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The Utility of Geographic Information System (GIS) in Transport Data Integration for Economic Development: Evidence from Ibadan, Nigeria

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Abstract - This study sets out to assess the capability of Geographic Information System (GIS) in Transport Data Integration for Economic development in Ibadan, Nigeria. The study entails an analysis of transport data need and an assessment of their relevance in economic planning. This need is set against the background of large body of data involved in transportation planning and management. The Methodology entails some processes such as data integration, data standardization and spatial referencing and interfacing. The study shows the importance of referencing of socio-economic data and location referencing in economic planning to assist in economic development. Arc GIS programme is employed for integrating data such as demand data i.e. demographic data, land use data, economic data and travel, supply data such as road networks and related facilities.

Keywords : *transport data integration, GIS, economic development.*

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The Utility of Geographic Information System (GIS) in Transport Data Integration for Economic Development: Evidence from Ibadan, Nigeria

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Abstract - This study sets out to assess the capability of Geographic Information System (GIS) in Transport Data Integration for Economic development in Ibadan, Nigeria. The study entails an analysis of transport data need and an assessment of their relevance in economic planning. This need is set against the background of large body of data involved in transportation planning and management. The Methodology entails some processes such as data integration, data standardization and spatial referencing and interfacing. The study shows the importance of referencing of socio-economic data and location referencing in economic planning to assist in economic development. ArcGIS programme is employed for integrating data such as demand data i.e. demographic data, land use data, economic data and travel, supply data such as road networks and related facilities. The significance of GIS/ Transport Data Integration in economic development is demonstrated at micro level in Ibadan using a case study approach.

The study reveals the utility of GIS in Transport Data Integration as an effective technique of data exchange for economic development, and also, as a robust system for linking data from different sources for strategic decision support for economic development.

Keywords : transport data integration, GIS, economic development.

I. Introduction

The ever increasingly urbanized world has created various problems of environment, climate, consumption of resources, and public health, which are closely linked to the side-effects of urbanization such as sprawl, congestion,housing affordability and loss of open space. These problems need to be addressed at various levels of spatial planning and decision making. For instance, in urbanization management, special and specific consideration should be given to the relationships between land use, transportation, and the environment. Fundamental to the urban problems are two separate yet related issues: urban structure and urban dynamics. Both issues can be seen fromphysical and socio-economic perspectives (Jiang and Yao, 2010). There is need to harmonize activity sector for economic development, and in most cases there are always conflicting interest.Services are major activity sector which has transport as one of its components in which transport component of the services comprises of road transport, rail transport and transport, air transport and other transport services (CBN, 2009). And transport component contributes significantly to the GDPs of Nigeria's economy; therefore it is important to give it the required effort.

There has also been a very close relationship between transport and economic theory. Some of the most important theoretical concepts that form the basis of analysis and evaluation have come from economic theory, such as the theory of consumer travel behaviour, the supply curve, equilibrium and welfare measures (Meyer & Miller, 1984). Also supply and demand relationship for urban transportation can be related to price determination technique in the demand-supply theory in economics (Okoko, 2006). In analyzing travel behaviour, utility functions make use of several economic variables, including transport services by various modes, monetary out-of-pocket costs on trip, and income (Huang, 2003). All these go a long way in determining the daily activities of individuals in any nation and thereby enhance or negate economic development.

Computer and information technologies have dramatically improved the capabilities of transport forecast and evaluation models. Transport software packages are available forvarious scales of application, ranging from strategic trend forecasts to detailed traffic assignment. Simulation models, particularly micro-simulation models, are applicable with the availability of advanced computing methods such as object-oriented programming and parallel processing (Algerset al, 1998). New data capture techniques such as Global Positioning Systems (GPS) provide a revolutionary means of data collection for transport planning and operations management. Data for transport planning are best managed by and retrieved from database management systems. More advanced techniques for data manipulation are available, including data warehousing, data mining and knowledge discovery. However, as data come from a variety of sources and in

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varying data formats,this presents a tremendous challenge in terms of linking and integrating transport data (Huang, 2003).

In the aspect of data integration, GIS provides a platform for many types of information which include maps, tabular data, pictures, multimedia, air photos and satellite images. Geographic

Location provides the frame of reference: "space as an indexing system" (Decrg, 2007).

