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An Assessment of Road Network Quality in Jos City, Nigeria: Using Geographic Information System (GIS)

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Abstract- Given the significance of spatial data in planning, management and utilization of a road network in any society, the current study provides empirical spatial data on the road network of Jos city Centre, examine its quality, create a spatial and attribute database and analyzes its bearing on traffic flow situation. On-field data acquisition through measurement, observation and counting were used to collect information on the road network quality variables, Geographic Information Systems (GIS) technique was used to digitize and in combination with the road network quality attributes used to produce a spatial and attribute database for the road network of the study area. The data were analyzed in Arc GIS 10.3 software environment. This provides an avenue for spatial querying of the various attributes of the streets. The result of the finding reveal that 3.91% of the road network are in good condition, 19.55% are fairly good, 51.40% are at an average condition, 23.44% are below average and 1.68% are under repairs. These have shown that the quality of roads in the study area can be termed to be at an average, this is fair, but not good enough to facilitate an excellent accessibility to the various socio economic activities within and around Jos City Centre and its environs.

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I. Introduction

Transportation represents one of the most important human activities worldwide. It is an indispensable component of the economy and plays a major role in spatial relations between locations. Transportation creates valuable links between regions and economic activities, between people and the rest of the world. Transport according to Rodrigue (2013) is a multidimensional activity whose importance is historical, social, political, economic and environmental. In the field of geography, a network is generally defined as "a set of geographic locations interconnected in a system by a number of routes" (Campbell, 2001). A transport network is defined as a number of links connecting the nodes all having their own characteristics (Steenbrink, 1974).

Transportation, if well planned contributes greatly to the economic development of a place, the standard of living, the level of economic growth as well as the standard of productivity of the people. These are no doubt determined by the efficiency of movement in the given area. This movement is facilitated by the availability of a good transport network (Hoyle, 1973). Interactions among and between people is promoted by the facilities involved in the movement of people, materials, goods and services. For interaction to really take place between cities there must be accessibility which has become a major area of concern for transportation geographer (Rodrigue, 2013). Transportation is a requirement for every nation, regardless of its industrial capacity, population size or technological development. Moving of goods and people from one place to another is critical to maintaining strong economic and political ties between regions in the same state; roads came into being to facilitate the movement of wheeled vehicles which in turn, fostered the development of regions (Obafemi. *et al.* 2011). This research defines road quality as the general condition of the total road length and its facilities.

One of the most special tools for solving spatial problem is the Geographic Information System (GIS), its capability in spatial planning and management has been widely acknowledged. GIS is a robust suite of technical software designed to accept, analyze, store and presents geo-database. Presently, the GIS technology is gradually but steadily marking inroads into transportation planning, development and management. It is becoming quite fashionable to use GIS to heuristically study transportation issues such as those relating to traffic congestion, optimum location of transportation facilities, network analysis, transport system modeling, analysis of transport-induce environmental problems, and so on (Uluocha, 2007).

The effective implementation of any project lies on proper planning and design of the spatial database which forms the heart of GIS. The process of designing such database is referred to as data modeling. It is the process in which real world entities and their inter-relationships are analyzed and modeled in sucha way that maximum benefits are derived while utilizing a maximum amount of data (Kufoniyi, 1998). It has been noted that improper design often leads to implementation problems and low cost recovery. Database Models are being used to describe the subset

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of an entity at different levels of abstraction. The architecture of a database can be classified into: Conceptual Data Model, and Logical Data Model Architecture. The conceptual, understanding the nature and structure of data at the user level independently of how the data is processed. The logical, transforming of the conceptual view into one or a combination of the following logical model: Relational Modeling, Object Relational and object oriented. This study however adopts the relational database modeling architecture.

The relational database architecture represents combination of related data values. These values can be interpreted as facts describing a real world entity or relationship, with the table name and column names used in interpreting the meaning of the values in each row of the table (Chang, 2010; Fazal, 2008 and Nyerge 1988).

An efficient road network promotes a high level of socio-economic activity and industrial production in any urban area. Inadequate supply of raw materials to industries as well as inadequate supply of industrial products to the markets may emerge as a result of inefficient or poor road network. Road transportation is the heart of the concept of accessibility in a region, and serves as a medium by which demand and supply, where they do not coincide in space are linked.

