A Gis Based Road Network of Port Harcourt, Nigeria

Amina DIENYE and Ajie EMMANUEL, Nigeria.

Key words: Road Network, GIS, Traffic Congestion, Port Harcourt, GPS.

SUMMARY

This is a summary on the paper on GIS based Road Network of Port Harcourt. The issue of an improved road network due to the dynamic and massive development of Port Harcourt calls for serious concern and adequate attention. The recent physical developmental projects within the metropolis, for example, the construction of a flyover along Ikwerre road, and the expansion of Ada-George road resulted in the demolition of structures because the government intends to create a conducive and optimized road network system.

The aim of this work is 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 Arc GIS 9.3 were performed on the road map signifying the versatility of GIS.

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 rather than reducing as is the case of most of the junction as seen on the field; 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; It is also recommended that at proximity of 500km from a developing area, a boulevard should be constructed at the junction linking such area to the center of the town. Example is the Wimpey/Iwofe junction; the government should ensure a proper plan is developed prior to construction of buildings; Provisions for taxi parks should be considered. 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.

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1. 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 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 problems or rather 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. Prior to the production of the map, data must be acquired using one or a combination of different techniques such as, Remote Sensing, Aerial Photogrammetry, traditional field survey methods, Global Positioning System (GPS). 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.

– Definition of Terms

GIS is defined by Burrough (1986) as "a powerful tool for collection, storage, retrieval, transforming and displaying spatial data from the real world. Goodchild (1997) defined GIS as "a computer system for handling geographic information in a digital form.

A map as defined by Ndukwe (2001) as a representation on a plane surface of the physical features (natural and artificial) of parts or the whole earth's surface, at a given scale, by the use of signs and symbols with the method of orientation indicated.

A road network is an intersection of various roads: expressways, major roads, minor roads, streets, lanes (Omunguye, 2004).

- **Statement of Problem**

One of the major problems affecting the road network of Port Harcourt is traffic congestion. The traffic flow data of Port Harcourt reveals that there is 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. See table below.

Table 1: Hourly traffic flow of some routes in Port Harcourt

S/No	Location	2008 traffic flow	2013 traffic flow
1	Ikwerre Road	**1286**	**1360**
2	East West	**771**	**816**
3	Obi-wale/Rumuigbo	**473**	**500**
4	Rumuepirikom/Ada George	**476**	**504**
5	Rumuokwurushi	**983**	**1040**
6	Eliozu	**1116**	**1181**
7	Aba Road/Woji	**3453**	**3653**
8	Harold Wilson/Churchill	**1069**	**1131**
9	Marine junction/Hospital road	**1240**	**1312**
10	Trans Amadi/Abuloma	**1246**	**1318**
11	LNG	**1334**	**1411**
12	Abonnema wharf	**964**	**1020**
13	Aba Express	**1122**	**1187**
14	East West Tank 1	**590**	**624**
15	East West 2	**882**	**933**
	Total	**17005**	**17989**

Source: Integrated Transport Master Plan, October 2008

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, 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).

Consequent upon these factors, the following is experienced on the road network:

- Services rendered with the aid of these routes are more or less paralyzed. Such services include delivery of hard currency, emergency rescue operations.
- Loss of life due to delayed rescue operations
- Psychological stress
- Injury from road accidents caused by poor design and presence of bad spots (pot holes).

The prevention of unnecessary traffic, which generates environmental burdens, should be the top priority of municipalities in urban centers (Oluwadare, Alade & Afolayan, 2009).

- **Study Area**

The study area is Port Harcourt, 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 (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 mufti-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 of the environments within Port Harcourt. A total of forty 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
vi) Woji Road

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

2. LITERATURE REVIEW

Maps are needed for nearly every aspect of government policies and for private sector activities including Environmental Management, Population control, utilities (drainage, pipelines, communication, electricity, water), property development, establishment of social and health facilities, land registration and transportation (Olagbadebo and Dienye, 2008). The analyses of

mapped data for decision making and solution findings has become an important part of planning of which road network analyses is also a part.

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). The figure below, shows Borikiri in the southern part of Port Harcourt, showing development with only one major road.

Figure1: Development in Borikiri.

