

## **A GIS-Based Model for Road Maintenance in Nigeria: A Case Study of Ikeja Road Network, Lagos, Nigeria**

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**Abstract:** Road damages and deterioration, its related consequences on the economy of this nation call for a novel technology with full potential and capacity that can effectively handle spatially referenced data. This study explored the potentials of Geographic Information System (GIS) in data capture, processing and analysis to produce a GIS-based Road Maintenance Model using Ikeja Road Network in Lagos, Nigeria as a case study. The methods adopted in this study include data acquisition, data conversion, attribute database creation, spatial database query and ground truthing. The study utilized the following assessment parameters – Road State Index (RSI), Visual Assessment (VA), Road Condition Surveys (RCS), and Detailed Visual Inspection (DVI). Using the rating criteria and threshold of road state, the spatial query analysis, in GIS application software of ArcGIS 10, indicate a number of good, fair, failed and bad roads, with various defects calling for minor and major repairs. The developed GIS-based Road Maintenance Model (RMM) is unique and utilizes a centralized road network database. The model is therefore recommended to the Nigerian Federal Road Maintenance Agency (FERMA) and State's own Road Maintenance Agencies, if we are to achieve proper performance and preservation of road integrity and serviceability.

**Keywords:** Geographic information system; Database; Road networks; Maintenance Model.

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### **I. Introduction**

Road transportation is the dominant mode of motorized transportation in Africa, accounting for 80 percent of the goods traffic and 90 percent passenger traffic on the continent (Ajani, 2001). Road network is the heart of any country's development and the major factor for its successful planning towards the achievement of sustainable development. Due to its large coverage and ability to provide door to door services, road transportation is most patronized among other modes of transportation especially in developing nations like Nigeria. Road constructions in Nigeria received a major boost in the 1970's during the 'oil boom' era and has since then become a major component of annual capital budgets at both the states and national levels. With the corresponding increase in traffic volumes on our road characterized by varying composition and axle loads, road deterioration and failure are experienced. The road networks in Nigeria have been plagued by a number of problems such as faulty designs, inadequate drainage system, potholes, washed away pavements, fallen bridges etc. these have made it difficult, expensive and more arduous to move products and services from producers to consumers, farm produce from rural to urban centers, which often lead to loss of man-hours and high cost of goods and services. The annual loss due to bad roads is valued at 80 billion naira, while additional vehicle operating cost resulting from bad roads is valued at 53.8 billion, bringing the total loss per annum to 133.8 billion (Federal Ministry of Works & Housing, 2003). This figure does not take into account the man-hour losses in traffic due to bad roads and other emotional and physical trauma people go through plying the roads and the consequent loss in productivity.

There is no doubt that road networks in the Lagos Metropolis with Ikeja inclusive have increased tremendously in last two decades. However, there is much to be done particularly in road maintenance. Currently, rehabilitation and maintenance of roads and bridges across Lagos state are being carried out under the supervision of both the Federal Road Maintenance Agency (FERMA) and State's road maintenance agencies.

In practical terms, the management of existing road networks in Nigeria poses great challenges to FERMA and various states' road maintenance agencies, in view of the ever-increasing rate of road damages and the dwindling resources (Ogwuche et al, 2013). One of the major constraints in preparing the road network improvement strategy is the large volume of data needed, considering the complications in developing, updating and processing road-related information. The deplorable state of Federal, State and local government roads is an indication that FERMA and states' road maintenance agencies are handicapped with operational problems, beside the inherent technical defects of the roads. This view is collaborated by Ayeni (2003) when he asserts that underlying the poor management situation is the lack of appropriate information base or the phenomenon of "planning without facts". A GIS-based Road Maintenance Model will offer access to accurate, up-to-date information on road infrastructure elements allowing management to quickly assess performance, improving

decision-making, and provide a steady availability of road data for effective management, as well as identify maintenance and rehabilitation requirements (Ogwuche et al, 2013). In view of this, the study explored the techniques of Geographic Information System (GIS) in data capture, processing and analysis to produce a GIS-based Road Maintenance Model (RMM) using Ikeja road network in Lagos state, Nigeria as a case study.

### **1.0 Aim And Objectives**

The aim of this research paper is to develop a GIS-based model for road maintenance in Nigeria using Ikeja road network in Lagos state for proper performance and preservation of road integrity and serviceability. In other to achieve this aim, the objectives are;

1. To apply GIS techniques in the identification and mapping out of road networks and their conditions.
2. To collate valuable spatially referenced road related data that will provide information for effective road maintenance by both federal and state agencies.
3. To explore the problems associated with road maintenance with a view to proffering solutions to them.

