Developing a GIS-Based Demand-Responsive (Intelligent) Urban Transportation System in part of Ibadan Metropolis, Nigeria

By

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ABSTRACT

Transportation is the movement of people and or goods from one place to another. In recent times, it has not been without one form of problem or the other. Demand-Responsive Transportation System (DRTS) was introduced which is designed to take transportation services to the door steps of users. The aim of the study is to develop a GIS-based demand-responsive (intelligent) urban transportation system in part of Ibadan in Oyo State. The objectives include designing a database for the entities in the study area; acquisition of 1.0m resolution Ikonos image of the study area from where the entities were extracted through head-on digitizing; creation of a suitable database and spatial analyses such as query, geocoding and routing were performed. Remote sensing and GIS techniques were adopted in the study. The methodology involved database design and implementation. The database design included conceptual design, logical design and physical design while the database implementation is the actual creation of the database in the implementation software. It was shown at the end of the study that over 70% of the road segments are good for the operation of DRTS; 328 uncompleted buildings are available for the operators to lease or buy for office locations. 639 buildings representing 4.06% of total buildings contravened setback rules in the study area. Geocoding of addresses was successfully done implying that demand from any of the buildings for services can be delivered to their door steps. The best route is shorter than the alternative route by a distance of 52.7m with a barrier on the best route. The study's aim and objectives were achieved. It is recommended that bad roads should be paved with asphalt or be expanded where there are congestions to allow free flow of traffic, uncompleted buildings in the study area should be completed and efforts should be geared towards strengthening Town Planning laws in Oyo State.

Keywords: Demand-Responsive, Information, Systems and Transportation.

1. INTRODUCTION

Transportation problem is fast becoming one of the social menace in urban centres around the country due to the rural-urban drift including Ibadan. The movement puts immense pressure on the available facilities in the city centres including transportation systems. The problem of transportation in Ibadan includes but not limited to bad roads, congestion at the peak periods due to volume of traffic on the major routes, non-availability of up-to-date digital road network maps and absence of Demand-Responsive Transportation System (DRTS).

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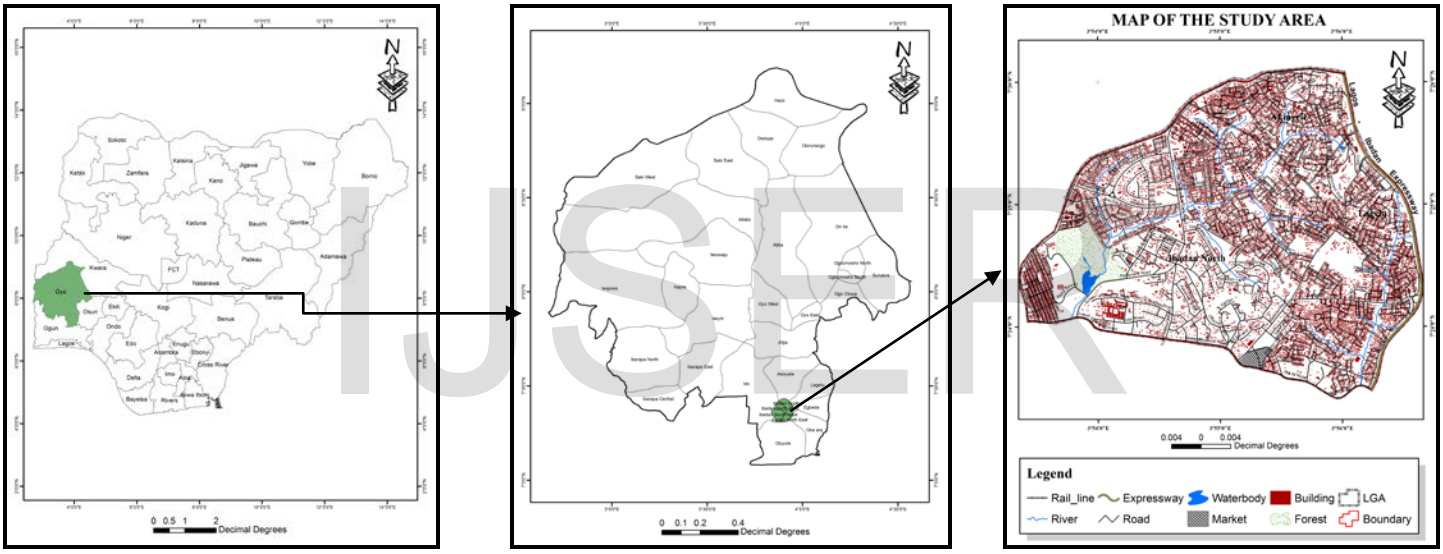
People waste a lot of man-hour in traffic at peak periods; the sick or injured die on their way to the hospitals during emergencies; it is either there is traffic congestion or the vehicles are not available. Such deaths can ordinarily be prevented if there were Demand-Responsive Transportation Systems in place. Also, the aged and the disabled are deprived of going to where they want because our conventional transportation systems cannot readily take care of their needs. The study is aimed at developing a GIS-based demand-responsive (intelligent) urban transportation system in part of Ibadan metropolis, Oyo State to address some of the problems associated with transportation in the study area. The aim will be achieved by designing a suitable geodatabase for the entities of interest in the study area; acquiring 1.0m resolution Ikonos image of the study area from where the features of interest are extracted through head-on digitizing; creation of a geodatabase for the entities of interest in the study area and spatial analyses like query, overlay, networking performed on the geodatabase.