Traffic snarls take place in most parts of Guwahati city consequent upon the following factors: lack of proportionate attributes of roads, population explosion, peak number of vehicles, rapid urbanization, location of social infrastructure, complex land acquisition, and habitation before construction of roads. These problems or challenges could be solved with the application of GIS to surveying and mapping.

This is because the GIS allows one to visualize, understand, question and interpret data in many ways that reveals relationships, patterns and trends in the form of maps, reports and charts. GIS draws concepts and ideas from many different disciplines which include cartography, computer science, engineering, environmental sciences, geodesy, landscape architecture, public policy, photogrammetry, remote sensing and surveying (Heywood, Cornelius, & Caver, 2006).
GIS serves three distinct transportation needs:

- Infrastructure management

- Fleet and logistics management
- Transit management

It offers insight for network planning, vehicle tracking and route planning analyses.

According to the Lagos Metropolitan Area Transport Authority (LAMATA), transportation GIS supports decision makers in the transport sector as they manage the comprehensive transportation planning process. It also assists the agencies' professionals in the following areas: transportation planning natural and human resources, ultimately contributing to the achievement of a sustainable transportation system despite population increase and travel demands.

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 LTA 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 Land Transit Authority (LTA) uses GIS to integrate transportation data and manage traffic incidents (Transportation GIS Trends, 2009).

Furthermore, Andrew, Olatunde and Dozie (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.

3. METHODOLOGY

– Hardware and Software Selections

Hardware components for data acquisition, manipulation, processing and presentation used for this work include 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), Colour Printer. (HP Deskjet 3050A J610series)

The software selected for analyses during the project was Arc GIS 9.3 version, AutoCAD 2007 version was employed in the digitization process. Geographic Calculator (GeoCAL) version 6.3 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 where used for production of the manuscript and presentation.

- **Data Acquisition**

For every surveying and GIS analyses processes, data acquisition is of top most priority. According to Stars and Estes (1990), data acquisition is the process of identifying and gathering data required for an application. The GPS receiver (map 76 versatile navigator), was employed to obtain the coordinate of the junctions, bad spots and schools. 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), 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). The two stages involved in the database design process are:

- The Design Stage
- 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; one to many; and many to many. The following tables were derived:

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

3. RESULT PRESENTATION AND ANALYSES

The primary appeal of GIS to many is the graphical capabilities as it has been stated that "a picture is worth a thousand words." Maps are the pictures GIS uses to communicate complex spatial relationships that the human eyes and mind are capable of understanding. The computer makes this possible, but still, it is the GIS user that determines what data and spatial relationships will be analyzed and portrayed, or how the data will be thematically presented to its intended audience.

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.

Furthermore, overlay operations done in Borokiri 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 alternative routes (only one major route) that would ease the congestion of the junctions. (see figure 2 below).

