Bus Rapid Transit (BRT) and Railway Transport System in Lagos: Geographic Information System Approach

Akpomrere, O. R.
Surveying and Geoinformatics Unit, Delta State Polytechnic, Ozoro, Nigeria.
Email: kporuf@gmail.com

Nyorere, O.
Department of Agricultural Engineering Technology,
Delta State Polytechnic, Ozoro, Nigeria.

ABSTRACT

Lagos metropolitan area is by far the largest and most complex urban area in Nigeria. With ever-increasing population, the transport system in Lagos is becoming complex in nature, due to the fact that, it combines different modes of transportation over a limited space in high-density areas with increasing transport demand. This research paper is to produce a GIS based transport system in enhancing Bus Rapid Transit (BRT) and Railroad Transport system of Lagos State. Point data (coordinates) of the train terminals and the BRT bus stops were obtained by hand held GPS, which were marked waypoints, saved in DXF file format and exported to AutoCAD environment. AutoCAD 2006 was then used in digitizing and geo-referencing the BRT and Rail line maps. The image obtained was overlaid using ArcGIS 9.2 on Lagos land use and street map available on Map Source stand-alone application for the purpose of correct alignment. A database was created and populated in the ArcGIS 9.2 environment. Line layers were created for BRT routes, Rail line and point layers for BRT Bus stops and Rail Terminals respectively. In addition, a time and cost model user interface application was developed using Visual Studios 2006 and ArcGIS 9.2. Routes analysis networks such as optimal route paths were carried out. Finally, a mathematical model was developed for estimating the average number of commuters, the number of vehicles for carrying such commuters, the number of trips required by the vehicles as well as the revenue that can be generated for such trips. It is recommended that a GIS controlled and organized transport system is a catalyst for effective transport system in Lagos State in particular and Nigeria in general.

Keywords: *GIS, BRT, Railroad, Transport System, Lagos.*

INTRODUCTION

Daily activities of man involve moving from one place to another. Such movements may take long distance. Essentially, transportation is the movement of goods and people from one place to another through specified mode such as air, water and land (rail and road). In Yinkore (2005), transport development is one of the indispensable catalysts for stimulating the tempo of a nation's socio-economic, political and cultural development. This therefore imposes on every government the imperative for the development of an efficient, flexible, dynamic, and integrated transport system as a means of binding the various components of a society at the local government, state, national or international levels. The level of transport development in any society largely determines and reflects the level of development and its function in society. An efficient transport system stimulates and enhances the productive

uses of human and material resources and thus economic development of the society. In the socio-political context, transport provides the instrument for enhancing human interaction, blending of cultures as well as the integration of socio-political groupings. Nigeria government's interest in the provision of roads, highways, and railway facilities is manifested in the enormous investment in the transport sector. The demand for public transport in Lagos metropolis is very high. Ogunsanya (1991) posits, many of the urban activities are not located in one place and there is an increasing need for people to travel to work, school, shopping and other places in the city so as to satisfy their daily need. To overcome the distance separating them from their activity requires the use of a particular means of movement and those without a personal vehicle must make use of the public transport for a journey. Adefolalu (1977) writes that the inability of the supply aspect of the urban transport is reflected in urban traffic congestion, auto-emissions, deteriorating urban environment and air quality in many urban areas.

In Abimbola (2004), public transport provision is capital and labour intensive. Government owned bus companies did not meet the rapidly rising need of the population in Lagos and the associated growing demand for land transport services and this encouraged the growth of private small bus operators. Bus public transport operation in Lagos is characterized by high levels of fragmentation and indiscipline. It is estimated that 75,000 buses in Lagos is being owned privately. Existing rail corridors are very few and grossly under-utilized. The Nigerian Railway Corporation operates only one train per day in each direction of the Agege to Iddo corridor. The National Inland Waterways Authority, a federal agency, regulates the use of the waterways in Lagos. Both the Federal and Lagos State governments provide ferry services and have built a number of jetties along the waterways of Lagos. The potential of both rail and water transport remain largely untapped as they carry less than one percent of overall traffic in Lagos. Bolade (1994) postulates that the estimates or urban transport demand in metropolitan Lagos in 1990 ranged from six million passenger trips daily and that the public transport share by road is about 85-90%. The Lagos area is therefore characterized by traffic congestion.

