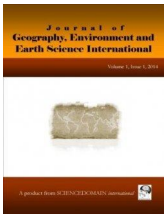

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# Road Condition Monitoring of Major and Minor Route in Part of Ibadan Metropolis Using Geo-spatial Approach

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author BAA designed the study, performed the statistical analysis, and wrote the protocol, author AGK wrote the first draft of the manuscript and manages the analyses, author OMA searches the literature of the study. All authors read and approved the final manuscript.*

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## ABSTRACT

Major and minor road conditions of part of Ibadan metropolis was assessed to analyze the effectiveness and efficiency of the road network system. The major objectives of the study are to locate and identify the road networks within the study area, evaluate the road conditions such as an area with defects such as potholes and crack, evaluate the features that observe and did not observe the right of way using geospatial approach. Single-frequency Hi-target differential global positioning system (DGPS), a steel tape was used for field observations and measurements. Google earth satellite imagery was used to determine the route and spatial location of potholes and cracks within the study area. Generally from the study, it revealed a total number of 81 potholes, 29 cracks and the result from the right of way showed that none of the features observed the specification of right of way thou some of those features exists before converting the road into two lanes for easy passage and flow of vehicle in order to avoid constant traffic congestions. Therefore,

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proper monitoring should be done by State and local government agency in charge of road construction/maintenance to avoid the improper location of features by an individual, corporate organization etc. along both the major and minor route from time to time and adequate checking on roads.

*Keywords: Transportation network; road condition; right of way; effectiveness; specifications.*

## 1. INTRODUCTION

Transportation is important in the physical and economic development of towns and cities all over the world. The road tends to increase in areas with expanding transportation networks and increase less rapidly in areas without such improvements. The rapid and continued rise in roads networks is expected in cities with transportation improvements and rapid economic and population growth [1]. Man, nations, regions and the world would be severely limited in development without transportation, which has a key factor for physical and economic growth [2]. Transportation systems and land use are interdependent. According to Bailey et al. [3], the transportation route is part of distinct development pattern or road network and mostly described by regular street patterns as an indispensable factor of human existence, development and civilization.

The Nigerian road network comprises Federal roads, State roads and Local Government roads. The problem of maintaining those roads has been given as one of the major factors leading to accidents, increasing road user cost and decreasing the economy of this nation [4]. Road networks are observed in terms of its components of accessibility, connectivity, and traffic density, level of service, compactness, and density of particular roads. Level of service is a measure by which the quality of service on transportation devices or infrastructure is determined, and it is a holistic approach considering several factors regarded as the measure of traffic density and congestion rather than overall speed of the journey [5]. Road network consists of a large number of interwoven roads exhibiting many patterns ranging from stars like to grid-like with irregular patterns becoming recognized [6]. According to Aderamo [7], road network constitutes an important element in urban development as roads provide accessibility required by different land uses and the proper functioning of such urban areas depends on efficient transport network which is a backbone to their very existence. The analysis of the road network involves the recognition of the patterns and qualities of the roads. The route network is a set node representing spatial locations and displays topological and geometric variations, while topology itself refers to the arrangement and connectivity of nodes and links of a network Wyatt [8].

Developments of various transportation modes have become pivotal to physical and economic developments. Such modes include human porterage, railways, ropeways and cableways, pipelines, inland waterways, sea, air and roads [9]. Urban road transportation system is one of the Centre's based on the assumption that consumers rationally choose a form of transportation, according to their social and spatial position within the urban marketing opined that the urban road transportation system acts as a basic components of urban areas, social-economic and physical structure it plays an essential role in the determination of scale, nature and form of urban areas as stated by Dickney [10], Balchin et al. [11]. Urban areas tend to develop at modal points in the transport network and places with the good road network. Urban location with such retrieve advantages is found where different transport routes converge with a high degree of compactness, connectivity, density, length and accessibility exhibited within the intra-and inter-urban road networks as stated by Wyatt [8].

Most poorly constructed and maintained roads are largely characterized by anomalies such as potholes, rutting, speed bumps and pavement cracks. These anomalies are causatives to several road traffic accidents leading to the loss of lives and properties [12], [13]. Often, these anomalies are induced owing to the use of poor quality road construction materials, inadequate drainage systems, and poor road maintenance culture [14]. They cause accidents and negatively impact the economic development of the affected areas. In conditions where anomalies persist, a new paradigm may be required to curb the rate of induced accidents. One approach from the vehicular point of view is to facilitate vehicles with the capability to sense, characterize and profile road anomalies [15],

[16]. This will provide early information to drivers warning them about impending anomalies to aid their navigation. In this regard, Smartphone-Based Accelerometers (SBAs) have been widely used in the literature [17,18]. [19] Reported that monitoring the road network is essential due to its great value as a public asset. One of the objectives set by [20] for 2018 is to reduce the maintenance backlog on local roads and adopt a regime that will result in preventive maintenance. Road condition monitoring consists of four main steps; raw data, defect identification, defect assessment, and road condition index (RCI) calculation [21].

Global Positioning System (GPS), Geographic Information System (GIS) and the traditional database applications will help in the management of the highway network using a common Locational Reference System (LRS) that will integrate all data on road and bridge inventories as described by Langunzad and Mcpherson [22]. They further stated that GIS provides the mechanism for integrating all of the above data into a single environment and to enable spatial querying and analysis of that data. According to RMGIS is necessary because nowadays, most road monitoring systems can not directly show the precise geospatial location of the monitored place as opined by Yu et al. [23]. Their (proposed) system makes use of the powerful functions of GIS to realize real-time monitoring and recording road conditions on the electronic map in the system Centre. Geographic Information System (GIS) and the Global Positioning System (GPS) are the two geospatial technologies that are being used in the monitoring of transportation generally as stated by Akomolafe et al. [24]. Therefore, no available information regarding the road conditions of major and minor roads of the area study. Various agencies in-charge of road management in Oyo state only have information about the road condition but not the actual position of defects such as cracks and potholes. As a result of these challenges, there is need to create information about road network conditions and the actual position of each pothole and cracks to minimize the damages caused to road transportation means within the study area.

