



# Development of a Road Maintenance Model (RMM) Using Geographic Information Systems for Road Maintenance in Nigeria: A Case Study of Abuja Phase 1 Road Network, Nigeria

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## Abstract

The dynamism and complexity of road damage, 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. 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 9.2, indicate a total of 65 fair and 2 failed 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 ministries of works if we are to achieve proper performance and preservation of road integrity and serviceability.

## Keywords

Geographical information system; Road networks; Maintenance model

## 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 [1]. Road network is the heart of any country's development and the major factor for its successful planning towards the achievement of sustainable development. In Nigeria, road network plays a vital role in its socio-economic and political development, being her major driving force for economic transactions across the country [2]. According to Olaleye,

road transportation is the most common system of transportation and accounts for nearly 95 percent of total transportation, especially since the collapse of the railway system.

The road networks in Nigeria are so much afflicted that they function below standard and design specifications [3]. The cause of these can be traced to successive governments' neglect, overstretched workloads, out-lived design lifespan, structural design defects, sub-standard construction materials and other natural phenomena [2]. 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 million naira, and this represents about 5.5 percent of the Gross Development Product (GDP) and more than 10 percent of annual budgets [4]. However, 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.

Presently, construction of new roads is re at a decline and an increasing share of the annual road works budget is directed towards preserving the existing networks through maintenance and rehabilitation. Currently, rehabilitation and maintenance of roads and bridges across Nigeria are being carried out under the supervision of the Federal Road Maintenance Agency (FERMA).

In practical terms, the management of existing road networks in Nigeria poses great challenges to FERMA, in view of the ever-increasing rate of road damages and the dwindling resources. 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. According to Olaleye the deplorable state of the highways is an indication that FERMA is handicapped with operational problems, beside the inherent technical defects of the road. 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" [5]. 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.

## The 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. Abuja (Federal Capital Territory) is situated in the heart (centre) of the Country. Described as one of the fastest growing cities in the world, Abuja, the federal capital city of Nigeria was planned to achieve the maximum degree of compatibility, decency and beauty. The accelerated rate of urbanization in the city is increasingly becoming uncontrollable. This clearly explains why Abuja phase 1 has one of the most complex road networks, hence its choice for this study. Abuja phase 1 has 5 districts, namely Garki, Wuse, Maitama, Asokoro, and the Central Area; and are captured in

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Received: March 14, 2013 Accepted: April 23, 2013 Published: April 29, 2013

the panchromatic Quickbird satellite imagery of 0.6m resolution for this study.

## Research Methods

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

### Data acquisition

The data acquired for this research include a panchromatic Quickbird satellite imagery of 0.6m resolution, covering the 5 districts of Abuja Phase 1, acquired from the National Space Research and Development Agency (NASRDA), Abuja; and a hardcopy Street map of Abuja acquired from Julius Berger Construction Company (Nig) Plc, Abuja.

### 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 9.2 software.

### Attribute database creation

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

### 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.

### Ground truthing surveying

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 in the imagery for the purpose of edition (Figure 1).

## Road Networks Assessment and Maintenance Procedures

Road networks assessment and maintenance procedures involve the use of the following assessment parameters [6-8].

### 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 (Figure 2):

- Visual Assessment (VA)
- Road Condition Survey (RCS)
- Detailed Visual Inspection (DVI)
- Rating Criteria (RC)

**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

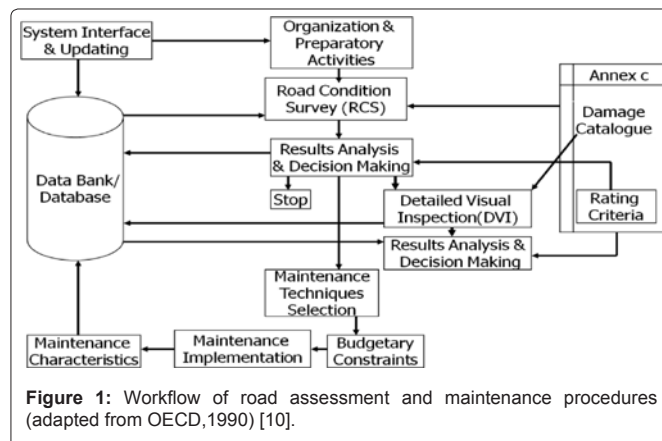


Figure 1: Workflow of road assessment and maintenance procedures (adapted from OECD,1990) [10].

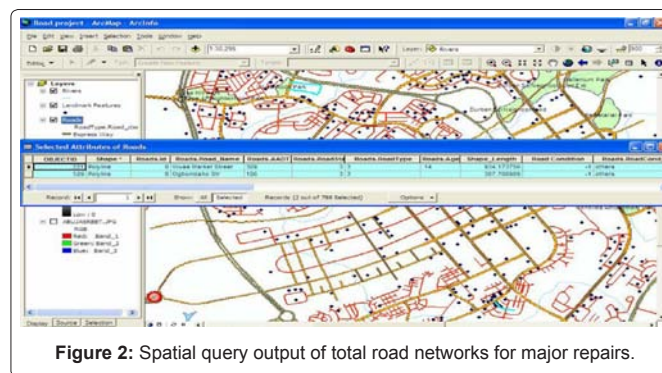


Figure 2: Spatial query output of total road networks for major repairs.

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.

**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.

**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.

### Rating Criteria (RC)

According to Badkoo et al. (2008), this is the process of assigning numerical value to the level of road damage [9]. Road State Index (RSI) rates the road network condition from 1-4, with (Table 1).