The aim of this study is to highlight the importance of spatial data tools and technologies for integrating and visualizing transportation data, with effort to demonstrate the utility at the micro level, using Ibadan as a case in point.

II. Economic Planning and Data Need

Diverse forms of information are required in economic planning. This section therefore looks into economic planning and Data need so as to see the importance of their integration in economic development.

a) *Economic Planning*

Planning is one of the basic principles of administration and about the most critical of it functions since it permeates all other aspects that are involved management ladder. Economic planning therefore becomes a necessary tool used by many governments and organizations to set their visions, missions, goals, and effective means of realizing development through effective direction and control(Ikeanyibe, 2009).

It is important to note that the planning system affects investment through provision of certainty of land use and infrastructure improvements.Economic dividends accrue when both public and private individuals apply the present resources and are sure of the future use of their own and surrounding land would be committed to investment.Productivity is enhanced by well-planned infrastructure, for instance by reducing journey times with increasing labour mobility, and by creating virile environments habitable for living and working.Innovations in economic planning can also bring about competition (Kefela, 2010).With the increasingly competitive and knowledge-driven global economy, data is required by the planning system. Planning system is a key lever the decision maker has to contribute towards improving productivity, and the country's long-term economic performance (DCLG, 2007).

Economic planning policies are expected to be in-depth in flexibility in order to respond to the economic challenges and opportunities that globalization and technological advances bring. To be able to actualize this task, exchange of accurate data is paramount. And most of these processes require real time data exchange; this includes responding to and harnessing opportunities from increased competition from businesses across the globe involving high-growth economies.There is need for economic forecast as it relates to transport system because it is a major contributor to the GDP of the economy; it allows communities to take full advantage of the economic opportunities available to them, sustaining and creating employment and prosperity (DCLG, 2007; CBN, 2009).

In respect to data need for economic development, it covers a wide range of development which include all traffic generating activities related development such as retail, leisure and offices, industries;housing;telecommunications and transport uses related to ports, airports and other inter-modal freight terminals.The core idea in most of the thinking was that economic development was based on accumulating and adding physical capital, capital being the binding constraint (Wallace, 2001).

b) *Data Need*

In order to attain excellence in economy, the economic operations must be run effectively and efficiently. This requires the ability to analyze operational performance, and various categories of data are needed. Accurate data is required to determine the impact and performance of economic decisions.There is need to be certain that appropriate actions are taken to build upon transport operation successes, initiate any corrective measures, and effectively plan for the future. For the economy to thrive, or perhaps even survive, operation and analysis must work together and reinforce each other; and up-to-date data is required for analysis (Business Objects, 2004).

There is need to identify the data sets needed for planning. Depending on the specific context, transport data needs may be assessed on the project basis, the business basis or the system basis. The purpose, content and extent of data needs are different for these three bases. For the purpose of economic planning and development, it could be all encompassing (Huang 2003).

Pisarski (1997) highlighted six data issues that border on data need; these include socio-economic data, financial data, supply and system characteristics data, demand and use data, system operations data, and impact and performance data. Jack Faucett Associates (1997) also put forward a data organization framework that incorporates the data components of supply, demand, system performance and system impacts.

III. Transport Data Integration

Data integration is a process of assimilating data from different sources and formats.Metadata, or data about the data, is poor or non-existing in many data sources. The lack of metadata regarding data

collection methods, data semantics, and basic data description greatly complicates the data integration process (Figliozzi and Tufte, 2009).Data integration allows for the consolidation of the current data contained in many operational or production systems and combine it with historical values. The creation of a data warehouse (or, on a more limited scale, a single-subject data mart) facilitates access to this data. Collecting and consolidating the data needed to populate a data warehouse or data mart and periodically augmenting its content with new values while retaining the old is a practical application of data integration (Business Objects, 2004).

The need for transport data integration can be justified from several perspectives. In general, transport planning and management consumes a large amount of data. These datahave to be integrated in a way that satisfies the needs of transport planning, modeling, evaluation and policy making(Huang 2003).The need to integrate and coordinate freight data collection efforts is widely accepted and recognized. Transport data is available from many public and private sources. However, the data may significantly vary in terms of collection method, time frame, format, and quality. The lack of coordination not only prevents the seamless integration of data sources but also limits the scope and quality of transportation studies (Figliozzi and Tufte, 2009).

