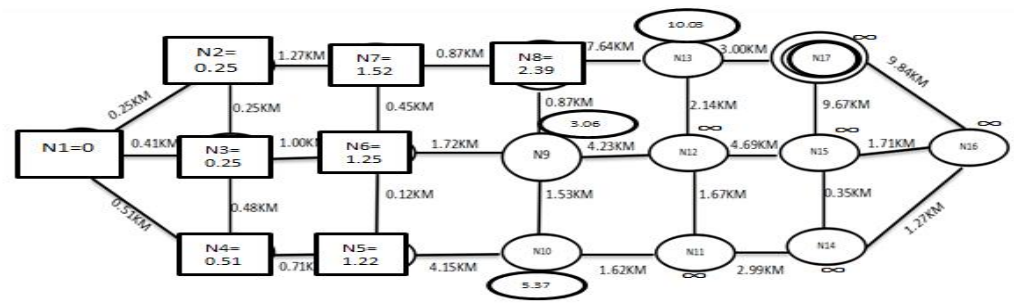

Fig. 11. At step 7, N7 is made a permanent label

- **Step 8**

  Compare the TLs for N8, N9 and N10 and make the smallest of them a PL. If TL(N8)≤TL(N9) AND TL(N8)≤TL(N10), then PL = N8 = 2.39 otherwise PL≠N8 and subject for further comparison test. Since the test condition is true, PL = N8 = 2.39. See Fig 12 below. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

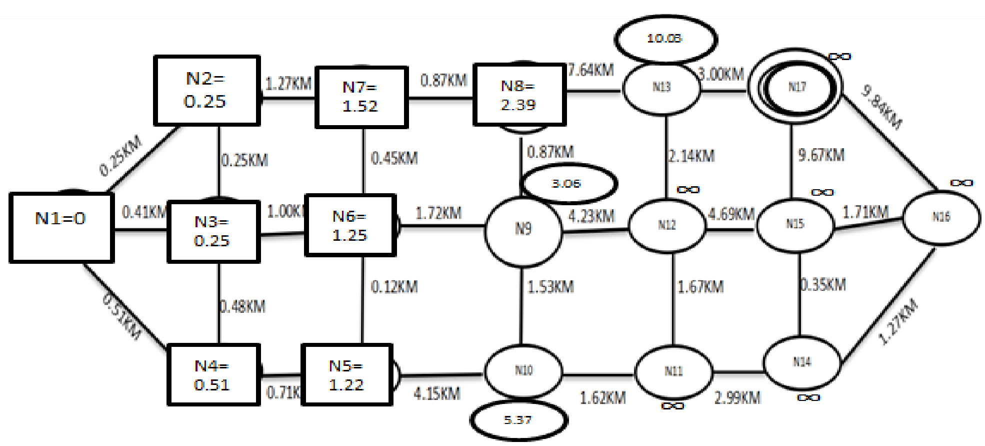

Fig. 12. At step 8, N8 is made a permanent label

- **Step 9**

Compare the TLs for N9, N10 and N13 and make the smallest of them a PL. If TL(N9)≤TL(N10) AND TL(N9)≤TL(N13), then PL = N9 = 3.06 otherwise PL≠N9 and subject for further comparison test. Since the test condition is true, PL = N9 = 3.06. See *Fig. 13*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

