Application of GIS Network Analysis For Proper Management of Refuse Disposal in Jimeta, Nigeria.

Musa, Abubakar. A.
Dept of Surveying & Geoinformatics
Modibbo Adama University of Technology (MAUTECH)
Yola, Adamawa State

Abstract:

The frequent appearance of illegal refuse bins scattered in the Jimeta metropolis and inability to clear the refuse regularly has been identified as a major problem. In a bid to find solution to the problem, this paper had tried to map out the refuse bins and also design a model for planning waste disposal management. With the help of the model, optimal routes were determined. Analysis was conducted on the model to determine the service areas of the refuse bins for 100m, 150m and 200m trekking distances. Likewise, analysis was conducted to ascertain the best route and sequence of visit to the respective bins so as to reduce workload, fuel consumption and time. It was concluded that refuse bins in Jimeta are grossly inadequate and those available are not equitably distributed. Also, in order to efficiently clear the refuse from the bins, three routes were considered appropriate. Thus a minimum of three trucks will be required to traverse the designated optimal routes at the same time.

Keywords: Refuse disposal, Network Analysis, Optimal routes, Service areas, network modelling.

Introduction:

Refuse as used in this paper refers to solid wastes. This in turn has been defined by Palnitkar (2002) as non-liquid waste materials arising from domestic, trade, commercial, agric, industrial activities and from public services. Rapid increase in population has resulted in pressure on existing facilities. One of such facilities is the refuse disposal system of a typical metropolitan city like Jimeta. The connection between population explosion and garbage generation is obvious from Oyeniyi's (2011) observation that Ibadan and Lagos, Nigeria's most populous cities rank first and fourth respectively among the dirtiest cities in the world. The rates at which solid wastes are being generated in Jimeta are not matched by the frequency at which the garbage is being evacuated. Ogwueleka (2009) explained that this was as a result of inefficient collection methods, insufficient coverage of the collection system and improper disposal of solid waste. This has often led to indiscriminate dumping of refuse in open spaces not designated for refuse. Even the legally designated refuse bins usually get buried in a heap of refuse before it is eventually cleared, not to talk of the illegal bins which usually take a while before they get noticed. The cumulative effect is heaps of refuse dumps scattered all over the city. For the vast majority of the populace, it is the stench exuding from such dumps that causes the greatest irritation. Hidden, unseen problems however include the fact that refuse dumps are often breeding grounds for most vectors. Such vectors include insects like mosquitoes, flies, cockroaches and rodents. These vectors can carry diseases got from such dumps to areas far away from the refuse dumps. Matters can quickly degenerate during the rainy season when rain water passes through such dumps and seeps into sources of drinking water, thus contaminating them. The cost of curtailing an epidemic by far outweighs the cost of evacuation of the refuse. The tourism potential of the city is also seriously hampered by the eye-sore created on seeing overfilled refuse bins with animals like dogs and goats scattering the refuse around the bins. In some extreme cases, the size of the refuse heaps are so large that roads could be completely blocked causing traffic jam.

Municipal workers responsible for evacuating refuse are often quick to defend themselves when accused of lackadaisical attitude towards refuse disposal. Usually they accuse government of not pumping enough money into the refuse disposal agency. Yet in cities where sufficient funds have been made available, a large chunk of the money is used in purchasing refuse trucks to replace the old unserviceable ones. After the purchases, sanity returns temporarily and refuse is promptly cleared again. But this only last for a few years after which a slow and steady decline is witnessed in the refuse disposal infrastructure. In a couple of years everything returns to square one and the accumulation of refuse returns. Ogwueleka (2009) rightly observed that 60% of refuse trucks available in Nigeria are always out of service at any one time and the remaining 40% breakdown frequently due to overuse. The case of Jimeta cannot be different from the rest of the country. The question we should ask ourselves is - what are we doing wrong? Proper planning of refuse disposal system is still lacking. Most of the planning done by our municipal governments still relies on obsolete analogue techniques depending on old theoretical models without the advantage of modern technology. This paper provides more accurate, detailed and scientifically advanced approach to planning the refuse disposal system - an approach that will reduce the stress on both man and machine. The system proposed is the GIS approach.