Transportation according to [1] is the movement of people and or goods from one place to another through a means. The means may be walking on land, vehicle on road, train on the rail and plane in the air or ship on the sea. They further stressed that transportation is a requirement for every nation regardless of its industrial capacity, political stability, population, size or technological development. Moving goods and people from one place to

another is crucial to maintaining strong economic and political ties between the various components of any given nation and among nations. The development of a DTRS in the study area is to further compliment the available transportation system already in place.

Geographic Information System (GIS) and Remote Sensing methods was adopted by [2] to show two major ways by which solutions could be proffered to traffic congestion in Port - Harcourt city. The first is the determination of the closest facilities within the study area. This information according to them will enable commuters and motorists to take rational decisions as to which route to take during peak hour travel. The second is the determination of appropriate queries and analysis that can evoke graphical response, which could be used to manage traffic congestion like use of shortest and alternative routes. The study showed that GIS is a veritable tool that can be used to sustain an endurable flow of traffic in Port-Harcourt city, provided it is built on a properly designed database, which must also be amenable to constant updating.

According to [3], Ibadan is the capital of Oyo State which is one of the South Western states of Nigeria. Ibadan is reputed to be the largest indigenous city in Africa, south of the Sahara. Ibadan had been the centre of administration of the old Western Region, Nigeria since the days of the British colonial rule. It is situated 78 miles inland from Lagos and is a prominent transit point between the coastal region and the areas to the north. Parts of the city's ancient protective walls still stand till today, and its population is estimated to be about 3,800,000 according to 2006 estimates [4]. The locational diagram of the study area is shown in Fig 1.



Map of Nigeria showing Oyo State Map of Oyo State showing the Local Government Areas Map of the Study Area

Fig 1. Locational diagram of the Study Area

2. MATERIALS AND METHOD

The materials and method adopted for this method were hinged on the principles of Geographic Information Systems and Remote Sensing. Vector data model was adopted for the study. The opinion of [5] about vector data model is that vector data model have advantages over the raster data model. The advantages according to [5] include, vector data model possesses more compact structure than the raster model, there is provision of efficient encoding of topology in cases of network analysis as shown in his work and the vector data is better suited to support graphics. The model also has its shortcomings because it is a more complex data structure than a simple raster amongst other disadvantages as listed by [5]. This is more reason why vector data model was adopted for the study because of the compact nature of the linear features (roads) that form the backbone of this study.

Ikonos image with 1.0m resolution was used for the study from where roads, buildings, rivers, waterbody, forest were extracted through on-screen digitizing using ArcGIS 3.0 as the implementation software. The locations of Bus stops were picked with Etrex GPS with a resolution of 3.0m. With improvements in technology, higher resolution images can be procured through the use of Unmanned Aerial Vehicle (UAV) also known as drown which was

used by [6] in environmental monitoring and management in urban centres where Ibadan is not an exception. [6] discussed potential applications of drones for use in environmental monitoring and management of urban spaces as well as the potential risks. This is necessary in such studies as Demand-Responsive Transportation System where high resolution imageries are required to carry out acquisition of features like roads, buildings and other related features that contribute to a successful development of a DRTS and constant monitoring of infrastructures that makes transportation possible like roads. Applications better suited to an Internet of Things approach include those in which frequently repeated or continuous measurements are needed from a location proximal to existing infrastructure [6].

