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*Full Length Research Paper*

# Development of a geographic information system (GIS) based road network in Port Harcourt

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**The aim of this work was to develop a geographic information system (GIS) based road network map of Port Harcourt city that can be used to analyze traffic congestion within the city and suggest possible solutions. The handheld global positioning system (GPS) was used to acquire geographic coordinates of major locations experiencing traffic jams, bad spots and schools. The transformed GPS coordinates were added to the ArcGIS environment to define the spatial locations. Prior to that, the road map was digitized and geo-rectified. Satellite Imagery from the remote sensing technology was used to acquire data of new roads, for map updating and revision. Geographic information systems (GIS) operations (buffering, overlay and networking techniques) using ArcGIS 9.3 were performed on the road map. The study recommends that: the road network in Borikiri axis of Port Harcourt should be improved by constructing a by-pass to ease the traffic along Harold Wilson road; the width of roads should be increased at T-junctions and cross-junctions; all public facilities especially those located along major roads should have good parking plots before approval for construction. It is also recommended that at proximity of 500 km from a developing area, a boulevard should be constructed at the junction linking such area to the center of the town, for instance, the Wimpey/Iwofe junction. The road network as predicted in this study is expected to contain a minimum of 217,360 cars in 2022 for the identified routes excluding larger vehicles like trucks.**

**Key words:** Road network, Geographic information systems (GIS), traffic congestion, Port Harcourt, global positioning system (GPS).

## INTRODUCTION

During the colonial era, the road network of Port Harcourt was planned in such a way that the streets were designed in a grid form. Social and recreational facilities provided were well situated; hence the quality of life of the inhabitants was enhanced. This is obviously due to the fact that transportation networks provide basic

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**Table 1.** Hourly traffic flow of some routes in Port Harcourt.

| Location | 2008 traffic flow | 2013 traffic flow |
|---|---|---|
| Ikwerre Road | 1286 | 1360 |
| East West | 771 | 816 |
| Obi-wale/Rumuigbo | 473 | 500 |
| Rumuepirikom/Ada George | 476 | 504 |
| Rumuokwurushi | 983 | 1040 |
| Eliozu | 1116 | 1181 |
| Aba Road/Woji | 3453 | 3653 |
| Harold Wilson/Churchill | 1069 | 1131 |
| Marine junction/Hospital road | 1240 | 1312 |
| Trans Amadi/Abuloma | 1246 | 1318 |
| LNG | 1334 | 1411 |
| Abonnema wharf | 964 | 1020 |
| Aba Express | 1122 | 1187 |
| East West Tank 1 | 590 | 624 |
| East West 2 | 882 | 933 |
| Total | 17005 | 17989 |

Source: Integrated Transport Master Plan, October 2008.

infrastructural framework for rapid economic development. Consequently, Port Harcourt began to experience rapid growth rate.

The rapid increase in population of persons and vehicles without proper planning, design and maintenance of the available roads within the city, as well as the improper location of public facilities resulted in an inadequate transportation network. This is because the volume of traffic outweighs the road capacity, resulting in traffic congestion. According to the UN and its Habitat Organizations, five comprehensive problem fields are relevant for the enhancement of living conditions within a city (UN Habitat, 2003) of which transport is a part. These challenges can be solved basically by employing surveying techniques and GIS. Surveying is the bedrock of any meaningful development. The end-product of its process, the map, is employed in planning. According to Olagbadebo and Dienye (2008), the digital production of maps which aid in improving the legibility, accuracy and updating procedures is achieved using geographic information system (GIS). Hence the development of a GIS based road network map of Port Harcourt for solving problems associated with the road network.

## Statement of problem

One of the major problems affecting the road network of Port Harcourt is traffic congestion, and the following factors are responsible for the traffic congestion: Bad spots at close distances along route, absence of alternative routes, flooding as a result of inadequate and poorly maintained and constructed drainage systems, small/sub-standard road width especially on approaching a junction, non provision of parking plots at the location of public facilities such as schools, markets, shopping malls.

The traffic flow data of Port Harcourt reveals that there was an increase in the number of vehicles within the city between the periods 2008-2013. This is obviously as a result of the rural-urban drift (Table 1).

## Study area

The study area, Port Harcourt, is named after Lewis Viscount Harcourt in 1913. Port Harcourt lies between longitudes 6°55' and 7°10' East of the Greenwich meridian and latitudes 4°40' and 4°55' north of the equator. The population of the city is estimated at 538,558 people (National Population Census, 2006), while projected population in 2012 was 573,621. The city has one international airport at Omagwa, and a local airport at Air force, two multi-national firms as well as other industrial concerns. Port Harcourt is the chief oil refining city in Nigeria.

## Scope of the study

The study is confined to some environments within Port Harcourt. A total of 40 junctions where observed, and six (6) major routes considered. The routes are: i) Harold Wilson Drive; ii) Ada George; iii) Ikwerre Road; iv) Aggrey Road; v) Abuloma Road and vi) Woji Road.