Network analysis, is the GIS tool used for identifying the most efficient routes or paths for allocation of services. This involves finding the shortest or least-cost route in which to visit a location or a set of locations in a network. The 'cost' in a network analysis is frequently either distance or travel time. The use of network analysis in managing refuse disposal is being practiced successfully in many countries in both developed and developing parts of the world. Ahmed (2006) used network analysis of the GIS as a decision support tool for planning waste management in Aurangabad, India. A model was designed for planning waste management which reduced the waste management workload. Likewise Kyessi and Mwakalinga (2009) used network analysis to coordinate solid waste collection in the Kinondoni municipality of Dar es Salam city, Tanzania. The new routes proposed spanned about 9,140m as against the old route of 14,570m that is about 5,430m less than the previous route. Thus bringing more profit at less charges. Lakhumi et al (2006) also used the network analyst extension of ArcView 3.2a to determine the optimum route for solid waste collection and disposal in Chennai, India. The optimum routes identified were found to be cost effective and less time consuming when compared with existing routes.

Attempting similar studies in Jimeta will greatly assist policy makers in making informed decisions regarding refuse disposal in the study area. This paper therefore aims at achieving three objectives. First, it will map refuse bin sites and their service areas in Jimeta. Secondly, it will design a model for planning waste disposal management in Jimeta. Lastly, it will determine the most efficient (optimal) route from origin (Adamawa Urban Planning & Development Board - ADUPDB) to the destination (main refuse dump) and the sequence with which to visit the refuse bins (stops) for optimal performance.

It is believed that the wastages, in terms of man hours, travel time and fuel consumption when traversing between refuse dumps will be eliminated. Reduction in workload of both man and truck will bring efficiency into the refuse disposal management of Jimeta-Yola.

Materials & Methods

Jimeta is the capital of Adamawa State – one of the 36 states making up Nigeria. The state itself is located at the north eastern part of Nigeria, sharing boundary with Cameroon. Jimeta is one of the twin cities forming the Jimeta-Yola metropolis. It has an approximate geographic coordinates of 9°14'21''N; 12°24'05''E. Jimeta, equally doubles as the headquarters of the Yola-north local government. It is almost encircled by the Yola south local government except at the northern edge where it is bounded by river Benue. With the presence of two universities and numerous other Federal establishments, the city had attracted many business concerns over the past 20 years. This has translated into a steady increase in population.

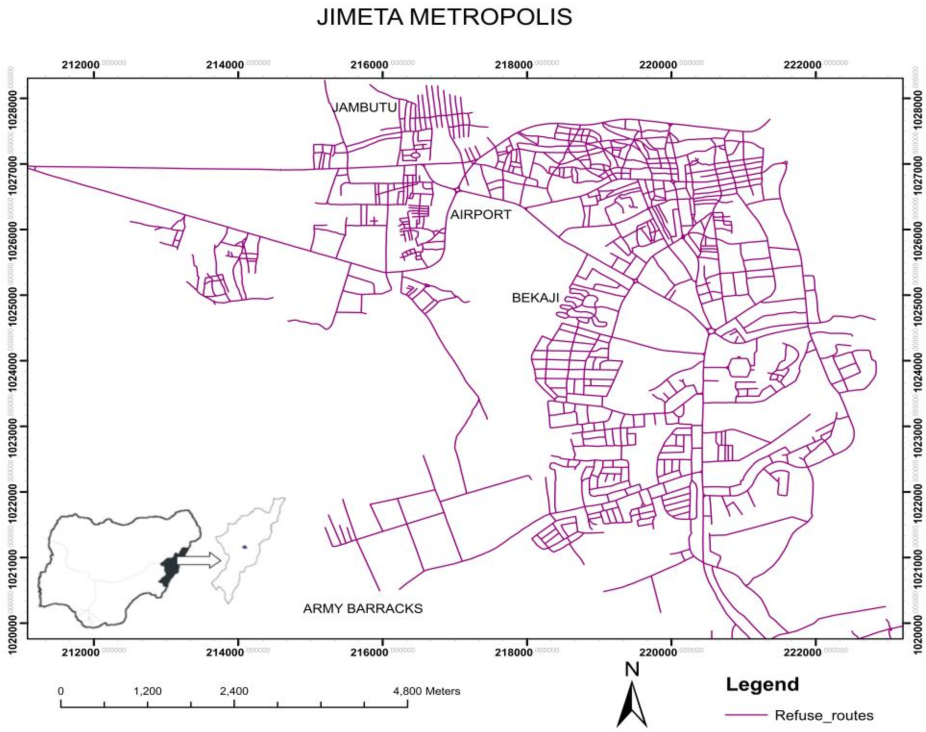

Fig 1: The Study area – Jimeta

The street network of the study area together with the refuse bins were modelled in the computer. This required that all spatial and attribute information of these features are acquired and merged into one single entity