Spatial database was designed and implemented. The attribute data collected from the oral interviews were linked with the geospatial data from the vectorization of the imagery using relational database system. This is one reason why Geographic Information Systems differ from other information systems because they are able to link geospatial data with attribute data. The product formed the basis for the geospatial analyses carried out on the entities in the study area. Database was designed and created for the entities in the study area that are relevant to the successful development of a Demand-Responsive Transportation System in Ibadan. The entities are the study area boundary, the rivers, the water body, roads and buildings. These tables were attached with the attribute information about the entities from oral interviews and other sources and this formed the basis upon which the analyses were performed.

3. SPATIAL ANALYSES

Geospatial analyses were carried out in the development of Demand-Responsive Transportation System in Ibadan. The analyses include but not limited to spatial extraction or query, proximity evaluation of buildings around water channels and routing.

3.1 Spatial Query 1

The database was queried to find from the 15,745 buildings digitized in the study area, how many are uncompleted so that the operators can lease or buy for use as office space. The result returned a total of 328 uncompleted buildings of various dimensions scattered all over the study area (Fig 2). This represents 2.08% of the total buildings in the study area. The formatted map in Fig 3 showed the buildings all over the study area as indicated.

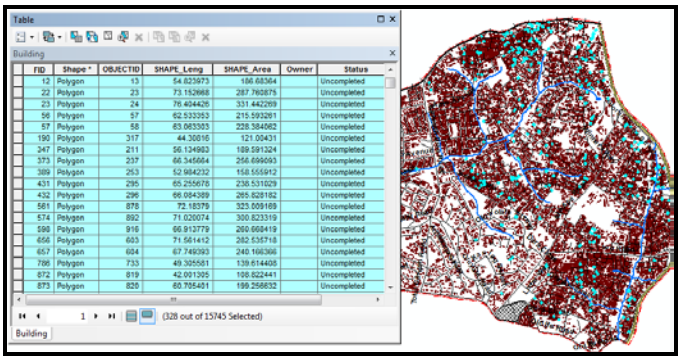


Fig 2. Result of query to show the Buildings that are uncompleted

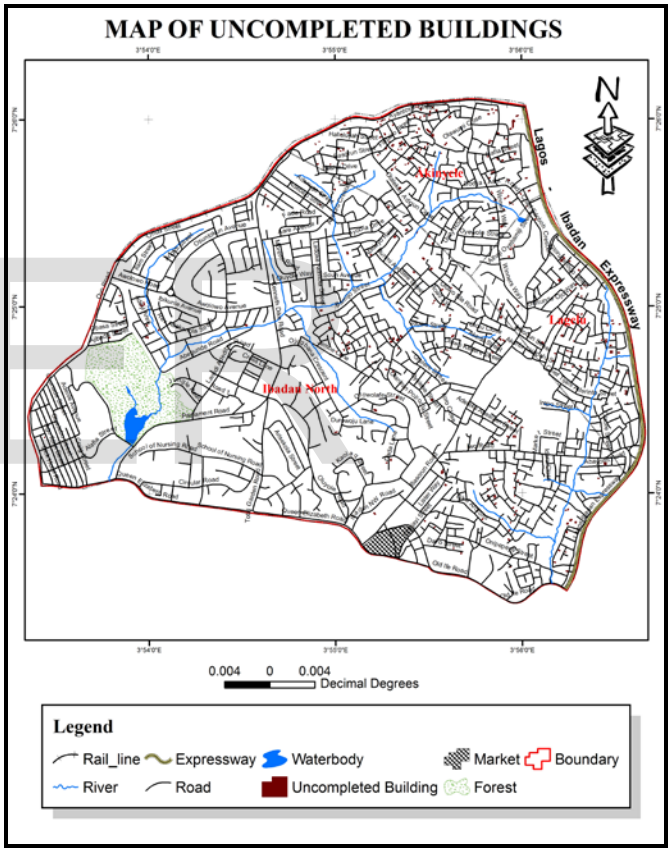


Fig. 3. Map of the Buildings that are uncompleted

digitized in the study area. The application of this query is to know whether the roads are motorable or not so that if the roads are chosen as the best route then the user can know the condition before using the roads and may consequently not necessarily be the fastest route.

