Geographical Information System (GIS) as a Tool for Urban Traffic Network Analysis (A Case Study of Federal Capital City, Abuja)

Sama'ila Saleh
Hassan Usman Katsina Polytechnic/Department of Civil Engineering, Katsina, Nigeria
Email: samailasaleh2003@yahoo.com

***Abstract*—Traffic models demand large amounts of data some of which are: time to travel a given road length, which streets are restricted for which vehicles, the speeds along the given road and which street are one-way. GIS is a natural tool for handling most of these data as it can ease the work process and improve the quality control. The research used ArcInfo to carry out urban traffic network analysis of Abuja, the Federal Capital City of Nigeria. The methodology can be used on not only a simple street network analysis but it can support multi edge sources to model a complex multimodal networks. The research covers the following tasks: Choosing and developing the source workspace, identifying the sources and the role they will play in the network, modeling the connectivity, defining attributes and determining their values. In addition, it also highlighted the following analyses: finding the best route, finding the closest facility, finding the service area and creating the O-D cost matrix.**

***Index Terms*—Geographical Information System (GIS), network analysis, urban traffic and federal capital city**

I. INTRODUCTION

Traffic models demand large amounts of data - some of which are: time to travel a given road length, which streets are restricted for which vehicles, the speeds along the given road and which street are one-way [1]. GIS is a natural tool for handling most of these data, as it can ease the work process and improve the quality control. There are several advantages of implementing traffic models in GIS, since the handling of data is easier and the presentation and quality control of results can be done more easily [2]. The research uses ArcInfo to carry out urban traffic network analysis of Abuja, the Federal Capital City of Nigeria.

The traffic network can be described by a complicated topology involving *links*, *nodes*, *turns* (e.g. given by turn tables), *routes* (e.g. given by dynamic segmentation) and *changes* between routes at *terminals* [3]. In addition traffic models will often contain different networks, e.g. car, bicycle and public transport networks [3], [4]. Some of these networks are fully related (e.g. cars, busses, bicycles and pedestrian in the same street), some are only partially related (car, bus and bicycle in the same street, but separated in bus-lanes, bicycle paths and sidewalks) and some are totally separated (e.g. motorways, railways, bicycle paths in their own right of way). A certain journey might use different traffic network (e.g. bicycle to the station, train to the city, walk to the bus stop, and walk to the work) [5].

Network used for this analyst was stored as network dataset. A network dataset was created from the sources that participate in the network. It incorporates advanced connectivity model that represent complex scenarios, such as multimodal transportation networks. It also possesses a rich network attribute model that helps model impedances, restrictions, and hierarchy for the network. The network dataset was built from simple features (lines and points) and turns.

GIS Technology. There have been so many attempts to define GIS that it becomes difficult to select one definitive definition [6]. The definition depends on who is giving it, his background and viewpoint. Therefore definitions are likely to change quickly as technology and application develop further. For example, [7] views; GIS as a computer system that can hold and use data describing places on the Earth's surface. [8] sees "GIS as a set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes,"

In general, the definitions of GIS cover three main components. They reveal that GIS is a computer system. This implies more than just a series of computer boxes sitting on a desk, but it includes hardware (the physical parts of the computer itself and associated peripherals), software (the computer programs that run the computer) and appropriate procedures (or techniques and orders for task implementation) [9]. It is also known that GIS uses spatially referenced or geographical data and carries out various management and analysis tasks on these data, including their input and output [10].

In short, GIS can be used to add value to spatial data: By allowing data to be organized and viewed efficiently, by integrating them with other data, by analysis and by the creation of new data that can be operated on in turn, GIS creates useful information to help decision making [11].

II. OBJECTIVE OF THE STUDY

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The aim of this research is to develop a GIS-base urban traffic network analysis of Abuja, the Federal Capital City of Nigeria. To achieve this aim, the research will follow the following objectives.

The objectives of this study are as follows:

- Choosing and developing the source workspace,
- Identifying the sources and the role they will play in the network,
- Modeling the connectivity,
- Defining attributes and determining their values and
- Performing the analysis.