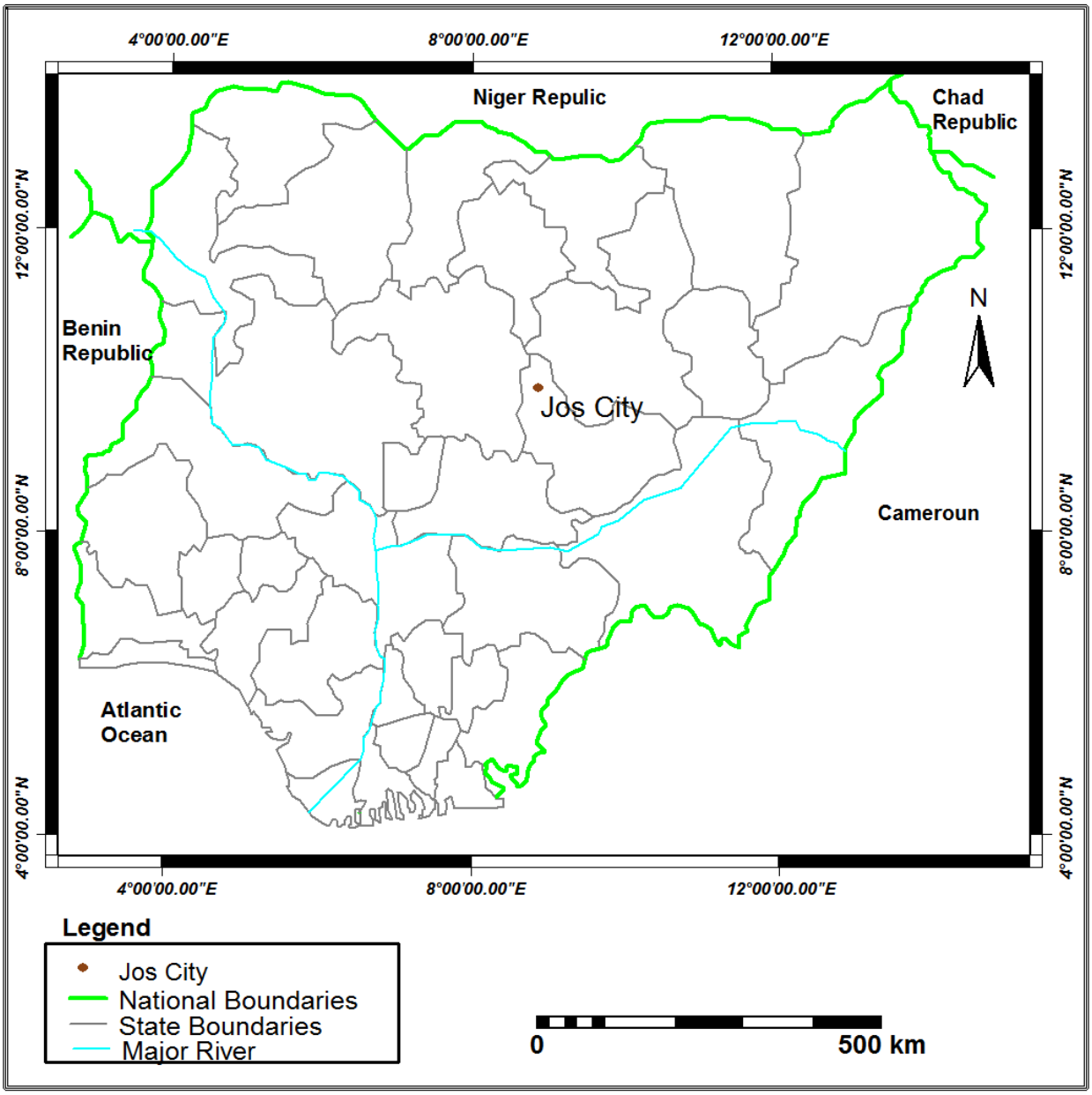
It therefore becomes imperative for a study on road network quality to be carried out in Jos city so as to examine the road network situation with reference to the conditions of road surfaces, the road type, width and thickness of the tarred, number of street light, pot holes, paint lines, drainage type, side walkway width and condition, availability of parking space, and the width of the road covered by traders as well as traffic problem. To this end therefore, this study examines the quality of the road network, create a spatial and attribute database and analyzes its bearing on traffic flow situation.

a) Study Area

Jos City (figure 1) is the capital of Plateau State Nigeria, Jos is located almost in the geographical center of Nigeria; it is about 1,000 Km north east of Lagos, 400 Km south of Kano, 900 Km north of Port-Harcourt, 600 km south west of Maiduguri, 1000 km south-east of Sokoto and 300 km away from Abuja. The state occupies an approximate total land area of about 39,934 square kilometers. The coordinates of the study area, "Jos Central" are given between latitude 9° 53"N and latitude 9° 56"N of the equatorial plane and longitude 8° 54"E and longitude 8° 52"E of the Greenwich Meridian, and have an elevation which rise between 1,276 M and 1,160 M above mean sea level. It is located at the northern point of the plateau, which bears its name at an elevation of about 1,200 M above mean sea level. As a town it is the most asymmetrically placed state capital in the whole of Nigeria, located at the extreme northern end of the State. Except on its northern part, the town is almost surrounded by hills. To the east are Dogon Dutse and Shere Hills which rise to over 1,400 M and 1,777 M respectively, on the west side are the Jentar Hills which also rise to over 1,280M above mean sea level. To the south are many other small and large inselbergs and rock out crops. In the north the topography is worsened by many un-reclaimed old mining paddocks (Morgan, 1979).

The city of Jos is synonymous with mining and commerce; it is mainly a colonial creation and one of the earliest and busiest cosmopolitan centers in Nigeria. Most inhabitants of this bustling city are immigrants attracted by the numerous commercial prospects available there in. Jos is indeed an attractive place to live in because of the unique physical features, favorable climate, variety and scenic beauty and pleasurable social atmosphere.

Jos city being the administrative capital, and the commercial nerve Centre of plateau state, is the most densely populated area in the state. According to the 2006 Nigerian census result, the city has a population of 836,910 people, and with a present projected population of about 1.1 million people. The city normally witnesses great influx of people from within and outside the state, for various socio economic activities, such as education, health services, and tourism and administrative purposes. Jos city will continue to attract and absorb more people and diverse forms of human activities from the already overloaded city center.