## 2. MATERIALS AND METHODS

### 2.1 The Study Area

The study area is part of Ibadan metropolis, Oyo State, Nigeria. The areas are commercial, academic as well as the market environment. It falls in the urban core area of Ibadan metropolis. It is located approximately between latitude 7º23'4" N to 7º23'35" N and longitude 3º55'56" E to 3º56'48" E.

### 2.2 Methods of Data Acquisition

Hi-target differential Global Positioning (DGPS) receiver was used to determine the spatial data (x, y) coordinates of each pothole and crack along both the major and minor routes. The major routes consist of Ojoo/University of Ibadan-Sango, Sango/Eleyele, the University of Ibadan to Bodija and Sango/Mokola while the minor routes are Agbowo, The Polytechnic Ibadan, Ijokodo, Apete and Agbaje that link Sango/Eleyele route, Sango/Housing and Sango-Mechanic/Samonda, and Oshuntokun Avenue-Bodija route. Two Hi-target DGPS receiver was used, one as the base and the other as the rover. The first one which was used as a base was set on a known control point located at Sango junction with reference number YZN 364 while the second Hi-target DGPS receiver used as a rover was carried around in acquiring the x, y and z coordinates of the potholes and cracks along the major and minor route. Extensive research has been performed in regards to the defect of cracks. Specifically, methods that perform crack classification [25;26;27]; depth estimation [28] and even sealing [29] have been presented. A comparison study of several methods that perform image segmentation for crack detection and classification was conducted by Tsai et al. [30]. Battiato et al. [31] Have also worked on patches; however, their method can't tell the difference between a patch and a pothole. Texture information for differentiating potholes from cracks was utilized by Lin et al. [32].

Shape information was used for detecting potholes in asphalt images [33]. Video data was used in detecting potholes [34]. One level deeper to measure the properties of potholes was worked by Jog et al. [35]. Steel tape was used to measure the encroachment of each feature such as buildings, shops and market place along the routes to know the features that fall within the specified right of way and those that are out of specification. Steel tape was used to measure the width and length of each pothole, while the depth was acquired using the differential Global positioning system (DGPS) receiver which is the height above the mean sea level to the reference ellipsoid. Stereo-vision can be used in road monitoring. Stereo-vision offers the possibility of

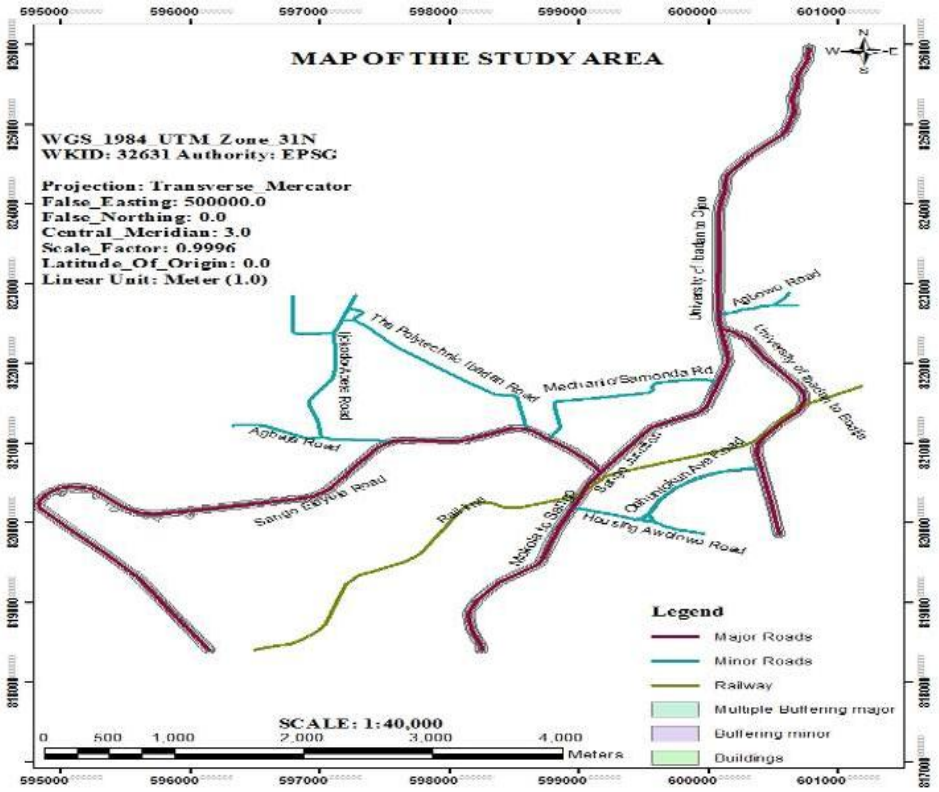



**Fig. 1. Showing the map of the study area**

reconstructing the surface with the aid of multiple video cameras. The applicability of such a technique for road reconstruction was experimented by Hou et al. [36] and Wang [37]. Additionally, [38] and [39] used it in a study for enhancing a method for highway condition assessment. Chang et al. [40] Applied it for measuring the depth of potholes and calculating the necessary filling material, [37] for detecting and classifying cracks and [41] for calculating crack depth. Also, the setback for each feature along the routes was recorded using steel tape. A steel tape was used to measure the encroachment of each feature such as buildings, shops and market place along the routes to know the features that fall within the specified right of way and those that are out of specification of the right of way. The specification for the right of way of major roads as specified by the state from the Centre of the road is 30 meters (98.42 ft).