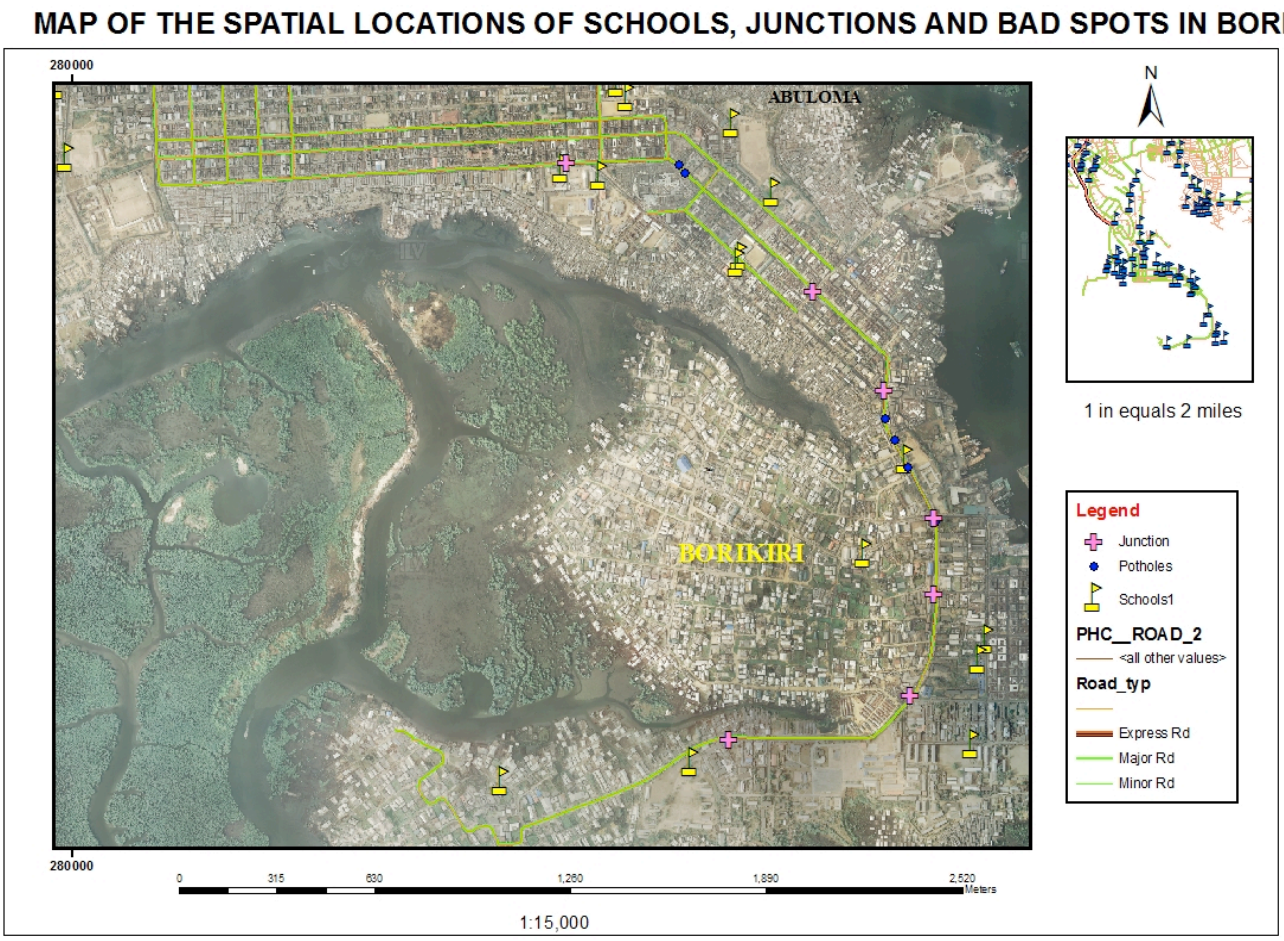

Figure 2: Overlay operation in Borikiri

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 borokiri axis, a buffer of 500m was created at UPE junction, see figure 12 below. 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 (4) 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.