Data:

- QuickBird satellite image of Jimeta-Yola, 2008
- Street guide map of Jimeta-Yola – Drawn and published by Gongola State Surveys, 1988; Updated by Adamawa State Ministry of Lands & Survey 2004.
- GPS field coordinates-used in mapping the location of refuse bins across the study area.

Software/Hardware

- ESRI's ArcGIS 9.3 (ArcMap & ArcCatalog)
- Hewlett Packard laptop (HD 222GB, Speed 2.00 GHz, RAM 2.93GB)
- GARMIN GPS12 (Handheld GPS)

Creating the GIS Database:

A database of both the road network and the refuse disposal sites of the study area were first created. Database creation began by first importing a QuickBird image of the study area together with its world file into ArcMap. The world file captures the georeferencing parameters of the image thus eliminating the need to georeference. Two shape files were then created in ArcCatalog, one for the road network and another to capture the locations of refuse dump sites.

The shapefile for the road network was opened and overlaid on the satellite image in ArcMap. Using the 'Editor tool', the network of roads in the satellite image was digitized onto the shape file. In order to ensure that nodes are created at every junction when the network dataset is eventually created, the roads were digitized such that junctions are also start/end points of digitized segments. Snapping options were set to 'vertex' and 'edge'. The vertex snap was used to ensure that at cross junctions each of the four arcs in the junction terminates at precisely the same point (node). The 'edge' snap on the other hand was useful when creating 'T' junctions. The snapping option ensured there were no overshoot or undershoot.

An attribute table was created for the road network. Apart from the three default fields in the table i.e. FID, Shape and id, three other fields were created – i.e. Hierarchy, Rd_Name and Drive_Time. Dual carriage ways were given a hierarchy of 1, roads joining the dual carriage ways were given a hierarchy of 2, while all the other roads were allocated a hierarchy of 3. The names of the respective roads were entered into the Rd_Name field. Roads were identified by comparing the spatial data with the street guide map. However, since the street guide map was created since 1988, it is acknowledged that some street names might have become obsolete. In the Drive_Time field, the lengths of each of the roads were initially inserted. Then depending on the state of disrepair of the road, the inserted figures were increased by a factor.

Creating the Network Dataset:

Network datasets are the format with which networks get analyzed by ArcGIS. A network dataset is created from the feature source or sources that participate in the network. It incorporates an advanced connectivity model that can represent complex scenarios. It also possesses a rich network attribute model that helps model impedances, restrictions, and hierarchy for the network. The network dataset is built from simple features (lines and points) and turns. In this study the shape file depicting the road network was used to build the network dataset.

The network dataset was created in ArcCatalog by right clicking the 'refuse routes' shape file and choosing 'New Network Dataset'. The default connectivity setting (i.e. connectivity only at coincident endpoints of line features) was adopted for the network. Turns were not modeled, rather global turns were adopted. Attributes of DriveTime, Rd_hierarchy and length were specified for the dataset. For each of the attributes, evaluator settings were specified.

Analysis:

Two types of analysis were conducted – service area analysis and route analysis. Service area analysis is the analysis conducted to determine the approximate areal coverage that a particular facility (in this case refuse bin) is supposed to cover. Using a trekking distance of 100m, 150m and 200m, three service areas representing the specified trekking distances were calculated and displayed by the GIS. The choice of 100, 150 & 200m trekking distances is based on two criteria. The first is a research carried out by Ahmed (2006) which concluded that majority of people prefer a trekking distance of 100m; and the second is the recommendation of CPHEEO, 2000 which recommended a maximum trekking distance of 200m.