IV. Significance of Gis/Transport Data Integration in Economic Development

This section discusses the categories of data and benefits of data integration in economic development.

a) Demand Data in Transport

Transport demand data are majorly demographic data, land use data, socio-economic data and travel demand data.

In Nigeria, demographic data are most commonly available from government statistical agencies through national population commission. Census data otherwise known as population data remain an invaluable source for demographic research. They are important variables in transport planning models i.e. economic base concept which requires data on the population. The service or non-service sector depends on the growth of the population of the local area (Okoko, 2006).

Different land use types are found in urban centres and pattern of a town is interrelated with the physical characteristics of its transportation network; and each type of land use is unique and has its own specific propensity to generate trips. There is correlation between the size or population of a land use type and its ability to generate traffic. Equally relationship exists between the attractiveness of a zone and the amount of traffic attracted to that zone (Okoko, 2006). Land use development is an effective indication of urban growth.Data on land value, land tax, land quality and land use policy are prerequisite for decision making in transport (Pisarski, 1997).

Economic data is vital, the expenditures of households and public enterprises on transport is an economic indicator, so it is a reliable component of forecast. In predicting trip generation, data on socio-economic characteristics of commuters must be established. In Nigeria, transport makes its own contribution to the economy, although the contribution is higher in developed countries. In Nigeria, transport sector contributed ₦3, 730.4 Million (5.5%) in 1985, ₦5438.8 Million (2.0%)in 1990, ₦50, 314.9 Million (2.6%) in 1995, ₦129, 092.0 Million (2.8%) in 2000, ₦385, 481.6 Million (2.7%) in 2005, and ₦506, 720.8 Million (2.1%)in 2009 to the GDP (current basic prices) of the nation's economy (CBN, 2009). In United State, it is up to 20 percent of total expenditure was spent all modes of transport in 1994 (USDOT& BTS, 1997). Therefore, household's expenditure including transport enterprises are strong economic indicator; and they are useful variables in economic planning and development.

There are other socio-economic factors such as household income, car ownership, age, sex, family size, coste.t.c that induced and influence various transport modes, and types of employment are all among the explanatory variables (Black, 1981, Okoko, 2006). These data play significant roles in economic planning.

Also, data on travel is another essential demand data; the statistic of passenger travel is required for travel demand modelling and represents a major effort in transport demand analysis. There are three principal elements that must be taken into account in demand modeling. These are people, their activities, and the space context within which the activities take place.It must put into consideration the interactions of these elements in terms of perception of space, travel mode and constraints on movement (Huang, 2003).Since, they are activities taking place in space with such great interactions; their data are required for economic planning.

Information on trip includes the following items, place of origin and destination (zone-based), purpose of trip i.e. office trip, touring, shopping, school e.t.c., car, bus, rail are element of trip mode. Others are vehicle type, number of persons cum size of load in vehicle, time of day (peak or non-peak), and trip duration (Hutchinson, 1974, Okoko, 1999). Comprehensive data for all these are required for proper economic planning and development and their integration is inevitable to achieve the feat.

b) Supply Data in Transport

The components of urban infrastructure include road networks and related facilities and they are fundamental to mobility. In urban transport planning, the layout and capacity of these transport facilities are the elements of the physical aspect of transport planning (Huang 2003).

In road network representation, the level of detail required is a function of the scale of transport analysis. The traditional transport planning utilizes all sorts of symbolized link node structure such as roads, intersections and zone centroids for accessibility analysis, shortest routes and trip assignment. The number of available bus stops, traffic signals, bus stations, train stations. The pedestrian facilities with adequate safety amenities are all part of supply data in transport. Others are data of road length, design capacity and speed, pavement and direction of flow. Supply data entails infrastructural data, the infrastructure must be adequately and properly maintained to give leverage and aid economic activities. There must be periodic assessment of these infrastructures, its adequacy and performance in respect to economic development.

c) Performance Data and Determinant factor

The real performance over time is shown by the operations of urban transport infrastructure and these data and metadata are required for the evaluation of system performance or for prediction of future trends. Pisarski (1997) highlighted the variables detected or monitored for the regression analysis or trend analysis to forecast traffic volume of a road network in the near future as follow:

