Assessment of road infrastructure using remote sensing and GIS methodology for monitoring the condition of paved and unpaved roads

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Abstract

This research primarily aims to develop a method in which road distress can be identified at early stage so that it could be maintained and fixed early thus avoiding critical damage. The primary source of data for the project was obtained by field survey with the use of vehicle and a handheld GPS to obtain the coordinates of each distress and a digital camera was used to take the pictures of the distress. The secondary sources of data include the Google Earth Imagery and the Remote sensing data. The approach adopted in this work involves obtaining the Global Positioning System (GPS) and the photographs of each distress noticed on the road, and then attaching the photographs to the classified map. The study was conducted in Yewa South Local Government in Ogun State in Nigeria which cover an area of 656,54 sqkm with population of 168,850 at the 2006 census. The study area has a total road length of 893.017 km. Assessment of road infrastructure using remote sensing and ArcGIS Geodatabase methodology for monitoring the condition of paved and unpaved road is an efficient approach utilized in management, planning and subsequent development of the road network in the study area.

1. Introduction

Roads are important for easy transportation of goods and resources, human beings and other transportable belongings. A good road network help to promote and quickens the fiscal growth of any country, through trade, tourism and other viable developments. It helps advance and quicken the financial development of any nation and this is achieved through improvement in businesses, exchange of goods and tourism [1]. In most African countries, road networks are in bad shape due to either construction using sub-par materials or poor maintenance or sometimes both. This work seeks to identify the benefits and potentials of the utilization of GIS and remote sensing tools in detecting the distress of paved and unpaved road (such as road surface cracks, potholes and surface roughness) at early stages in order to apply maintenance on time. Early detection of road surface cracks provides information about the network condition of the road before the repair costs become expensive. Also, to create and develop up to date digital database of road connectivity, accessibility of public utilities services which can allow proficiency in monitoring, administration, planning and ensuing development of
the road network in the study area. This study will also examine the strengths and weaknesses of the application of Remote sensing and GIS techniques in developing nations. The old-style method of monitoring surface road is by physical inspection, this method is very tedious and time-consuming, costly and requires much manpower and materials. It also creates danger to the monitoring team, etc. As more roads are constructed, the traditional method for road inspection fails to meet its required purpose. It is therefore of high importance to develop new and sustainable methods, tools and technologies that can be used to monitor roads adequately [1].

For this reason, the application of remote sensing and GIS is employed as a better option for road monitoring, using Yewa south local government area as a case study.

The local and state governments in general are responsible for the construction and maintenance of roads. The local government often fails in making sufficient funds available for the provision of manpower and monetary resources thereby leading to inadequate road maintenance [2]. The resources of local infrastructure engineers must therefore be adjusted in the process of monitoring the road conditions and organizing maintenance activities. Inspection of every section of roads in the local government would most likely not be carried out to its full extent within a single trip by officials. Although the federal and state government transportation department assess the condition of road surfaces, it is of paramount importance to identify and repair impaired roads caused by road base damage and loss of crown. GPS and camera are used as a platform for obtaining road data, and an effective system is developed for processing satellite image and evaluating road condition parameters such as road surface roughness and potholes.

2. Study Area
The study was conducted in Yewa South L.G.A Ogun State, Nigeria. The Area is in the west of Ogun State. The area is located along the Longitudes 2°47′24″E and 3°6′48″E of the Greenwich Meridian and Latitudes 6°37′46″N and 6°55′42″N of the Equator as shown in Fig.1. The mean annual rainfall of the area is about 14500 mm and the mean annual temperature is about 25°C. The topography is very unequal. Lowlands and small basins are the major landforms of the area. The vegetative cover is of the shrub lands and semi natural vegetation: also included in the vegetative cover are mixed forest, palms, herbs, and grassland lands.

The study region is populated with Residential, Commercial, Industrial, and Transportation Facilities. The soils type is clay and loamy Soils with erosion and water loss. The study area gifted with conducive climatic conditions for agricultural pursuits throughout the year. Its tropical nature ensures that the raining season starts in March and ends in November and it naturally precedes a dry season. Notwithstanding the huge outflow of fertile land with large deposit of mineral resources, industry and agriculture remains the largest employer of labour with a few people engages in mechanized farming while others engages in trading activities. The area is confined in the East by Ifo and Ado – Odo/Ota Local Government Area while in the West by Ipokia Local Government and north by Yewa North. The population of the study area is about 150,850 and it has a total area of 629.38 square kilometers.