**Figure 1.** Development in Borikiri.

The spatial location of 221 schools (primary and secondary) where defined within the metropolis; the location of schools being a factor to traffic volume.

Road congestion in Port Harcourt is similar to that of Guwahati, capital city of Assam in Northeastern India. Urbanization peaked without consequent development of the social and physical infrastructure like roads, bridges and settlements (Deka, 2009; Obinna, et al., 2010). Figure 1 is a map showing Borikiri in the southern part of Port Harcourt, developing with only one major road. Traffic snarls take place in most parts of Guwahati city consequent upon the following factors: lack of proportionate attributes of roads, population explosion, and peak number of vehicles, rapid urbanization, and location of social infrastructure, complex land acquisition, and habitation before construction of roads. These challenges could be solved with the application of GIS to surveying and mapping. The prevention of unnecessary traffic, which generates environmental burdens, should be the top priority of municipalities in urban centers (Oluwadare et al., 2009; ITMP, 2008).

According to Matt (2009), Singapore, a southeastern Asian Island since its independence in 1965 realized the need for GIS in 1995 when it formed LTA, having acknowledged the transportation needs of about 4.6 million people. The decision was based on the features and functionality of ESRI's ArcGIS software, aiding Land Transit Authority (LTA) to manage its assets and resources, as well as giving it the freedom to collaborate with other government, private and public agencies having the common interest of a free-flowing transportation system. Singapore LTAuses GIS to integrate transportation data and manage traffic incidents (Transportation GIS Trends, 2009).

Furthermore, Andrew et al. (2011) employed GIS for assessing the road network in Trans-Amadi, Port Harcourt. They concluded that the road network in Trans Amadi was in good condition and the connectivity level was high. They recommended that the study should be carried out on a larger scale considering vehicular movement and impedance at other locations within the city.

## METHODOLOGY

### Hardware and software selections

Hardware components for data acquisition, manipulation, processing and presentation used for this work included the following: Computer-windows 7 (4.00GB RAM space, 64-bit Operating System, 21″ colour monitor), A0 Scanner (Crystal G600 Wide format), CD-Rom Drive, Hard Drives (flash drive), GPS Map 76, versatile navigator, Plotter (HP Design jet 500 plus 42), and Colour Printer (HP Deskjet 3050A J610series).

The software selected for analyses were ArcGIS 9.3 version and AutoCAD 2007 version. Geographic Calculator (GeoCAL) version 6.3 was used for coordinate system conversions of GPS coordinates in Excel sheet. The coordinates from the Excel sheet where imported into the ArcGIS (Arc Catalog) environment using the 'Add data' tool. Microsoft Word 2007, Microsoft Excel and Power Point 2007 were used for production of the manuscript and presentation.