3.2 Spatial Query 2

This is to extract from the database those buildings from the study area that did not conform to the setback rules applicable in the study area. The rivers were buffered by

20m, water body by 20m, rail line by 30m and rivers by 20m. Architectural and urban planning activity has always been the most important component of the social and political life of any country and has always been subject to regulation as was found in the work of [7]. However, the nature, scope and organization of this regulation were different and depended on many factors [7]. Ibadan is an urban centre and it was found out that a lot of buildings contravene building regulations that were enacted into law.

Table 1. Table showing buldings within buffer zones

S/N	Buffering from Feature	Distance of Buffer	Number of affected Buildings	% of Total
1	River buffer zone	20m	468	2.97
2	Waterbody buffer zone	20m	0	0
3	Forest buffer zone	20m	49	0.31
4	Rail Line buffer zone	30m	122	0.77
	Total		**639**	**4.05**

The number of houses that fall within the setbacks is presented in Table 1. A total of 468 buildings are within the river setback, none for water body because of its location in the study area being a government establishment, 49 around the forested area which had been seriously encroached and 122 buildings are within the rail line buffer that bounded the study area in the north western part and totaling 639 in all.

3.3 Spatial Query 3

The third query issued was to retrieve from the database those roads that are in good condition (Fig 4). The study greatly depends on the availability of good roads for easy and fast access. A total of 505 road segments are in good condition representing 21.90% of the total road segments

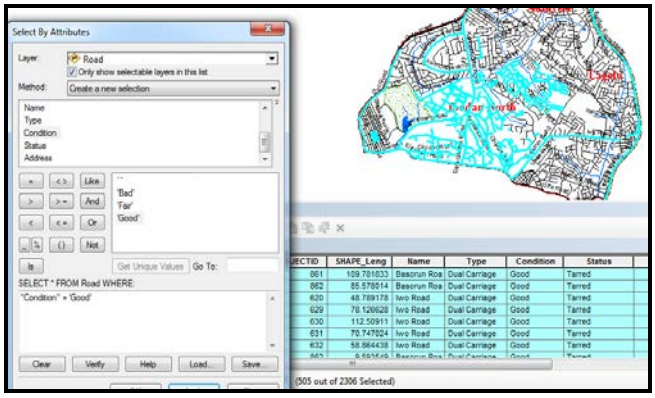


Fig 4. Result of query to show the Roads that are in good condition

The remaining road segments were categorized as fair and bad. The result of the queries for fair and bad roads' conditions are shown in Fig 5 and Fig 6 respectively.