Source : National Centre for Remote Sensing Jos, Nigeria.

Figure 1 : Map of Nigeria Showing Jos City

II. Methodology

Needed information were obtained through direct field survey of the study area, the exercise of measurements and observation of the road quality attributes (in terms of width of the road, nature and numbers of pot holes, drainage system types, nature of edges of the entire road network, the width of the road covered by traders, availability of parking space, paint lines, thickness of tarred and number of street lights,) was carried out for each street. A structured observation chart was design and used as a guide in the field, to assemble data on each road and nodes in the field.

Information on road width, width of road covered by traders, and width of sidewalk ways were obtained through direct field measurements and recordings, all measurement was made in meters. Measurements were taken at 3 main points of the road (at the beginning, middle and end nodes of each street), an averaged was taken to ascertain the road width, while the road length was obtained from the digitized map of the study area. On the other hand, information on the nature of the surface of the road, drainage type and the nature of the edges of the road were obtained through observation. Observations on road surface condition, considering the incidences and frequencies

of pot holes on roads. Information on the number of street lights and number of painted lines was through counting in the field.

a) Data Processing

i. *Basic Procedure/Operations*

The following operations were carried out in this research;

- Geo-reference Quick-bird satellite image of the study area "captured in 2013" and the greater Jos road network map were acquired.
- The Quick-bird satellite image was imported in to the Arc GIS 10.3 software, in which the desire portion of the image was subset using the clip (extract) operation function of the software.
- Since the image has already been geo-referenced, polyline shape file was created for the digitization of the roads (streets). In the digitization, all routes were digitized as an arc. The digitization was done in such a way that a street was digitized from the beginning to the end without stopping before starting another street (so each street has its own unique identity number), this was to have an easy and efficient way of measuring the length and integrating the network map (spatial database) with the attribute database.
- The greater Jos Street map was used to abstract the names of the Street, which was used in naming the digitized streets in the attribute table of the database.
- The road network quality data obtained from the field completion, was used in building the attribute table, for the formation of the database of the network, by using the Add-field function of the attribute table, to create a column for each of the street attribute quality, in which the various quality attribute were input into the table.
- From the road network map produce and link with the quality attribute data (database of the network), both spatial and attribute data queering of each street and each attribute can now be carried out.

The create report tool, of the attribute table in Arc GIS 10.3 environment was used in analyzing the results of the findings.

III. Results and Discussion

The quality measure of a road network is one of the important measures of road network development. In assessing road quality in Jos City the study considers its attributes as regards the road width, road type, road lane, length, thickness of road tarred, pedestrian work way, drainage type, street lights, painted lines, width of the road covered by traders and the general surface condition of the roads.

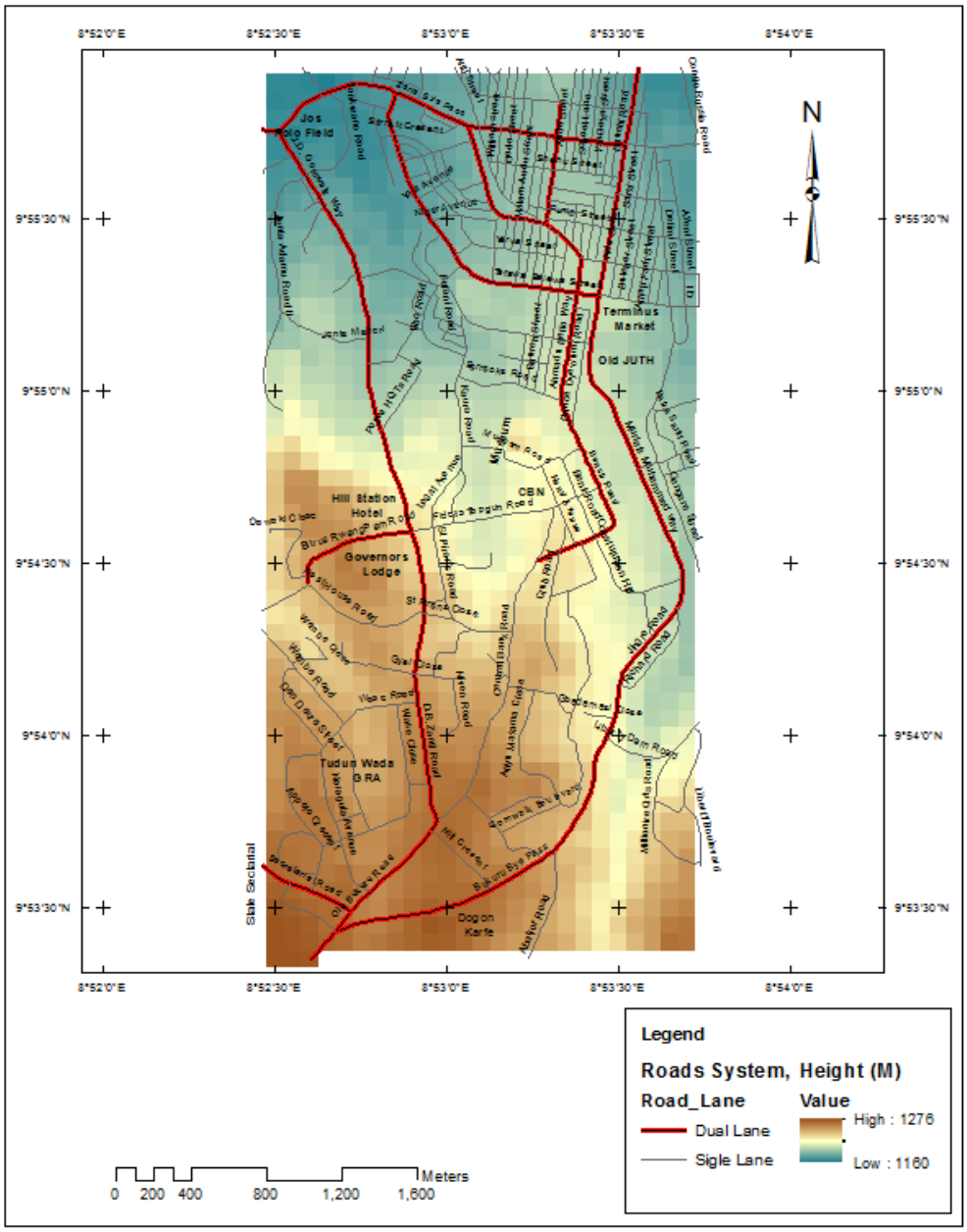
The road type is an important index of assessing the network quality; this is because it helps examine the various functions each street or road way performs. The study categorizes the roads into 3 classes of expressway, major arterial and collector roads, an attribute query of the network database in table 1 reveals that Jos City Centre has 8.38% streets as expressways, 48.6% of the streets as major arterial and 43.02% of the street as collector's road. The value of the streets as expressway is low and that of the arterial roads is not sufficient for a city Centre, which is a state capital and the commercial nerve Centre of a state. This can be associated with the various circulation (accessibility) delays experienced on the road network of the study area, thus the need for the construction and upgrading of roads as expressway and arterial roads, so as to improve the speed of accessibility into the various goods and services provided by the city.