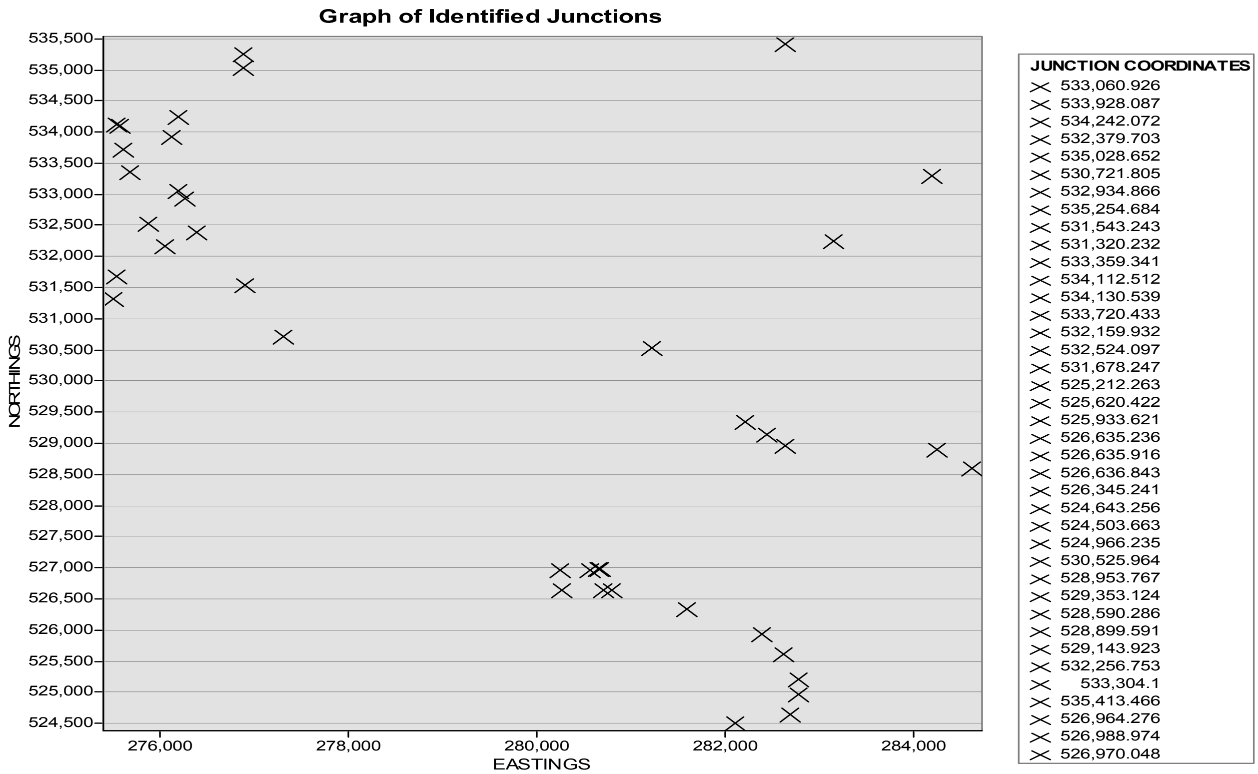


**Figure 2.** Coordinates of junctions that experience traffic jams.

#### Data acquisition

The GPS receiver (map 76 versatile navigator) was employed to obtain the coordinate of the junctions (Figure 2), bad spots and schools (Figures 3 an 4). The coordinates (Minna Datum) obtained were converted using Geographic Calculator (GeoCAL) version 6.3 software.

The study also made use of Secondary data derived from the road network map at a scale of 1:20,000 obtained from the Rivers State Geographic Information System (RIVGIS), the population data of Port Harcourt in 2006 obtained from the National Populations Commission (NPC) (2010), and hourly traffic flow rate of vehicles along routes. The satellite imagery of the study area was also obtained. The road map and the imagery were geo-rectified in ArcGIS to geographic coordinates.

#### Database design

Database design constitutes one of the core tasks in developing any GIS application. It involves the process by which the real world entities and their interrelationships are analyzed and modeled in order to derive the maximum benefits while using the minimum quantity of data (Kufoniyi, 1998, Ghilani and Wolf, 2008). The two stages involved in the database design process are: the design stage, and the implementation stage.

The design stage consists of four elements. These are:

##### *View of reality*

For this application, the view of reality includes roads, locations of traffic congestion, built up areas, boundary of the study area.

##### *Conceptual design*

In the conceptualization stage, the basic entities were determined, their spatial relationship and the attributes of each entity. This project classified roads as linear features and the boundary of the study area as polygon feature. The road junctions, location of schools and potholes, were taken as point features.

##### *Logical design*

The entities or GIS layers and their attributes were translated into a geo-relational data structure. Each layers with the necessary tables and the tables then related or joined together with appropriate cardinalities ranging from one to one (Table 2); one to many (Table 3); and many to many (Table 4).

## RESULTS AND DISCUSSION

### Spatial analysis

Overlay analysis was used to merge spatial data by combining two or more spatial data sets to produce a new spatial data set where the feature attributes are a union of the input. The road network map was overlaid on the imagery to aid assessment and appreciation of the ratio between road length and total area. The ratio between the total area and the total route length in the network is such that the road density is high.