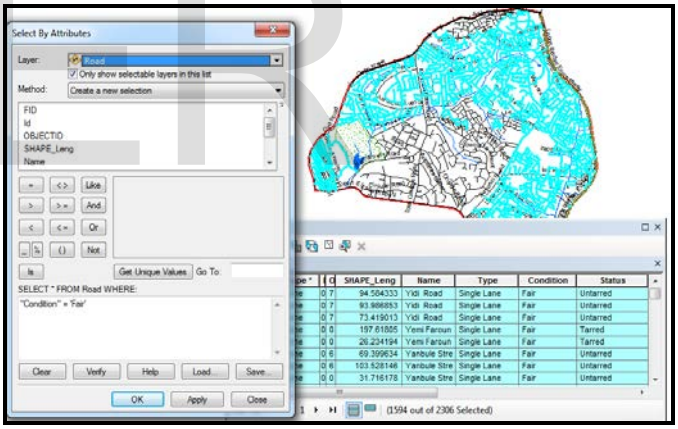


Fig 5. Result of query to show the Roads that are in fair condition

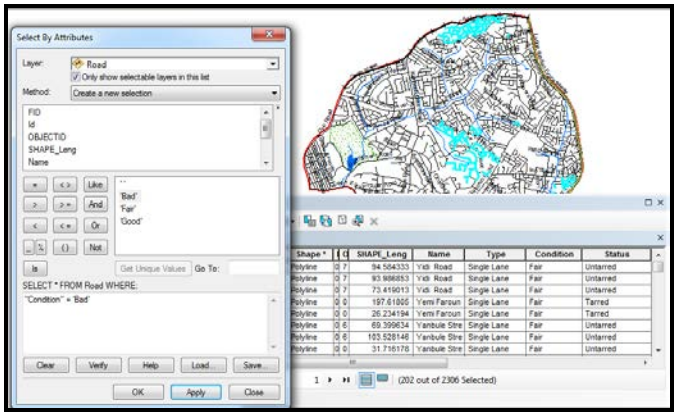


Fig 6. Result of query to show the Roads that are in fair condition

1594 road segments (69.12%) were fair and 202 segments (8.76%) were in bad condition and almost impassable during the study.

3.4 Geocoding

Geocoding according to [8] is a process to find the mathematical representation of the location of a geographic feature, such as a street address, a street intersection, a postcode, a place, a point of interest, a street light, a bus stop, a tree, or a photograph, so that the feature can be mapped and spatially analyzed on geographic information systems. The essence of geocoding in this study is to be able to convert the passenger's address into a point along the network of roads and dispatch cabs or buses to the address by taking the optimal route using the network of interconnected nodes and segments of the roads. This networks allow turns at junctions for optimal and economical service delivery. The geocoding adopted a single field approach by populating the address of the buildings in one of the fields or tuples of the attribute tables of the buildings shapefile created using ArcGIS 3.0. The result is illustrated in Fig 7.

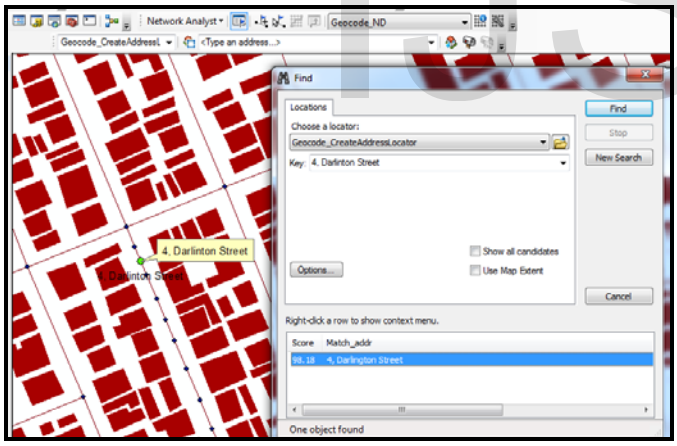


Fig 7. Geocoded address indicated with Callout

3.5 Routing

Routing according to [8] is the act of selecting a course of travel. The route in this study is the path taken by a cab across a network of roads in the study area in order to locate and pick a passenger from origin to destination. Routing is the most fundamental logistical operation in network analysis. As in location on networks, the choice of a route is frequently modeled as an optimization problem [8]. The geocoding located a passenger who demanded for cab service at 10, Darlinton Street and was to be picked up by a cab at Iwo Road. The origin is located as Point 1 which serves as the Cab stand at Iwo Road, while the destination is point 2 which is a passenger waiting to be picked up at 10, Darlinton Street (Fig 8). The best route between the two locations is generated automatically which is the calculated shortest distance that can be taken between the two locations indicated as shown in Fig 9.

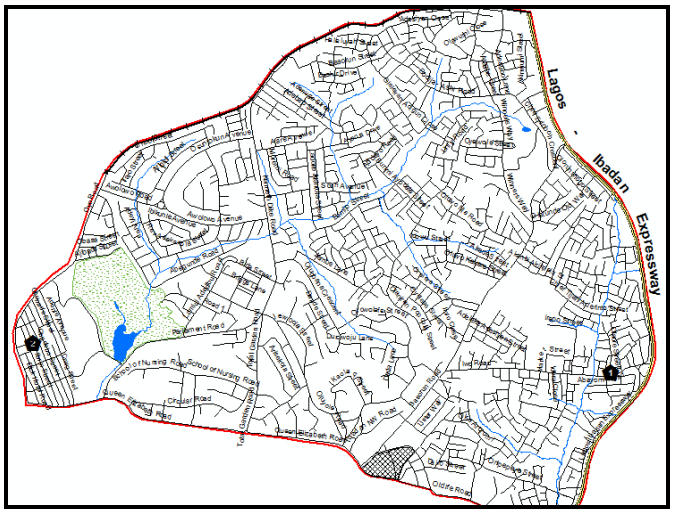


Fig 8. Location of Cab (1) and the Passenger (2)