III. MATERIALS AND METHODS

A. Data Sources

The data used involve two sources i.e. primary and secondary data sources. The primary data source involves direct collection of information on the field, using GPS (Global Positioning System) [12], oral interview and observations. The data collected from primary sources, therefore include: the geographic coordinates of some places (i.e. the control points), pictures of traffic-congested zones, information on traffic-congested junctions (points), the roads (lines) attributes and the land use (areas).

The secondary data source involves sourcing information from existing records. Such data include: Traffic Counts for different road junctions in the city which were collected from Federal Road Safety Commission and Road Traffic Department of the Federal Capital City, Land Use Images, Topographical and Street Guide Maps of Abuja, which were collected, using Google Maps and Google Earth software.

The database was then structured in a format for implementation in a software environment, using the application of Arc GIS 9.3 for digitizing the topographical map and the images.

Similarly, Microsoft Words was used for writing reports in textual format and Arc GIS 9.3 with the network analysis extension was used for the building the database, processing of the maps and performing the analysis.

B. Designing the Network

The network dataset was created in a geodatabase that supports multiple edges, turns and junctions sources. The connectivity for the network dataset was established using the ArcGIS Connectivity model in conjunction with the elevation field model. And the connectivity policy for each edge and junction source was determined. Special scenarios, such as bridges were also addressed. The impedances used during network analysis and their values from the network sources were determined.

C. Creating the Network Dataset

All the feature classes that participated as sources in a network were placed in one feature dataset. Fields representing the network impedance values like distance, travel time, and so on as well as other network attributes like one-way, z-elevation etc were provided.

The network was created using the new Network Dataset wizard by naming the network dataset, identifying the network sources, setting up the connectivity, identifying elevation data, specifying turn sources, defining attributes (such as costs, descriptors, restrictions, and hierarchy), and setting up the directions reporting specifications. After create a network dataset it was built. Building is a process of creating network elements, establishing connectivity, and assigning values to the defined attributes. And finally new turn feature class were created in the geodatabase from the context menu in the ArcCatalog.

IV. RESULT AND DISCUSSIONS

The study highlights common network problems, such as finding the best route across a city, finding the closest emergency vehicle or facility, identifying a service area around a location, or servicing a set of orders with a fleet of vehicles.

A. Finding the Best Route

The Analyst finds the best way to get from one location to another or the best way to visit several locations. The locations were specified interactively by placing points on the screen, or by entering an address, or by using points in an existing feature class or feature layer. The best route was determined for the order of locations as specified by the user. Alternatively, the analysis can determine the best sequence to visit the locations, Fig. 1.

B. The Best Route

The best route can be the quickest, shortest, or most scenic route, depending on the impedance chosen. If the impedance is time, then the best route is the quickest route. Hence, the best route can be defined as the route that has the lowest impedance, where the impedance is chosen by the user. Any valid network cost attribute can be used as the impedance when determining the best route.

In the example below, the first case uses time as impedance. The quickest path is shown in brown and has a total length of 3536 meters, which takes 3 minutes to traverse.

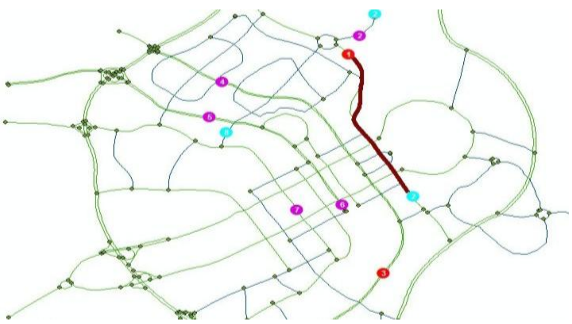

Figure 1. Finding the best route using time as impedance

In the next case, distance is chosen as the impedance. Consequently, the length of the shortest path is 3536 meters, which takes 3 minutes to traverse.

Along with the best route, Analyst provides directions with turn-by-turn maps that can be printed.