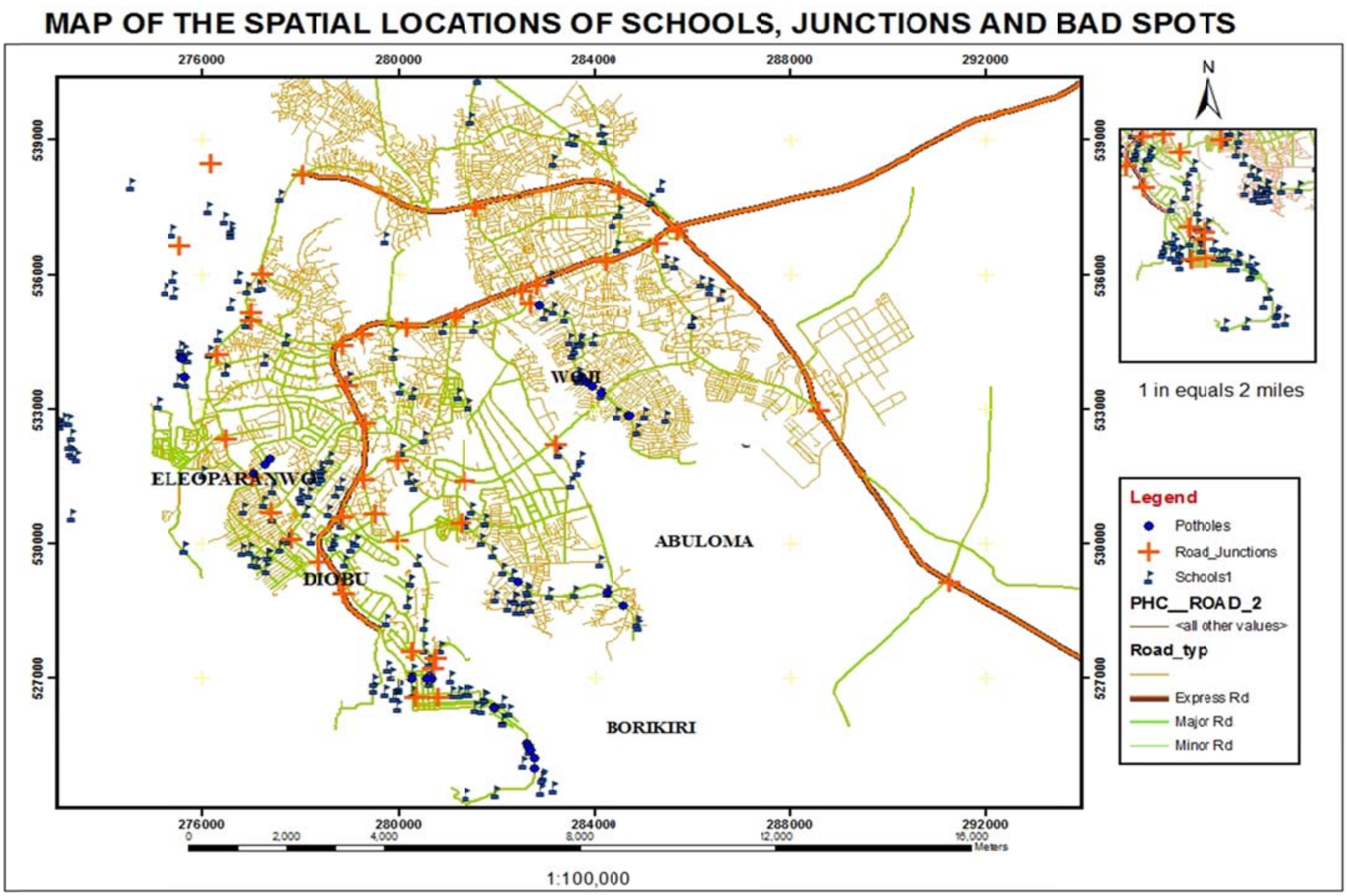


**Figure 3.** Spatial locations of schools, junctions and bad spots.

Furthermore, overlay operations done in Borikiri shows that, most of the identified bad spots were very close to the identified congested junctions along the Harold Wilson drive. The number of schools along this same route would rather require a smooth flow of traffic which is obviously not certain due to the pot holes at the major junctions and the lack of alternative routes (only one major route) that would ease the congestion of the junctions (Figure 5).

## Proximity analysis

Buffering is a means of performing this practical spatial query to determine the proximity of neighbouring features. By point buffering, features (junctions, bad spots) within a prescribed distance from a point, line, or area, are determined. Along the borikiri axis, a buffer of 500m was created at UPE junction (Figure 6). This point in the field is known to be highly congested during peak hours. The buffer captures three (3) junctions, four (4) schools and four major bad spots along the same road. Hence the combination of three factors responsible for traffic congestion is found within the buffered zone. There is no alternative for users to consider in the case of an emergency.

## Network analysis

Unlike proximity analysis that searches in all directions from a point, line, or area, network analysis is restricted to searching along a line, such as a route, or throughout a network of linear features, such as the road network. Network analysis can be used to define or identify route corridors and determine travel paths, travel distances, and response times. For example, network analysis may be used to assess the traffic volume impact of a road closure on adjacent roadways.

For this work, the presence of a barrier at the GRA Junction and considering the one way movement of the traffic was adopted. The alternative route is presented thus in Figure 7, having a driving distance of 9361.3 m