The Route Analysis option of the network analyst layer has three properties – stops, routes and barriers. Under the 'stop' property the refuse bin point map was loaded. The location of ADUPDB was inserted manually using the 'Create Network Location' tool. Under the Route property, three routes were specified. The routes were named Truck1, Truck2 and Truck3. The barrier property was left empty since no route had a barrier. In order to allocate the respective stops to each of the three routes, the properties of each stop was opened; and in the field for the RouteName property the route name (i.e. Truck1, Truck2 or Truck3) was inserted. The stops were then rearranged such that for each route the first stop was ADUPDB while the last stop was the main refuse dump. Finally, the solve button was clicked to run the analysis.

While the network analysis was successfully created, It must however be borne in mind that it has some inherent shortcomings. The most fundamental shortcoming is the fact that adequate ground verification was not done. This is because of the magnitude of work involved in doing so. This inadequate ground verification manifested in various ways. For instance, the hierarchy of the road networks was decided from the satellite image. Some roads might appear prominent on the image but in actual fact are not motorable. Likewise the traffic conditions of the roads were not put into consideration. Also, to arrive at 'Drive_Time' values, the vehicle is actually supposed to be timed at normal speed on any chosen road. But instead the lengths of the roads were converted to seconds, meaning that vehicles travel at 1m/sec. For roads that are in a bad state of disrepair their 'Drive_Time' value is increased by a factor which is determined by how bad the condition of the road is.

Result and Discussion:

Figure 2 shows the distribution of the refuse bins within Jimeta metropolis. Even with a casual glance, it is evident that refuse bin sites are not only insufficient but also not equitably distributed. However, to subject the data to a more scientific test, the service area analysis of the GIS was performed so as to determine service areas based on a 100m, 150m and 200m trekking distance. Even at 200m trekking distance, the area serviced by the available refuse bins are less than 25% of the total residential area of Jimeta metropolis. Places like the barracks and the airport are grossly subserviced. This, in the view of this writer, is the root cause of illegal refuse dumps scattered about the city. The present existing refuse bins are grossly inadequate. Special attention however should be made for the Jimeta bye-pass, which have refuse bin sites so close to each other that their service areas overlap. If the refuse are meant to be disposed at the main refuse dump, then appropriate authorities should make conscious effort to reduce their number. However, if the aim is to reclaim land through refilling, then it should be done properly. That is, to cover the refuse with a layer of soil before spreading another layer of refuse. This alternation of refuse and soil layer will make the reclaimed land more stable.

Based on the existing refuse bin sites, route analysis was also conducted to ascertain how best to collect the refuse from the refuse bins scattered around the city in a manner that will minimize workload, fuel consumption, wear & tear of the vehicles, thus increasing efficiency. Figure 3 is the result of the analysis. The three routes recommended are coloured red, blue and green. The order in which the stops (i.e. the bins) are numbered indicates the sequence with which the trucks should visit the bins. Thus all trucks will depart stop 1 (the location of ADUPDB), from where each truck takes its separate routes and finally converge at the main disposal site where the contents of the trucks are deposited.

Conclusion

The GIS model designed for planning refuse disposal, for all practical purposes, is reliable. The GIS has proved to be a very useful tool for managing refuse disposal in Jimeta. Its ability to display spatial data in a clear and comprehensive manner is unparalleled. Thus, the gross inadequacy of refuse bins in Jimeta needs no further confirmation. Its ability to also use spatial data to make rapid computations to reveal new environmental information has again been confirmed in the route and service area analysis performed. To ensure efficient refuse disposal management, more refuse bins should be made available. Service areas should be computed as a means of determining the quantity and location of new refuse bins. After which route analysis should be done to confirm how best to transport the refuse across the city to its final destination.

Acknowledgement:

I wish to acknowledge the role played by Mal Bashir Gambo of the Adamawa Urban Planning Development Board for providing me with the geographic coordinates of refuse bin sites of Jimeta-Yola.