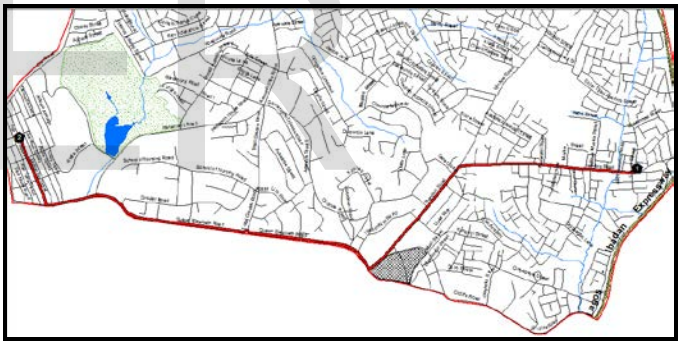


Fig 9. Best route between the Cab and the Passenger

The direction window shown in Fig 10 interpretes the diagram in Fig 9. It shows the travel directions and the distances covered as the cab travels on the route from Mr Biggs, Iwo Road Bus Stop to 10, Darlinton Street along the road network. The total travel distance is approximately 6.52Km. Fig 11 shows a well formatted map showing the best route in red.

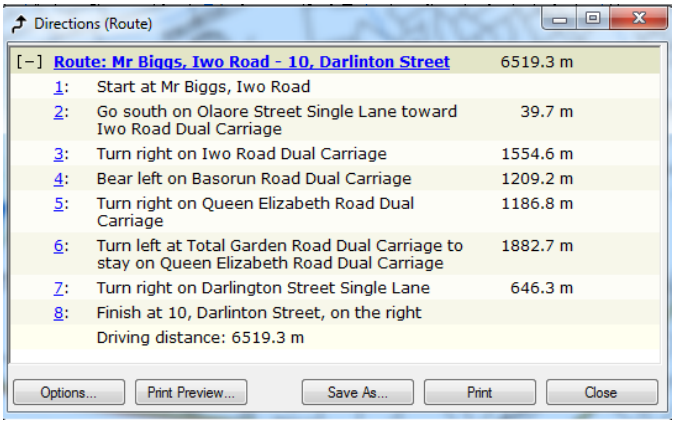


Fig 10. Direction window between location of Cab and the Passenger

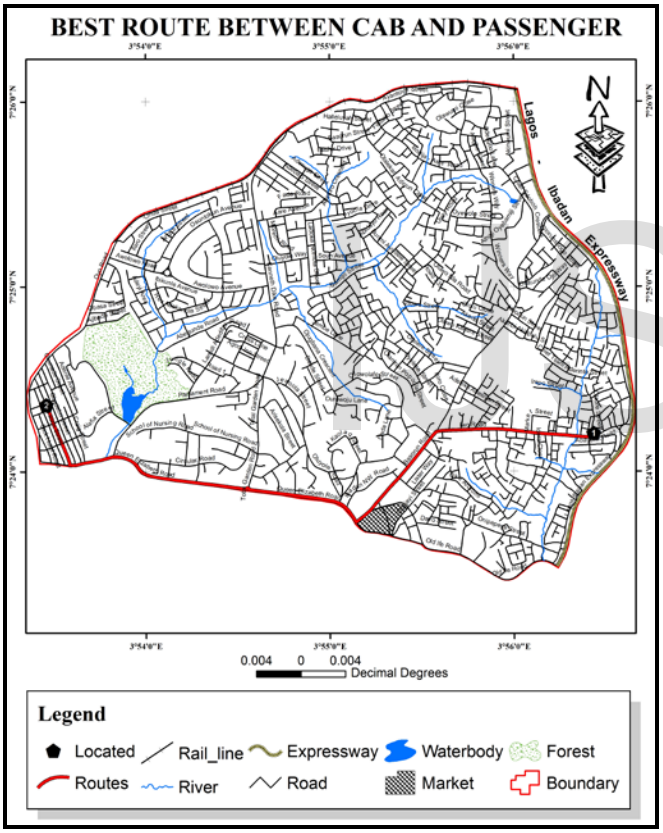


Fig 11. Map of the best route between Location of Cab and the Passenger.