Table 1 : Roads Types Distribution

S/N	Road Type	Frequency	Percentage
1,	Expressway	15	8.38%
2,	Major Arterial	87	48.60%
3,	Collector	77	43.02%
	Total	179	100%

Source: Author's Fieldwork (2013)

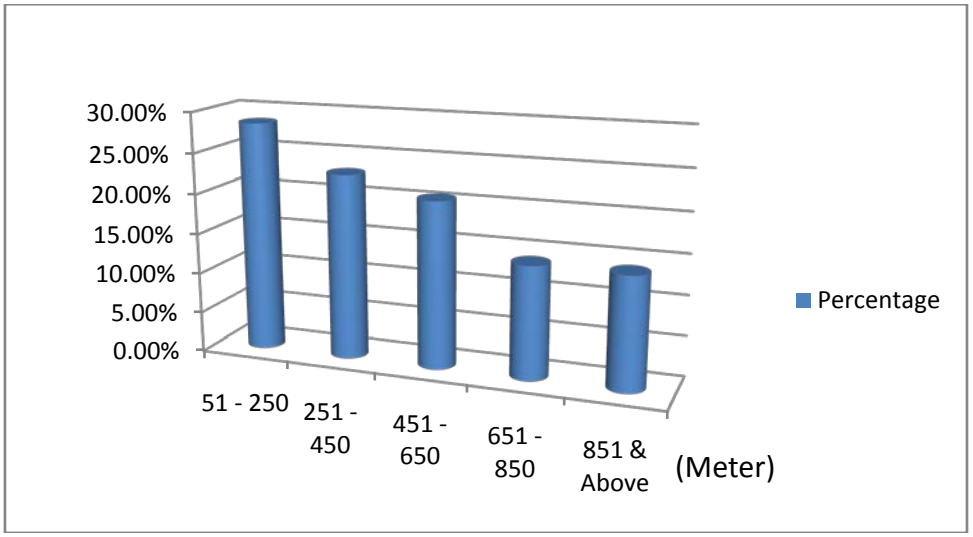
The lane of the road is an important attribute index of assessing the road quality, this is because it aids in coordinating the flow of traffic on the road. The study area is an urban area and a city Centre with the status of a state capital, commercial Centre with a population of over one million inhabitants. The need for multiple lanes of roads is imperative, the study reveals that the study area has 10.06% of dual lane roads and 89.94% of single lane roads, the percentage of dual lane roads is low for a city Centre such as Jos city circulation of goods and services hence, the need for network development in terms of upgrading some of the single lane routes to dual lane, so as to enhance the level of accessibility into the city services. Figure 2, shows a spatial analysis of the dual and single lane routes from the database of the road network, in the study area.



Source; GIS Analysis (2013)

Figure 2 : Spatial Analysis, of Dual and Single Lane Routes in the Study area

The length of the roads is an important index in assessing the quality and level of connectivity of the road network. An attribute analysis of the road network database reveals that the study area has a total sum of 93,407.09 meters of road length, with an average length of 521.83 meters, a standard deviation of 398.80 meters, with 2293.04 meters being the longest street length and 51.58 meters being the shortest street length. The lengths of the roads in this study are categorized into the following classes; 51 – 250 meters are termed short length roads, 251 - 450 meters are termed fairly short lengths, 451 - 650 meters are termed average length roads, 651 - 850 meters are termed fairly long length and 851 & above are termed long length. From figure 3, it can be seen that the study area is dominated by short length and fairly short length roads. 28.48% of the streets are short, 22.91% are fairly short, 20.67% have an average length, and 13.97% have fairly long length and also13.97% of the streets have long length. This is important because it would aid planners, policy makers and individuals in making decision in terms of network development, e.g. which street should be reconstructed? What is the length of the street, what will be the cost implication? Can the street be transformed? And so aid in planning for an excellent accessibility on the road network.