- *Travelling speed, rate of flow, density and volume on various links*
- *Types of vehicles travelled through monitoring sites*
- *Incidents such as level of congestion and accidents*
- *Operating restrictions, e.g. vehicle speed, height and weight limits*
- *Tolls and other facility-specific charges*
- *Functional class of highway segment*
- *Frequently updated condition measures for bridges, arterial and street systems,and other facilities*
- *Inventory of materials used in construction and maintenance*
- *Information on agency or company responsible for maintenance and operation ofthe facilities so that data on supply and cost can be related.*

These data are germane to system evaluation or performance calculations, which serve as indices for the measurement of the effectiveness and operational efficiency of a transport system. The ease of travel, the quality of service provision based on adopting this methodology, would accomplish the principles of good access which are Safety,Affordability, Accessibility and Reliability in public transport (Olowosegun and Okoko, 2012).This would determine the operational performance the system, these are crucial factors in provision and sustaining acceptable levels of mobility, and level of mobility determines a lot in economic activities and economic viability.

V. Micro Level Demonstration of Transport Data Integration Using Ibadan, Nigeria

Transport data integration in geo-information systems starts with the proper representation and standardisation of these data. The tools for data representation include relational data models, feature-based models, object-oriented models and temporal data models which the analogy can be shown with cartographic model (Olowosegun, 2010).

a) Methodology

The process involves data standardizing, spatial referencing, data integration and interfacing. This micro level demonstration relies on the data from National Population Commission, GPS data, accident data, traffic data from past work of this research authors.

i. *Demand Data*

This study relies on population data of 5 L.G.A. in Ibadan, socio-economic data of sampled population in Ibadan, car ownership are backend data otherwise known as attribute data.

ii. *Supply Data*

The supply data for this analysis includes the roads in selected L.G.A in Ibadan with their length, 72 bus stops coordinates (X, Y, and Z) obtained with GPS.

iii. *Performance Data*

This includes accident data in Ibadan, traffic volume in Agodi-Gate Ibadan and best route for public in Ibadan North L.G.A.

b) Integration of Supply, Demand and Performance Data in Ibadan

Figure 1a below is the visual output of demographic data of five L.G.As of Ibadan metropolis with transport routes. The backend data which is the attribute data include the population data, sex , the length of the roads, the street names e.t.c. The attribute data can be queried, it can be analyzed i.e spatial analysis, economic decisions such as location of facilities can be facilitated. Figure 1b shows the visual output without the road network but showing the graphs of accident data in Ibadan. It can help in determining the area with high prevalence of accidents and suitable locations for accident response centres and even location of orthopedic hospitals can be done when analyzed at broader level i.e accident trend in Nigeria.
Integration of all category of data is also shown in Figure 2, Ibadan North L.G.A is extracted from figure 1 in order

to show clearer visual output. Showing the route analysis and 72 bus stops in Ibadan North taken with GPS. Analysis shows that there are four (4) very good bus stops (5.56%), thirty five (35) good bus stops (48.61%) and thirty three (33) bad bus stops (48.83%) in Ibadan North L.G.A. (Olowosegun and Okoko, 2012).

The map of Agodi-Gate (Figure 3) is extracted from figure 2 and it shows the traffic volume in PCU at four locations for a particular day. It shows the level of traffic in the area and decisions on traffic congestion and other traffice vices can be improved.

