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Full Length Research Paper

Development of GIS based road network map of Port Harcourt to resolve issues with road network

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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, Geogra**p**hic informat**i**on systems (GIS), traffic congestion, Port Harco**u**rt, global positioning **s**ystem (GPS**)**.

INTRODUCTION

During the colo**n**ial era, the road network of Port Harc**o**urt was planned in such a way that th**e** streets were designed in a grid form. So**c**ial and recr**e**ational facilities provided were w**e**ll situated; **h**ence the q**u**ality of life **o**f the inhabitants was enhance**d**. This is ob**v**iously due to the **f**act that transportation networks **p**rovide 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.

T he spatial location of 221 schools (primary a nd sec ondary) wh ere defined within the metropolis; he loc ation of scho ols being a factor to traffic volume.

R oad conges ion in Port Harcourt is similar to that of Guwahati, capital city of As sam in Nort heastern Ind ia. Urb anization peaked without consequent development of the social and physical infrastructure like roads, bridg es an settlement s (Deka, 2009; Obinna, et al., 2010). Figure 1 is a m p showing Borikiri in the southern part of Po t Harcourt, developing with only o ne major ro ad. Tra ffic snarls take place in most parts of Guwahati ity con sequent u pon the f llowing fac tors: lack of proportionate attributes of roads, popul ation explosi on, an peak num ber of vehicles, rapid urbanization, a nd loc ation of socia l infrastructure, complex land acquisiti on, an habitation before construction of roads. The se cha llenges coul d be solved with the application of GIS to surveying and mapping. Th prevention of unnecess ary traffic, which g enerates env ironmental b urdens, should be the top pri ority of municipalities in urban cent ers (Oluwadare et al., 2009; ITM P, 2008).

A ccording to Matt (2009), Singapore, a southeast ern Asian Island since its independence in 1 65 realized he ne d for GIS in 1995 when it formed LTA, having ack nowledged the transportation needs of about 4.6 mil ion people. The decision was based on the featu res an functionality of ESRI's A rcGIS softwa re, aiding La nd Tra nsit Authority (LTA) to manage its assets a nd resources, as well as giving it the freedo m to collabor ate wit h other gov ernment, private and p ublic agencies havin g the common interest of a free-flowing transportation sy stem. Sing apore LTAuses GIS to integ rate transportation data a nd manage traffic incidents (Tran sportation G IS Trends, 20 09).

Fur thermore, A ndrew et al. (2011) employed GIS for asse ssing the road network in Trans-Amadi, Po t Harc ourt. They co ncluded that the road network in Trans Ama di was in go od condition and the connectivity lev l was high. They r ecommended that the stu dy should be carrie d out on a larger sc ale considering vehicular move ment and i pedance at other locatio ns within the city.

METH ODOLOGY

Hardw are and softw are selections

Hardw are compon ents for data acquisition, manipulatio , proce ssing and presentation use d for this wo k included the followi ng: Computer -windows 7 (4.00GB RAM space, 64-bit Opera ting System, 21″ colour monit or), A0 Scann r (Crystal G600 Wide format), CD-Ro m Drive, Hard Drives (flash d rive), GPS Map 76, ve rsatile navigator, Plotter (HP Design jet 500 plus 42), and Colour Printer (HP D eskjet 3050A J6 10series).

The software selec ted for analyse s were ArcGIS 9.3 version and AutoC AD 2007 version. Geographi c Calculator (G eoCAL) version 6.3 as used for coordinate ystem conver sions of GP S coordinates in Excel sheet. The coordinates from the Excel she t where imported into the ArcGIS (Arc Catalog) environment using the 'A dd data' tool. Microsoft Word 2007, Micr osoft Excel and Power Point 2007 w ere used for production of the manuscript and prese ntation.