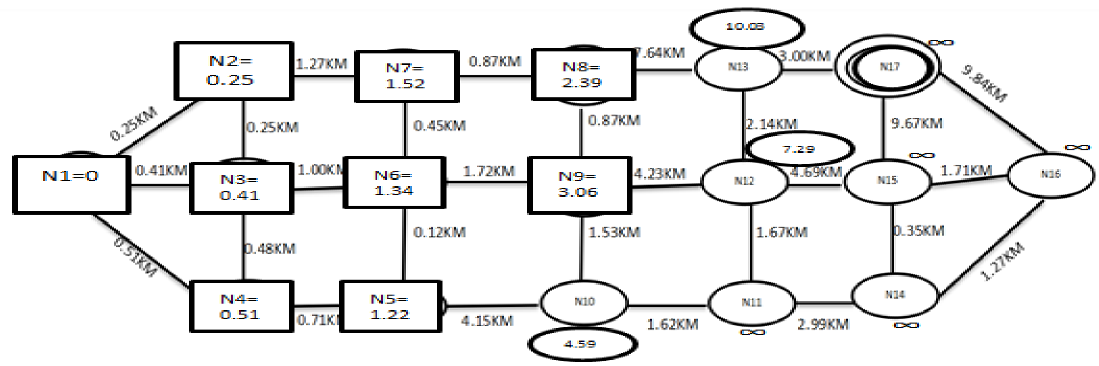

Fig. 13. At step 9, N9 is made a permanent label

- **Step 10**

Compare the TLs for N10, N12, and N13 and make the smallest of them a PL. If TL(N10)≤TL(N12) AND TL(N10)≤TL(N13), then PL = N10 = 4.59 otherwise PL≠N5 and subject for further comparison test. Since the test condition is true, PL = N5 = 4.59. See *Fig. 14*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

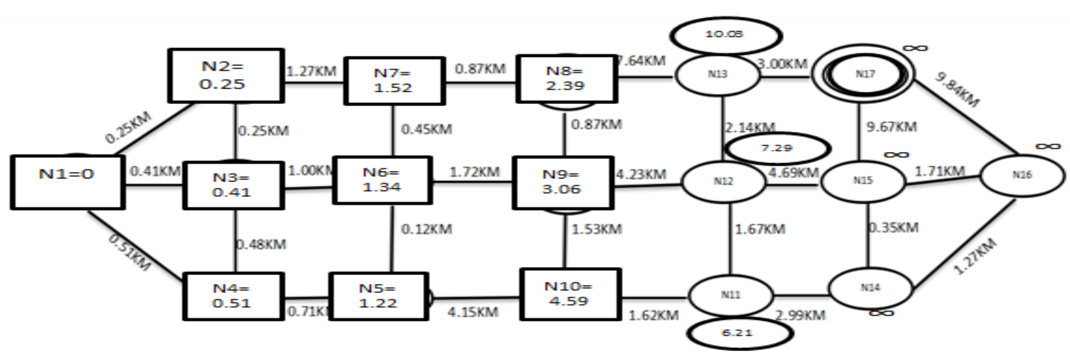

Fig. 14 At step 10, N10 is made a permanent label

- **Step 11**

  Compare the TLs for N11, N12, and N13 and make the smallest of them a PL. If TL(N11)≤TL(N612) AND TL(N11)≤TL(N13), then PL = N11 = 1.22 otherwise PL≠N11 and subject for further comparison test. Since the test condition is true, PL = N11 = 6.2. See *Fig. 15*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

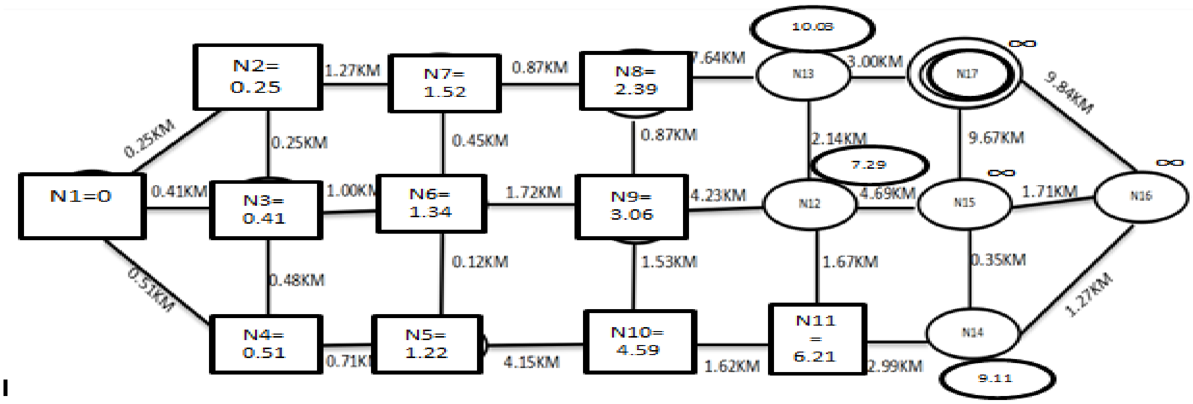

Fig. 15. At step 11, N11 is made a permanent label

- **Step 12:**

  Compare the TLs for N12, N13, and N16 and make the smallest of them a PL. If TL(N12)≤TL(N13) AND TL(N12)≤TL(N16), then PL = N12 = 7.29 otherwise PL≠N12 and subject for further comparison test. Since the test condition is true, PL = N12 = 7.29. see *Fig. 16*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