On the other hand, an obstacle like traffic congestion on the best route will either elongate the travel time or cause the driver to travel through an alternative route which may be farther than the optimal route. At the popular Gate market at the southern part of the study area, there is always grid lock almost every hour of the day, so a barrier placed at that location along the best route will cause the system to take an alternative route as indicated in Fig 12.

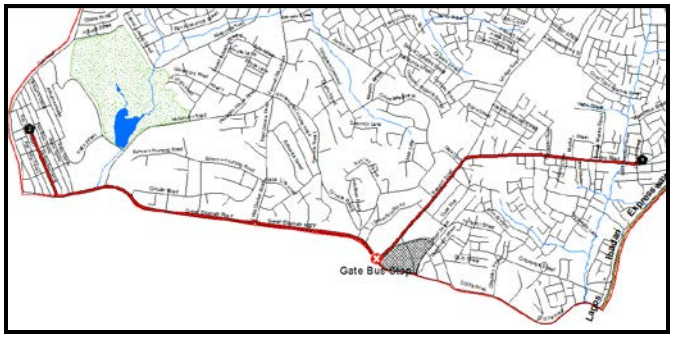


Fig 12. Gate Bus Stop as barrier on the Best route between the Cab and the Passenger

The alternative route was generated because of a barrier on the best route at the market junction at the terminal end of Queen Elizabeth Road. The diagram is shown in Fig 13 and Fig 14 shows the direction window with the distances on each road segment. The formatted map of the alternative route is shown in Fig 15.

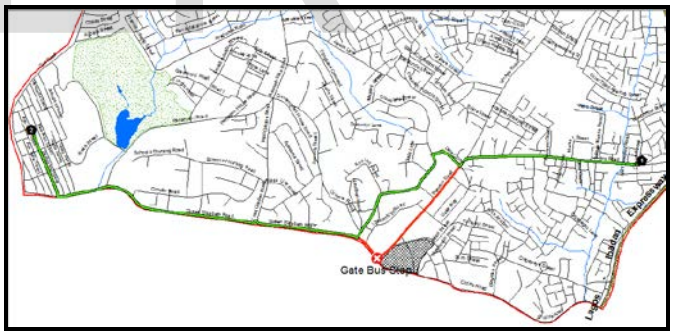


Fig 13. The Alternative route between the Cab and the Passenger

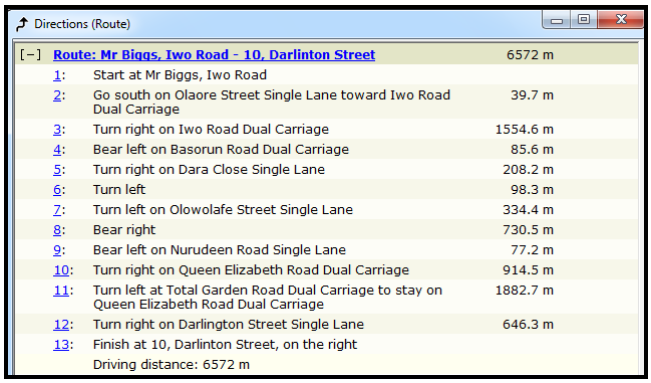


Fig 14. Direction window of Alternative route between location of Cab and the Passenger