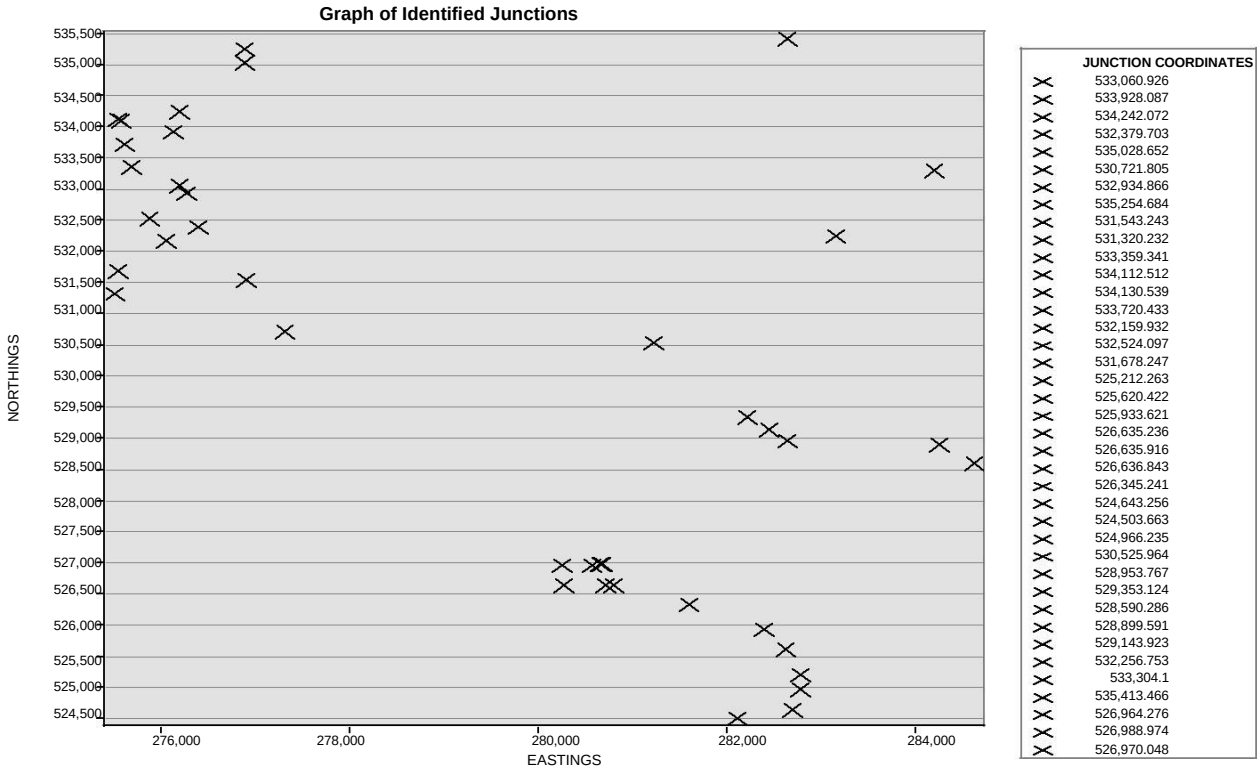


Figure 2. Coordinates of junctions that experience traffic jams.

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.