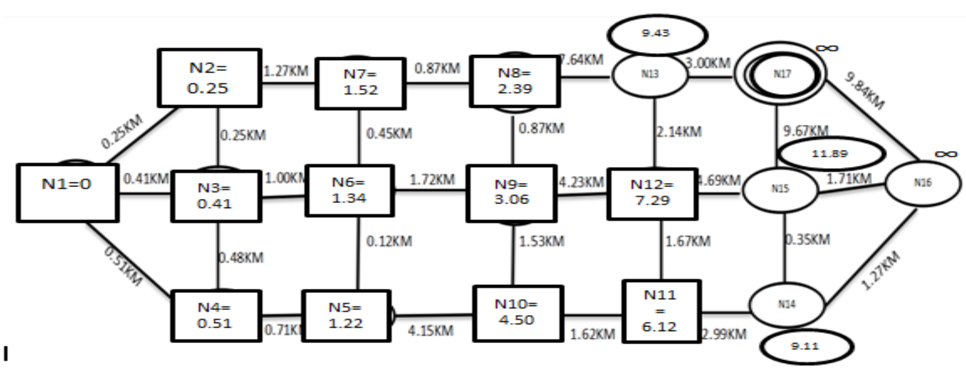

Fig. 16. At step 12, N12 is made a permanent label

- **Step 13**

Compare the TLs for N13, N15, and N16 and make the smallest of them a PL.

If TL(N13)≤TL(N15) AND TL(N13)≤TL(N16), then PL = N13 = 9.43 otherwise PL≠N13 and subject for further comparison test. Since the test condition is true, PL = N13 = 9.43. See *Fig. 17*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

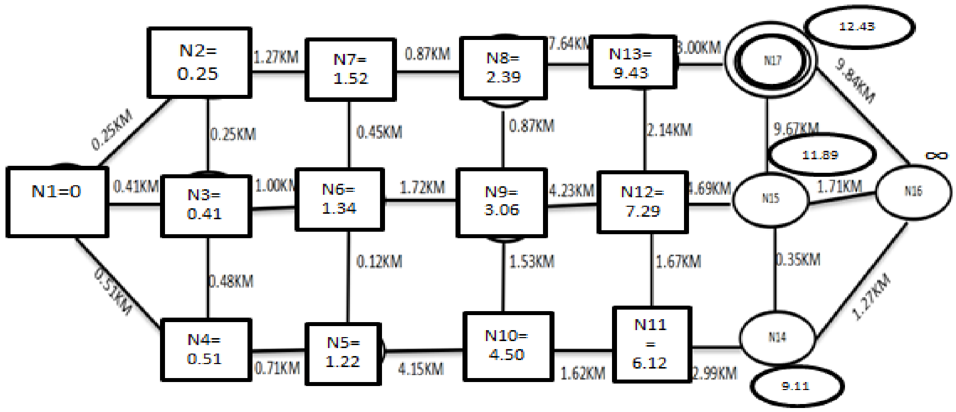

Fig. 17. At step 13, N13 is made a permanent label

- **Step 14**

Compare the TLs for N14, N15, and N16 and make the smallest of them a PL. If TL(N16)≤TL(N14) AND TL(N16)≤TL(N15), then PL = N16 = 9.46 otherwise PL≠N16 and subject for further comparison test. Since the test condition is true, PL = N16 = 9.46. See *Fig. 18*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