### **1.1 History, Structure And Operation Of Road Maintenance In Nigeria**

#### **1.2.1. History and Structure of Roads Maintenances in Nigeria**

Integrated road development in Nigeria dates back to 1925, when the road board was established by the then colonial administration. The Board had the responsibility to resolve blueprints for truck road network connecting major administrative centres in the colonial time. As at 1951, 1,782km out of the total of 44,414km of road built in Nigeria was surfaced. The roads were however lacking in standard designs and were in single lane with sharp bends and poor drainage system. By 1952, 15,785km of bituminous surface and 75,200km of earth/gravel surface roads were already in place in Nigeria. The estimated current total road network is about 200,000km (Federal Ministry of Works & Housing, 2003). The Nigerian road system is classified in four broad categories;

1. The Federal Truck 'A' Roads: these are under Federal Government ownership and they are developed and maintained by the Federal Government.
2. The Federal Truck 'F' Roads: These were formerly under state ownership, but were taken over by the Federal Government, with a view to upgrading them to highway standards.
3. The State Truck 'B' Roads: these are under the ownership and management of the component states.
4. The Local Government Truck 'C' Roads: These are under Local Government ownership and development.

#### **1.2.2. Operation of Roads Maintenance in Nigeria**

Road maintenance means the preserving and keeping of road structures as near as possible in their original state. It consists of correcting deficiencies that have developed as a result of age, use and the effects of the elements, and taking steps to prevent or delay the development of other deficiencies. For proper maintenance, operation of road maintenance in Nigeria is classified into the following categories;

1. Routine Maintenance: routine maintenance is required to be carried out continually on every road irrespective of its engineering features or volume of vehicular traffic. Expenses are treated as fixed-cost. This type of maintenance include lane marking, drainage clearing, bridges and culvert maintenance, grass cutting e.t.c
2. Recurrent Maintenance: this is required at intervals during the year. The frequency of this kind of maintenance depends on the topographic and climatic characteristics of the area and volume of traffic. This kind of maintenance includes maintenance of pavements of paved roads, repairing of potholes and grading for unpaved roads.
3. Periodic Maintenance: this involves major repairs or rehabilitation of roads that have deteriorated over the years. This includes surface dressing or resealing, re-gravelling of both paved and unpaved roads.
4. Emergency/Special Repair: this kind of maintenance is caused mainly by unexpected substantial landslide, when road is abruptly cut or a bridge washout occurs and some time due to seismic factors.

### **1.3 Study Area**

Nigeria is located in West Africa, between latitudes 4°N and 14° north of the Equator, and longitudes 2° 20'E and 14° 30' east of the Greenwich Meridian. Lagos state is situated in the south west of Nigeria bounded in the west by the Republic of Benin, to the north and east by Ogun state with the Atlantic Ocean providing a coastline on the south. Ikeja occupies a unique position among the local government areas of Lagos state and also doubles as the state capital. It harbors most of the medium scale industry and lies in upland area of Lagos state. Ikeja is covered by a road networks that extends across with many links, some narrow, others wide.