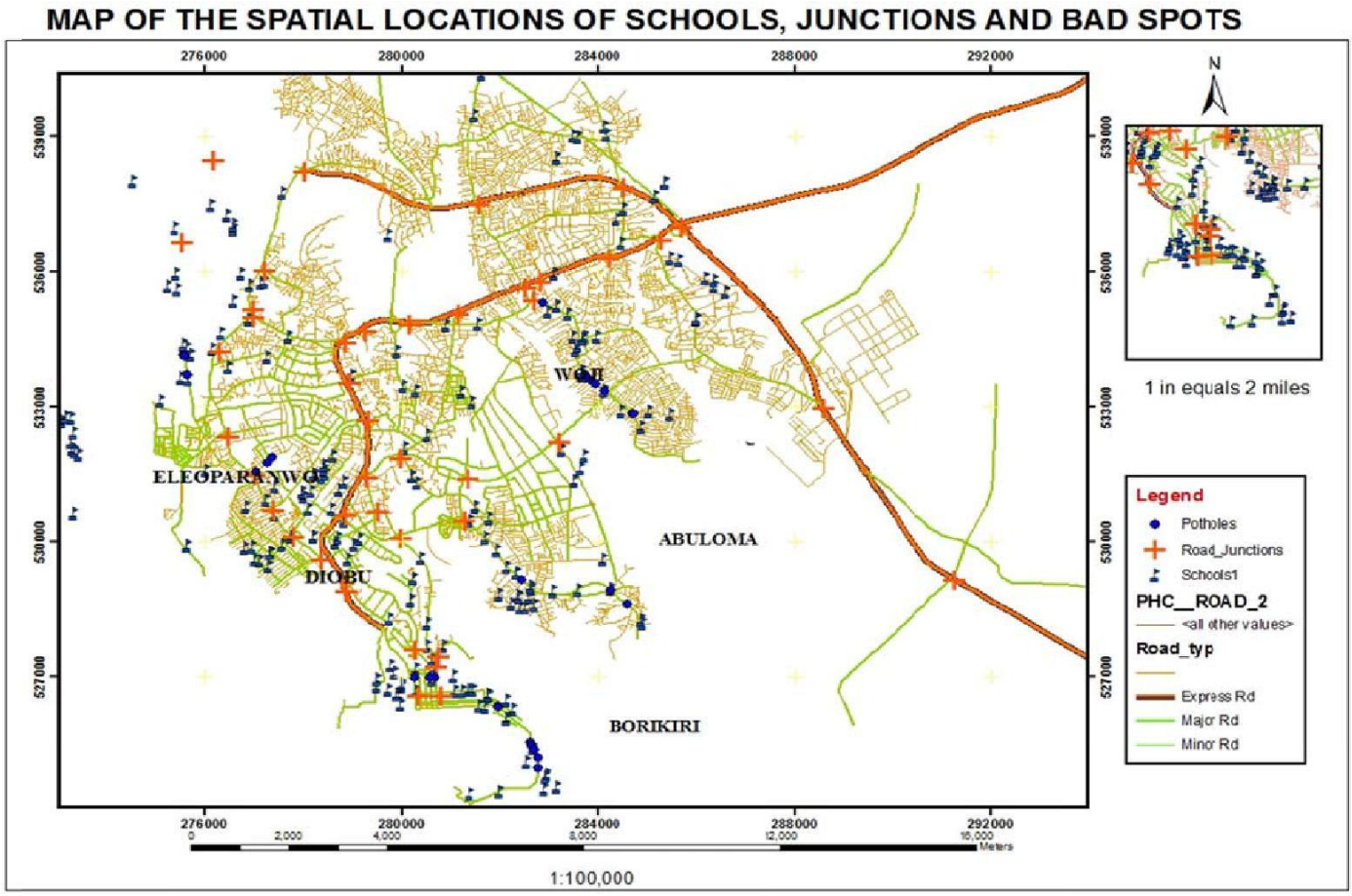


Figure 3. Spatial locations of schools, junction and bad spots.

F urthermore, o verlay oper ations done i n Borikiri sho ws that, most of th e identified bad spots we re very close to the identified congested j unctions along the Harold Wilson drive. The number of schools along this sa me route would rat er require a smooth flow of traffic which is o bviously not certain due o the pot holes at the ma jor junctions and the lack of lternative routes (only o ne major route) th at would ease the con gestion of the junctions (Figur 5).

Pro ximity anal sis

Buf fering is a m eans of performing this practical spatial qu ry to determine the proximity of neighbouring features. By point bufferin g, features (junctions, b ad spo ts) within a prescribed distance from a point, line, or area, are deter mined. Along the borikiri axis, a buffer of 50 m was created at UPE ju nction (Figur e 6). This po int in the field is kn own to be highly conges ted during pe ak ho rs. The buffer captures three (3) jun ctions, four (4) scho ols and four major bad s pots along the same road . Hence the combination of three factors r sponsible for traffic congestion is found within the buffered zone. There is no alternative for users to onsider in t e case of an emergency.