Source : Fieldwork and Analysis (2013)

Figure 3 : Variations in Street lengths

The width of a road is also one of the most important attributes used in assessing the quality of a street, how wide or narrow the road width is, helps in assessing its accessibility. An attribute analysis of the road network database reveals that, the study area has an average width of 7.04 meter, with a standard deviation of 1.51 meter, and 13.8 meter as its widest width and 4.1 meter as its narrowest width. Table 2 analysis of the roads width attribute reveals that 3.91% of the roads have narrow width, 21.78% have a fairly narrow width, 41.34% have an average width, 25.14% have wide width and 7.82% have a very wide width. The width of the road, if not adequate for an area will affect the level of flow of goods and services, this also aids when making decisions about network development, e.g. should the width of the road be expanded or the number of lanes be increased?

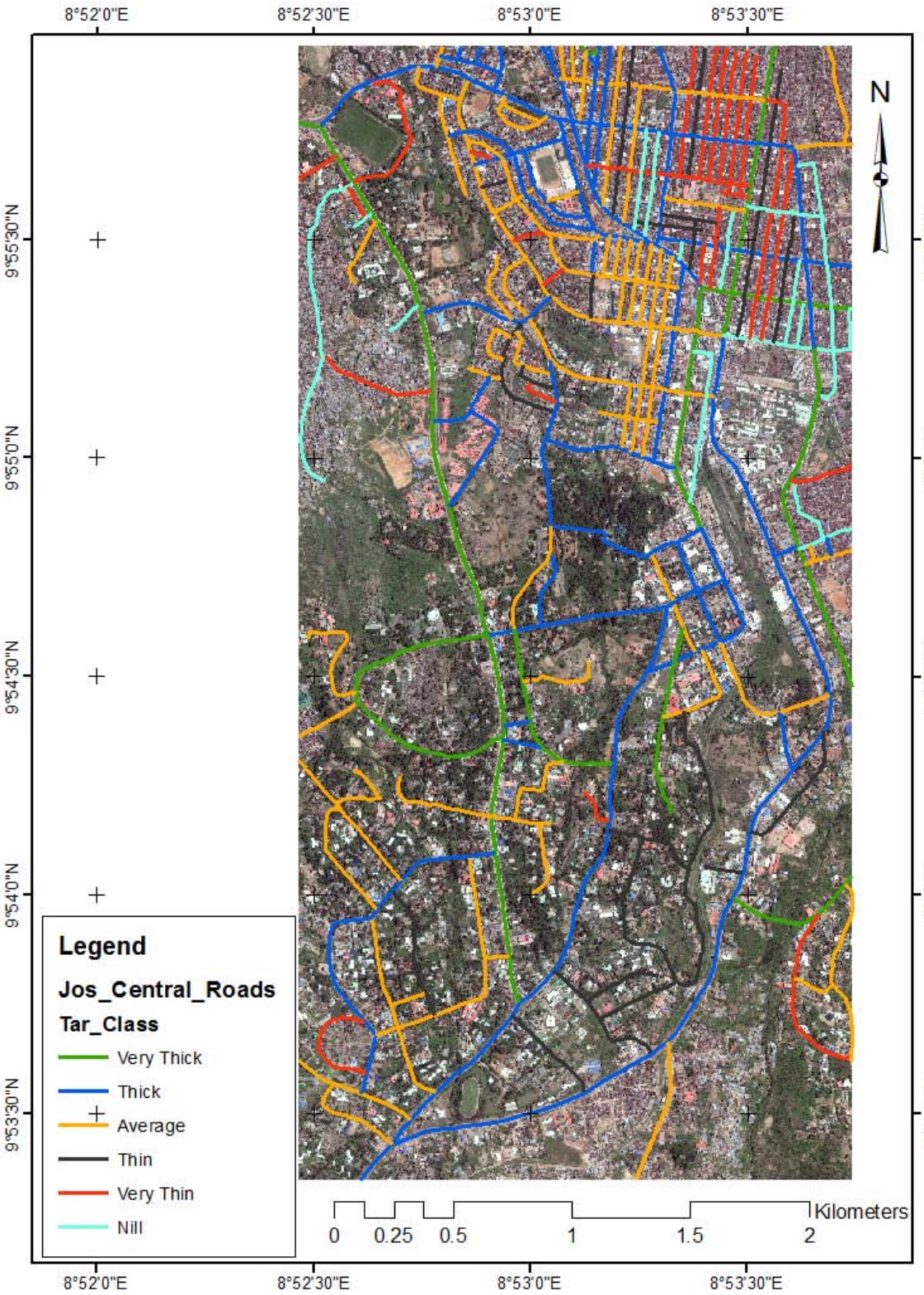
Table 2 : Road width Categories

S/N	Road Width (M)	Frequency	Percentage
1	3 – 4.4	7	3.91%
2	4.5 – 5.9	39	21.79%
3	6 – 7.4	74	41.34%
4	7.5 – 8.9	45	25.14%
5	9 & above	14	7.82%
	Total	179	100%