Mass Transit, according to White (1976), can be defined as a high capacity means of transport of large number of people within a given network with relatively short-term head ways and reasonable turn round time. Byung, Soon and Jeong (2006) state that in general, there are three kinds of transportation mode for inland transportation from ports: land, rail and water. It is worthwhile to note that transport system organized in such a way that the various modes complement or supplement one another is regarded as an integrated or co-ordinated transport system (Issa, 2000). However, over concentration on road development has led to the neglect of rail development in Nigeria which is the most essential means of mass transit world-wide (NRC Hand Book, 1990).

BRT, Light Rail Mass Transit and GIS: BRT means Bus Rapid Transit. BRT is a transport option, which relies on the use of dedicated 'interference' free segregated lanes to guarantee fast and reliable bus travel. The BRT buses run on physically segregated lanes (Figure 1) and thus make them run faster in a situation where there is traffic congestion. It is one of the several options available for tackling the huge public transport predicaments

of Lagos. The Light Rail Mass Transit scheme is a proposal to introduce a Light Rail Transit System within the existing Nigerian Railway Corporation (NRC) corridor from Iddo in Lagos State to Ijoko in Ogun State. Geographic Information System (GIS) is widely used in different applications. The Environmental Systems Research Institute (ESRI) (2001) defines GIS as an organized collection of hardware, software, geographic data and personnel designed to efficiently capture, store, update manipulate, analyze and display of all forms of geographically referenced information. Certain complex operations are possible with GIS that would otherwise, have been difficult, time consuming and impracticable. Experience has shown that GIS is an effective tool for solving optimization task with spatially distributed linear objects such as railways, roads and pipelines. Thirumalaivasan and Guruswamy (2000) in their work entitled: Optimal route analysis using GIS (1999 – 2000)**,** make use of the Chennai City, the largest City in India as a case study to help establish the fact that GIS and remote sensing play a very important role in the transportation and urban planning applications. A good railroad and bus rapid transit management system must be able to show availability of trains, buses, trip schedules, and trip fare, parking facility, number of lines, infrastructure, and the package details (Akjol, 2007). Bus public transport operation in Lagos is characterized by high levels of fragmentation and indiscipline. Lack of organized public transport system has resulted in the high reliance on the private transport to provide transport services, which have created a chaotic transport system in Lagos State. This research therefore is on Bus Rapid Transit (BRT) and railway transport system in Lagos; the GIS approach. The sole aim is to produce a GIS based transport system in enhancing Bus Rapid Transit and Railroad Transport System of Lagos State. Lagos state is located in south western Nigeria and spans from the Guinea Coast of the Atlantic Ocean for over hundred and eighty kilometres from the Bight of Benin on the west to its boundary with Ogun State in the east. The Lagos metropolitan area spreads over much of Lagos State (3345km^2/1292sq mile), which is located on four principal islands and adjacent parts of the Nigerian mainland.

METHOD

Data Acquisition: In this paper two sets of data were acquired, namely cartographic (map) data and attribute data associated with the cartographic data. The cartographic data used includes: BRT map and proposed railroad network map obtained from Lagos Metropolitan Area Transport Authority, (LAMATA), and the operator of the Lagos state transport services. Lagos land use and street map available on Map Source stand-alone application. Point data (coordinates) of the train terminals and the BRT bus stops were obtained by hand held Garmin 76 GPS, which were marked waypoints and saved in DXF file format to be exported to AutoCAD environment. The attribute data used include: the names of the train/bus stations, statistical data of boarding count by stop gathered from Lagos BRT Evaluation Draft Report maintained by LAMATA and Statistical data of boarding records obtained from the Nigeria Railway Corporation.

Data Conversion: The BRT map and the railroad network map were scanned in bits due to the size of the images. The images were brought into the Autodesk Raster Design 2006 on AutoCAD 2006 environment separately. The images were selected and then they were

merged and geometric corrections were made. The image was then saved separately for georeferencing and digitizing process.

Projected Coordinate System:	*WGS 1984 UTM zone 31*
Projection:	*UTM*
Geographic Coordinate System:	*GCS WGS 1984*
Datum:	*Clark 1880*

The geo-referenced image was vectorized on screen in the computer system. Different layers were created for the various features: point feature and line feature. After the geo-referencing process, an overlaying process was carried out on the image with Lagos land use and street map available on Map Source stand-alone application for the purpose of correct alignment.