Netw ork analysis

Unlike proximity a nalysis that searches in all directions from a point, line, or area, ne work analysis is restricted to searching alon g a line, suc as a route, or throughou t a net work of line ar features, such as the road network . Network analysis can be used to define or identify route corrid ors and det ermine trav l paths, tra vel distances , and r esponse tim es. For exam ple, network analysis may be u sed to asse s the traffic volume impact of a road closure on adjace nt roadways.

For this work, the presence of a barrier at the GR A Junct ion and con sidering the one way mo vement of the traffic was adopt ed. The alte rnative route is presented thus in Figure 7, having a dri ving distance of 9361.3

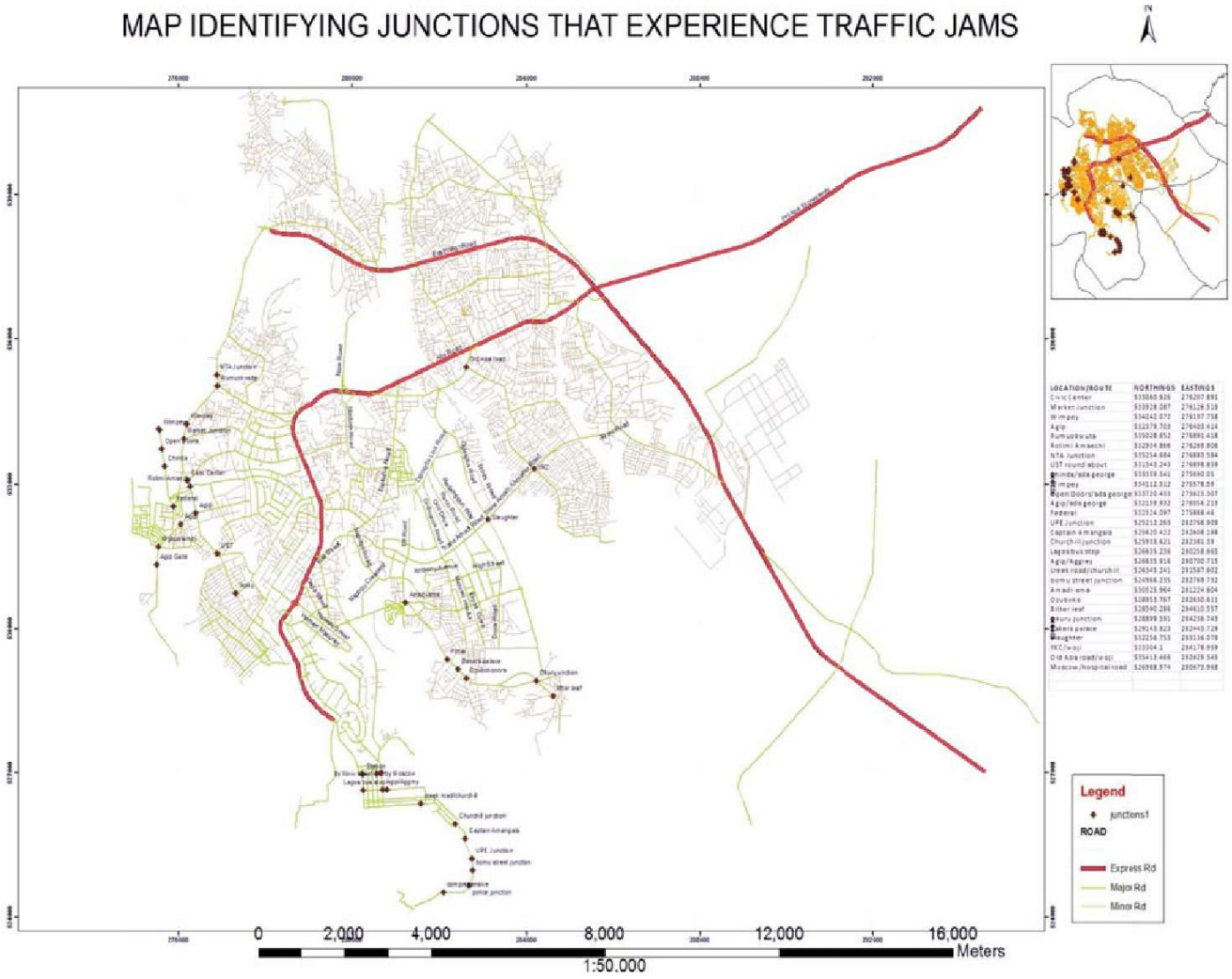


Figure 4. Ju nctions that Exp erience Traffic Jams.