References

Ahmed. S (2006) *Using GIS in Solid Waste Management Planning: A case study for Aurangabad, India* ISRN: LIU-IDA-D20--06/004—SE. Masters Thesis. IDA, Linköpings University

CPHEEO (2000) *Manual on Municipal Solid Waste management*. 219-227. Central Public Health and Environmental Engineering, New Delhi, India

Kyessi Alphonce & Mwakalinga Victoria (2009): *GIS Application In Coordinating Solid Waste Collection: The case of Sinza Neighbourhood in Kinondoni Municipality, Dae es Salam City, Tanzania*. FIG Working Week 2009. Surveyors Key Role in Accelerated Development. Eilat, Isreal, 3-8 May 2009

Lakshumi. A. P, Ramiya. A. M & Ssthya. R (2006): *Optimal Route Analysis for Solid Waste Disposal Using Geographic Information System*. Dowmloaded on December 20, 2012 from http://www.gisdevelopment.net/proceedngs/mapindia/2006/student%20oral/mi06stu_113.htm

Ogwueleka. T. (2009); Municipal Solid Waste Characteristics and Management In Nigeria. *Iran*

Journal of Environmental Health Science Eng'g. Vol **6**(3). 173-180. Downloaded from http://journals.tums.ac.ir/ on Tuesday, February 19, 2013.

Oyeniyi. B. A.(2011); Waste Management in Contemporary Nigeria: The Abuja Example. *International Journal of Politics and Good Governance.* Vol. **2**(2) Quarter II. ISSN:0976-1195

Palnitkar. S, (2002). *Manual of Solid Waste Management*, AIILSG, Mumbai. pp. 9.

Shahriar Rahman & Syed Hafizur Rahman (2011) Application of GIS Techniques in Urban Solid Waste Management In A Part of Dhaka City: Mohammadpur Thana; *Journal of Sustainable Development and Environmental Protection.* Vol **1**(2).