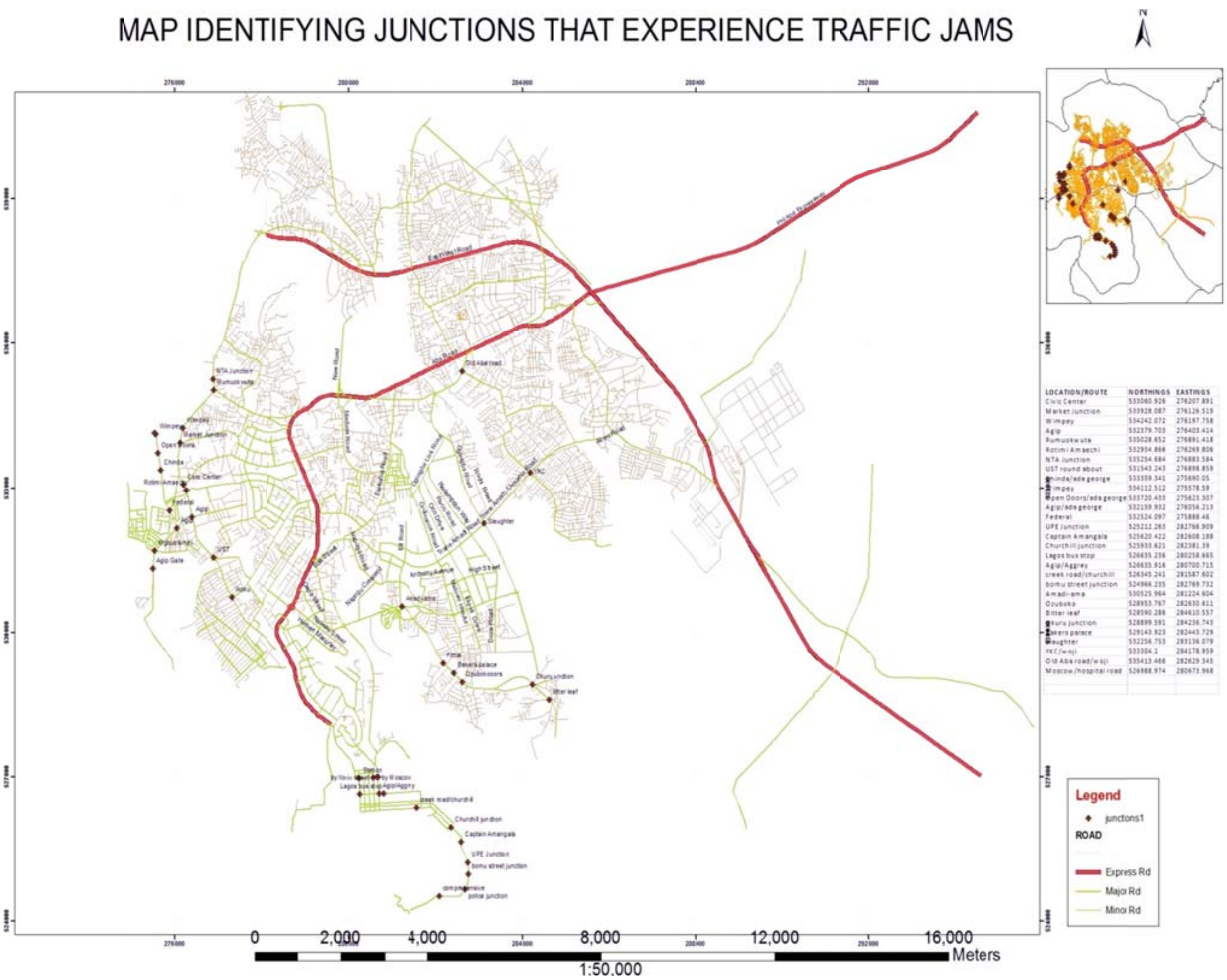


**Figure 4.** Junctions that Experience Traffic Jams.

**Table 2.** Road Layer (obtained by digitizing).

| RD_ID | RD_NAME | RD_SURFACE | RD_LENGTH |
|---|---|---|---|
| 54 | Ikwerre Road | Tarred | 9775.662721 |
| 133 | Ada George | Tarred | 4412.095238 |
| 48 | Harold Wilson Drive | Tarred | 2198203394 |
| 56 | Woji | Tarred | 3443.434173 |

**Table 3**. Traffic Location (junctions).

| LO_ID | LO_Name | RD_ID |
|---|---|---|
| 01 | Market Junction | 54 |
| 02 | Wimpey junction | 54 |
| 11 | Wimpey/Iwofe | 133 |
| 17 | UPE | 48 |
| 05 | Ikoku | 54 |
| 34 | YKC | 56 |

**Table 4.** Location of facility (schools).

| LO_ID | ACC_RD | FAC_NAME | BUA_CLASS |
|---|---|---|---|
| 01 | Ikwerre Road | Community Secondary school, Nkpolu | Dense |
| 11 | Ada George | Istan Comprehensive high school | Dense |
| 17 | Harold Wilson | State Secondary school UPE | Dense |
| 05 | Ikwerre Road | St. Thomas State School. | Dense |