Table 2. Road Layer (ob tained by digiti zing).

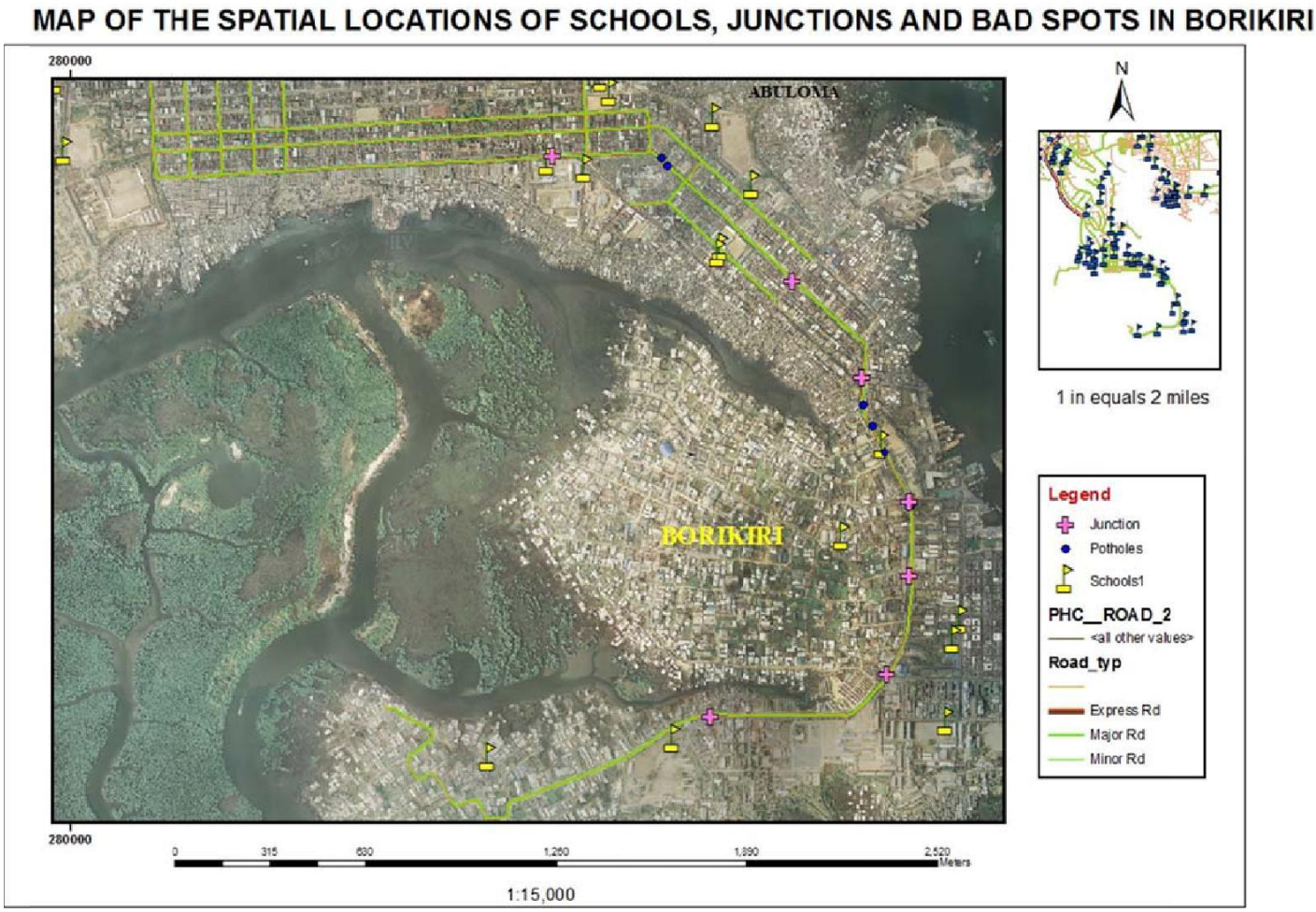
RD_ID	RD_NA ME	RD_SURFA CE	RD_LENGTH
54	Ikwerre Road	Tarred	9775.662721
133	Ada G orge	Tarred	4412.095238
48	Harold Wilson Drive	Tarred	2198203394
56	Woji	Tarred	3443.434173