Source: Fieldwork (2013)

The qualities of the roads were also assessed by its physical condition as it relates to the thickness of tar. A spatial and attribute data analysis of the road network thickness of tar from the study database reveals that 8.94% of the streets have no tar, 12.85% of the Streets have tar of between 0.5 – 1.4 cm thicknesses which were tagged very thin tar, 13.97% have tar of between 1.5 – 2.4 cm and tagged thin tar, 31.28% have 2.5 – 3.4 cm which were tagged averagely thick tar, 25.70% have 3.5 – 4.4 cm thickness and tagged thick tar and 7.26% have tar of thicknesses 4.5 cm and above which were tagged very thick tar, a spatial distribution of the thickness tar, from the study area database is presented in figure 4. It was observed from the study that streets with very thin and thin tar have more frequent potholes; this implies that those streets get easily deteriorated, does affect the free flow of goods and services.

The quality of the road network was also assessed using the pedestrian facilities and their condition; this is a function of the side walkway width and its condition. An attribute data analysis of the roads pedestrian facility condition from the database shows that 3.91% are in good condition, 15.64% are in fair conditions and 17.88% are in a deteriorating condition while 62.57% of the roads do not have any existing pedestrian facilities? This implies that most of the roads in Jos City are in need of pedestrian facilities and streets with deteriorated pedestrian facilities need to be repaired, so as to improve the level of circulation on those roads.



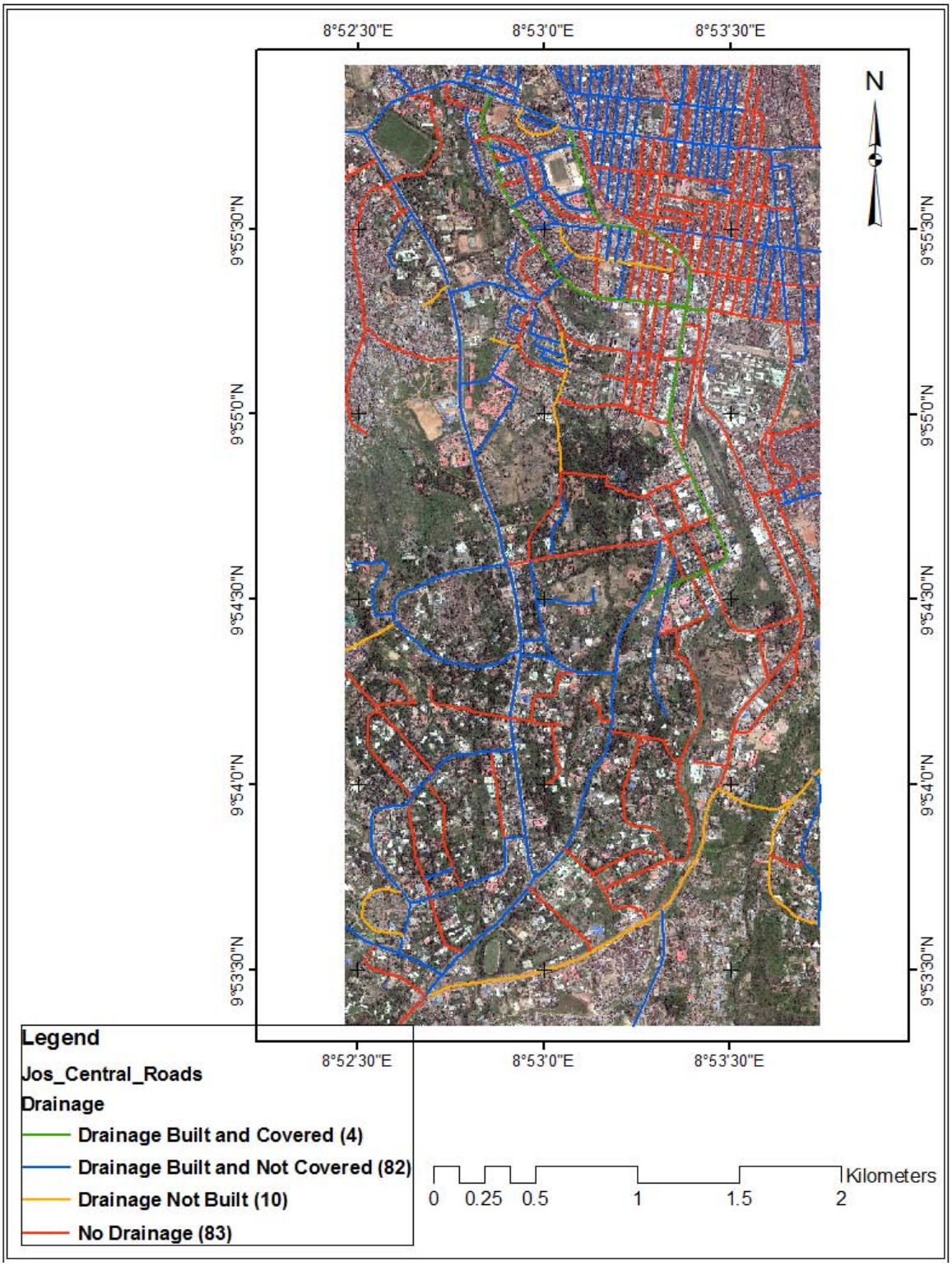
Source: Author's Fieldwork and GIS Analysis (2013)