Appendices

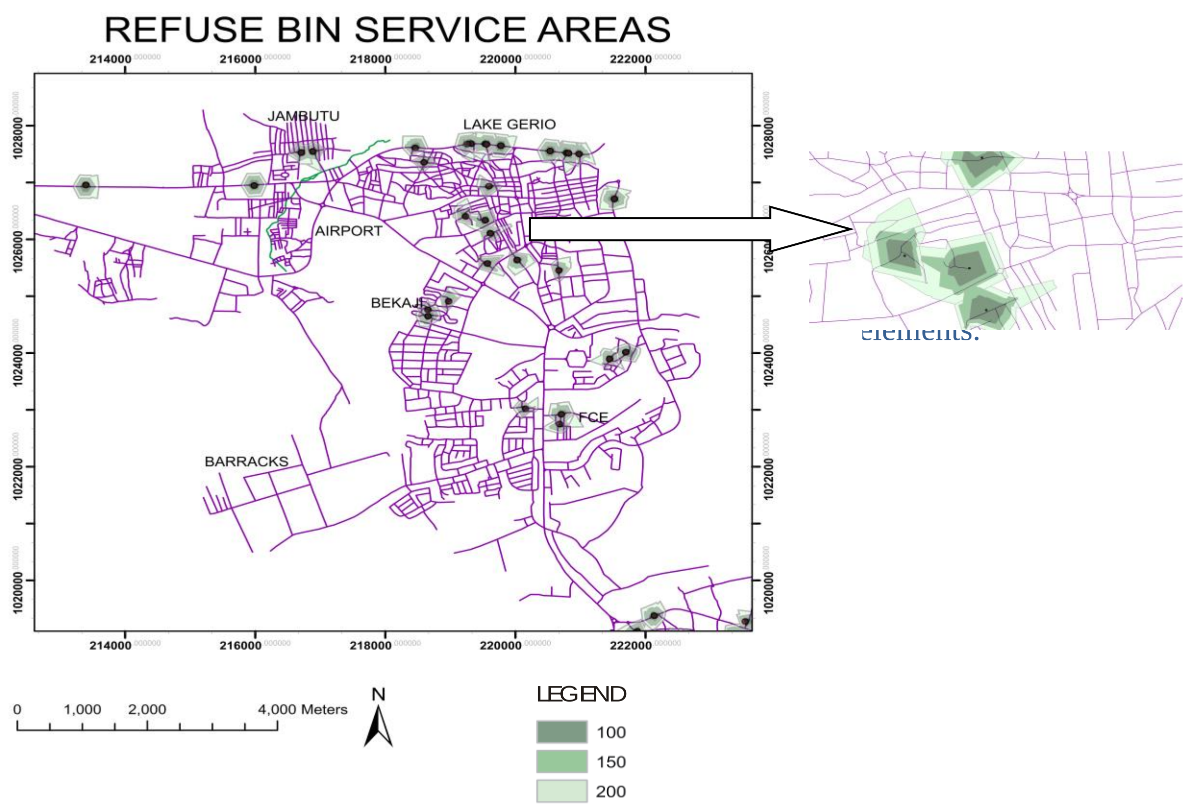

Fig 2: Refuse bin sites and their

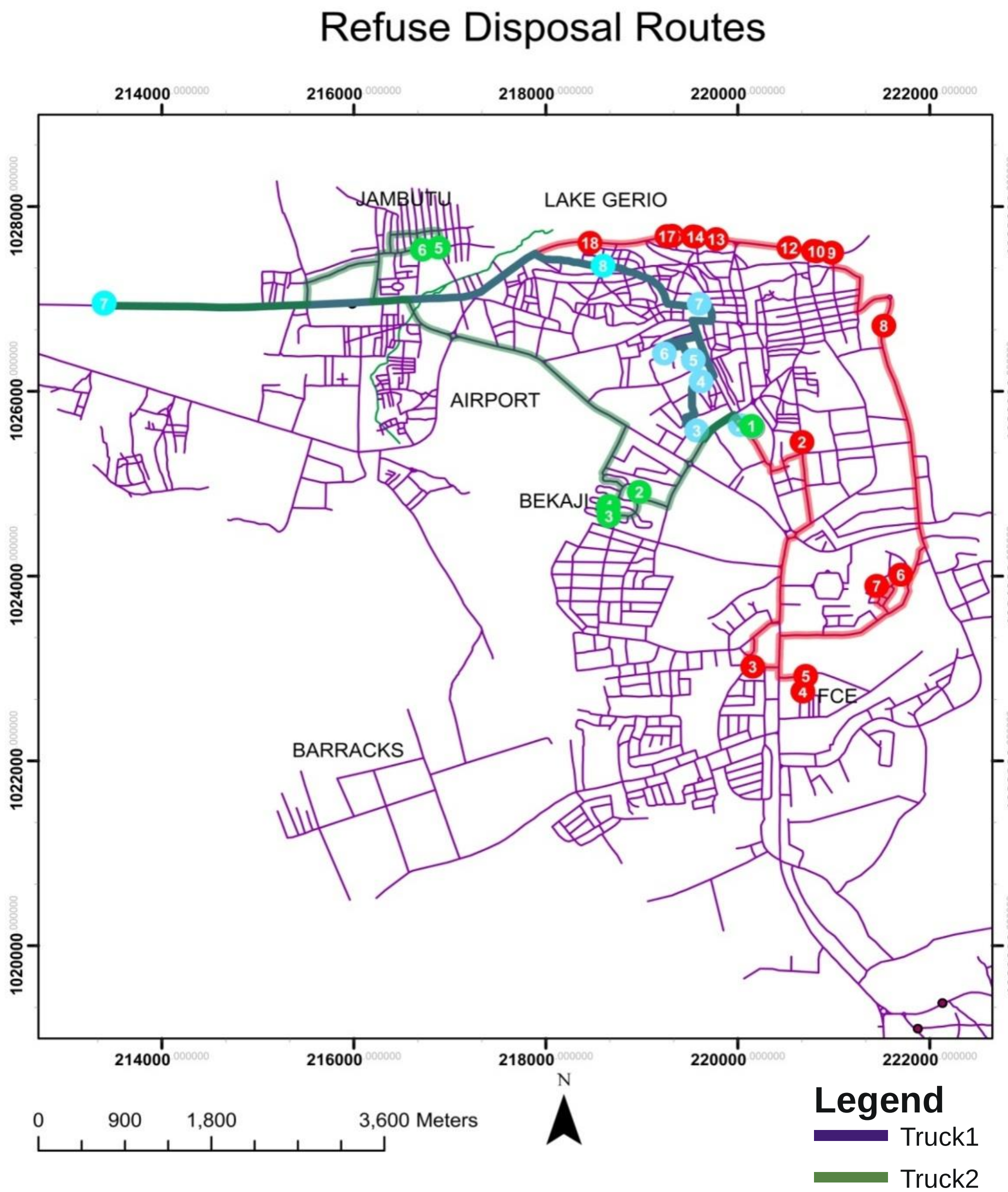

Fig 3: Refuse disposal Routes