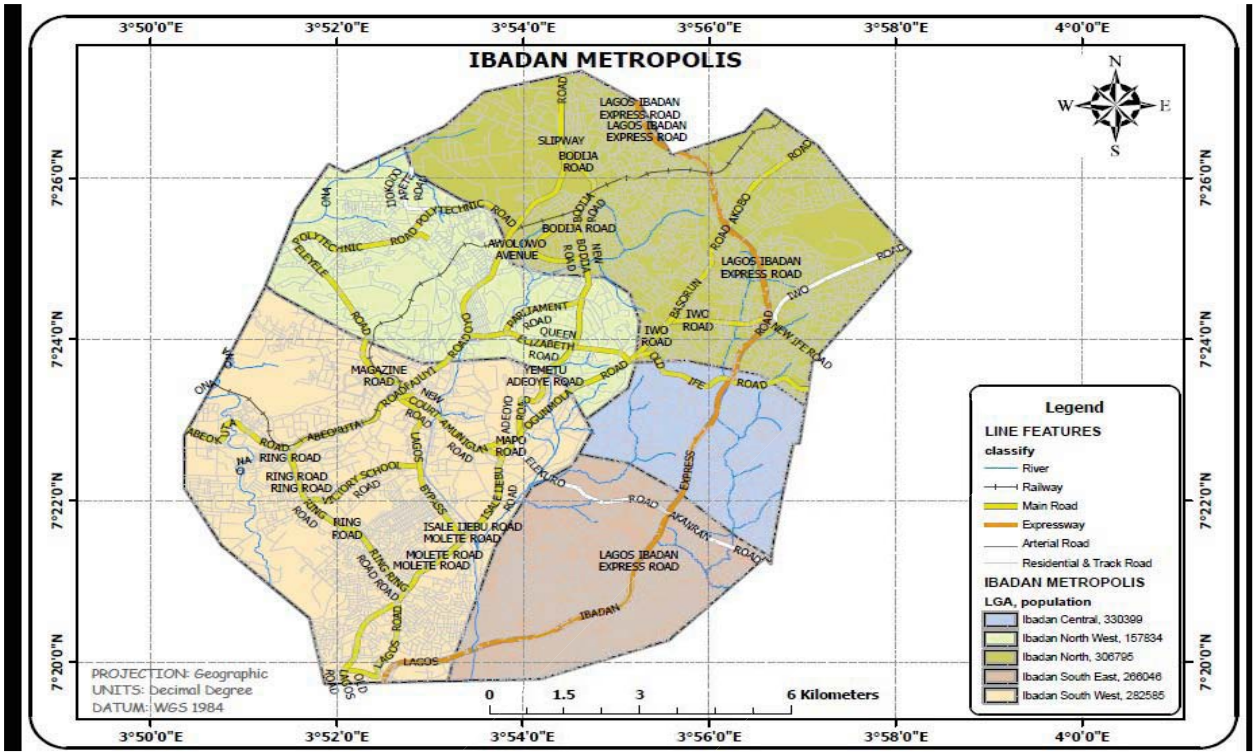

Figure 1a : Integrated Map of Ibadan Metropolis.

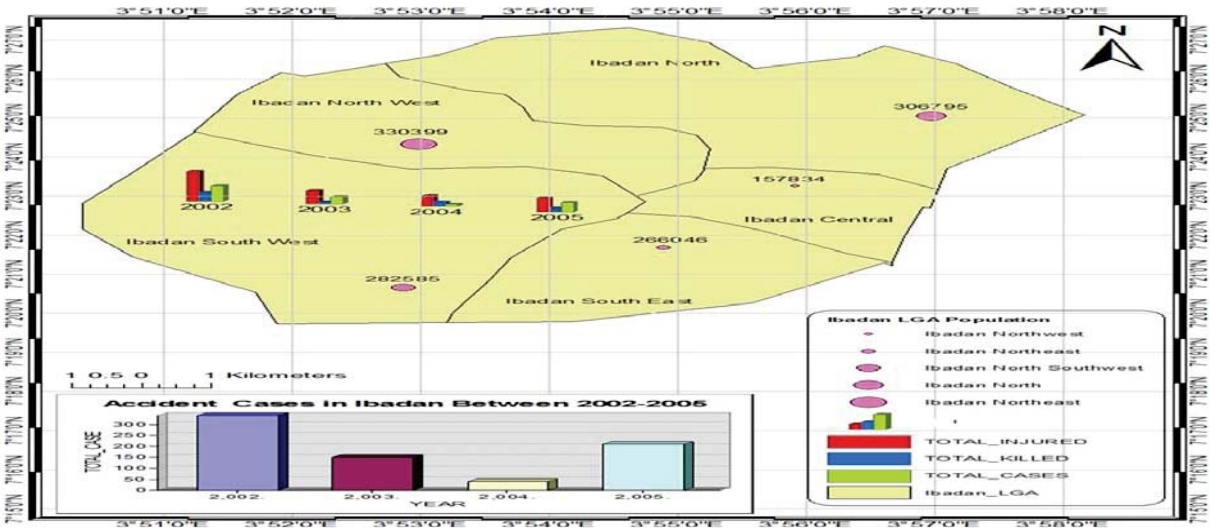

Figure 1b : Integrated Map of Ibadan Metropolis without Road Network.