System Development: ArcGIS 9.2 software was deployed in designing and implementing this project. Analyst extension was deployed extensively to create: the geodatabase, editing, data management and storage, performing spatial analysis and visualization. The drawing (graphic) in AutoCAD that was saved as DXF file format was exported into ArcGIS 9.2 and separated into single symbols and converted to shape-files of point, line and polygon themes.

Lagos State BRT and Railroad Application: Visual Studios 2006 was used to develop the Lagos State Rail and BRT application that can be used to manage the Rail and BRT systems. This application developed to interact with the feature classes and tables in the geodatabase is a robust data-driven application expected to Add, Update, Manipulate and Query spatial and non-spatial data. The application can also sort and filter request data quickly. It was constructed with windows control such as: Textbox controls, Labels, Command buttons, Group box, List box, Model form and objects such as: Binding Source, Table Adapter and Rail_BRTprojectgeodbaseDataSet.

Numerical Formulation for Estimating the Parameters of BRT and Rail Transportation: The attribute data acquired (Tabes 1 and 2) was used to develop a mathematical model for BRT and Rail transport in Lagos State. The following assumptions were made:

i. Busses or Trains stop at all bus stops or terminals along a route;
ii. Operation time is between 6 am -10 pm for the BRT (16 hours' time window) and Railway transport system is 12 hours time window;
iii. Service is provided all year round;
iv. Boarding time is equal to the combination of loading and unloading time at bus stops or rail terminals;
v. The time taken to move from the start of route to its end is the same to go back to the start point and
vi. A round trip is a to and from journey.

Model Formulation: Important formulated parameters are the number of commuters, buses and trains, number of round trips and the revenue that can be generated. Numerical formulas for estimating the values of the formulated parameters are shown on tables 3 and 4.

RESULTS AND DISCUSSION

Figure 1 shows the dedicated interference free segregated lane of the Bus Rapid Transit. This lane is not plied by any other vehicle including private cars. Figure 2 shows the entire process of the journey model of the study. First, a bus or a train arrives at the bus stop or rail terminal and starts loading. It then moves to the next station to load/offload until it gets to the last station and continues back to make a round trip. Furthermore, all operators work within a time window, which was assumed as the time during which buses, or trains were allowed to run on the routes.

BRT and Railroad Map: This study is the applicability of GIS in enhancing BRT and Railroad transport system. The final product of a GIS is a detailed map and a linked attribute table. Figure 3 shows the BRT and Railroad corridor map.

Spatial Database Query: Figures 4 and 5 are the queries showing all BRT Bus Stops and all Rail Terminals respectively. Figure 6 shows the query that defines all the BRT routes networks.

Route Network Analysis: In every developing area, it is important to have in existence reliable routes for movement in terms of the delivery of goods and the rendering of services so that people can get to their destinations as quick as possible. In this study, three scenarios were tested, the optimum route from mile 12 to mile 2, TBS to Isolo and from Bariga to Ikeja respectively. Figure 7 shows the optimum route from mile 12 to mile 2.

User-Friendly Interface Model Manager: This is an application in Visual Basic, an application that has a familiar appearance to the user. It is a customized event-driven command application developed in this study to alternatively access the feature classes and the tables in the geodatabase. The stand-alone application model manager is expected to show the zones in the BRT corridor, the cost of travelling within/across the zones and the time it takes to travel from one bus stop to another. Figure 8 shows the time it takes in moving from Anthony bus stop to Bariga bus stop. Given boarding delay, traffic delay and environmental delay totally 7 minutes, commuters travelling this route will spend 11 minutes and would have covered a distance of 3.7982km if the bus travels at a speed of 55km/h.

Applying the Derived Mathematical Model to the Two Modes of Transportation

The mathematical model was tested on two scenarios: Route A: Jibowu to Ikeja and Route B: Iganmu to Agege for the two modes of transportation. The result (table 5) shows that at present, BRT has more patronage than the railroad as a mode of transportation system in Lagos metropolis. In addition, given the patronage of the BRT transport system, it generates more revenue than the railroad transport system. Whereas the BRT can bring in revenue of N7,354,057.2 using 525 buses and carrying 105,057.96 commuters within a time window of 16 hours for approximately 3 trips, the rail road system has N729,000 using 2 trains that make approximately 3 trips within a time window of 12 hours and carrying 6,075 commuters.