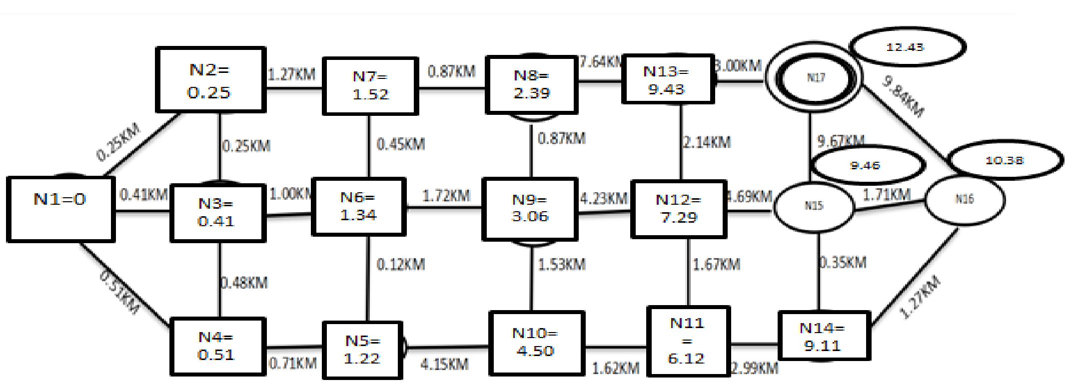

Fig. 18. At step 14, N14 is made a permanent label

- **Step 15**

Compare the TLs for N14, N15, and N17 and make the smallest of them a PL. If TL(N15)≤TL(N14) AND TL(N15)≤TL(N16), then PL = N15 = 9.81 otherwise PL≠N15 and subject for further comparison test. Since the test condition is true, PL = N15 = 9.81. See *Fig. 19*. If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

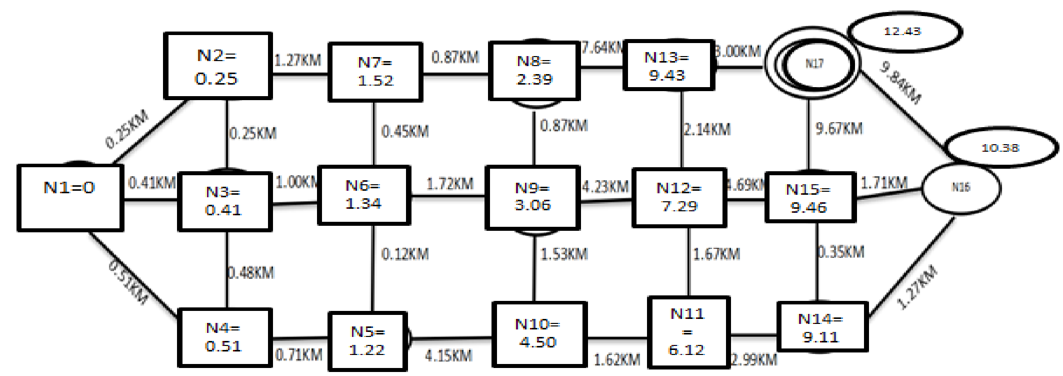

Fig. 19. At step 15, N15 is made a permanent label

- **Step 16**

Compare the TLs for N16, and N17 and make the smallest of them a PL. If TL(N16)≤TL(N17), then PL = N16 = 10.73 otherwise PL≠N16 and subject for further comparison test.Since the test condition is true, PL = N16 = 10.73. See *Fig. 20***.** If new TL≤old TL, then replace old TL with New TL otherwise the old TL will remain unchanged.

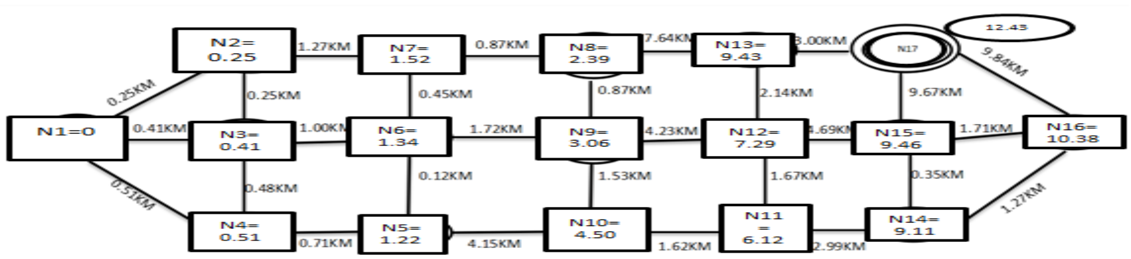

Fig. 20. At step 16, N16 is made a permanent label

- **Step 17**

Update N17 and change its label status to PL. since N17 is final node, the algorithm converges to a halt and the weight cost becomes the shortest weight cost in the network. **See** *Fig. 21***.**