Table 3. Traffic Loc ation (junctions) .

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

Table 4. Location of facility (schools).

LO_ID	ACC_RD	FA C_NAME	BUA_CLASS
01	Ikwerre Ro ad	Co mmunity Seco ndary school, Nkpolu	Dense
11	Ada Georg e	Istan Comprehe sive high sch ool	Dense
17	Harold Wils on	State Secondary school UPE	Dense
05	Ikwerre Ro ad	St. Thomas Stat e School.	Dense



Fi gure 5. Overlay operation in B orikiri.

fro m Rumuokw uta to Nwaja at Trans Amadi. One c an con veniently de termine the travel time based on he dis tance given by the analysis tool an d the travelling spe ed of the ve icle (Table 5).

Conclusion

Th e application of Geographic Informatio n System in the de elopment an d maintenance of Road Network can not be overemphasized. Port Harcourt is bound to expe rience growth in popu lation and a predicted mini um of 7,36 0 cars in 20 2 for the id ntified routes excluding larger vehicles lik e trucks; he nce there is unav o idable incre ase in the demand for roa d usage along these routes.

In r elation to es timated proj ected population figures, a direc t proportional increase in the number of vehicles is expe cted. In 2013 we have an increase of 32.2% in traffic flow. It is expecte that there will be an incre ase of 37.1%