Source: GPS Map prepared and integrated with other data by the authors

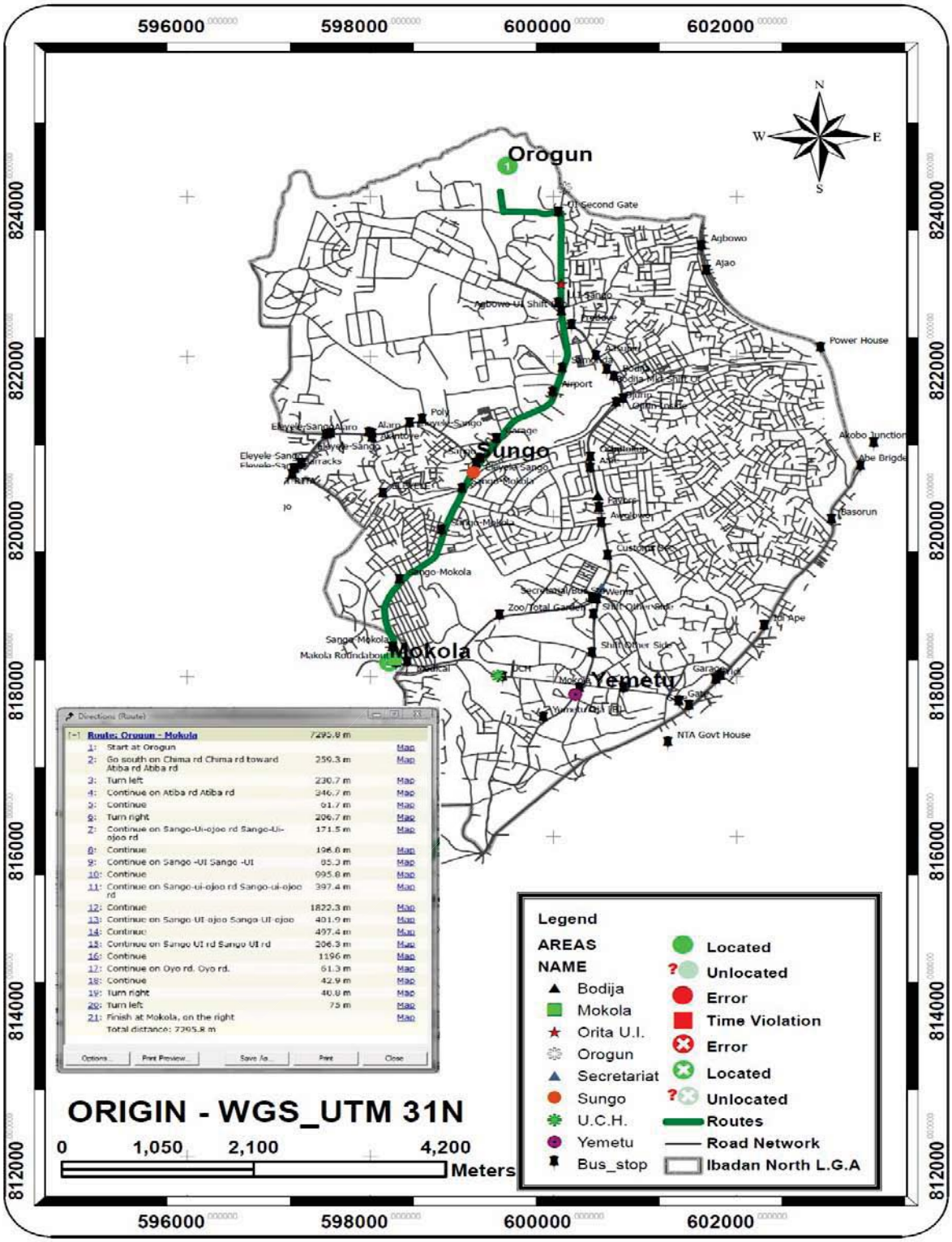

Figure 2 : Integrated Map of Ibadan North L.G.A.