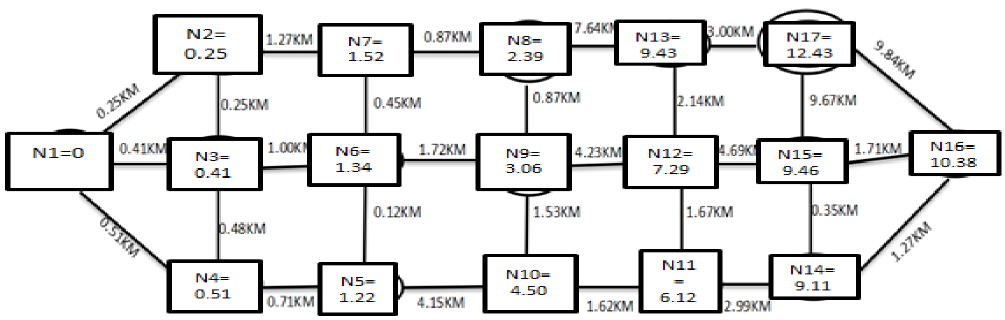

Fig. 21. Algorithm converges to a halt at N17

5 RESULT

The results obtained from the design are discussed in this section. With the waste management system, the public would be able to lodge complaints about filled waste bins within the area as shown in *Fig. 22*.

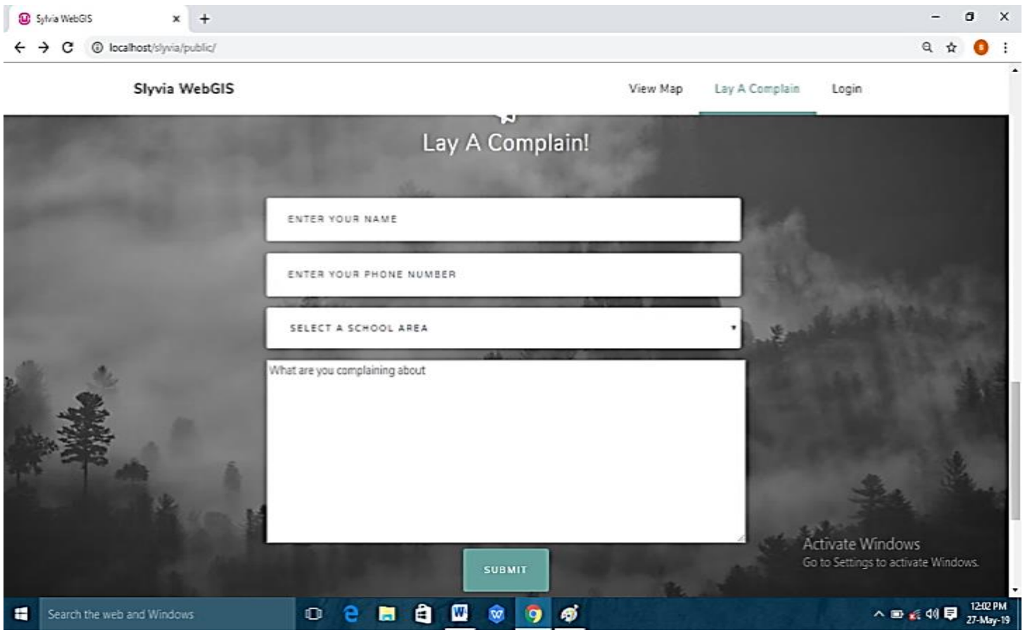

Fig. 22. Screen shot of the home screen application

The details of the information provided by the public would be viewed by the administrator who could be the supervisor of a WARD in a Local Government Area. The Ward Supervisor would be able to service waste bins in all areas of the Local Government because the system is able to give a spatial view of the locations of all registered waste bins in an area. See *Fig. 23*