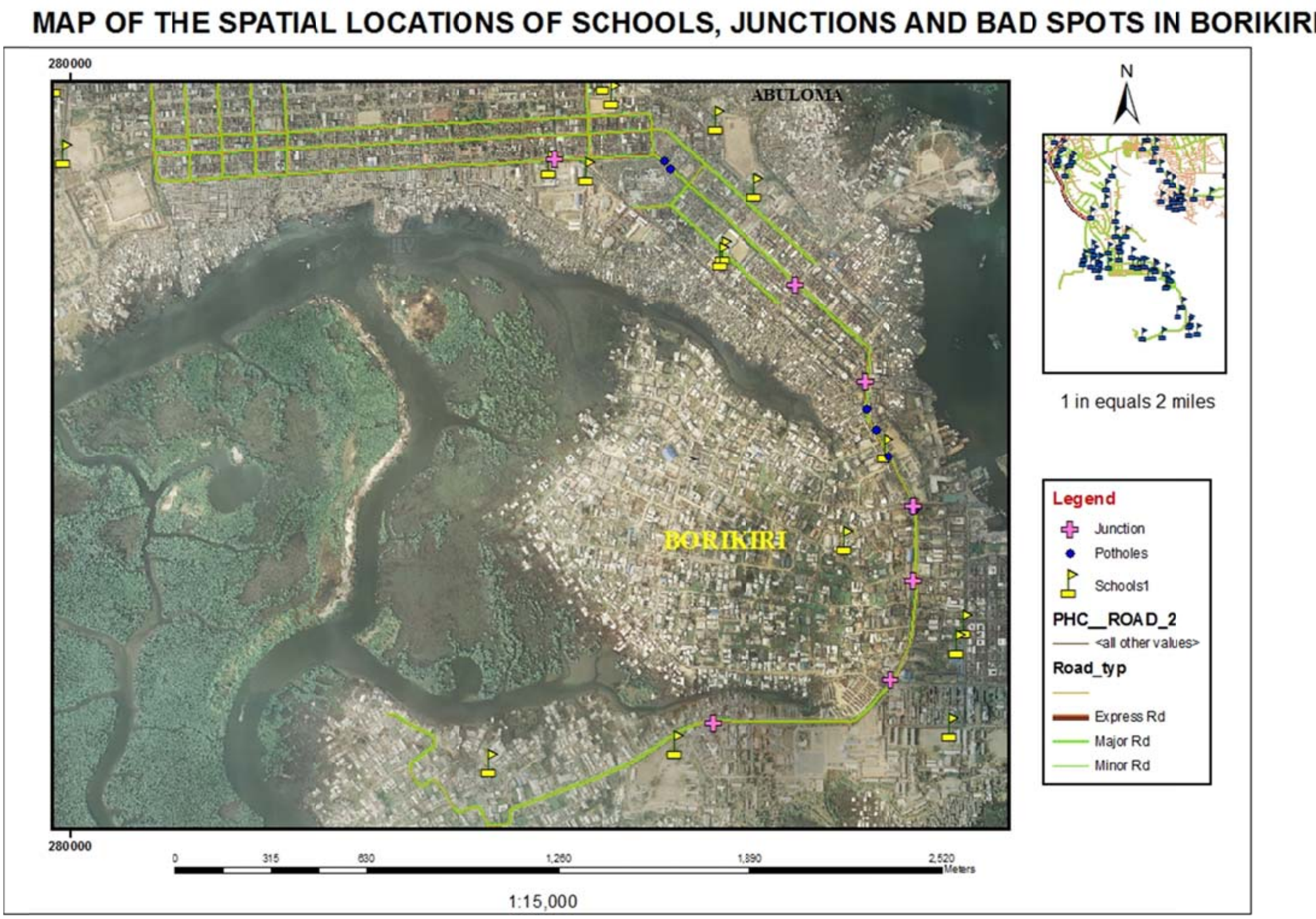


**Figure 5.** Overlay operation in Borikiri.

from Rumuokwuta to Nwaja at Trans Amadi. One can conveniently determine the travel time based on the distance given by the analysis tool and the travelling speed of the vehicle (Table 5).

## Conclusion

The application of Geographic Information System in the development and maintenance of Road Network cannot be overemphasized. Port Harcourt is bound to experience growth in population and a predicted minimum of 7,360 cars in 2022 for the identified routes excluding larger vehicles like trucks; hence there is unavoidable increase in the demand for road usage along these routes.

In relation to estimated projected population figures, a direct proportional increase in the number of vehicles is expected. In 2013 we have an increase of 32.2% in traffic flow. It is expected that there will be an increase of 37.1%