Figure 4 : Spatial Distribution of Tar Thickness

Drainage types are important index of road network quality assessment, as thus helps in defining the flow of water on a street; this is because most roads not well drained seem to be swampy on a rainy day, such affects the ease of accessibility on such roads, it is also of negative effect to the tar of the roads in the area, as it causes the tar to deteriorate easily, which results in frequent potholes, thus, affects the free flow of goods

and services. The study reveals that 2.74% of the streets have drainages built and covered, 45.25% have drainages built but not covered, 5.64% have drainages that have not been built and 46.37% have no drainages, figure 5 shows the spatial distribution of the drainage types in the study area. The spatial analysis shows that only the northern part of the city has drainages built and covered, while the other drainage types are distributed all over the study area. These implies that there is the need for the construction of drainages in streets without drainages and those not constructed, so as to aid control the movement of water, which will prevent flooding and protect the road tar from easy deteriorating, this will give room for free movement of goods and services within the road network of the city.

The study was able to identify the streets that have street lights and how many street lights are there in a street. An attribute data analysis of the street light, from the study database reveals a total of 987 street lights in the study area, distributed over 22 streets, this also shows that only 12% of the roads have street lights and 88% don't have street lights, and of the streets having street lights none seem to be properly functional as at the time of this study. The study also reveals that only Ahmadu Bello way have a defined parking space which is not adequate, hence, vehicles are mostly parked by the road shoulder in which part of the vehicles block part of the road, which results in some form of traffic holdups and affects the free flow of goods and services, and is of a negative influence to the socio economic development of Jos City.



Source: Author's Fieldwork and GIS Analysis (2013)

Figure 5 : Spatial Distribution of Drainage Types

The width of the road covered by traders is also an important attribute used in assessing the quality of accessibility in a street, this is because traders seems to block through traffic on a street, as their activities on the road seems to hinder the free flow of traffic on the roads, hence slows accessibility to the various goods and services in the city. An attribute analysis of the width of the road covered by traders from the database of the study in table 3 reveals that 19.55% of the streets have traders blocking the free flow of traffic on the roads and

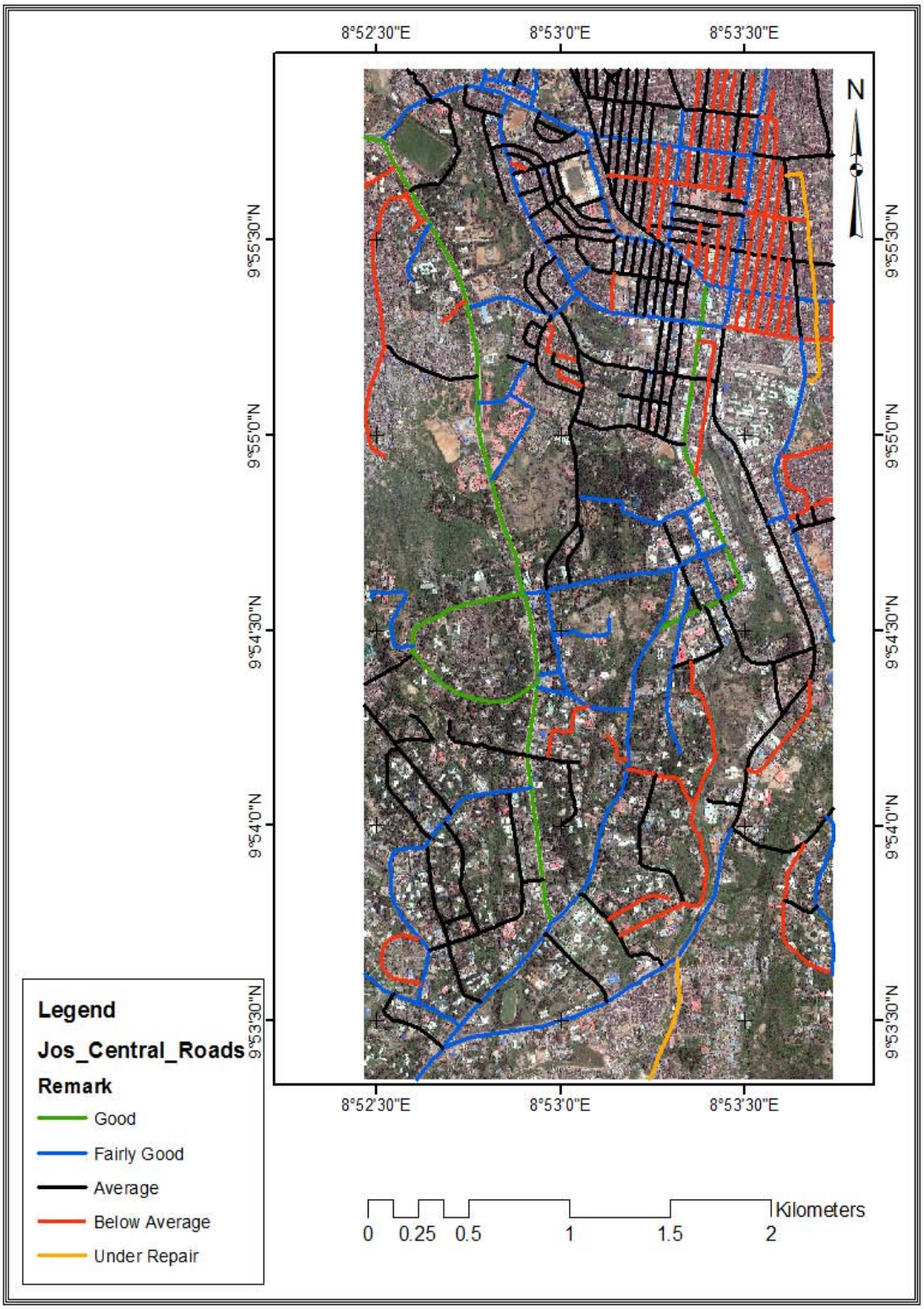
80.45% of the streets have no traders blocking the road. The study also reveals that the flow of traffic on streets like Prince Oyewumi Road and market road seems to be impossible due to the activities of traders on those streets. Thus, there is no doubt that the activity of traders is affecting the easy of accessibility within the road network.