## 2.3 Specification Design

Setback, width for major and minor roads, potholes and cracks specifications used in this study are listed in Table 2. A setback is a minimum distance which a building or other structures must be set back from a street, or road, river or other streams, shore or flood plain, or any other place which is deemed to need protection as defined by [42]. Highways (Federal or State) are of two types namely; the primary and secondary highways. The requirement for the setback from the primary (Federal or State) highways was 90m right of way that is 45m from the Centre of the road while that of secondary was 60m right of way that is 30 m from the Centre of the road [43], as secondary roads are chosen by the state highway departments and appropriate local officials cooperatively, subject to approval by the Bureau of public road [43]. Local Roads (State) setback was 24 m, 18 m, 15 m, 12 m that is 12 m, 9 m, 7.5 m, 6 m from the Centre of the road and that of the rail line was a minimum distance of 21 m between the property and the railway lines and 60m between property and unmanned railway crossing level [44].

## 2.4 Data Processing

The acquired data was downloaded and processed using (HGO) Hi-target Geomatics Office Global Navigation Satellite System (GNSS) solution software Figs. 2 and 3.

**Table 1. Coordinate of the control point used**

| Point identify | Northing | Easting | Height |
|---|---|---|---|
| YZN 364 | 820651.379 | 599156.600 | 243.144 |

**Table 2. Specification for Oyo State major and minor routes**

| S/N | Features | Type | Width in (m) | Setback from the centre of the road in (m) |
|---|---|---|---|---|
| 1 | Major Road | Line | 9-15 | 30 |
| 2 | Minor Road | Line | 7-10 | 15 |
| 3 | Potholes | Polygon | 0.3-0.7 | Nil |
| 4 | Cracks | Line | Nil | Nil |

*Source: Oyo State ministry of works*

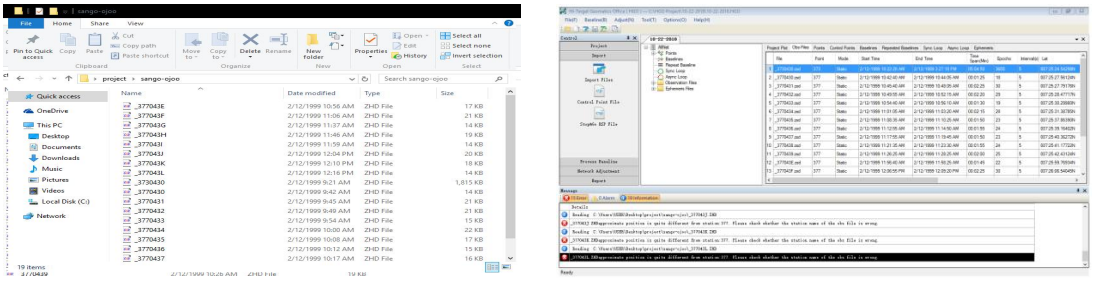


**Fig. 2. Raw data downloaded and data in Rinex format using HGO software**

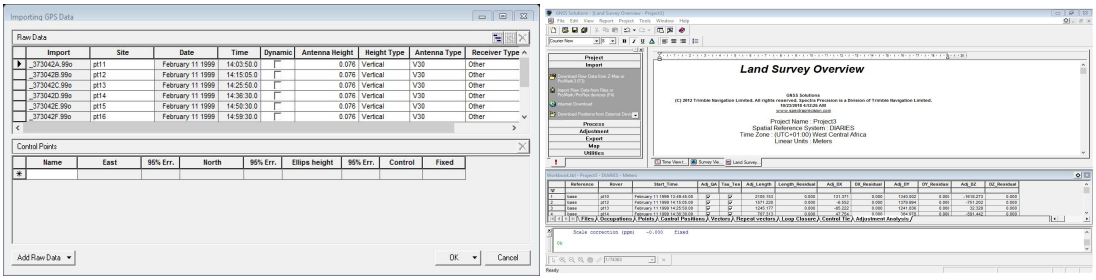



**Fig. 3. GNSS solution in rinex data and result overview report in coordinate format**

## 3. RESULTS AND DISCUSSION

The results and analysis in this study were as a result of field observations and measurements carried out. The width of the major road measured was 14 metres with 7metres measured from the Centre of the road to the edge of the road on both sides respectively. The result from the study showed a total number of 81 potholes, 29 cracks from different routes within the study area. Out of these were several potholes and cracks which fall into different categories of road type. The Tables describe further, the analyses of the fieldwork of the study area. The total length of the major roads from Ojoo/University-Sango-Mokola was 8.43 kilometres in which Ojoo-University/Bodija Junction covers 3.74 kilometres, the University of Ibadan-Sango Junction covers 2.12 kilometres, Sango-Mokola covers 2.57 kilometres. Sango-Eleyele covers 5.04 kilometres and the University of Ibadan to Bodija covers 2.95 kilometres. For the minor roads, the distance from University of Ibadan to Agbowo road clipped was 508.76 meters, Sango to Housing road was 1.71 kilometres, Housing Rounabout to Oshuntokun Avenue Bodija was 1.15 kilometres, Mechanic–Samonda was 1.73 kilometres, The Polytechnic Ibadan road covers 2.01 kilometres, Sango Eleyele road to Agbaje cover 458.37 meters, Sango Eleyele to Apete covers 1.05 kilometres and Sango Eleyele to Ijokodo covers 2.50 kilometres.

### 3.1 Identification of Roads with Potholes and Cracks

The two major defects identified on major and minor roads in the study area are the potholes and cracks. Table 3 described the locations, the road types and the number of defects types.

From Table 3, it can be deduced that the road network from Ojoo/University of Ibadan-Sango has the highest number of potholes followed by that of Sango-Mokola road. Thirty-seven (37) representing 45.68% number of potholes are on the major roads while forty-four (44) representing 53.32% number of potholes on minor roads while thirteen (13) representing 44.83% number of cracks are on major road and sixteen (16) representing 55.17% number of cracks on minor road which can be traced to the daily activities such as movement of vehicles, heavy carriage trucks and other road transport medium which occur on daily bases, material used by the road construction companies such as the soil type etc.