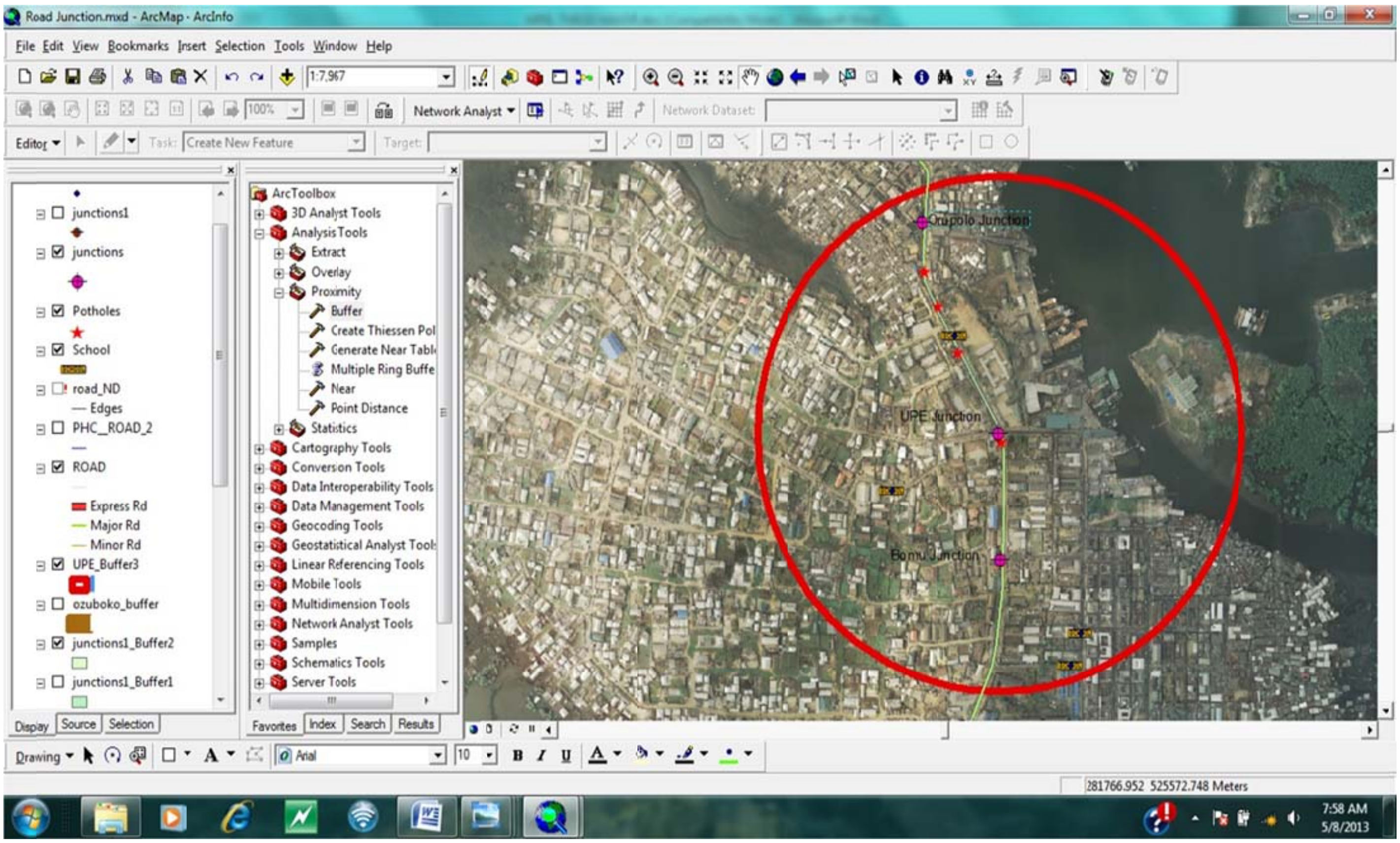


**Figure 6.** Road Point Buffer (UPE junction Borikiri).

between 2012 and 2022. From calculations made, traffic flow is directly proportional to the estimated population. We had 21.77% increase between 2008 and 2013, 61% increase between 2008 and 2022 and 32.18% increase between 2013 and 2022). From these, it was ascertained that the number of vehicles (private saloon, and bus) expected to ply the identified routes in about 10 years time from 2013 is 217,360. With this, adequate decisions towards the construction and improvement of the road network could be made either by government or other relevant private organizations.

## Recommendations

The road network in Borikiri axis of Port Harcourt should be improved by constructing a by-pass to ease the traffic along Harold Wilson road.

All public facilities especially those located along major roads should have good parking plots before approval for construction.

The government should encourage the use of GIS techniques by training and retraining personnel in their various fields of application regarding road usage.

The government should be engaged in projects that would ease traffic flow along the roads through the Ministry of Transport and Ministry of Works. Such projects should include daulization of all major routes, and covering of potholes that develop especially at road junctions.

The width of roads should be extended on approaching major cross junctions with more than 12 conflict points.

It is also recommended that at proximity of 500 km from a developing area, where population is expected to increase, a boulevard should be constructed at the junction linking such area to the center of the town example is the Wimpey/Iwofe junction.

In areas to be developed, the government should ensure a proper road plan is developed prior to construction of buildings. Provisions for taxi parks should be considered.

## Conflict of Interests

The author(s) have not declared any conflict of interests.