Table 3 : Percentage of Streets with Traders covering part of the Road

S/N	Street Traders Availability	Frequency	Percentage
1	Streets with Traders	35	19.55%
2	Streets Without Traders	144	80.45%
		179	100%

Source: Fieldwork (2013)

The general surface condition of the roads is a function of the number of potholes on a road and how rough or smooth the surface of the road is, it is an important attribute of the road quality, connectivity and accessibility. The surface condition of the roads is categorized into the following classes; very smooth surface with no potholes are termed good, very smooth surface with less potholes are termed fairly good, smooth surface with less potholes are termed averaged, un-tarred and rough surface condition with frequent potholes area termed below average and streets under reconstruction are termed under repair. A spatial and attribute data analysis of the database reveals that 3.91% of the roads have good surface condition, 19.55% have fairly good surface condition, 51.40% surface condition is said to be at an average, and 23.46% have surface condition below average and 1.68% were under repair, the spatial analysis of the roads as shown in figure 6 reveals that most of the roads whose surface condition is below average and average are in the northern part of the city with just few in the southern part of the city, the remaining classes are fairly well distributed in the city. These have shown that the quality of the roads can be termed to be at an average, which is not good enough for an efficient circulation of goods and services within a city Centre.



Source: Author's Fieldwork and GIS Analysis (2013)

Figure 6 : Spatial Distribution of the Road Network General Surface Condition

IV. Conclusion and Recommendation

Planning being an act of preparation for future action, availability of background information, such as this, constitutes a major preliminary exercise in the planning process, for the development of the road network of Jos City. It is also pertinent to note that one essential pre-requisite of any planning exercise is a clear understanding of the existing conditions in a given area, the enviable capacity of GIS to solve spatial problems

as it relates to road network planning and database management have been utilized in this study. The quality of the roads in Jos City Centre can be termed to be at an average. A general assessment of the roads shows that the dual carriage ways are considered the best in the town since they have smooth surfaces, less or no pot holes with good pedestrian's facilities, street lights and wide width for easy flow of traffic. These implies that the quality of roads in the study area is affecting the speed of accessibility to the various goods and services provided by the city, most especially on the major arterial and collector's routes. Thus to improve the level of accessibility, there is the need for the provision of adequate transport facilities around the study area, through the upgrading of the existing facilities e.g. Street lights, Paint lines, Car parks, Bus stops etc.; this will instill some form of orderliness on the various road users who flock these roads. Furthermore, it is obvious that pedestrian's lanes around the City Centre have not been clearly demarcated, thus, there is the need for the provision and clear demarcation of pedestrian lanes.

References Références Referencias

1. Campbell, J. (2001). *Map Use and Analysis*. McGraw Hills Publishers, United State of America, Forth edition.
2. Chang, K.T. (2010): *Introduction to Geographic Information System.* McGraw-Hill Publishers, United States, International Edition.
3. Fazal, S. (2008): *Geographic Information System Basics*. New Age International Publishers, New Delhi, Bangalore.
4. Hoyle, B.S. (1973). *Transportation and Development*, London: Macmillan Publishers.
5. Kufoniyi, O. (1998), Basic concept of Geographical Information System and Database Design and creation in Ezeigbo C. U. (Ed) Principle and Application of GIS, Panat press, Lagos, Nigeria.
6. Morgan, W.T.W. (1979). *The Jos Plateau; a Survey of Environment and land use*. University of Durham, Department of Geography, Occasional Publication (New series) No 14, Durham England.
7. *Nyerges, T.L., (1988). "Schema Integration Analysis for the Development of GIS Databases," International Journal of Geographical Information Systems.*
8. Obafemi A. A. Eludoyin, S. O. and Opara, D. R. (2011).Road Network Assessment in Trans-Amadi, Port Harcourt in Nigeria Using GIS. *International Journal for Traffic and Transport Engineering, 2011, 1(4): 257 – 264.*
9. Rodrigue, J.P. and Ducruet, D. (2013): *The Geography of Transport System*, Third Edition, Hofstra University, New York.
10. Steenbrink, P.A. (1974). *Optimization of Transport Network*. John wiley and sons Ltd. London, UK.
11. Uluocha, O.N. (2007). *Elements of Geographic Information Systems*. Sam Iroanusi publications, Lagos, Nigeria.