From Figs. 5, it shows that minor roads are besieged with a large number of potholes and cracks, followed by minor roads. However, the reasons for this may be attributed to the type of construction firm, compartment of the underlaid soil before putting asphalt, poor drainage system, low-quality material during construction and failure to repair the road at the specified period.

Table 4 showed that most of the major roads are very fair in condition, Sango-Housing minor road; Housing R/about to Oshuntokun Avenue, Mechanic-Samonda road and The Polytechnic Road is in fair condition while Agbowo, Agbaje, Ijokodo and Apete minor road is in bad condition and requires urgent attention by the state and local road maintenance agency in charge of road construction/renovation. The result generally showed that none of the major and minor roads in the study area portrays good road quality. A good road is a road which meets its best purpose and what makes a good road are; long life span without requiring major repairs, no potholes, reflective cracking, smooth movement of vehicles, save during winter, solid foundation during reconstruction, water resistance, compaction of soils well, best soil use, investment protection etc.

### 3.2 Identification of Features along the Major Roads

Right of way according to Paul [45] is a type of easement granted or reserved over the land for transportation purpose which can be for a highway, public footpath, railway, canal, as well as electrical transmission lines, oil and gas pipelines. Features such as buildings, filling stations, relaxation Centre's etc. along the major roads were observed and recorded. A larger percentage of the features is very close to the roadside which indicates that rules and regulation governing the right of way are not observed. 145 features were observed. The Table 5 describes the different features and their distance to the road.

From Table 5, the minimum and maximum distance observed from the Centre of the road to the features ranges from 0.62-30.45 m. Since the distance of features to the Centre of the road either to the left or right of the road is30 m (98.42 ft) and that of the study area is 30 m, then it showed that only one (First Bank) beside The Polytechnic Ibadan was within the specified

**Table 3. Locations of potholes and cracks on a major and minor road of the study area**

| S/N | Road name | Road type | No. of potholes | No of cracks |
|---|---|---|---|---|
| 1 | Ojoo/University of Ibadan-Sango | Major Road | 16 | 4 |
| 2 | Sango-Mokola | Major Road | 11 | 1 |
| 3 | Sango-Eleyele | Major Road | 6 | 4 |
| 4 | University of Ibadan-Bodija | Major Road | 4 | 4 |
| 5 | Agbowo Road | Minor Road | 5 | 2 |
| 6 | Agbaje Road | Minor Road | 6 | 1 |
| 7 | Apete road | Minor Road | 8 | 1 |
| 8 | Polytechnic Road | Minor Road | 4 | 2 |
| 9 | Samonda/Mech. Road | Minor Road | 7 | 3 |
| 10 | Ijokodo Road | Minor Road | 7 | 3 |
| 11 | Sango-Awolowo/Housing Road | Minor Road | 4 | 2 |
| 12 | Housing R/about-Oshuntokun Ave. | Minor Road | 3 | 2 |
| Total | | | 81 | 29 |

distance while others are not within the specification of right of ways. with a distance of 30.45 m. The reason for the encroachment was as a result that all these major roads are single lane before and some of the features already exist before the road was later converted to double lane to ease the constant occurrence of traffic delay along the four major routes.

### 3.3 Potholes and Cracks along the Major and Minor Roads

Pavement deterioration and degradation arise as a result of many factors such as lack of proper design, poor road surface drainage, heavy truck/vehicle overloading, seepage, improper road maintenance [46]. He further stated that these factors mentioned could be adverse affects the traffic flow. Highways and road maintenance is a way of preserving and keeping different categories of the roadway, roadside and structures as closely as possible in its original condition as constructed or as later improved the way of making use of highway and road facilities and services to ease transportation process [47]. There are various highway and road maintenance functions which are drainage and roadside maintenance, bridges constructed maintenance, traffic service and road surface maintenance leading to potholes and cracks. Potholes are caused by the gradual formation of cracks along the road. Potholes are bowl-shaped depression varying sizes in the pavement surface having sharp edges and mostly occur on road with a thin surface course [46]. Cracks are formed by many factors such as water accumulation on the road, oil spill, stripping, drying shrinkage etc. [46]. Table 6 described the spatial location values (x, y) coordinates, length, depth and width of the major and minor roads in the study area.

From the Table 6, the minimum and maximum length and depth of pothole range from 0.04-1.64 m, 0.05-0.89 m and crack minimum and maximum length and width range 0.17-0.88 m, 0.20-0.82 m which implies that the road is the fair condition. Therefore, all the affected areas should be renovated to avoid expansion of the affected parts.

Fig. 7 showed multiple buffering rings of 15m interval and buffering features within and beyond the specified right of way along the route of the study area. The area with purple accent colour shows those features within 45m right of way, the area with colour olive green are the features within 30 m right of way while the area with an orange accent colour is the features that are within 15 m distance.

### 3.4 Analysis of Multiple Ring Buffering

The features along the major roads were buffered regarding the specified right of way which is 30 m (98.42 ft) standard distance from the Centre of the road. From the result in Fig. 7, it showed clearly that at 45 m distance, 92% of

**Table 4. Roads of the study area and their conditions (Good, very fair, fair, bad)**

| Location | Road type | Condition | Total numbers of road |
|---|---|---|---|
| Ojoo/University of Ibadan-Sango to and fro.<br>University of Ibadan Junction to Bodija to and fro.<br>Sango-Mokola to and fro.<br>Sango-Eleyele to and fro. | Major Roads | Very fair | 4 |
| None | Major Roads | Good | 0 |
| None | Minor Roads | Good | 0 |
| Sango/Awolowo-Housing Road<br>Housing R/about to Oshuntokun Ave<br>Mechanic Road-Samonda<br>The Polytechnic Ibadan Road | Minor Roads | Fair | 4 |
| Agbowo Road<br>Agbaje Road<br>Ijokodo Road<br>Apete Road | Minor Roads | Bad | 4 |