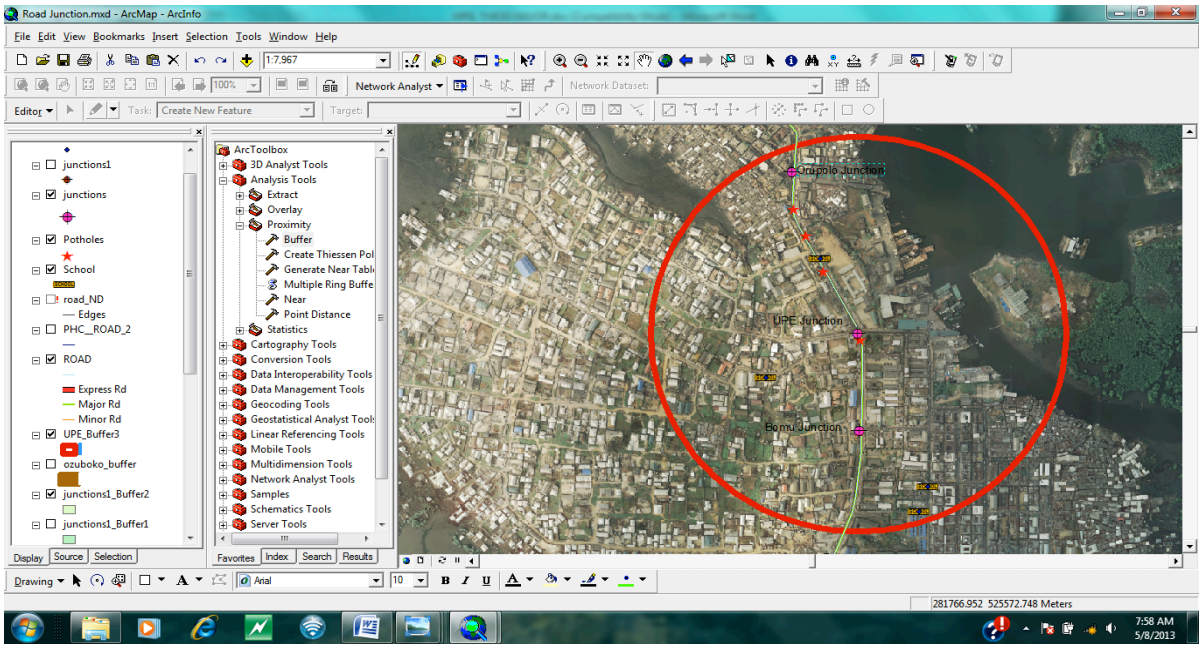

Figure 3: Road Point Buffer (UPE junction Borikiri)

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 4 below, having a driving distance of **9361.3m** 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.

Direction Details from Rumuokwuta to Nwaja Trans Amadi.

0m	Start (Go South West)	8.8m
8.8m	Make sharp left turn	2077.1m
2085.9m	turn left @ Rumuola road	292.1m
2378.1m	Turn right	443.2m
2821.2m	Turn right	295.7m
3116.9m	turn right	118.3m
3235.2m	turn left	247m
3482.2m	turn right	1301.7m
4783.9m	Turn right	484.2m
5268.1m	turn left	228.7m
5496.8	Make sharp right turn	139.3m
5636.1m	Turn left	289.9m
5925.9m	turn left	246.8m

6172.7m	Turn right	108.5m
6281.2m	Turn left	314.6m
6595.7m	Turn left	483.7m
7079.5m	Turn right	671.9m
7751.3m	Turn right @National Supply Road	852.4m
8603.7m	Make sharp right turn	53.7m
8657.4m	Make sharp left turn	690.9m
9348.3m	Turn left	13m
9361.3m	Finish@ Amadi-ama.	