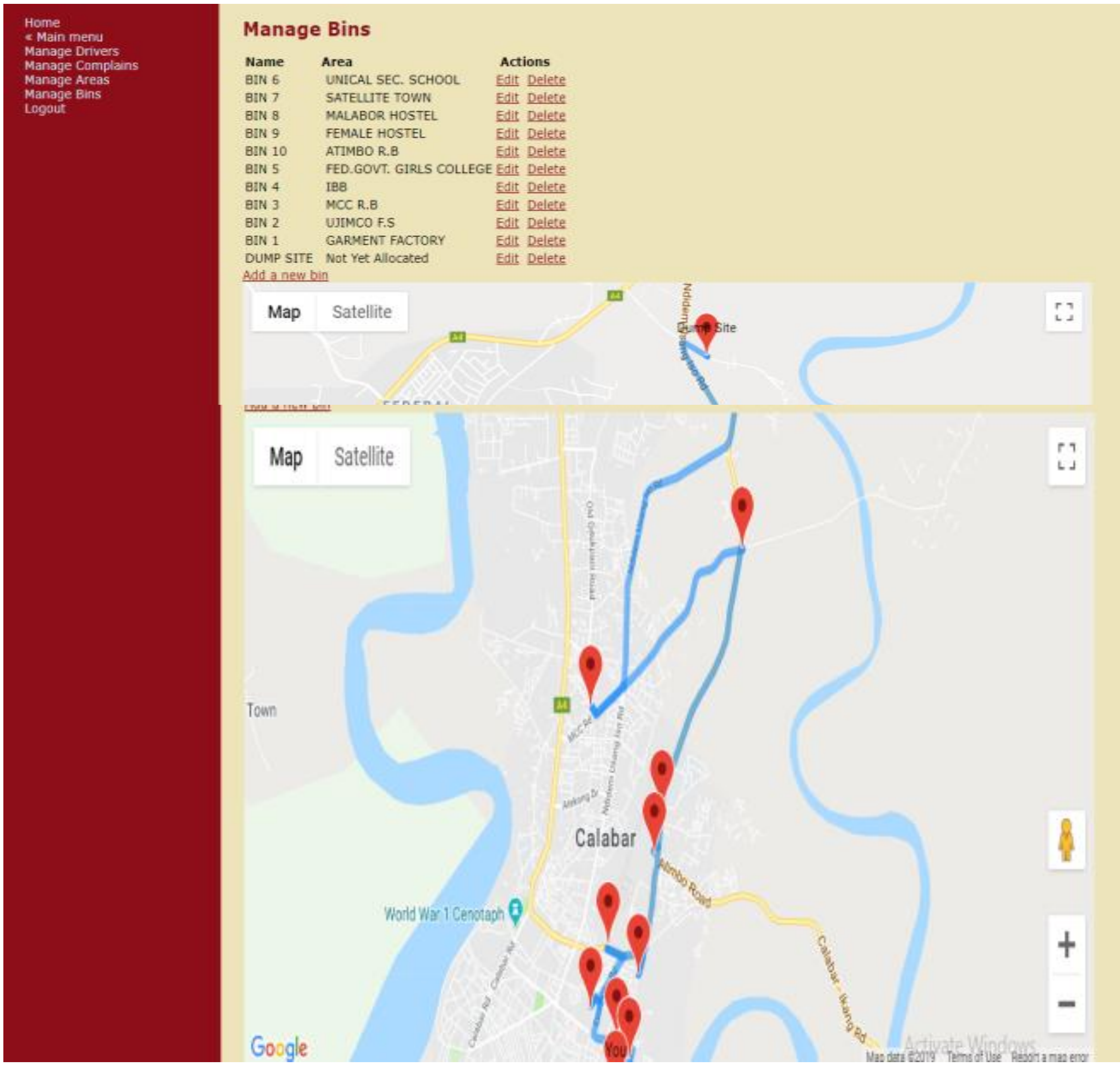

Fig. 23. Screen shot of the interface showing bin locations in the Administrator's section.

If new areas are in existence within the Local Government, and new waste bins are kept in place, the system is capable of adding new areas with the new waste bins. The supervisor would also have information of the Garbage truck drivers he is supervising , this gives the supervisor access to monitor the truck Drivers to know if they attend to filled waste bins or not. Because the Garbage Truck Driver knows the area he/ she is handling, the driver can login to his/her account to see the locations of filled waste bins as shown in *Fig. 24.*