**Table 5. Distance between roads and the features within the study area**

| Features right of way along Ojoo/University of Ibadan road-Sango | | | |
|---|---|---|---|
| **Features identify** | **Distance to road(m)** | **Features identify** | **Distance to road (m)** |
| Fat oil fueling station | 1.70 | Uncompleted building | 5.80 |
| Bukky eleja | 11.30 | Keto fillling station | 4.40 |
| Lailad fueling station | 1.65 | Shopping complex | 14.00 |
| C L J event place | 9.45 | Police station | 3.05 |
| Total fueling station | 2.84 | Police station | 4.04 |
| Ventura shopping mall | 3.60 | Shops | 6.00 |
| N B C building | 1.25 | Shops | 4.15 |
| Aerodrome entrance | 9.30 | Alleluyah filling station | 2.04 |
| Samanda | 2.70 | Alleluyah hotel | 1.01 |
| Samanda | 3.25 | Alleluyah bar | 6.48 |
| Furniture point | 2.37 | Car dealer office | 3.90 |
| Car wash | 2.95 | Expoyo main gate | 28.05 |
| Total fueling station | 3.50 | Scripture union | 19.60 |
| Agbowo complex | 5.50 | CBN centre | 21.35 |
| Agbowo complex | 2.40 | Wall fence | 4.07 |
| F c m b bank | 2.80 | Redeemed church | 19.35 |
| Shopping complex | 6.00 | MFM church | 3.10 |
| Mobile fueling station | 4.45 | ADC building | 3.10 |
| Richbam tower | 3.90 | Restaurant | 5.70 |
| Completed building | 5.00 | Mobile filling station | 3.40 |
| Completed building | 6.95 | Wall fence | 6.75 |
| Sabsons fueling station | 2.30 | Immanuel college | 9.30 |
| Stanbic bank | 4.53 | Wall fence | 12.00 |
| Ikeolu shopping complex | 4.83 | Havannal hall | 12.00 |
| Uncompleted building | 5.80 | Main stream bank | 9.05 |
| **Features right of way along Sango-Mokola road** | | | |
| **Features identify** | **Distance to road (m)** | **Features identify** | **Distance to road (m)** |
| Zenith bank | 4.30 | Shopping complex | 3.00 |
| Vita foam | 3.50 | Water cooperation | 2.05 |
| ADC party house | 2.58 | St. Bridget covenant | 5.20 |
| Canteen | 3.00 | St. Gabriel church | 5.20 |

| | | | |
|---|---|---|---|
| Shops | 2.50 | PHCN office | 5.00 |
| Gastab fueling station | 3.00 | Oando filling station | 2.90 |
| Master furniture building | 5.20 | Alafia primary school | 4.00 |
| Etisalat customer centre | 3.90 | Vetenary hospital | 4.50 |
| Beer parlor | 4.10 | Shopping complex | 3.28 |
| Redeemed church | 3.25 | Badejoko hospital | 3.01 |
| Shopping complex | 3.27 | City royal motor park | 3.50 |
| Primary education board | 10.45 | Feed well | 0.62 |
| Modern school | 6.60 | GTB bank | 3.00 |
| Bethel hospital | 3.50 | Tejuoso complex | 2.50 |
| Providence court | 3.55 | Shopping complex | 5.28 |
| Cocacola depot | 5.50 | M.R.S | 3.00 |
| Goshen event centre | 2.10 | Shops | 3.00 |
| Completed building | 2.50 | Oando | 5.00 |
| Shops | 1.65 | Carlcare centre | 8.90 |
| Army barrack | 8.40 | Cementary | 3.20 |
| Shops | 1.25 | C.A.C church | 7.02 |
| Shopping complex | 3.00 | Wema bank | 3.09 |
| Shopping complex | 4.50 | Sango market | 6.02 |
| GTB bank | 3.00 | | |

**Features right of way along Sango-Eleyele road**

| **Features identify** | **Distance to road (m)** | **Features identify** | **Distance to road (m)** |
|---|---|---|---|
| Total fueling station | 3.70 | Ansa-rudeen sch | 12.00 |
| Living spring | 2.85 | Filling station | 8.10 |
| Merry bet building | 3.45 | Reliance building | 12.00 |
| Gastab fueling station | 2.90 | Oshiokoya building | 9.60 |
| Building | 4.95 | Emperor station | 1.50 |
| Shop | 3.15 | Ascon station | 4.00 |
| Ennies Nurs and pri sch | 3.53 | Forsquare church | 15.00 |
| Intercontinental bank | 2.12 | Advocate filling station | 7.20 |
| Spac church | 9.90 | Heritage bank | 3.10 |
| Biskan garden heritage | 2.40 | Fataj oil | 3.90 |
| Stationary | 1.60 | Powa shop | 4.70 |
| Mr Biggs | 4.15 | Barracks shop | 1.50 |
| Nipco fueling station | 2.21 | Anglican church | 5.17 |