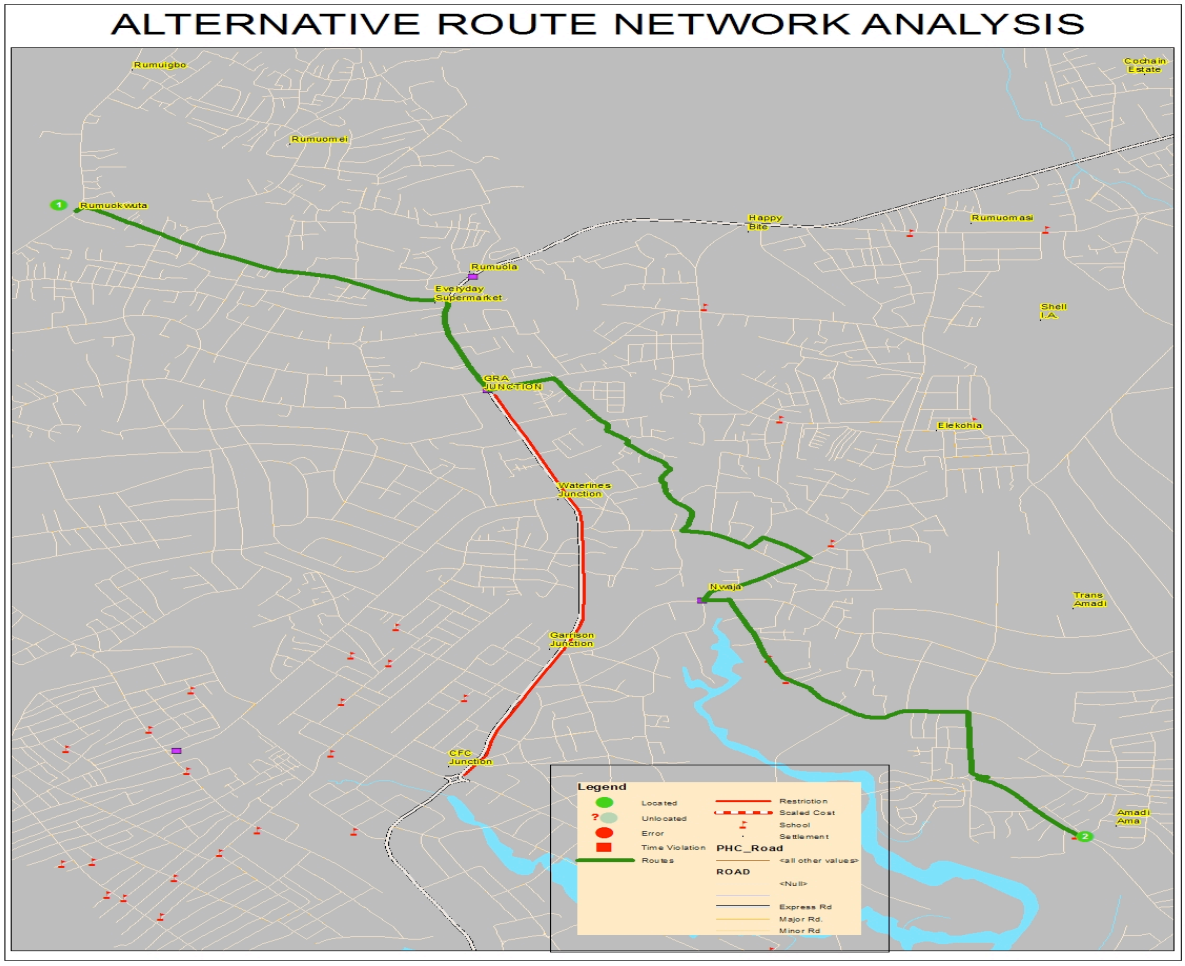

Figure 4: Alternative route analysis map.

CONCLUSION AND RECOMMENDATIONS

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 7,360cars in 2022 for the identified routes excluding larger vehicles like trucks. Hence an 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. There is expected to be an increase of 37.1% between 2012 and 2022. From calculations made traffic flow is directly proportional to the estimated population. We have 21.77% increase (2008-2013), 61% increase (2008-2022) and 32.18% increase (2013-2022). 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 vehicles. 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

1. 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.
2. All public facilities especially those located along major roads should have good parking plots before approval for construction.
3. The government should encourage the use of GIS techniques by training and retraining personnel in their various fields of application regarding road usage.
4. 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, covering of potholes that develop especially at road junctions.
5. The width of roads should be extended on approaching major cross junctions with more than twelve conflict points.
6. It is also recommended that at proximity of 500km 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.
7. In areas to be developed, the government should ensure a proper road plan is developed prior to construction of buildings.
8. Provisions for taxi parks should be considered.

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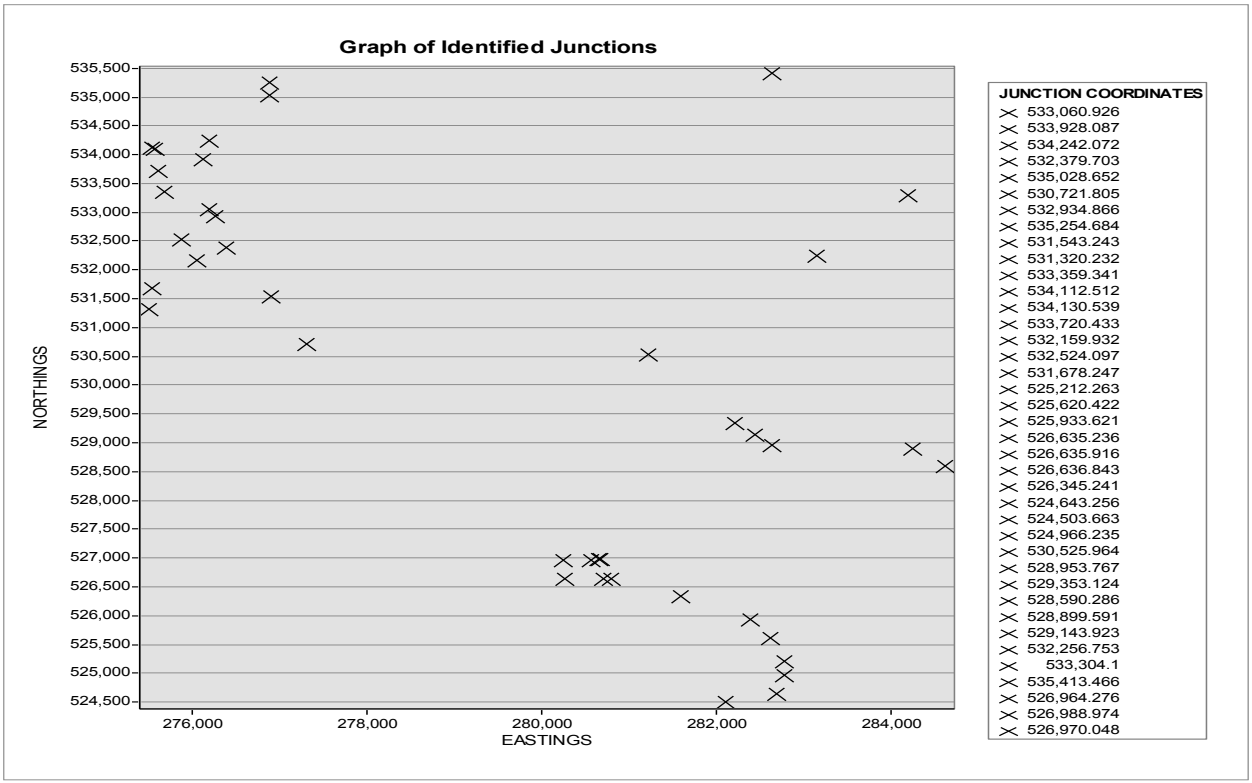
Appendices