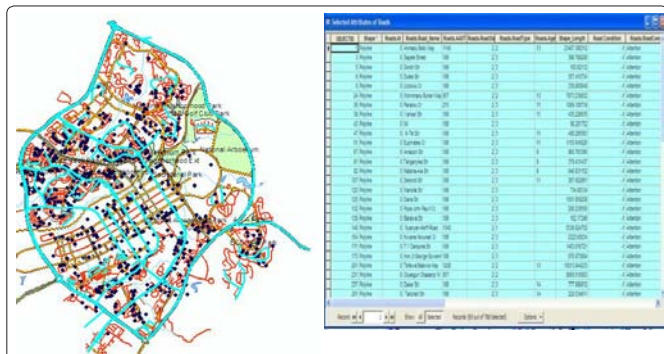
- 1) Being good roads,
- 2) Being fair roads,
- 3) Being failed roads, and
- 4) Being bad roads.

### Result Analysis and Presentation

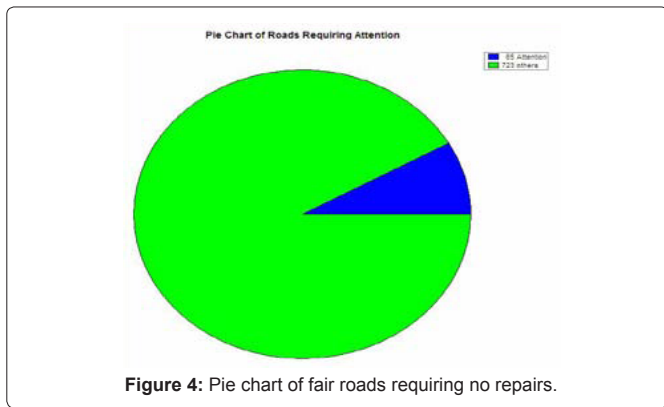
The spatial query analysis, which involves the extraction of relevant information from sets of spatial and attribute data of the road database earlier created were carried out for effective road

**Table 1:** Rating criteria and thresholds of road state.

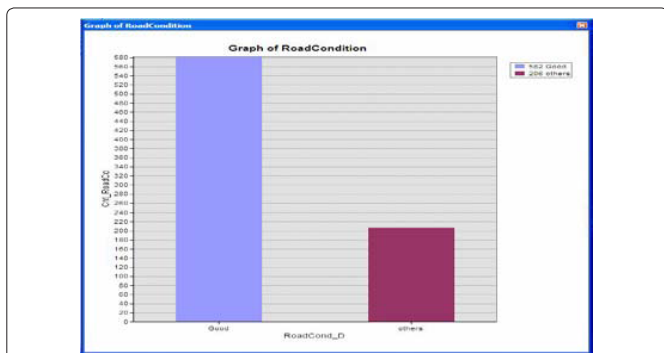
Rating	Road State	Descriptions	Maintenance Action
1	Good	No Alligator Cracks, No Potholes No Slippage Cracks	Do Nothing
2	Fair	Alligator Cracks, No Potholes	Minor Repairs
3	Failed	Alligator Cracks, Potholes	Major Repairs
4	Bad	Slippage Cracks, Potholes	Total Resurfacing



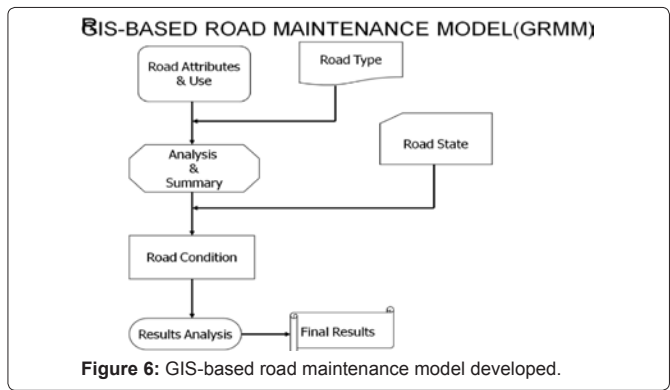
**Figure 3:** Spatial query output of total road networks for minor repairs.



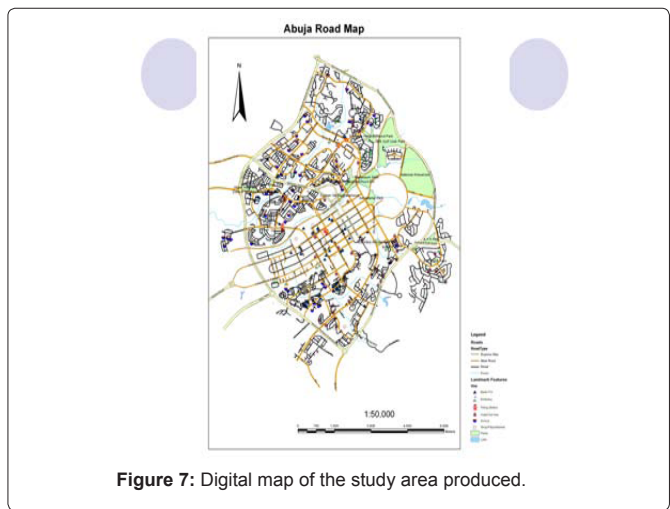
**Figure 4:** Pie chart of fair roads requiring no repairs.



**Figure 5:** Graph of good roads requiring minor repairs.



**Figure 6:** GIS-based road maintenance model developed.



**Figure 7:** Digital map of the study area produced.

maintenance. The results of these spatial queries are shown thus in Figures 3-7.

### 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.

### Recommendation

FERMA, the authority in charge of road maintenance in Nigeria is 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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