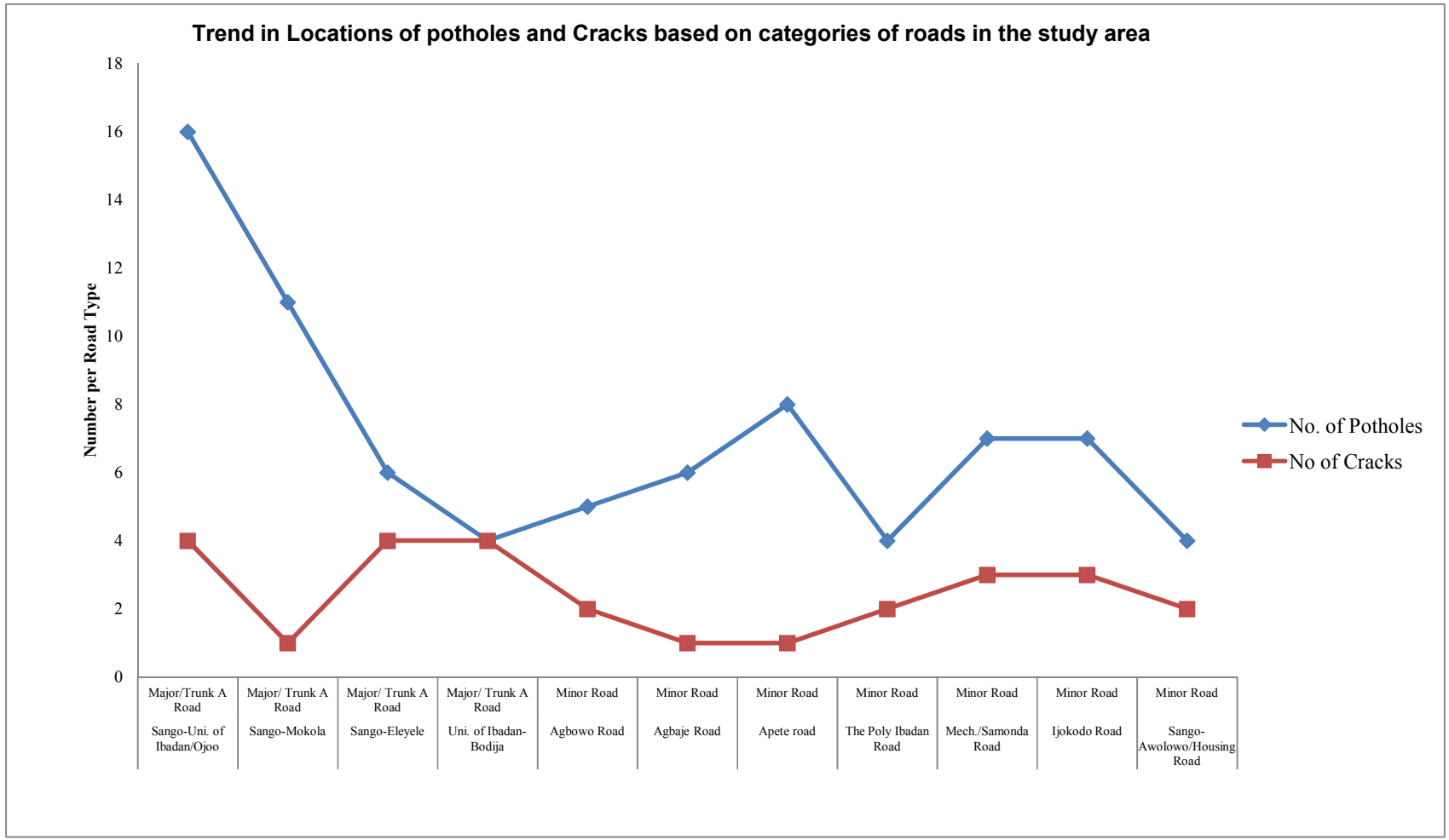
| | | | |
|---|---|---|---|
| Psalmist Christian centre | 10.85 | First bank | 30.45 |
| Shops | 4.00 | Conoil | 1.37 |
| Uncompleted building | 8.45 | Poly fence | 12.73 |
| Academy/concept building | 4.45 | Tafo arena | 20.60 |
| Hill top hotel | 4.10 | Okanlawon plaza | 11.00 |
| C.A.C church | 12.45 | Cinnati pharmacy & store | 4.89 |
| Sioa plaza | 3.75 | Redeemed church | 11.00 |
| Sugar house hotel | 3.30 | St david church | 10.28 |
| Total fueling station | 6.15 | Gbaremu shop | 4.79 |
| Gbaremu market | 7.41 | St rita's catholic church | 10.96 |
| Daplan event centre | 9.45 | NMPC | 7.40 |