Figure 1: BRT, Dedicated 'interference' free segregated lane.
Source: Lagos Metropolitan Area Transport Authority (LAMATA 2009).

Table 1: BRT Weekday Boarding Count by Stop

	Count 1-Weds 29th October		Count 2-Thurs 30th October	
	Southbound	Northbound	Southbound	Northbound
Mile 12	19,122		17,411	
Ketu	11,332	3,684	11,265	5,778
Ojota	15,070	1,076	14,660	839
New Garage	373	81	559	54
Maryland	2,385	1,549	2,670	2,161
Idiroko	2,670	1,028	2,984	967
Anthony	2,708	3,216	2,699	2,677
Obanikoro	1,335	2,225	1,688	2,432
Palm Grove	1,867	6,657	1,992	6,872
Onipanu	2,182	10,016	1,869	11,312
Fadeyi	7,506	8,638	7,506	8,130
Moshalasi	3,269		3,474	
Barracks	5,104	7,285	3,092	4,487
Stadium	2,993	4,974	2,992	6,562
Leventis	12,394	9,334		
CMS	2,816	4,937		
TBS	10,578	9,575		
Total/dir	**77,916**	**7,216**	**74,861**	**76,118**
Daily total	**154,133**	**150,980**		

Source: Lagos Metropolitan Area Transport Authority, (LAMATA); Lagos BRT Evaluation/Reporting/Draft Final Report, 1990.

Table 2: BRT Weekend Boarding Count by Stop

	Count 1-Weds 29th October		Count 2-Thurs 30th October	
	Southbound	Northbound	Southbound	Northbound
Mile 12	16,766		14,453	
Ketu	9,864	5,926	8,808	29
Ojota	14,677	483	9,556	360
New Garage	237	46	89	13
Maryland	1,796	1,717	792	825
Idiroko	1,448	693	268	273
Anthony	1,397	2,463	394	400
Obanikoro	610	1,630	139	467
Palm Grove	1,404	7,350	413	3,126
Onipanu	1,410	11,017	625	8,302
Fadeyi	6,076	8,395	2,950	6,229
Moshalasi	1,895		3,269	
Barracks	3,549	8,093	1,319	4,487
Stadium	1,833	4,149	814	1,698
Leventis	7,396	645		
CMS	3,490	1,065		
TBS	6,900	3,602		
Total/dir	**62,961**	**69,748**	**43,888**	**31,521**
Daily total	**132,709**	**75,408**		

Source: Lagos Metropolitan Area Transport Authority, (LAMATA); Lagos BRT Evaluation/Reporting/Draft Final Report, 1990.

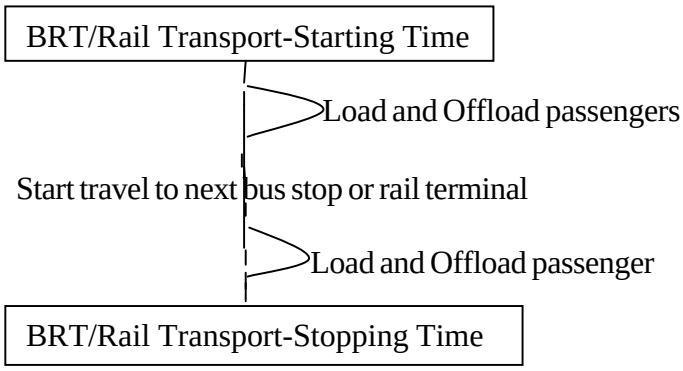

Figure 2: Journey model of study.

Table 3: Constant parameters to estimates the formulated parameters and the values of constant parameters

Notations	Description	Input Values
Fp	Peak factor	1.02 for BRT 1.35 for Rail
Wd	Working hours per day	16 hours for BRT 12 hours for Rail
Cpd	Loading capacity of vehicle	82 for BRT 1000 for Rail
Zc	Route travel cost	N70 for BRT N120 for Rail
T t	Trip time	As generated from route map.