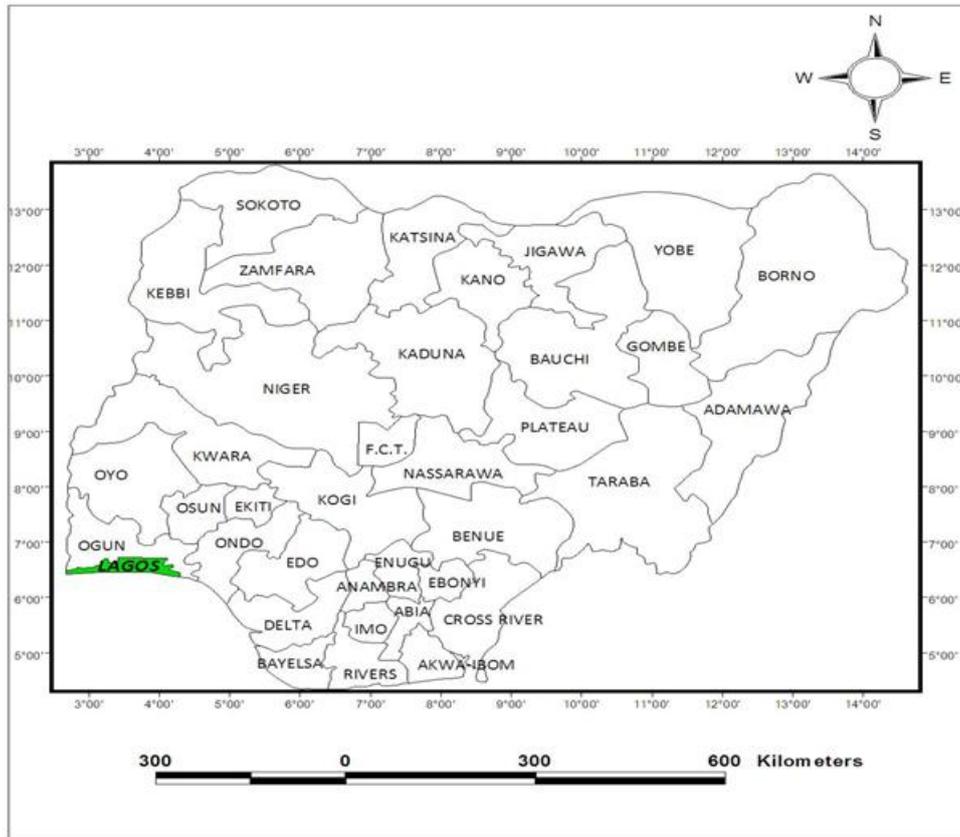


Figure.1. Map of Nigeria showing Lagos State

Source : Lagos state ministry of Land and Survey, 2010

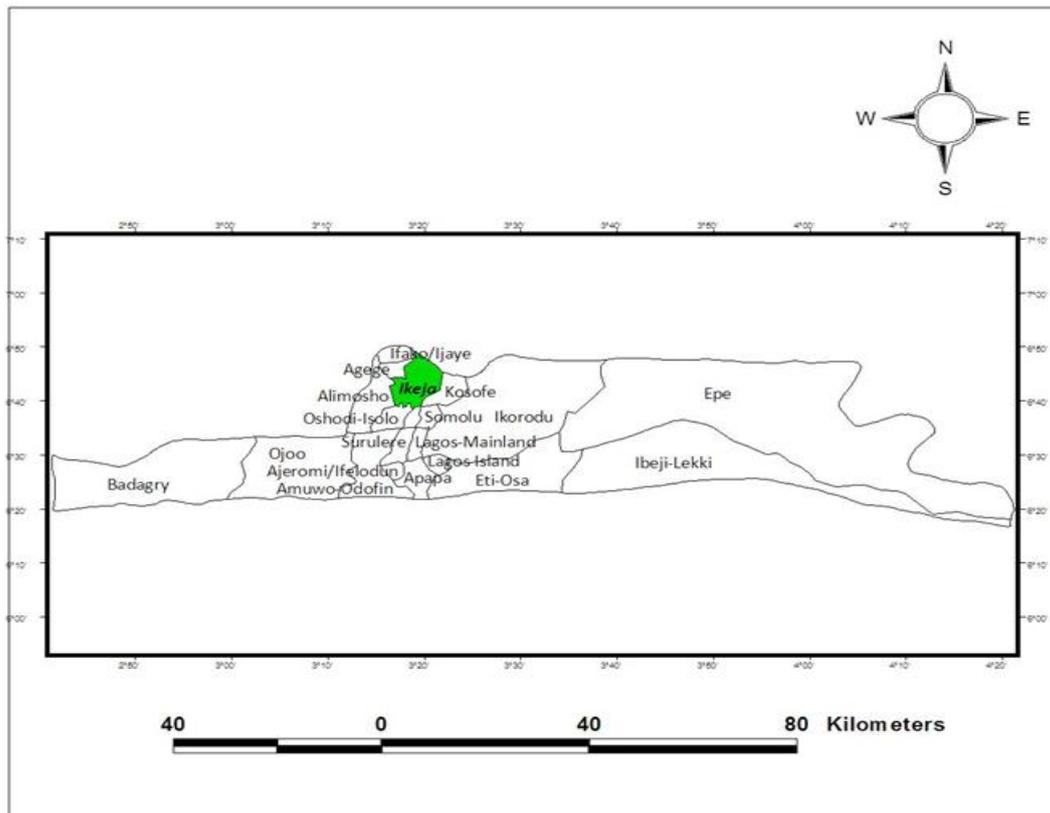
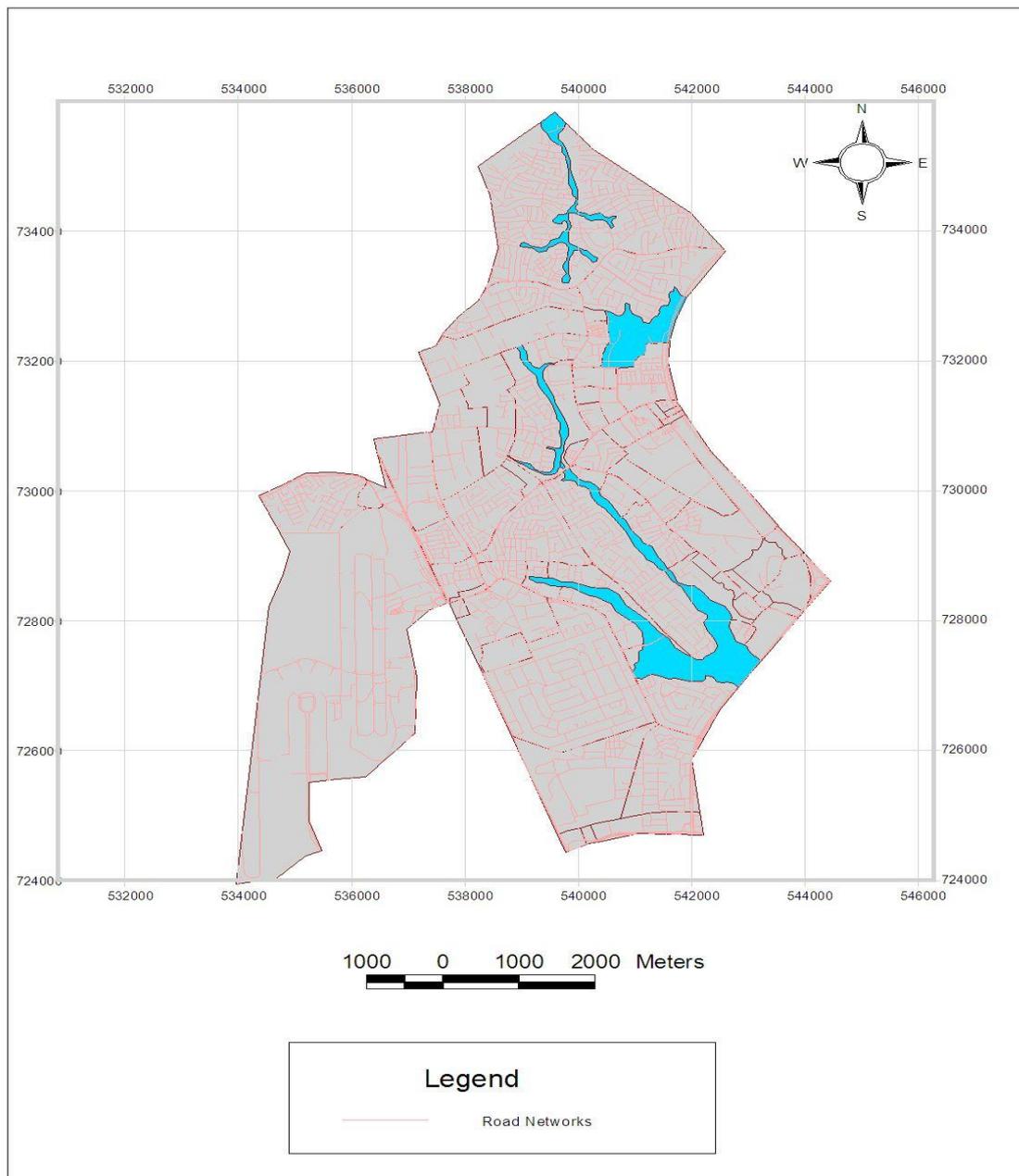