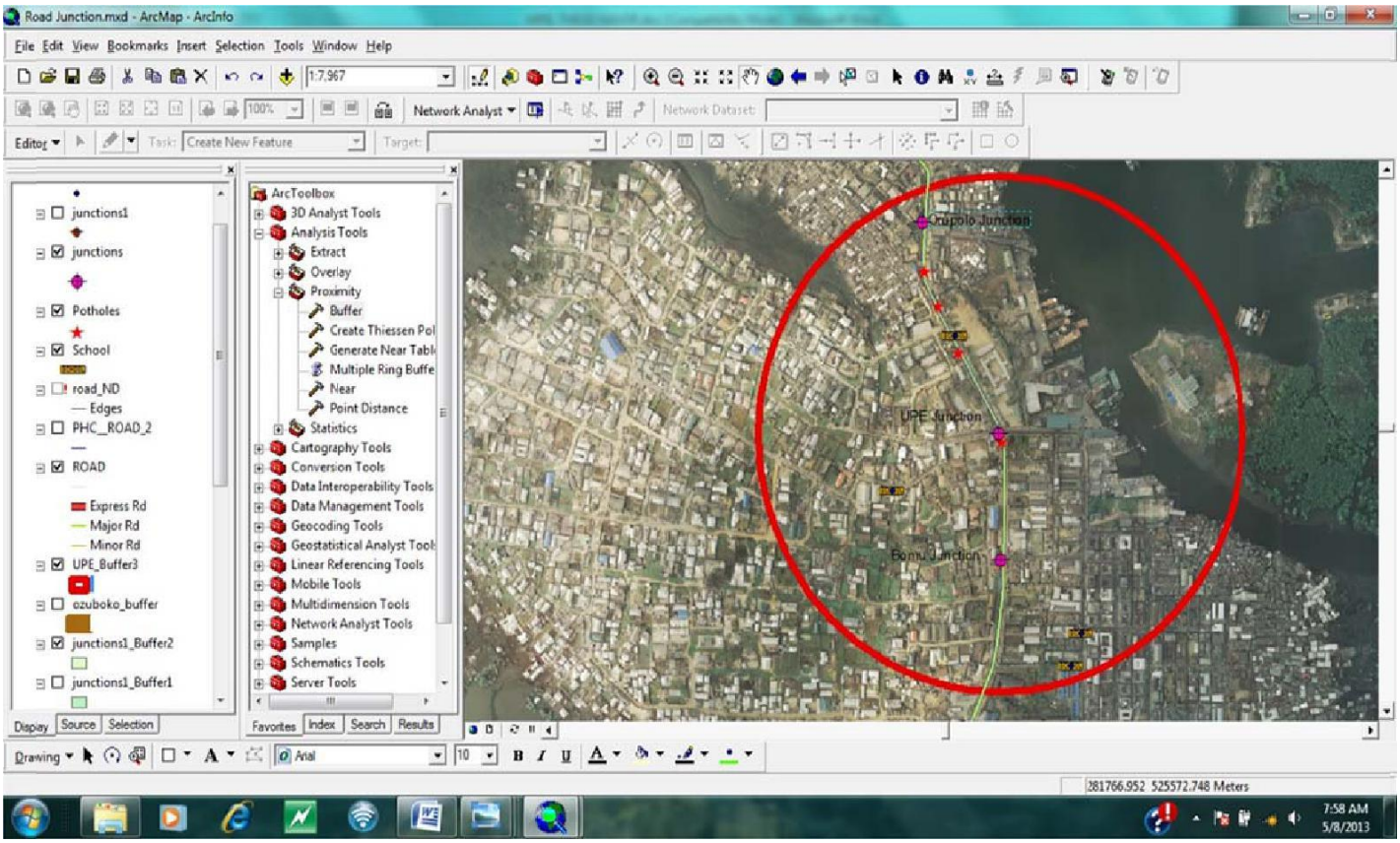


Fig ure 6. Road Point Buffer (UPE junction Borikiri).

between 2012 a nd 2022. Fr om calculations made, traffic flo is directly proportional to the estim ted populati on. We had 21.77% increase be tween 2008 and 2013, 6 1% inc rease betwe en 2008 and 2022 and 32.18% increa se between 2013 and 2022). Fr o m these, it was ascertain ed that the numbe r of vehicle s (private saloon, and b us) exp ected to ply the identifie d routes in about 10 ye ars time from 2013 is 217,360. ith this, adequate decisio ns tow ards the co nstruction and improvem ent of the ro ad network could be made eit er by government or ot her rel vant private organization .

Recommendations

Th e 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 f cilities espe cially those located alo ng major roads s hould have good parking plots bef ore ap roval for construction.

The govern ent should encourage the use of G IS techniques by t raining and retraining per sonnel in their vario us fields of a pplication regarding road u sage.

Th e governmen t should be engaged in projects tha t woul d ease traff ic flow along the roads through the Ministry of Transport and Ministry of Works. Such projects should i nclude dauliz ation of all major routes , and covering of potholes that develop esp ecially at road junctions.

Th e width of roa ds should be extended o n approaching majo r cross juncti ons with mor e than 12 con flict points.

It is also recom mended that at proximity of 500 km fro a de veloping ar a, where p opulation is expected to incre ase, a boulevard should be constructed at the junction linking s uch area to the center of the town exam ple is the Wimpey/Iwofe j unction.

In areas to b e developed, the gover nment should ensu re a proper road plan is developed prior to cons- tructi on of buildin gs. Provisions for taxi parks should be considered.

Conflict of Interests

The uthor(s) have not declared any conflic of interests.