The Local Government is delineated into ten (10) wards (Ilaro I, Ilaro II, Ilaro III, Iwoye, Idogo, Owode I, Owode II, Ilobi/Erinja, Oke – Odan and Ajilete. The inhabitants are mainly Yoruba, speaking various dialects and comprises of Yewa- Ketus.
3. Data Acquisition and methodology

The primary source of data was obtained by field survey. Most of the existing roads of Yewa south L.G.A were surveyed with the use of vehicle; a handheld GPS was used to obtain the coordinates of each distress and a digital camera was used to take the pictures of the distress.

The secondary sources of data include the Remote sensing data (Satellite image) which was downloaded from [www.earthexplorer.usgs.gov](http://www.earthexplorer.usgs.gov) were stated in Table 1.

| Item                     | Source                        | Date Acquired |
|--------------------------|-------------------------------|---------------|
| Study Area Shapefile     | Google                        | 2018          |
| Google Earth Imagery     | Google Earth Pro              | 2018          |
| 2018 Satellite Imagery   | USGS website ([www.earthexplorer.usgs.gov](http://www.earthexplorer.usgs.gov)) | 2018          |
| Ground Road Point and Images | Author                       | 2019          |

3.1 Field work and geotagging

The hand-held GPS was used to determine the geographic location (Easting and Northing Coordinates) for each point along the road in the study area and a digital Camera was used to snap the photos of each distress. The camera has to be strong enough to detect the crack on the surface. The geographical identification metadata for each point was added to every photo taken at each point for geo-tagging.
3.2 Image Geo-Referencing
The study area (i.e. Yewa south L.G.A) was downloaded from the Google earth and the shape file of the study area was loaded into google Earth as shown in Figure 2. The google image be georeferenced and placed on it actual position as if it is on ground, this process is called Image Geo-Referencing.

All the features in the imagery were Georeferencing to be in the same coordinate system, that is, the Google earth image was coordinated (image coordinates) and the image coordinates were then saved in a created folder.

After digitizing the road networks and known settlements within on the Google Earth Image, the captured road points of interest during a field survey were gathered and collated in a word document. The Coordinates of the points of interest were then collected into an excel file and loaded into the ArcGIS environment.

3.3 Creating Feature Geodatabase
In order to account for the road infrastructure, in terms of status and conditions, a geodatabase was created within the ArcGIS workspace for the road networks and other features identified on the Google Earth image.

3.4 Image Digitization
The process of converting a raster image to a vector form is normally termed Digitization. In order to manipulate and maintain a geodatabase of the road infrastructure within the study area, the road networks must be in a vector form and this was done through image digitizing. After digitizing the road networks and known settlements within the Google Earth Image, the captured road points of interest during a field survey were gathered and collated in a word document. The Coordinates of the points of interest were then collected into an excel file and loaded into the ArcGIS environment.
3.5 Populating the Geodatabase

After digitizing the road features and settlements within the study area, also importing points of interest on the road, there is a need to describe the captured data and update additional information concerning the data. The other spatial data (also known as attribute data) of the road infrastructure and road point of interest were captured in the attribute table (in this case we can call it the Geodatabase) of the features.

3.6 Acquisition and importing Classified Land use/Landcover Image

For efficient and effective management of road infrastructure, the land use/land cover of the study area must be updated so as to access the functionality and importance of each road network. The image with path and row of 191/55 was downloaded from the USGS website which is www.earthexplorer.usgs.gov. Radiometric errors due to variations in scene illumination and viewing geometry, atmospheric conditions, and sensor noise and response have been corrected by USGS. In this research, the author did not execute any form of geometric and radiometric correction. The images were classified using the unsupervised classification in K-means and maximum likelihood classifier (MLC) algorithms respectively. The classified image was imported into the GIS workspace as shown in Figure 3.