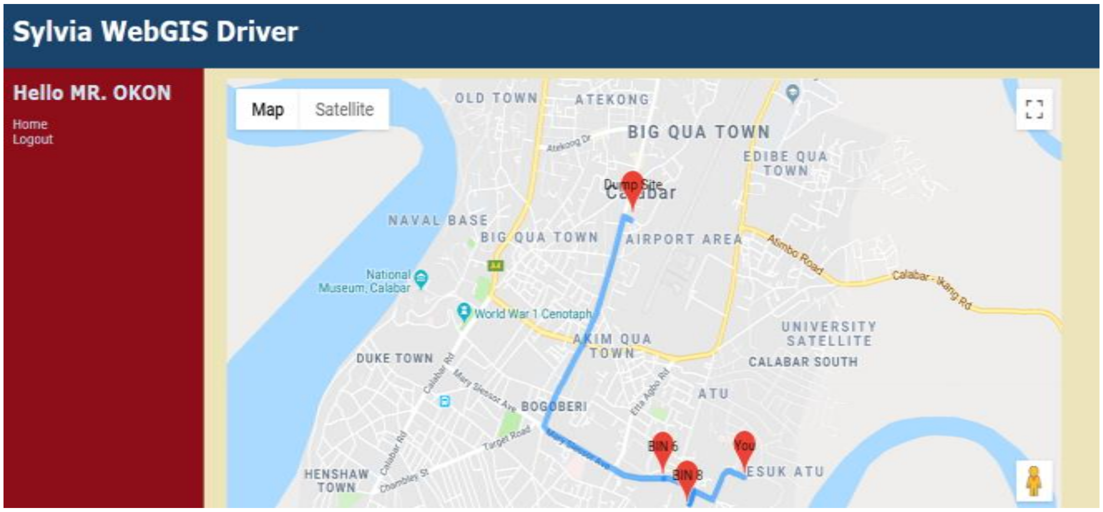

Fig. 24. Screen shot of Garbage truck driver showing allocated bins

From the application of the Comparism Additional Model it was derived that the garbage truck driver can obtain the shortest route it would take to dispose waste at the landfill from the location of the filled waste bin. From the analysis of the network, Node 1(Malabor hostel) was used as the source bin location and Node17 (Lemna dump site) was used as the destination. Eight (8) arbitrary routes were obtained from the source bin location to the destination and the least cost of each route was obtained. It was identified that R1 had the least cost as shown in *Fig. 25* and at a constant speed of 45km/hour, the minimum time was obtained for the 8 arbitrary routes. This is shown in *Table 3*. From the table, a bar chart was created to display the route with least cost and minimum time as shown in *Fig. 26*. From the chart, it can be seen that the route with the least cost is Route1 i.e **R1**= N1-N4-N7-N6-N9-N12-N11-N17. This means that Route 1 = Malabor hostel-> Main library-> college-> UNICAL secondary school-> Satellite town-> IBB-> Federal Government Girls' College-> Lemna. From the given constant speed, assuming there is no traffic congestion, it would take 16 minutes 5 seconds to dispose waste at the major dump-site from the selected source of waste bin. Transportation route was also optimized based on analysis of waste collection bin locations which results in ensuring that minimal time is spent on disposing waste into the landfill.

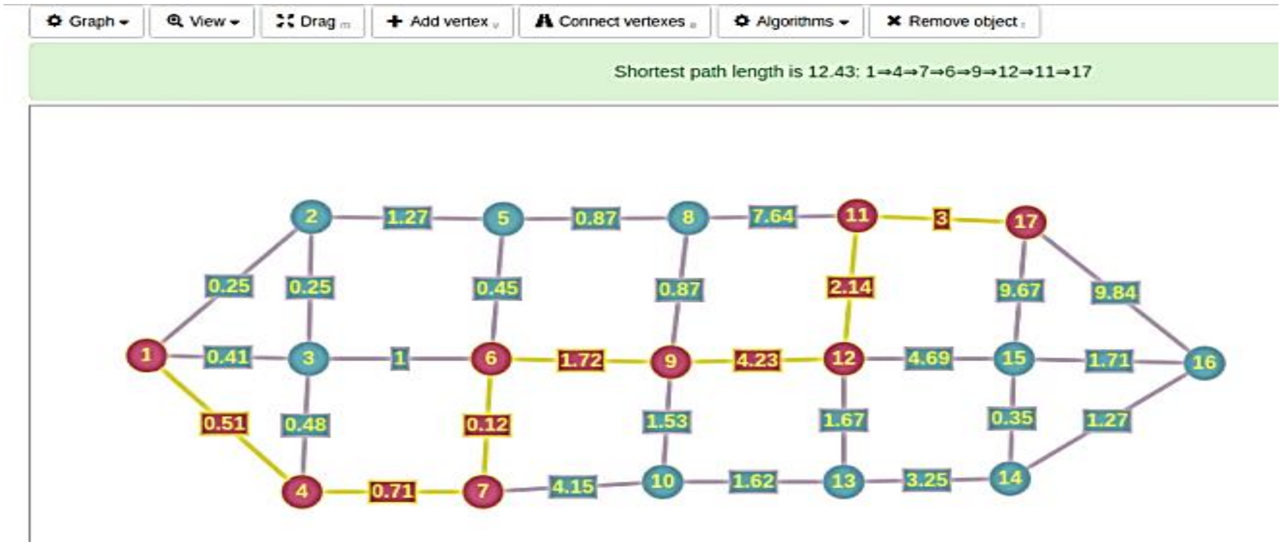

Fig. 25. Screen shot of shortest route from Node 1 to Node 17

TABLE 3: Table Showing Results of Arbitrary Routes and their Equivalent Time.