Table 4: Numerical formulas for estimating the values of the formulated parameters

Notations	Description
BPD	Boarding along a route per day $BPD = \bar{x}Fp = \left(\frac{\sum_{i=1}^{n} xi}{n} \right) \left(1 + \frac{\bar{y}\, lowest\ board}{\bar{y}\, highest board} \right)$ 1
TPR	Number of round Trip along a route per day TPR = Wd/2Tt.....2
VPD	Number of Vehicles required along a route per day VPD = BPD/TPR x Cpd.....3
RPD	Revenue generated along a route per day RPD = BPD x Zc.....4

Table 5: Results of the derived mathematical model

Scenario	Transport Mode	BPD	TPR	VPD	RPD	Difference in BPD	Difference in TPR	Difference in RPD
Route A	BRT	78,875.07	3.66	262.81	5,521,254.9	73,475.07	1.08	4,873,254.9
	Rail Road	5,400	4.74	1.14	648,000			
Route B	BRT	105,057.96	2.44	525.08	7,354,057.2	98,982.96	0.42	6,625,057.2
	Rail Road	6,075	2.86	2.12	729,000			

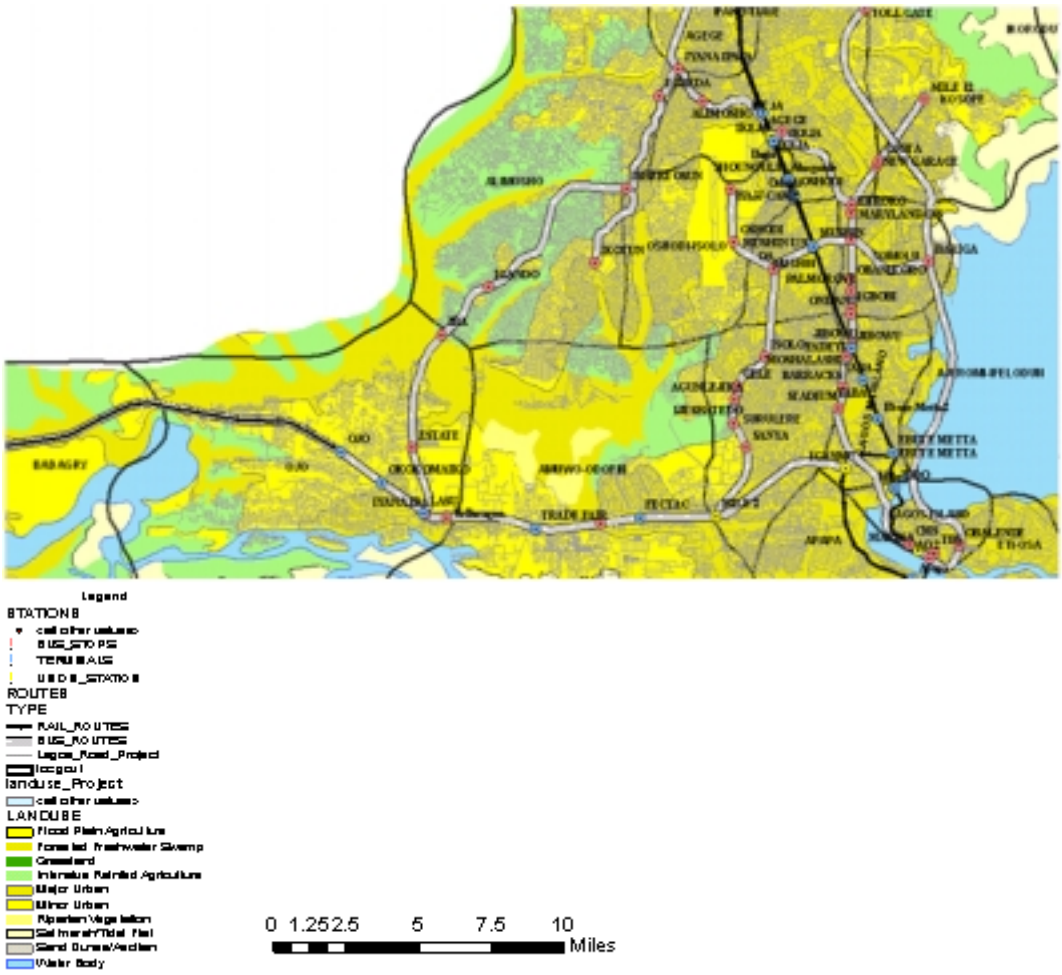

Figure 3: Full extent map of the BRT and Rail Network

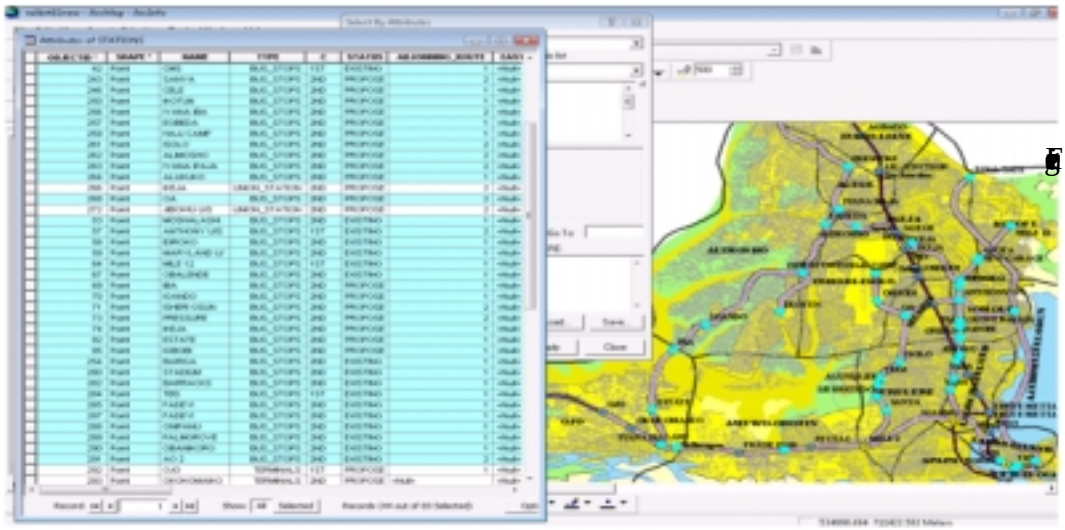

Figure 4: Query showing all BRT Bus Stops (in green)

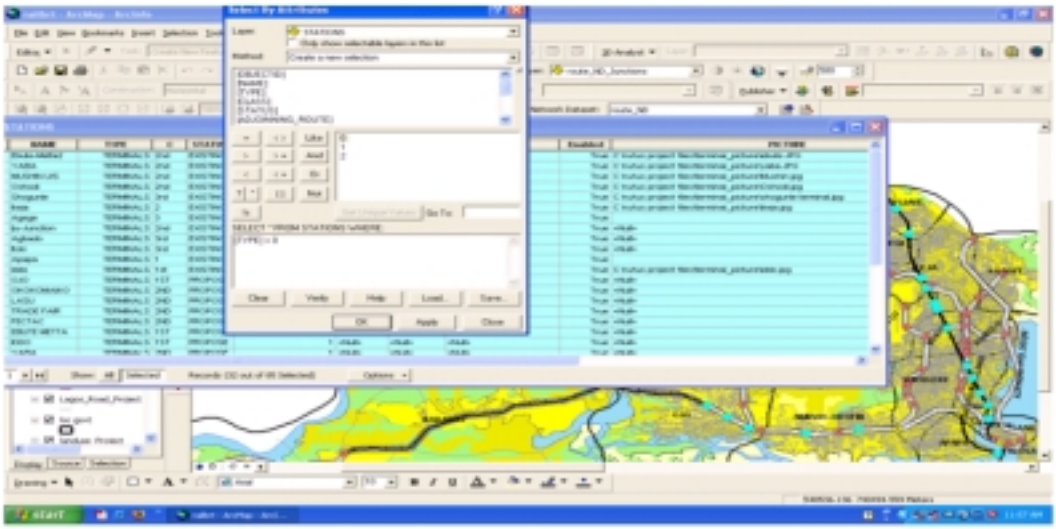

Figure 5: Query showing all Rail Terminals (in green)