Figure 2. Map of Lagos state showing Ikeja local government area

Source : Lagos state ministry of Lands and Survey, 2010



**Figure.3.** Map of Ikeja showing the road networks

Source : Lagos state ministry of Lands and Survey, 2010

## **II. Methodology**

The methods adopted in this study include data acquisition, scanning, georeferencing, digitization, attribute database creation, spatial database query and analysis and groundtruthing.

### **2.1 Data Acquisition**

The data required for this study were acquired from Lagos state ministry of lands and survey, Lagos state ministry of works and infrastructure, Federal road maintenance agency and Lagos state ministry of transport.

### **2.2 Data Conversion**

This includes all the processing performed on the acquired data in order to transform them into a format useful for this research. The procedures performed on the data include scanning, geo-referencing and digitalization of road networks using the on-screen digitizing capabilities of ArcGIS 10.0 software

**2.3 Attribute Database Creation**

The road attribute database was created from the acquired secondary data in GIS environment. The attributes of each road section or segment digitized were populated in the database table.

**2.4 Spatial Database Query**

This is the process of extraction of relevant and needed information for road maintenance purpose from the database of road earlier created.

**2.5 Ground truthing Survey**

Survey of the roads conditions was conducted in the study area to actually ascertain the existing state of the sections or sub-sections of roads affected, and some that were not captured for the purpose of edition.

**2.6. Road Networks Assessment and Maintenance Procedures**

Road networks assessment and maintenance procedures involve the use of the following assessment parameters (Ogwuche et al, 2013);

**2.6.1. Road State Index (RSI)**

Road State Index is an index developed for this study to quantify road surface distress. The index is a product of the following procedures (Ogwuche et al, 2013).

**1. Visual Assessment (VA)**

This is the visual analysis of the road networks condition either through primary or secondary sources. Primary source is the assessment of the direct contact with the network under investigation, whereas secondary source is the process of assessing the road network condition as captured from remote sensing source and other recording devices.

**2. Road Condition Survey (RCS)**

This is the survey conducted over the entire networks to ascertain the general condition of the roads. RCS provides a regular assessment of road network condition and all maintenance needs. The purpose of RCS is to identify those sections or sub-sections of the road network which are in critical condition and those requiring maintenance or structural overlay within the near future.

**3. Detailed Visual Inspection (DVI)**

This is the process involved in quantifying the extent and severity of the distress of those sections or sub-sections of the network identified from the RCS as damaged. The extent may be defined as that part of the road affected by the damage, whereas the severity of the damage can be expressed as light, moderate and severe.