Graph of Identified Junctions
NORTHINGS
EASTINGS
535,500
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284,000
JUNCTION COORDINATES
533,060.926
533,928.087
534,242.072
532,379.703
535,028.652
530,721.805
532,934.866
535,254.684
531,543.243
531,320.232
533,359.341
534,112.512
534,130.539
533,720.433
532,159.932
532,524.097
531,678.247
525,212.263
525,620.422
525,933.621
526,635.236
526,635.916
526,636.843
526,345.241
524,643.256
524,503.663
524,966.235
530,525.964
528,953.767
529,353.124
528,590.286
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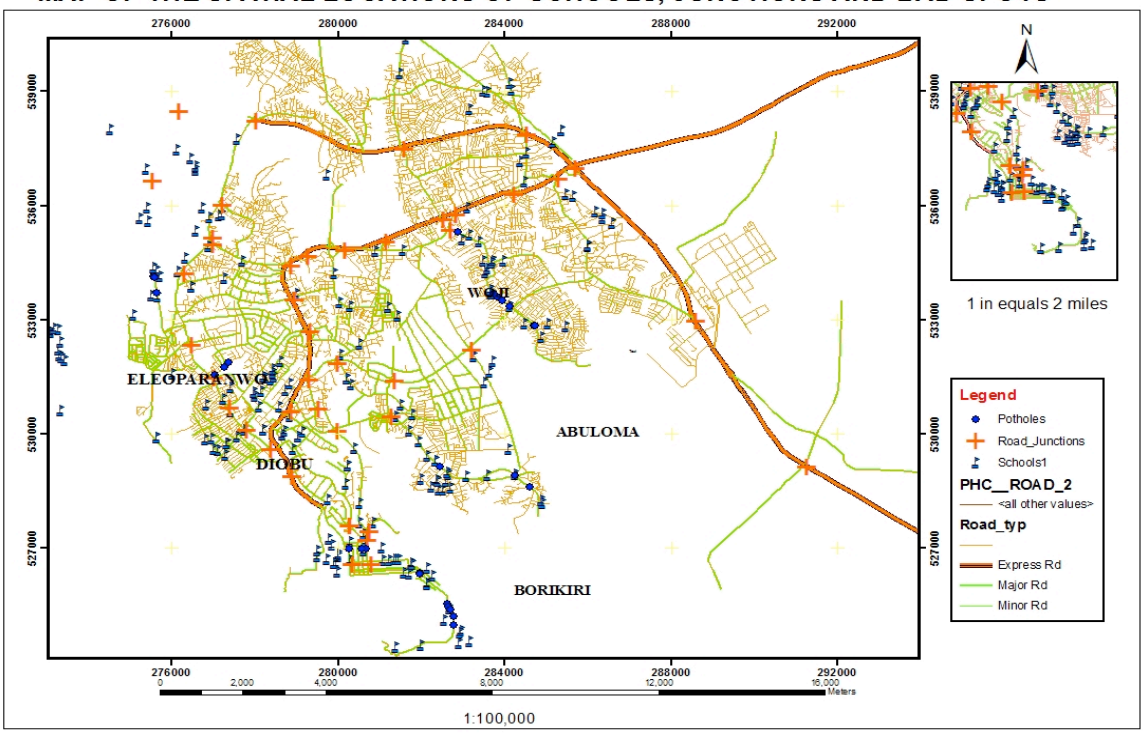
532,256.753
533,304.1
535,413.466
526,964.276
526,988.974
526,970.048