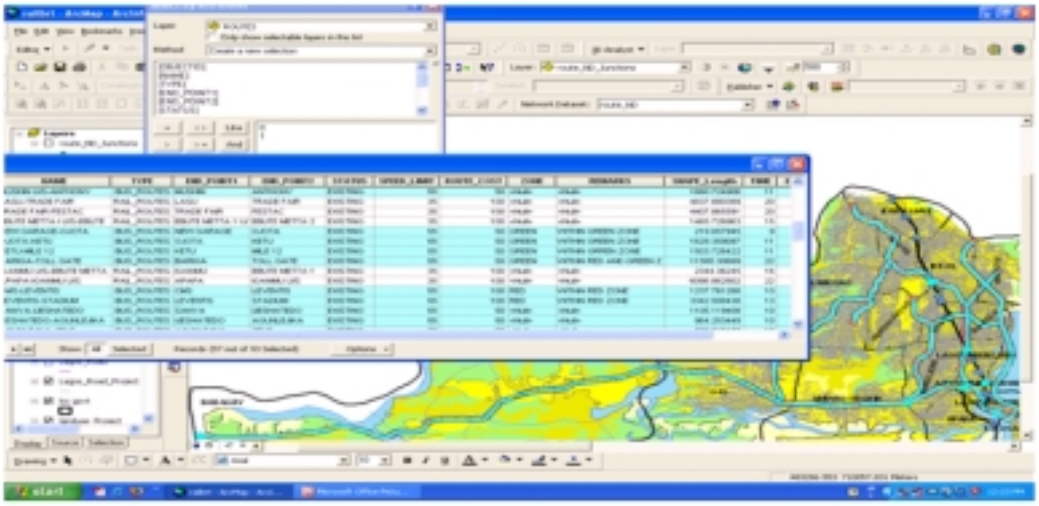

Figure 6: Query showing all Bus routes networks (in green).

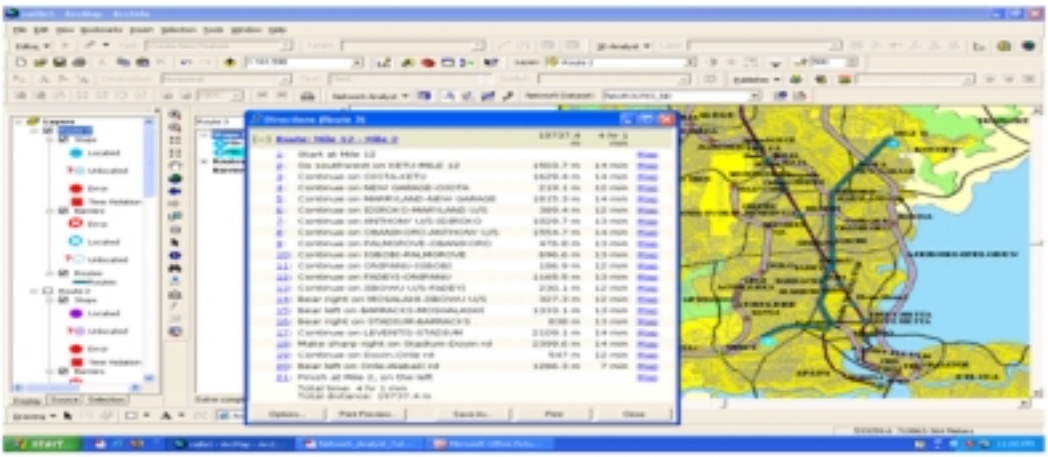

Figure 7: Optimum route from mile 12 to mile 2(In blue)