**4. Rating Criteria (RC)**

Rating	Road State	Descriptions( Road conditions)	Maintenance Action
1	Good	No Alligator Cracks, No potholes, No slippage cracks	Do nothing
2	Fair	Alligator cracks, No potholes	Minor Repairs
3	Failed	Alligator Cracks, potholes	Major Repairs
4	Bad	Slippage Cracks, potholes	Total Resurfacing

**Table.1: Rating criteria and thresholds of road state (adapted from Ogwuche et al, 2013).**

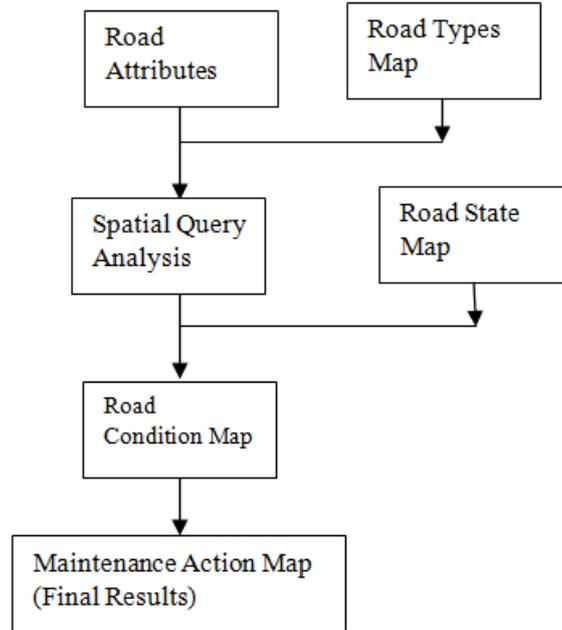
According to Badkoo et al. (2008), this is the process of assigning numerical value to the level of road damage. Road State Index (RSI) rates the road network condition from 1-4, as shown in Table .1 above.

- 1) Being good roads,
- 2) Being fair roads,
- 3) Being failed roads, and
- 4) Being bad roads.

**III. Results And Discussions**

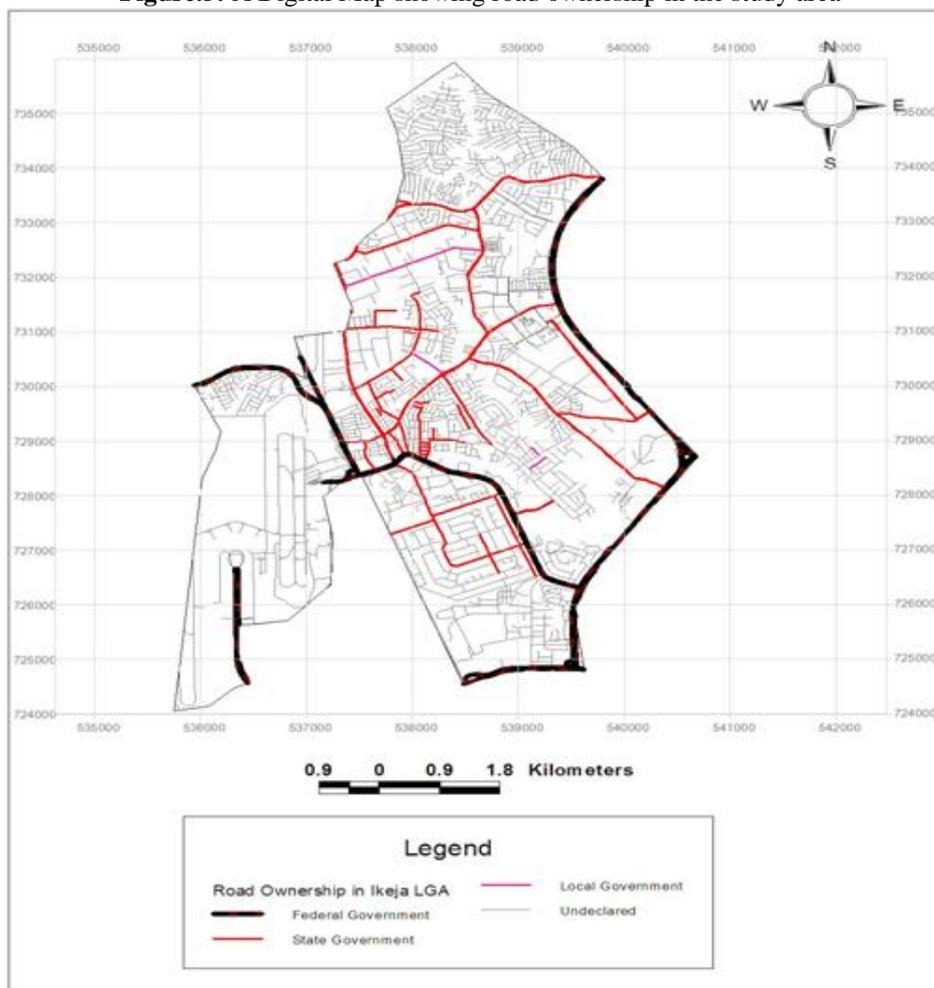
The spatial query analysis, which involves the extraction of relevant information from sets of spatial and attribute data of the road database earlier created were carried out for effective road maintenance.