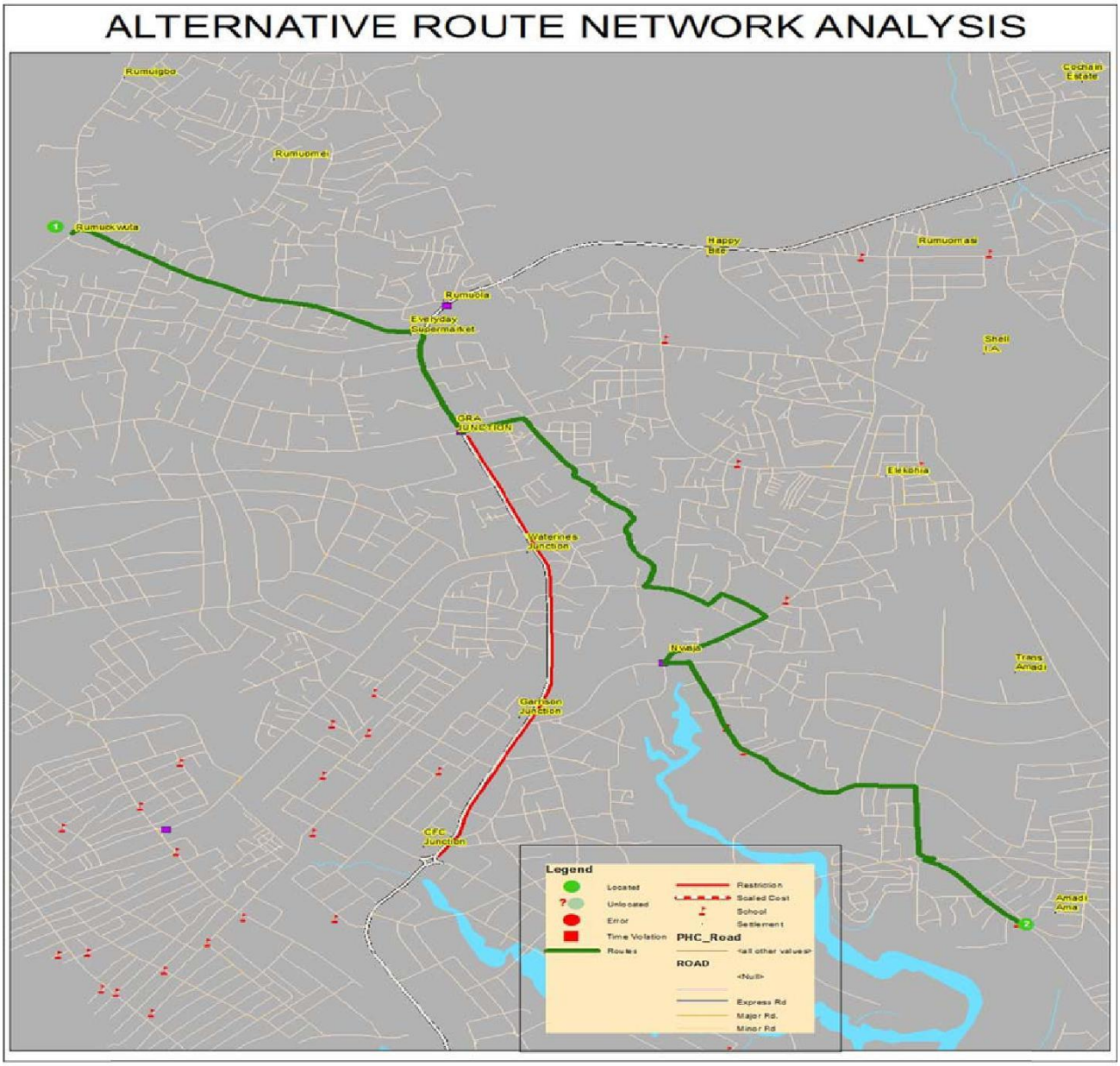


Figure 7. A lternative route analysis map.

T able 5. Directio n Details from Rumuokwuta to Nwaja, Trans Amadi.

Driving distan ce intervals (m)	Driving direction	Cumula tive driving distance (m)
8.8	Start (go south west)	0.0
2077.1	Make sh arp left turn	8.8
292.1	Turn left at Tumuola Road	2085.9
443.2	Turn rig ht	2378.1
295.7	Turn rig ht	2821.2
118.3	Turn rig ht	3116.9
247	Turn rig ht	3235.2
1301.7	Turn rig ht	3482.2
484.2	Turn rig ht	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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