Source: Prepared by the Authors

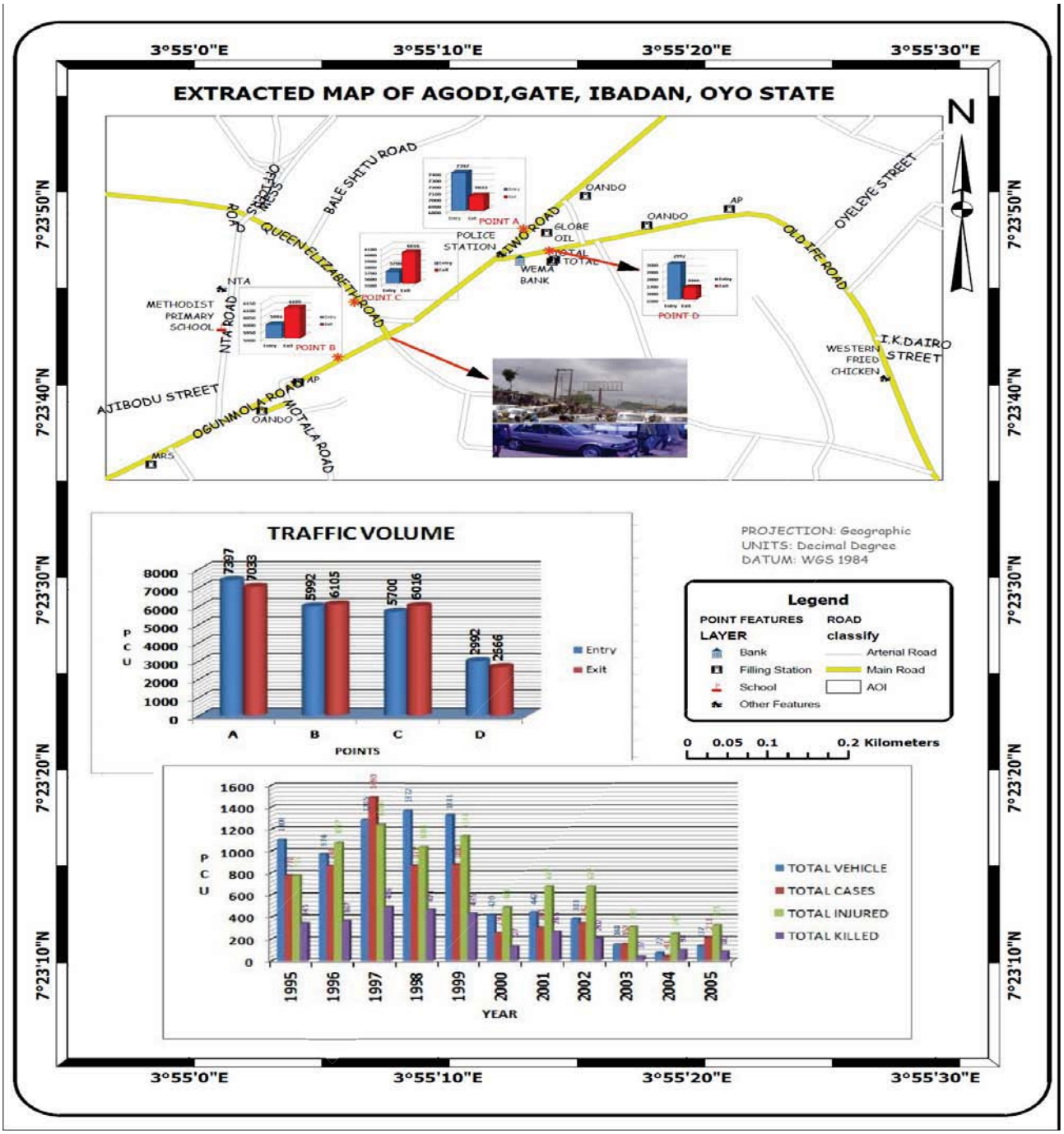

Figure 3 : Extracted Map of Agodi Gate Ibadan from Integrated Map of Ibadan North L.G.A.