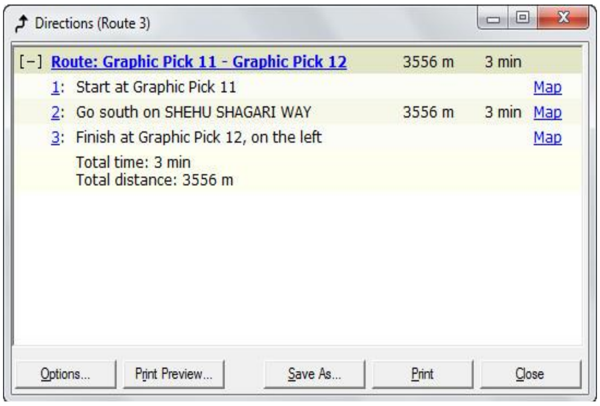

Figure 2. The turn-by-turn map of the best route

C. Finding the Closest Facility

Finding the closest hospital to an accident, the closest police cars to a crime scene, and the closest store to a customer's address are all examples of closest facility problems. When finding closest facilities, you can specify how many to find and whether the direction of travel is toward or away from them. After finding the closest facilities, the best route to or from them was displayed, the travel cost for each route was returned, and the directions to each facility displayed. Additionally, an impedance cutoff beyond which the Analyst should not search for a facility can be specified. For instance, a closest facility problem to search for an Abuja_Network_Junction within 200 seconds drive time of the incident (Wuse 1) was set up. Any junction that takes longer than 200 seconds to reach was not included in the results.

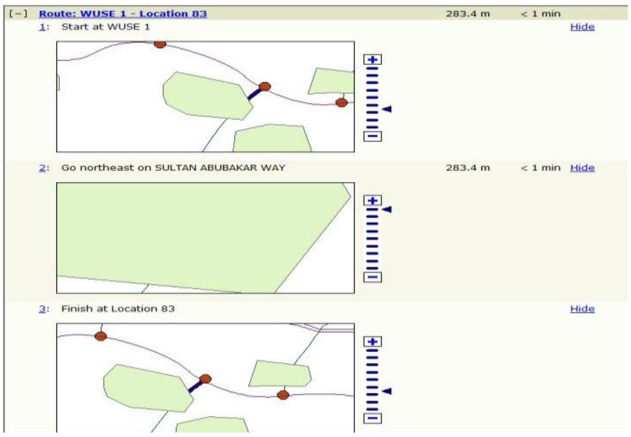

Figure 3. The turn-by-turn map of the closest facility

The junctions are referred to as facilities, and the Wuse 1 is referred to as an incident. The Analyst allows performing multiple closest facility analyses simultaneously. This means that it is possible to have multiple incidents and find the closest facility or facilities to each incident.

D. Finding Service Areas

The Analysis finds service areas around any location on the network. A network service area is a region that encompasses all accessible streets, that is, streets that lie within a specified impedance. For instance, the 10-minute service area for a facility includes all the streets that can be reached within ten minutes from that facility.

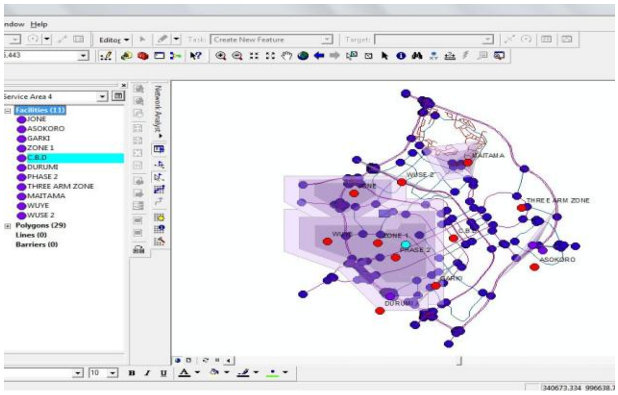

Figure 4. Service area solver

Accessibility refers to how easy it is to go to a site. In this Analyst, accessibility was measured in terms of travel time. And it can be measured base on any other impedance on the network. Evaluating accessibility helps in answering some basic questions, such as, "How many people live within a 10-minute drive from a movie theater?" or "How many customers live within a half-kilometer walking distance from a convenience store?" Examining accessibility also determined how suitable a site is for a new business. It also identified what is near an existing business to help you make other marketing decisions.

E. Evaluating Accessibility

One simple way to evaluate accessibility is by a buffer distance around a point. For example, find out how many customers live within a 5-kilometer radius of a site using a simple circle. However, considering people travel by road, this method won't reflect the actual accessibility to the site. Service networks computed by an Analyst can overcome the limitation by identifying the accessible streets within five kilometers of a site via the road network. After creating it, the service networks obtain what is alongside the accessible streets, for example, finding competing businesses within a 5-minute drive.