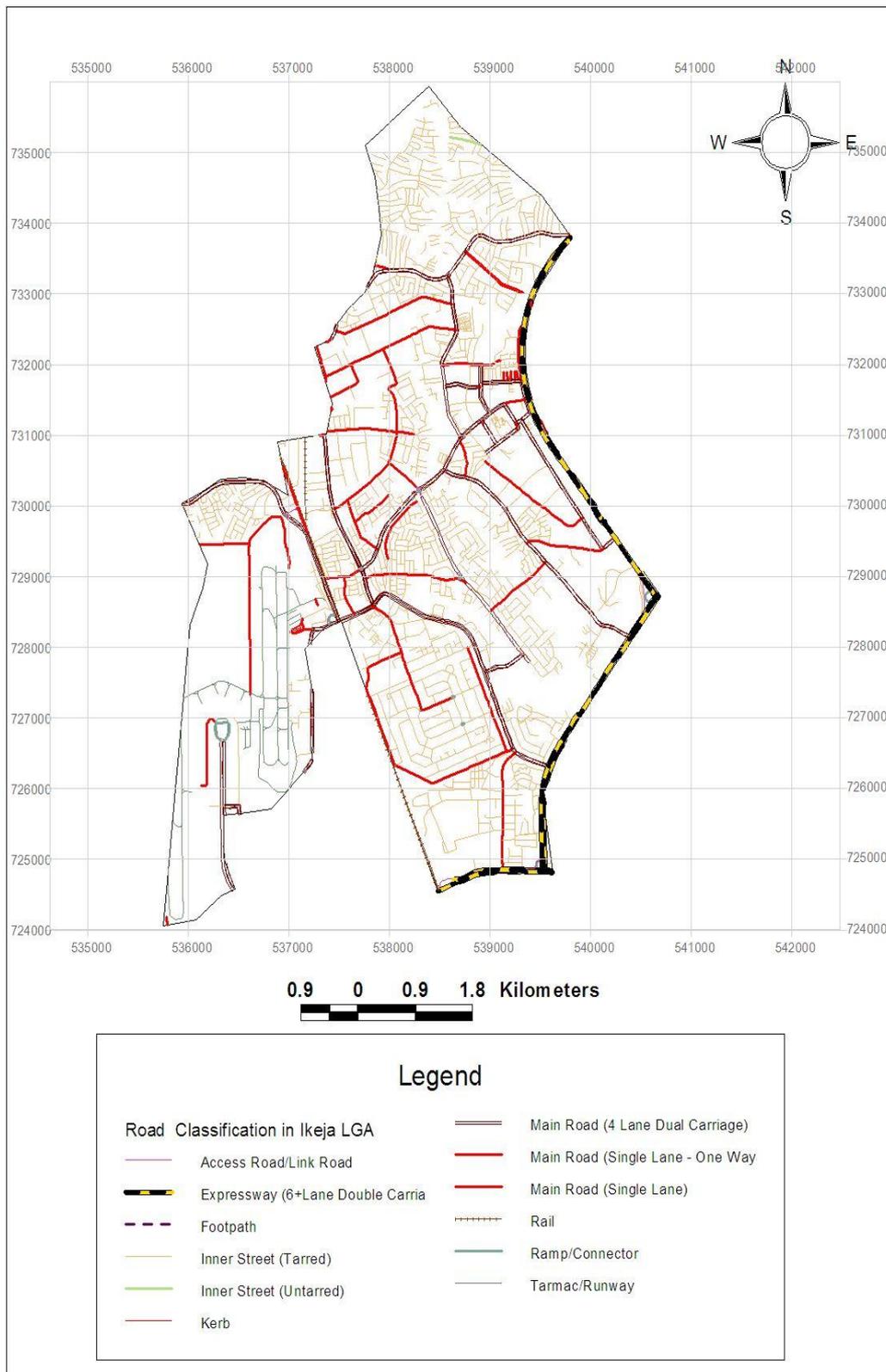
**Figure.4:** GIS- based road maintenance model diagram developed