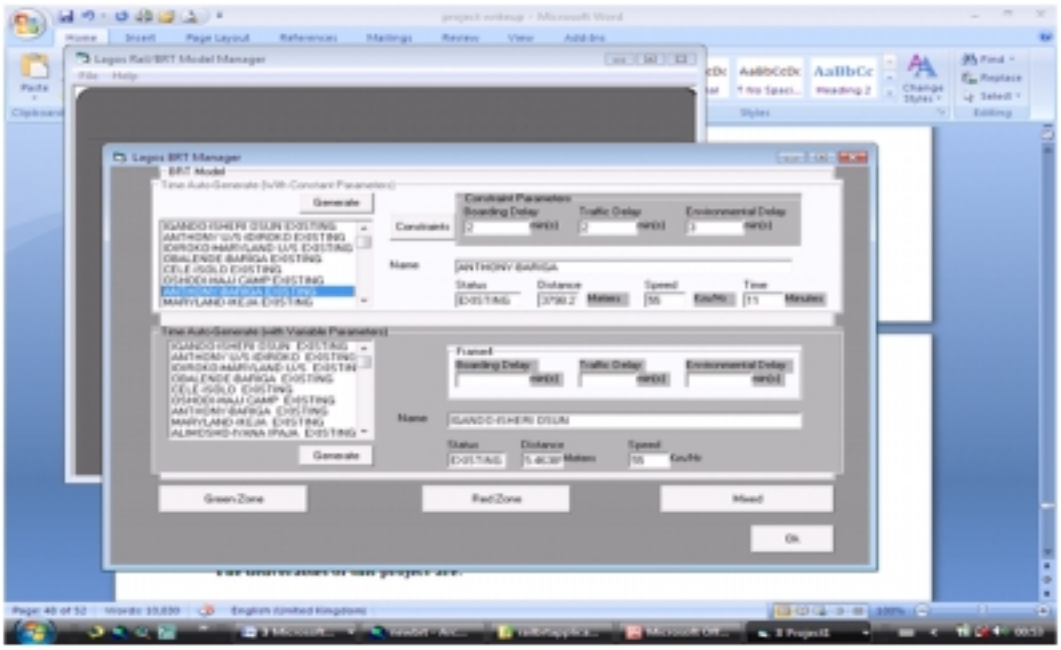

Figure 8: BRT/Rail model form showing BRT route, distance, and time

CONCLUSION AND RECOMMENDATIONS

Any journey by public transport constitutes four basic elements: access time, waiting time at the bus stop, journey time in the bus and access time at the destination. It is therefore expedient that transportation network in urban setting allows for free movement of people, traffic and goods within a short time. GIS is a powerful technology for effective planning and management of transportation network. The mathematical model was developed for estimating the average number of commuters, the number of vehicles for carrying such commuters, the number of trips required by the vehicles as well as the revenue that can be generated for such trips given some constant parameters. The effective and efficient management of the Bus Rapid Transit (BRT) and Railroad transport system in Lagos will depend largely on comprehensive, up-to-date, reliable digital geographical database, which is managed by a computer technology such as GIS. It is recommended that the model is a good base for starting a comprehensive transport data model, which will cover the needs of transport planning and management of the city authorities and for private and public companies, whose activities involve some kind of transportation data. In addition, adequate transportation infrastructure and control mechanisms should be put in place by the government and a law enacted for traffic regulation in Lagos State.

REFERENCES

Abimbola, O. (2004). A study of Bus provision and use in metropolitan Lagos. In University of Lagos. Phd Thesis.

Adefolalu, A. A. (1977). Traffic Congestion the city of Lagos. *Geographic Journal*, 20, 2

Akjol, D. (2007). Mlticriteria decision making and GIS for railroad planning.

Bolade ,A. A. (1994). *The High way risk in Nigeria.* Ibadan: University Press.

Burroughs, P. A . (1986). *Principles of Geographical Information Systems, Principles and Applications.* London: Longman

Byung Kwon Lee, Soon Oh Park and **Jeong Hoon Seo** (2006). A Simulation Study for Designing a Rail Terminal in a container Port. Proceeding of 2006 Winter Simulation Conference.

ESRI White Paper (2001). Organizational Structure for Local Government GIS, A survey: *http:// www.esri.com.*

Issa, M. El-Shair (2000). *GIS and Remote sensing in urban transportation planning.* Department of Geography, Faculty of Arts, Yarmouk University.

Lagos Metropolitan Area Transport Authority, (LAMATA) (2009). In Lagos BRT Evaluation/Reporting/ Draft Final Report.

Nigeria Railway Corporation (NRC) (April, 1990). *Hand Book.* Lagos: Nigeria Railway Corporation

Ogunsanya A. A. (1991). *Accident control and safety measures in mass transit operation in Nigeria.* Ibadan: University Press

Thirumalaivasan, D. and **Guruswamy, V.** (2000). *Optimal route analysis.* Anna: University Press.

White, P, R. (1976). *Planning for Public Transportation.* London: Hutchinson Publications, U.K

Yinkore, W. A. (2005). *Legends of Nigerian Railway Corporation since 1955 - a Chronicle.* Lagos: Promocomms Limited, Ebute.Metta,.