F. Creating an OD Cost Matrix

The Analyst can create an origin–destination (OD) cost matrix from multiple origins to multiple destinations. An OD cost matrix is a table that contains the network impedance from each origin to each destination. Additionally, it ranks the destinations that each origin connects to in ascending order based on the minimum network impedance required to travel from that origin to each destination.

The best network path is discovered for each origin-destination pair, and the cost is stored in the attribute table of the output lines, which are straight lines. The graphic below shows the results of an OD cost matrix analysis that was set to find the cost to reach the four closest destinations from each origin.

The best network path is discovered for each origin-destination pair, and the cost is stored in the attribute table of the output lines, which are straight lines. The graphic below shows the results of an OD cost matrix analysis that was set to find the cost to reach eleven (11) closest destinations from each origin.

ObjectID	Shape	Name	OriginID	DestinationID	DestinationRank	Total_DRIVE_TIME
9	Polyline	MAITAMA - HUMAN RIGHT VIOLATION COMMISSION	9	5	1	207.63
10	Polyline	MAITAMA - SOUTH AFRICAN EMBASSY	9	3	2	207.8
11	Polyline	MAITAMA - RUSSIAN EMBASSY	9	1	3	230.8
12	Polyline	MAITAMA - NIGERIAN RAILWAY COORPORATION	9	2	4	238.36

Figure 5. Origin Destination (O-D) cost matrices

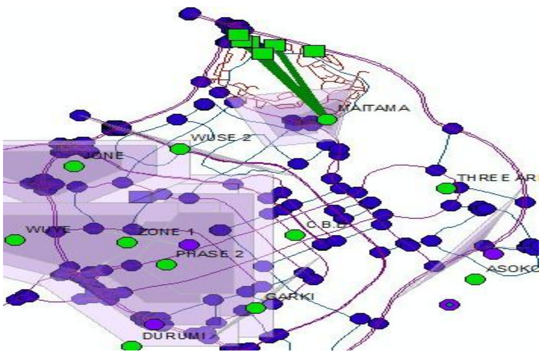

Figure 6. Origin Destination (O-D) cost matrices

The Straight lines used only symbolize the various ways, such as by color, representing which point they originate from; or by thickness, representing the travel time of each path.

The closest facility and OD cost matrix solvers perform very similar analyses; the main difference, however, is in the output and the computation speed. The OD cost matrix solver is designed for quickly solving large M×N problems and as a result does not internally contain information that can be used to generate true shapes of routes and driving directions. If driving directions or true shapes of routes are needed, the closest facility solver should be use, otherwise the OD cost matrix solver to reduce the computation time.

V. Conclusion

The GIS based network analysis developed in this paper wraps together a set of procedures for performing road traffic network of an urban area in a GIS environment. The steps proposed include:

- Choosing and developing the source workspace,
- Identifying the sources and the role they will play in the network,
- Modeling the connectivity,
- Defining attributes and determining their values and
- Performing the analysis.

The analyses will ease decision making processes significantly by providing useful information to the motorists, other road users, government, transport operators, other stake holder of transports and the entire general public. Among others, some of the information that can be obtained from the analyses is:

- The best route (the quickest, shortest, or most scenic route) to a destination
- Finding closest facilities (like a bus stop, police station, shopping, hospital etc)
- Finding service areas within a specified impedance

Acknowledgments

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Sama'ila Saleh was born at Yargoje Katsina State Nigeria on 3rd May, 1979. I Studied B. Eng Civil Engineering at Bayero University Kano – Nigeria (2004). And M. Sc. Civil Engineering at Ahmadu Bello University Zaria – Nigeria (expected March, 2013).

Engr. Sama'ila Saleh worked under Afdin Construction Company as CIVIL ENGINEER and under Job+Days Nig. Limited as a PROJECT ENGINEER. Presently under Hassan Usman Katsina Polytechnic – Nigeria as a LECTURER.

Engr. Sama'ila Saleh is a member of the Nigerian Society of Engineers, NSE, Nigerian Institute of Civil Engineers, NICE and a registered engineer by the Council for the Regulation of Engineering in Nigeria COREN.