The results of these spatial queries are shown thus in figures 5-10

**Figure.5:** A Digital Map showing road ownership in the study area





**Figure.6:** Digital Map showing Road classification in the study area

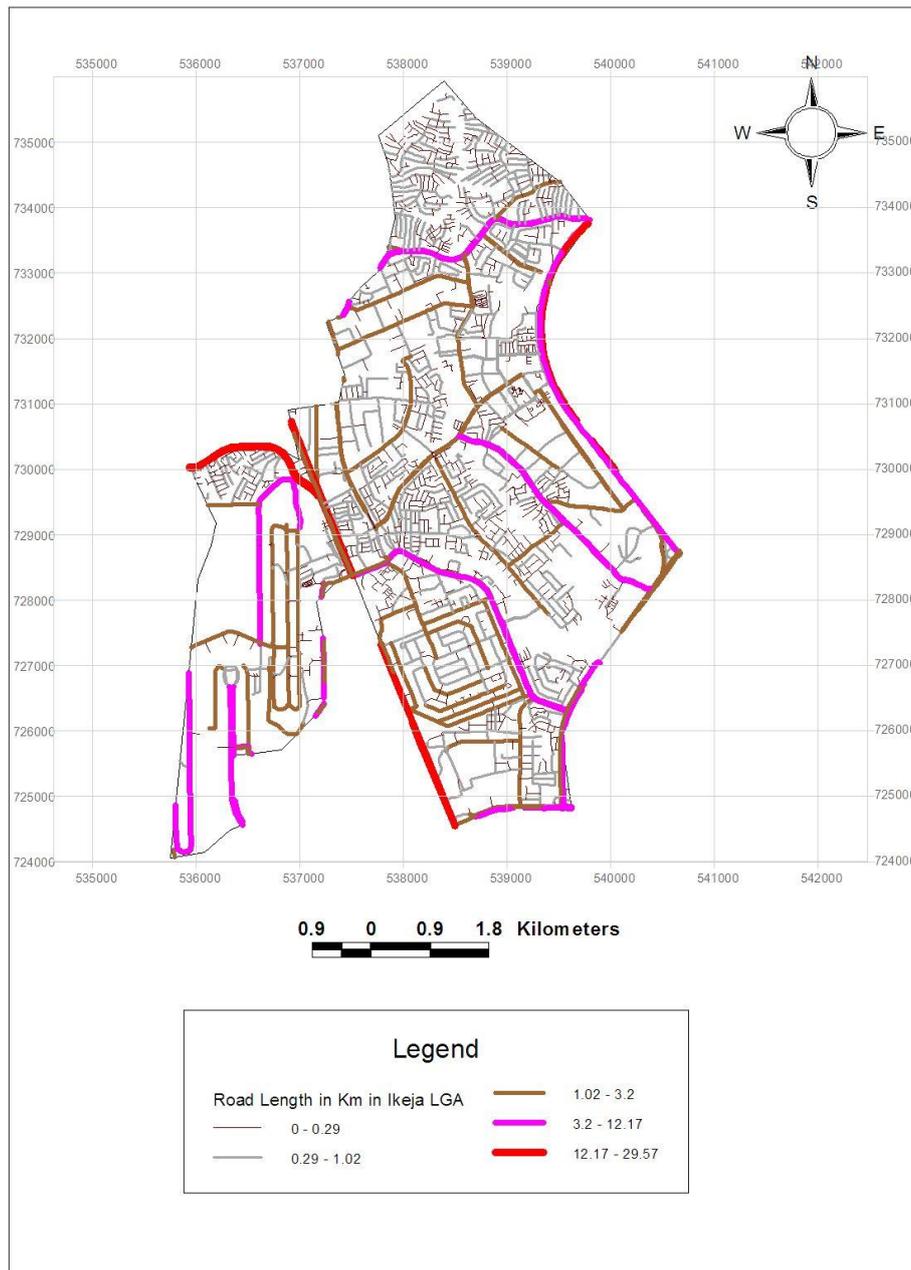


Figure. 7: Digital Map the study area showing Road Length in Km

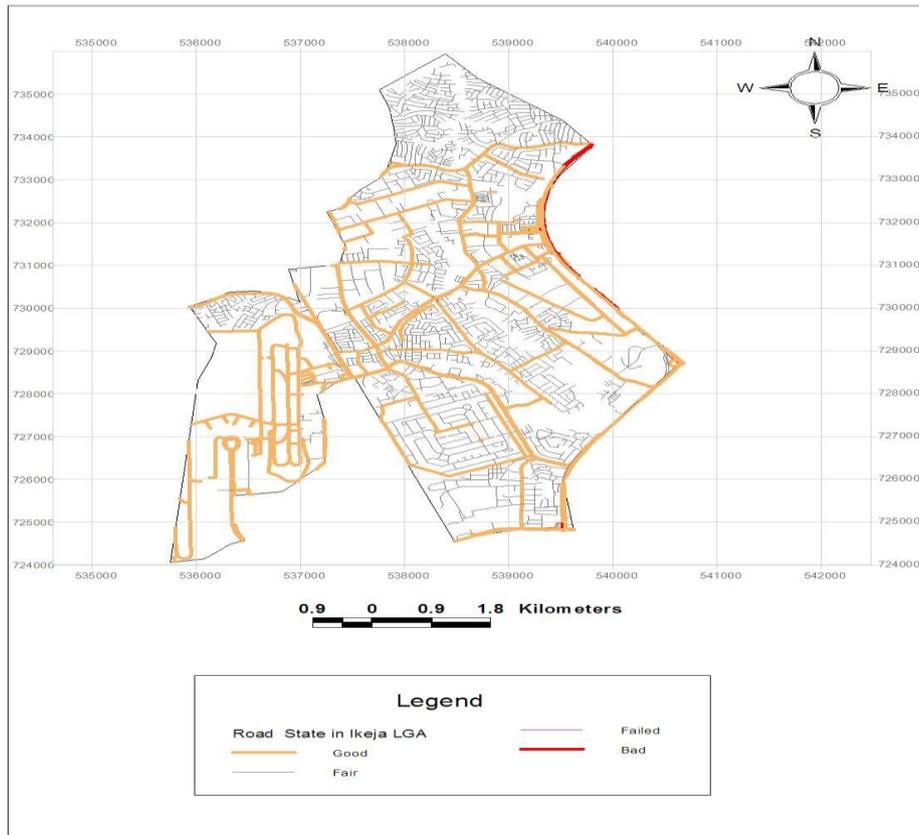


Figure.8: Digital Map showing the state of roads in the study area

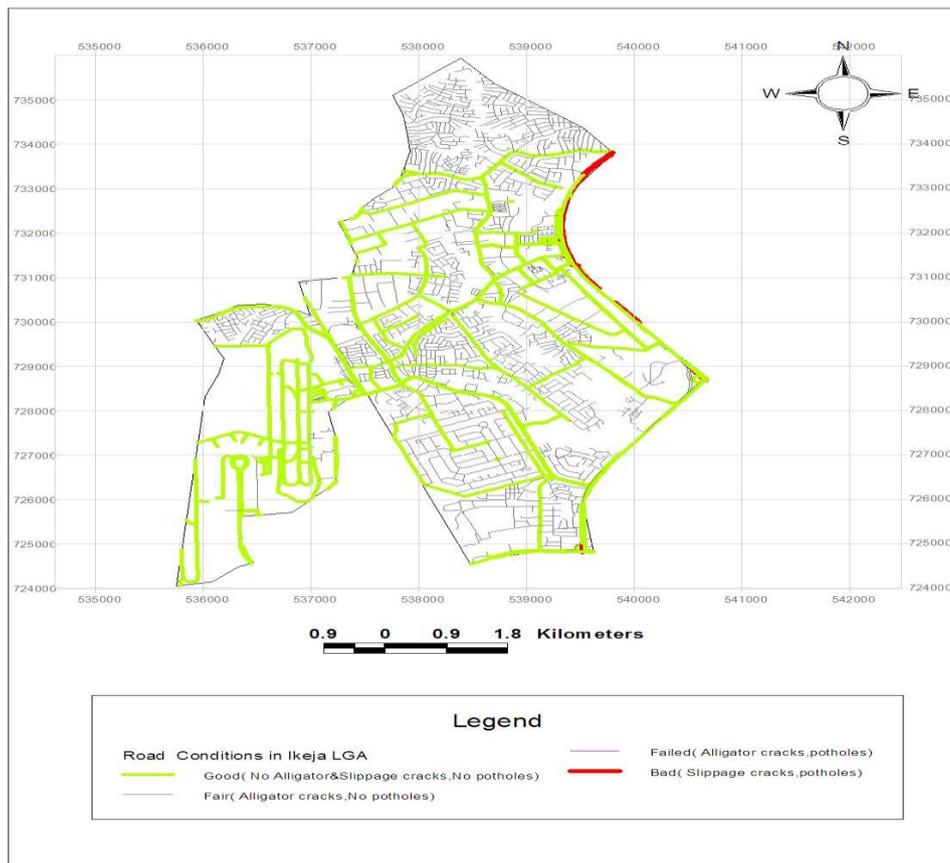


Figure.9: Digital Map showing the conditions of road in the study area



**Figure.10:** Digital Map showing road maintenance action needed in the study area

#### **IV. Conclusion And Recommendation**

##### **4.0. Conclusion**

Road networks play a vital role in the socio-economic and political development of the country. It is therefore necessary to explore the problems associated with road maintenance with a view to proffering solutions to them. To cope with the pace of maintenance of the ever increasing rate of road damage, there is need for sufficient spatially referenced road related data, centralized geo-database for the spatially referenced data, and real time access to road data information and models for effective management. GIS technology is the answer. The capabilities of Geographic Information System (GIS) in data capturing, processing and dissemination will greatly boost road maintenance, as it can handle spatially referenced data with speed and at the cheapest cost.

#### **4.1. Recommendation**

Federal, State and other road maintenance agencies, authorities in charge of road maintenance in Nigeria are by this study, invited to join a host of other countries that have acquired this technology and considered it most beneficial in solving real-world problems with dexterity. The agency should therefore adopt this novel technology to boost data capture, data processing and dissemination to solve the technical, operational and logistic problems afflicting our road networks.

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