Source: Prepared by the Authors

VI. Benefits of Transport Data Integration in Economic Development

The flexibility in combining data sets is meticulous;this creates enormous simplicity in estimation and generates new indicators on performance transport system as it relates to economic development. One of the indisputable strength of GIS is the capability to eliminate some forms of respondent error.This is useful in compilation of historical data and predictive data; the entire process helps in economic planning thereby enhancing the reliability, dependability and efficacy of the process. This enhances the various determinants and indices required in economic development to reliably develop in a systematic way to reduce error to the minimum threshold. Another significant benefit of transport data integration in GIS environment is the ability to facilitate scenario analysis e.g figure 2, network analysis.This can be exemplified in

the placement of new infrastructures and its consequences i.e. the effect of new bus stop placement. This comes with visualization and therefore presents additional insights and new hypotheses that pen-ultimately foster economic development.

The whole process allows for querying and asking very specific questions at various levels of economic development.It creates links to rich travel behavioural pattern and other socio-economic information including the household level information. It allows for metadata intensive compilation with overwhelming details and this is a pointer for firm decision making in economic planning and development. The overall analysis using standard techniques is robust being a viable tool in application of GIS to transport which is pivotal to economic development.

VII. Recommendation and Conclusion

a) Recommendation

The conventional method of data gathering, processing and analysis is overwhelmed with great limitations and weaknesses. There are potent lessons in transport data integration that require expedient consideration to enhance economic development. This study recommends that an articulate method of data integration in transport should be adopted in order to eliminate some weaknesses found in traditional methods such as lack of spatial statistical analysis, respondent error cum documentation, poor metadata and geographical information.This will help in taking full advantage of technology by rethinking data integration methodologies for transport planning process and economic development and equally improve data quality and the visualization performance indices.

This study equally recommends that the facilities scenario analysis should always be carried out e.g figure 2 and 3 i.e. new bus stop placement and trip generating activities as to have the predictive insight to the consequences of such development; this will help in firm decision and subsequently showing economic activities performance index. Metadata is an important ingredient in achieving optimal result therefore the study recommends that the socio-economic data should be linked with their spatial reference and must include the metadata as much as possible (the attribute data in Figures 1a, 1b, 2, 3) i.e. traffic count, the number of vehicle counted is the data while the metadata are GPS coordinates (X, Y and Z) and the metadata of the method of collection of the traffic count which may include a picture of the location with the installation, model of device used and the research team (figure3).The process allows for links to be created between different data sources.

It is important to develop transport performance data indices that take into account data mapping, transferability and if possible that real time with optimal communication system.Since most transportation data possess strong spatial component, the performance of its contribution to the economic development can be measured reflecting strong spatial component.This allows for specific questions to be asked i.e querying of the attribute data; the backend of the map which is the frontend.Therefore, it is recommended that in economic planning in Nigeria, the role of spatial analyst must be guaranteed as to articulately incorporate all these qualities.

b) Conclusion

This study tapped from the robustness of GIS package and explicitly demostrate the utility of GIS in Data Integration especially as it relate to transportation. The significance of Transport data integration in economic planning and development is highlighted by revealing its benefits. Equally, the imminent failure of large body of data management involved in transport planning must be guarded against, therefore, it is necessary to fashion out a national database to take care of ravaging situation in the area of lack of unified data giving room for fashion of data in the country .i.e. annual accident figures and even the map of Nigeria.

The study has identified and equally demonstrated the spatial analysis capability of GIS technology for integrating all forms of spatially referenced data to give reflection and impacts of the activities in the environment; therefore it is a pointer to an articulated decision making in transport management and other aspects of economic development. The detail and complex data required in transport planning tools is managed better in GIS environment. Therefore, it is not out of place for Nigeria to adopt fully the strong power of integration and spatial analysis tools in GIS to foster its economic development in the area of data gathering, processing, manipulation and analysis. This is because all the vital economic decision must be based on strong economic, socio-political argument which can only come from the volume of data (information) available which must not be bereft of accuracy.

Finally, inculcating the principle and dynamics of data integration would posit out-rightly a sound foundation for virile decision making because of its capability that is reflected in performance indices and impact analysis. Therefore, it is a unique tool available for decision makers for economic development.

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