**Table 6. Spatial coordinate X, Y, length and width of potholes, cracks on major roads**

| X coordinate (m) | Y coordinate (m) | Length (m) | Depth (m) | X coordinate(m) | Y coordinate (m) | Length (m) | Depth (m) |
|---|---|---|---|---|---|---|---|
| 599185.142 | 820684.266 | 1.05 | 0.20 | 599930.871 | 821393.007 | 0.06 | 0.30 |
| **Potholes along Sango-University of Ibadan/Ojoo major road** | | | | | | | |
| 599206.573 | 820713.635 | 0.82 | 0.25 | 600045.727 | 821708.246 | 1.04 | 0.10 |
| 599351.036 | 820902.389 | 1.33 | 0.44 | 600124.309 | 821933.512 | 1.02 | 0.60 |
| 599529.312 | 821157.581 | 0.20 | 0.53 | 600072.715 | 822631.498 | 0.23 | 0.56 |
| 599563.840 | 821196.474 | 1.00 | 0.05 | 600072.717 | 823076.951 | 0.61 | 0.47 |
| 599687.983 | 821275.730 | 1.52 | 0.28 | 600065.968 | 823822.403 | 0.35 | 0.10 |
| 599709.018 | 821286.446 | 1.00 | 0.80 | 600144.549 | 824363.424 | 0.48 | 0.71 |
| 599785.218 | 821311.052 | 0.04 | 0.60 | 600586.986 | 824910.914 | 0.55 | 0.66 |
| **Potholes along Sango-Eleyele major road** | | | | | | | |
| 599534.507 | 821183.986 | 0.72 | 0.45 | 595459.950 | 820224.690 | 0.31 | 0.09 |
| 599108.362 | 820700.954 | 0.10 | 0.30 | 595396.902 | 820287.653 | 1.00 | 0.30 |
| 597779.123 | 821031.689 | 0.61 | 0.35 | 595343.144 | 820329.205 | 1.10 | 0.35 |
| **Potholes along Sango-Mokola major road** | | | | | | | |
| 599000.214 | 820313.448 | 0.35 | 0.52 | 598208.190 | 818528.880 | 1.02 | 0.13 |
| 598671.443 | 819471.907 | 0.20 | 0.35 | 598220.451 | 818519.220 | 1.60 | 0.44 |
| 598530.684 | 819378.774 | 0.80 | 0.80 | 598228.033 | 818500.106 | 1.01 | 0.28 |
| 598350.723 | 819228.490 | 1.45 | 0.12 | 598234.010 | 818482.509 | 0.10 | 0.49 |
| 598146.733 | 818747.371 | 1.20 | 0.42 | 598234.341 | 818446.791 | 0.41 | 0.50 |
| 598211.827 | 818546.078 | 1.40 | 0.70 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Potholes along University of Ibadan-Bodija major road** | | | | | | | |
| 600298.670 | 822309.476 | 0.65 | 0.55 | 600682.358 | 821410.102 | 0.77 | 0.44 |
| 600653.397 | 821750.644 | 0.47 | 0.39 | 600446.878 | 820382.802 | 0.62 | 0.36 |
| **Potholes along Agbaje minor road** | | | | | | | |
| 596945.184 | 821064.661 | 0.54 | 0.84 | 596703.746 | 821155.155 | 0.71 | 0.78 |
| 596890.832 | 821069.435 | 0.65 | 0.67 | 596593.681 | 821205.835 | 0.49 | 0.45 |
| 596793.916 | 821109.286 | 0.62 | 0.88 | 596375.975 | 821227.753 | 0.69 | 0.52 |
| **Potholes along Apete minor road** | | | | | | | |
| 596560.700 | 823450.830 | 0.55 | 0.56 | 595803.270 | 823510.690 | 0.66 | 0.28 |
| 596252.920 | 823538.350 | 1.64 | 0.88 | 595594.250 | 823468.470 | 0.58 | 0.46 |
| 596198.020 | 823554.250 | 0.76 | 0.71 | 595355.430 | 823458.670 | 0.48 | 0.40 |
| 596098.780 | 823582.910 | 1.37 | 0.89 | | | | |
| **Potholes along Mechanic-Samonda minor road** | | | | | | | |
| 598833.531 | 821169.588 | 0.30 | 0.54 | 599238.252 | 821591.386 | 0.56 | 0.44 |
| 598842.130 | 821196.046 | 0.52 | 0.76 | 599523.080 | 821637.273 | 0.48 | 0.56 |
| 598826.447 | 821342.689 | 0.82 | 0.58 | 599634.373 | 821769.473 | 0.71 | 0.49 |
| 598859.515 | 821533.002 | 0.44 | 0.62 | | | | |
| **Potholes along Ijokodo minor road** | | | | | | | |
| 597402.597 | 821035.049 | 0.81 | 0.35 | 596973.033 | 821304.134 | 0.74 | 0.61 |
| 597180.423 | 821049.240 | 0.66 | 0.52 | 596911.733 | 821501.951 | 0.68 | 0.52 |
| 597052.761 | 821061.740 | 0.58 | 0.28 | 597075.952 | 821785.320 | 0.41 | 0.21 |
| 596994.147 | 821151.939 | 0.49 | 0.55 | | | | |
| **Potholes along Awolowo-Housing minor road** | | | | | | | |
| 599230.657 | 820110.991 | 0.47 | 0.36 | 599968.624 | 820589.814 | 0.47 | 0.47 |
| 599272.250 | 820094.163 | 0.38 | 0.46 | 600211.001 | 820664.232 | 0.55 | 0.62 |
| 599762.191 | 819912.765 | 0.71 | 0.29 | 599315.271 | 820080.035 | 0.36 | 0.22 |
| 599687.088 | 820388.328 | 0.56 | 0.36 | | | | |
| **Potholes along Agbowo minor road** | | | | | | | |
| 600161.651 | 822638.233 | 0.44 | 0.35 | 600471.654 | 822730.353 | 0.37 | 0.58 |
| 600254.521 | 822674.773 | 0.64 | 0.61 | 600548.085 | 822791.300 | 0.44 | 0.38 |
| 600443.676 | 822727.555 | 0.52 | 0.52 | | | | |
| **Potholes along the polytechnic Ibadan** | | | | | | | |
| 598567.865 | 821311..048 | 0.66 | 0.55 | 598162.374 | 821774.276 | 0.47 | 0.58 |
| 598545.377 | 821440.234 | 0.82 | 0.49 | 597639.338 | 822163.873 | 0.74 | 0.77 |

| X Coordinate(m) | Y Coordinate(m) | Length(m) | Width (m) | X Coordinate(m) | Y Coordinate (m) | Length (m) | Width (m) |
|---|---|---|---|---|---|---|---|
| **Cracks along Sango-University of Ibadan/Ojoo major road** | | | | | | | |
| 600065.692 | 822759.766 | 0.22 | 0.35 | 599994.890 | 821526.049 | 0.61 | 0.45 |
| 600332.710 | 824639.721 | 0.40 | 0.32 | 599843.718 | 821346.812 | 0.51 | 0.19 |
| **Cracks along Sango-Eleyele major road** | | | | | | | |
| 595290.414 | 820385.631 | 0.44 | 0.82 | 597396.895 | 820888.810 | 0.17 | 0.55 |
| 595668.968 | 820116.565 | 0.56 | 0.26 | 598726.782 | 821080.011 | 0.23 | 0.63 |
| **Cracks along Sango-Mokola road** | | | | | | | |
| 598607.159 | 819428.101 | 0.50 | 0.25 | 598733.342 | 819623.159 | 0.62 | 0.47 |
| **Cracks along University of Ibadan-Bodija major road** | | | | | | | |
| 600375.023 | 822161.987 | 0.63 | 0.54 | 600392.777 | 821027.717 | 0.80 | 0.66 |
| 600601.763 | 821828.036 | 0.44 | 0.47 | 600475.416 | 820248.050 | 0.63 | 0.42 |
| **Cracks along Agbaje minor road** | | | | | | | |
| 596479.354 | 821229.556 | 0.63 | 0.81 | | | | |
| **Cracks Along Apete Minor Road** | | | | | | | |
| 595937.310 | 823566.310 | 0.69 | 1.20 | 595121.900 | 823437.870 | 0.65 | 0.44 |
| **Cracks along Mechanic-Samonda minor road** | | | | | | | |
| 599005.949 | 821552.769 | 0.56 | 0.51 | 599398.328 | 821617.434 | 0.43 | 0.35 |
| 599756.115 | 821784.696 | 0.62 | 0.70 | | | | |
| **Cracks along Ijokodo minor road** | | | | | | | |
| 596950.622 | 821370.171 | 0.55 | 0.32 | 596780.657 | 822654.616 | 0.70 | 0.64 |
| 597108.492 | 822098.696 | 0.64 | 0.41 | | | | |
| **Cracks along Awolowo-Housing minor road** | | | | | | | |
| 599073.327 | 820160.270 | 0.77 | 0.45 | 599619.577 | 820294.227 | 0.42 | 0.63 |
| 599637.896 | 819973.810 | 0.50 | 0.34 | 600052.632 | 820627.781 | 0.56 | 0.29 |
| **Cracks along Agbowo minor road** | | | | | | | |
| 600316.844 | 822688.795 | 0.44 | 0.39 | 600589.989 | 822737.170 | 0.57 | 0.66 |
| **Cracks along the polytechnic Ibadan minor road** | | | | | | | |
| 598538.885 | 821477.529 | 0.88 | 0.48 | 597892.919 | 821958.961 | 0.60 | 0.69 |