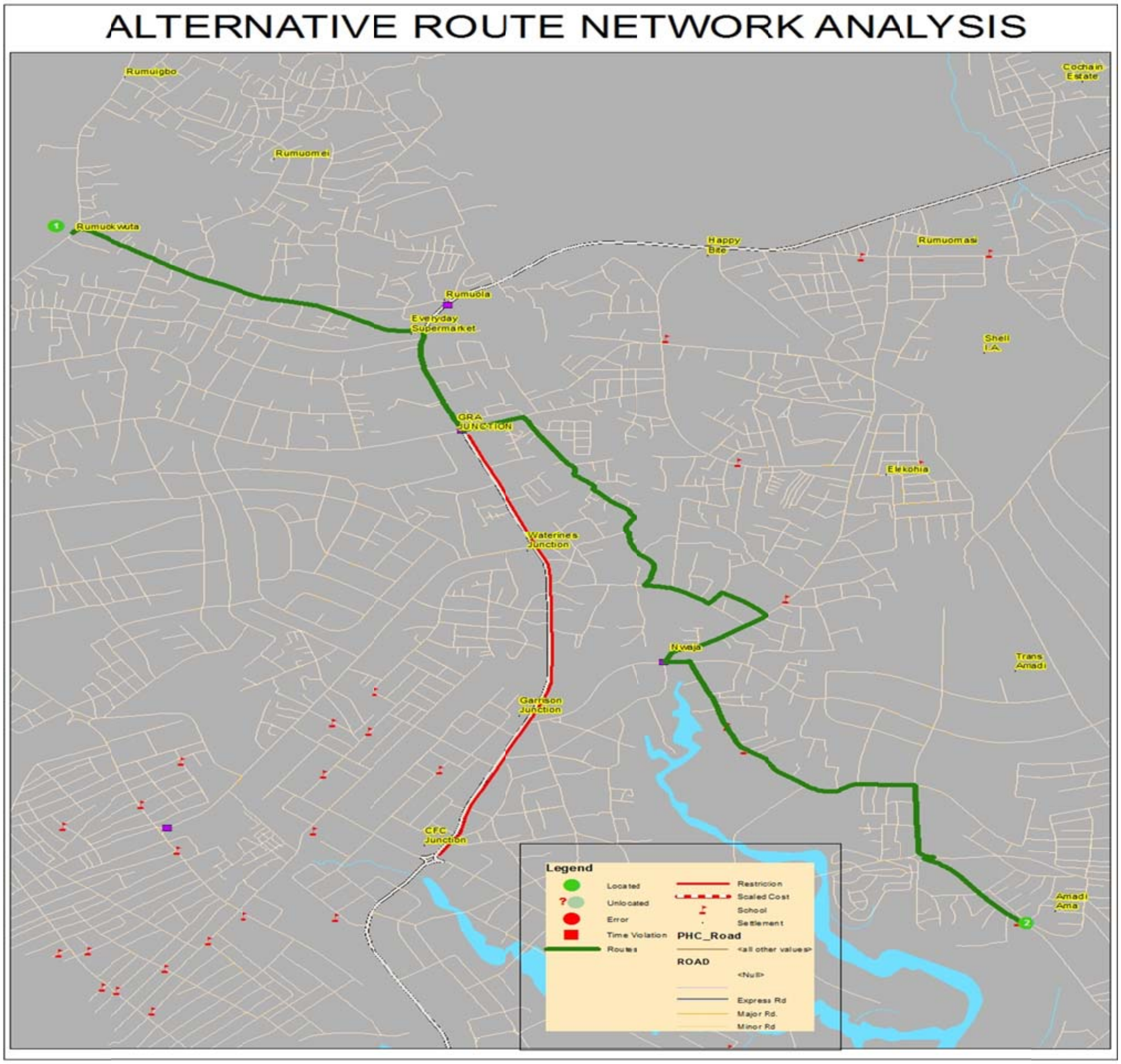


**Figure 7.** Alternative route analysis map.

**Table 5.** Direction Details from Rumuokwuta to Nwaja, Trans Amadi.

| Driving distance intervals (m) | Driving direction | Cumulative driving distance (m) |
|---|---|---|
| 8.8 | Start (go south west) | 0.0 |
| 2077.1 | Make sharp left turn | 8.8 |
| 292.1 | Turn left at Tumuola Road | 2085.9 |
| 443.2 | Turn right | 2378.1 |
| 295.7 | Turn right | 2821.2 |
| 118.3 | Turn right | 3116.9 |
| 247 | Turn right | 3235.2 |
| 1301.7 | Turn right | 3482.2 |
| 484.2 | Turn right | 4783.9 |

**Table 5.** Contd.

| Driving Distance Intervals (m) | Driving direction | Cumulative Driving Distance (m) |
|---|---|---|
| 228.7 | Turn right | 5268.1 |
| 139.3 | Make sharp right turn | 5496.8 |
| 289.9 | Turn right | 5636.1 |
| 246.8 | Turn right | 5925.9 |
| 108.5 | Turn right | 6172.7 |
| 314.6 | Turn right | 6281.2 |
| 483.7 | Turn right | 6595.7 |
| 671.9 | Turn right | 7079.5 |
| 852.4 | Turn right at National Supply road | 7751.3 |
| 53.7 | Make sharp right turn | 8603.7 |
| 690.9 | Make sharp left turn | 8657.4 |
| 13 | Turn left | 9348.3 |
| | Finish at Amadi Ama | 9361.3 |

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