MAP OF THE SPATIAL LOCATIONS OF SCHOOLS, JUNCTIONS AND BAD SPOTS
276000
280000
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1 in equals 2 miles
WOJI
ELEOPARA/WOJI
ABULOMA
DIOBU
BORIKIRI
Legend
Potholes
Road_Junctions
Schools1
PHC__ROAD_2
<all other values>
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Express Rd
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Minor Rd
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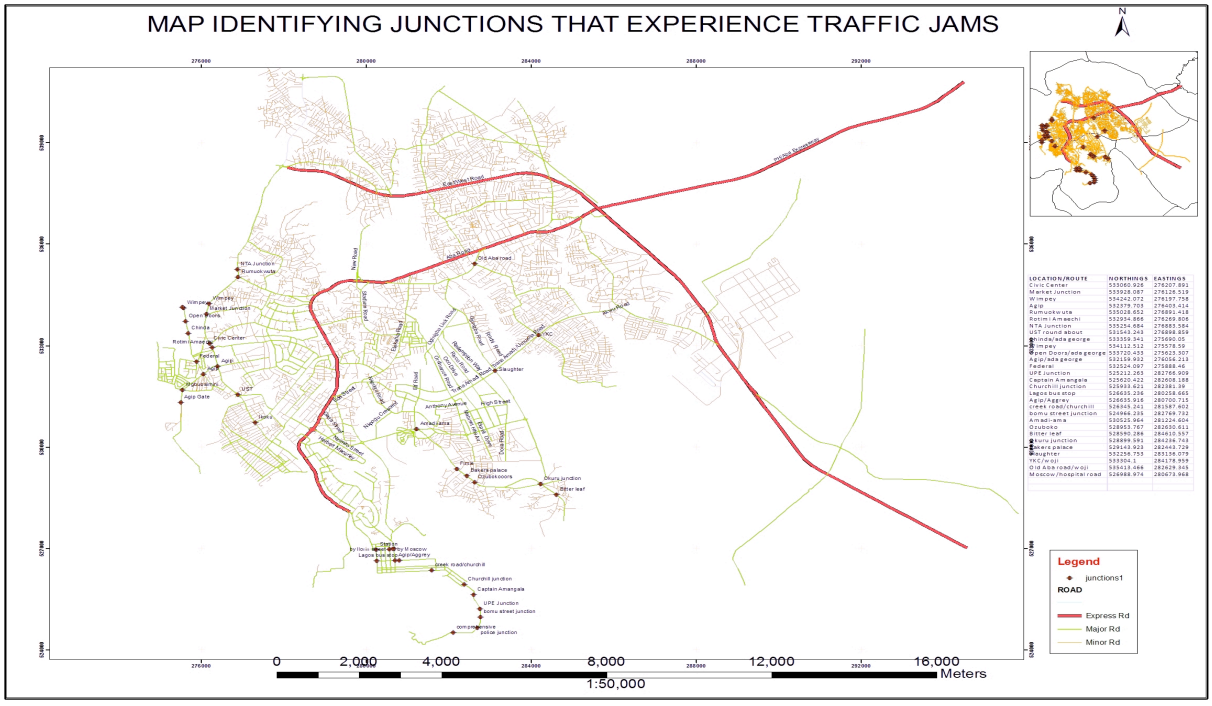
MAP IDENTIFYING JUNCTIONS THAT EXPERIENCE TRAFFIC JAMS
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Legend
junctions1
ROAD
Express Rd
Major Rd
Minor Rd
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8,000
12,000
16,000
Meters
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