![Figure 3. Classified Landcover Image](image)

4 Experimental Results and Discussion

A Comprehensive map showing the road network was prepared from the data gathered and some analysis in term of querying were carried out. The Geodata base clearly showing the details and the condition of the road surface. It is possible to monitor and assess the condition of road surface with satellite images as showing in Figures 6, 7 and figure 8.
4.1 Querying the Geodatabase

Having the information on the road network the following queries were performed

4.1.1 Number of Paved Roads with Potholes

Using the attribute commands within the GIS workspace, the number of paved roads with potholes were queried and two roads fall under this condition. Trunk A road and trunk B road s shown in Figure 4.

![Figure 4: Query to determine number of Paved Roads](image-url)
Table 2: Paved Roads with Potholes

| Road Name            | Road Type | Road Lengths (meters) | Ground Images |
|----------------------|-----------|-----------------------|---------------|
| Owode – Oke Odan Road| Trunk A   | 31673                 |               |
| Oke Erinja Road      | Trunk B   | 1336                  |               |
| Ndoji Road           | Trunk A   | 31634                 |               |
4.1.2 Number of Trunk “A” Roads
The query on number of Trunk “A” roads passing through the study area was performed and the following were discovered.

![Figure 5: Query to determine length of trunk A Roads](image)

**Table 3: Trunk "A" Roads**

| Road Name                  | Road Length (meters) | Status                      |
|----------------------------|----------------------|-----------------------------|
| Owode – Oke Odan Road      | 31673                | Paved road with Potholes   |
| Oja Odan Road              | 56292                | Paved road with Potholes   |
| Ndoji Road                 | 31634                | Paved road with Potholes   |

4.1.3 Point of Interest along Idogo Road
Another query was performed to select the number of points of interest along Idogo road as shown in Figure 6.
4.2 Creating Feature Geodatabase

In order to account for the road infrastructure, in terms of status and conditions, a geodatabase was created within the ArcGIS workspace for the road networks and other features identified on the Google Earth image as indicated in figure 7, Figure 8 and Table 3.
5. Results and Discussion
A comprehensive map showing the road network was prepared from the data gathered and some analysis were carried out. The roads are clearly seen on the imagery and road surface conditions can be determined from the satellite images. Remote sensing images show clearly details of the roads. Since remote sensing data can be regularly acquired, it is possible at any time to use satellite images to monitor and assess the conditions of roads. Figure 6 shows an overlay of digitized road network on imagery. The roads were clearly identified on the images. Remote sensing made possible the satellite image to digitize the roads and overlay them on the satellite imagery and a good overview of the road network is obtained. These roads can then be monitored and maintenance planned can be done as necessary. The road network database was generated or created in Table 4. In the database are the names of roads identified in the study area; their types, and conditions, etc. The study attests to the fact that remote sensing satellite images can capture more information about roads than field surveys and can assist in a number of situations.
6. Conclusion
The present study highlighted the importance of the application of GIS and remote sensing to understanding
the economical method to generate a database for effective monitoring of road surfaces in Yewa South
L.G.A.
The results obtained from this study affords local authorities accountable for infrastructural maintenance
with various possibilities for better improvement of road infrastructure. The database provides various
information concerning the road infrastructure without manually surveying the road regularly, this helps the
local authorities to determine the extent of road damage and effectively provides adequate resources
required in the rehabilitation and maintenance of roads.
This method offered a simple and cost-effective technique in road surface monitoring. The method improves
efficiency by rationalisation work processes when obtaining field data and GPS data. It also increases the
productivity by working with geo-tagged road distress photographs and processing the data in a geospatial
setting.
The combination of satellite image and data collected from field measurements integrated into GIS
environment, makes it possible to monitor the roads surface conditions. Where damages are detected, quick
maintenance are planned and carried out because the position of such will be clearly shown or known from
the satellite images based on the analysis.

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References
[1] Onuigbo I C Orisakwe K U 2013 Applications of Geographic Information System and Remote Sensing
in Road Monitoring in Minna and Environs, Nigeria. IOSR Journal of Environmental Science,
Toxicology and Food Technology (IOSR-JESTFT) e-ISSN: 2319-2402, p- ISSN: 2319-2399. 3 (6)
(May. - Jun. 2013), 01-05 www.iosrjournals.org

[2] Zhang S 2014 Monitoring the condition of unpaved roads with remote sensing and other technology,
Geographic Information Science Center of Excellence. South Dakota State University