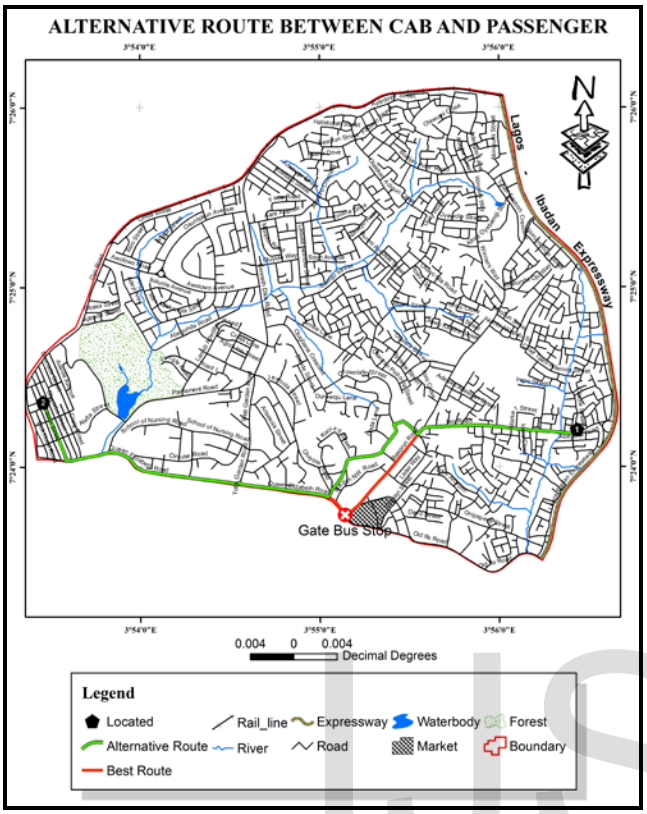


Fig 15. Map of the Alternative route between Location of Cab and the Passenger.

Table 2. Difference between the Best and the Alternative routes

Route	Best	Alternative	Difference
Distance between the Cab and the Passenger	6519.3m	6572m	**52.7m**

Table 2 shows the summary and comparison of the two routes as travelled by the cab between the two locations - Iwo Road and 10, Darlinton Street. The cab travelled additional 52.7m in order to avoid the barrier at the popular Gate Bus Stop.

4. DISCUSSION OF RESULTS

The various results generated for this study are of immense benefits to the development of a Demand-Responsive Transportation System in Ibadan. It was discovered that 328 uncompleted buildings of various dimensions are scattered all over the study area (Fig 2). This represents 2.08% of the total buildings in the study area. They can be bought or leased to be used for office accommodation. The second query is locational because it showed buildings that are within setbacks of river, water body, forest and rail line. A total of 639 buildings fall into this category implying that none of these buildings are suitable for official use by the DRTS operators. The condition of the road is paramount to the successful implementation of a GIS-based DRTS in Ibadan. Over 70% of the roads fall within the good and fair categories which is a boost for the operation. Geocoding of the addresses in the study area was successfully carried out and that formed the bases for locating addresses on the road network in the study area.

The routing operation on the network of roads produced the best route and the alternative route when travelling from Iwo Road to the geocoded address. The best route was 52.7m shorter than the alternative route with a barrier at Gate Market junction on Queen Elizabeth Road.

5. CONCLUSION

The analytical capabilities of Geographic Information System was deployed in the development of a GIS-based Demand-Responsive Transportation System in Ibadan. The design and implementation of a spatial database was carried out. Data were collected and imported into ArcGIS 10.3 for analyses as shown in the study. It is believed that the aim and objectives of the study were achieved because the results generated can form the basis of a development of a GIS-based Demand-Responsive Transportation System in Ibadan and other parts of Nigeria where transportation is a major hindrance to economic development.

6. RECOMMENDATIONS

The following are the recommendations from the findings.

i. The owners of the uncompleted buildings scattered around the study area should be informed of the need to keep weeding the bushes around the buildings to avoid being hideouts to miscreants to carry out nefarious activities which can discourage investment by local and foreign investors.

ii. Erection of buildings within the setbacks of the features like rivers should be discouraged because of the danger inherent in such acts. Also, the enabling laws should be strengthened and if not in place should be enacted. The staffers of the Oyo State Town Planning Board should be as a matter of need and urgency be trained on the use of modern tools

like GIS and Remote Sensing to carry out their duties.

iii. The conditions of the roads should be improved and where they are very narrow should be widened or rather can be converted into a dual carriage way to allow free flow of traffic at all times.

iv. The constant traffic congestion along Iwo Road to Gate market is often caused by the presence of the Gate spare part market in the study area. The market should be moved elsewhere to allow free flow of traffic at that end of Queen Elizabeth Road.

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