Route	Least Cost In Kilometers	Equivalent time in minutes
R1= N1-N4-N7-N6-N9-N12-N11-N17	12.43	16.5
R2= N1-N3-N6-N9-N12-N13-N17	12.50	16.6
R3= N1-N2-N3-N6-N9-N12-N13-N17	12.59	16.7
R4= N1-N4-N5-N10-N11-N12-N13-N17	13.80	18.4
R5= N1-N2-N7-N8-N13-N17	13.03	17.3
R6= N1-N3-N6-N9-N8-N13-N17	14.64	19.5
R7=N1-N3-N6-N9-N12-N15-N17	18.72	25.0
R8-N1-N4-N5-N10-N11-N14-N15-N17	20.26	27.0

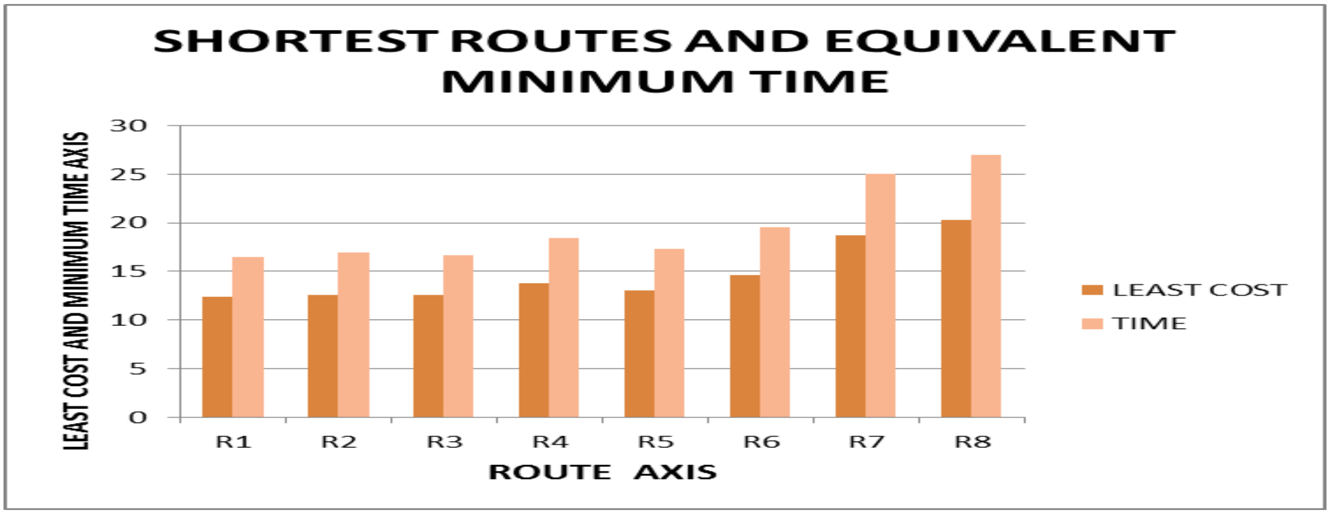

Fig. 26. Screen shot of Bar chart displaying the route with least cost and minimum time.

6. CONCLUSION

The study captured the development of a system consisting of three modules that works together to achieve the objectives of generating a map to show all routes, bin locations and major dump-sites in the covered regions, an interface where complaints about full waste bins would be lodged and accessed by the users of the system and a web based monitoring system using GIS that will monitor, manage and maintain waste collection bins in the covered region and also give the shortest time possible to dispose waste collected to major dump site. This system demonstrates that web based systems integrated with Geographic Information Technology can enhance waste collection and disposal management. The system can receive information dynamically at real time about waste bin situations within the study area and proactively take an action to evacuate waste from storage locations. This research applied the modified Dijkstra's algorithm with Comparism Additional Model which uses a priority queue to improve the transit time for garbage truck drivers in disposing waste at the landfill or major dump-site. Our result shows that at a constant speed of 45km/hr., it will take sixteen (16) minutes to dispose waste at the major dump-site (Lemna) if **R1** is used. The transportation route has therefore been optimized based on the analysis of waste collection bin locations. This will ensure that less time and cost is spent on disposing waste at the landfill or major dump site.

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Dedication

Not mentioned.

Conflicts of Interest

There are no conflicts to declare.