Trend in Locations of potholes and Cracks based on categories of roads in the study area
Number per Road Type
18
16
14
12
10
8
6
4
2
0
No. of Potholes
No of Cracks
Major/Trunk A Road
Sango-Uni. of Ibadan/Ojoo
Major/ Trunk A Road
Sango-Mokola
Major/ Trunk A Road
Sango-Eleyele
Major/ Trunk A Road
Uni. of Ibadan-Bodija
Minor Road
Agbowo Road
Minor Road
Agbaje Road
Minor Road
Apete road
Minor Road
The Poly Ibadan Road
Minor Road
Mech./Samonda Road
Minor Road
Ijokodo Road
Minor Road
Sango-Awolowo/Housing Road

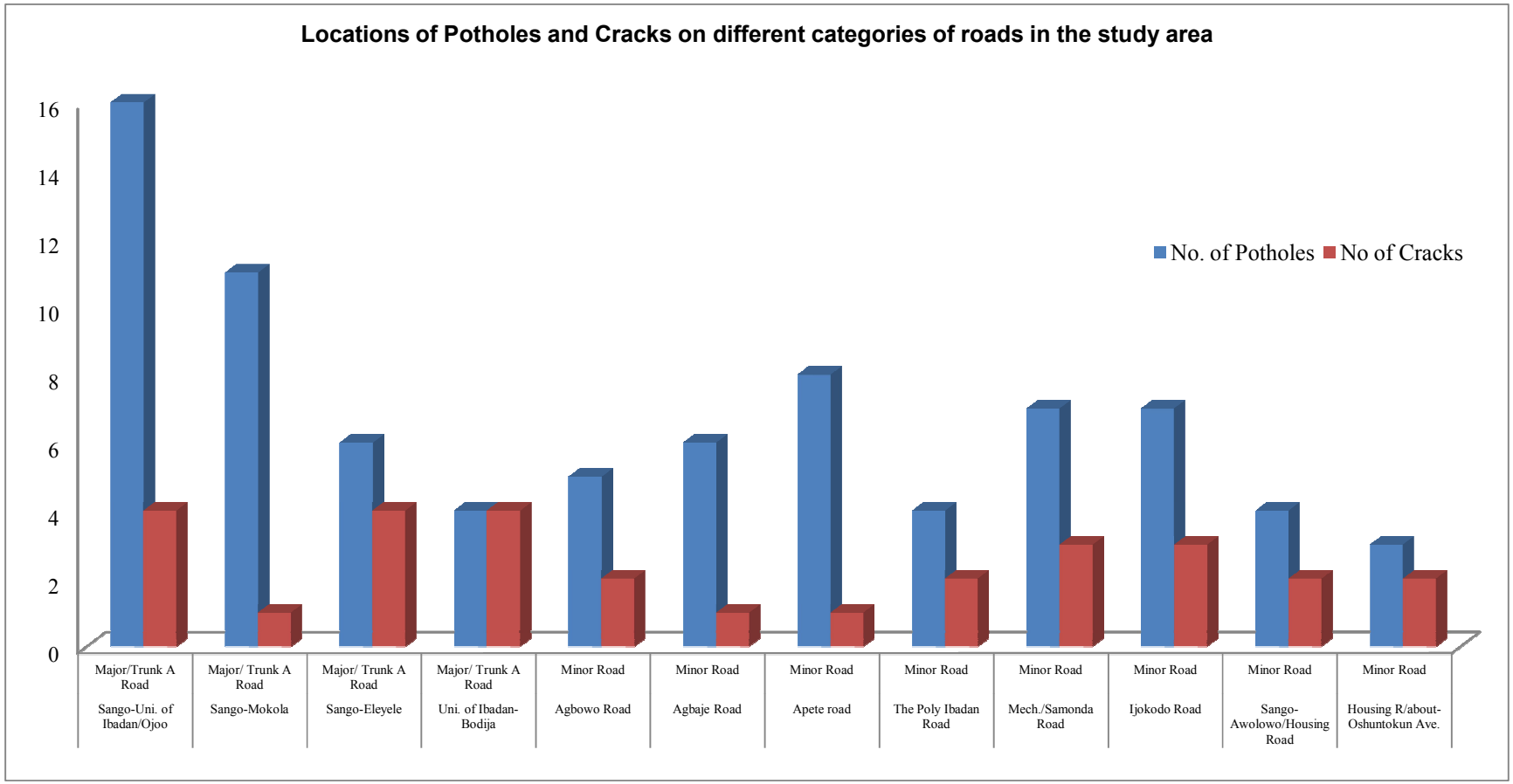



**Fig. 4. Location of potholes and cracks in the study area**

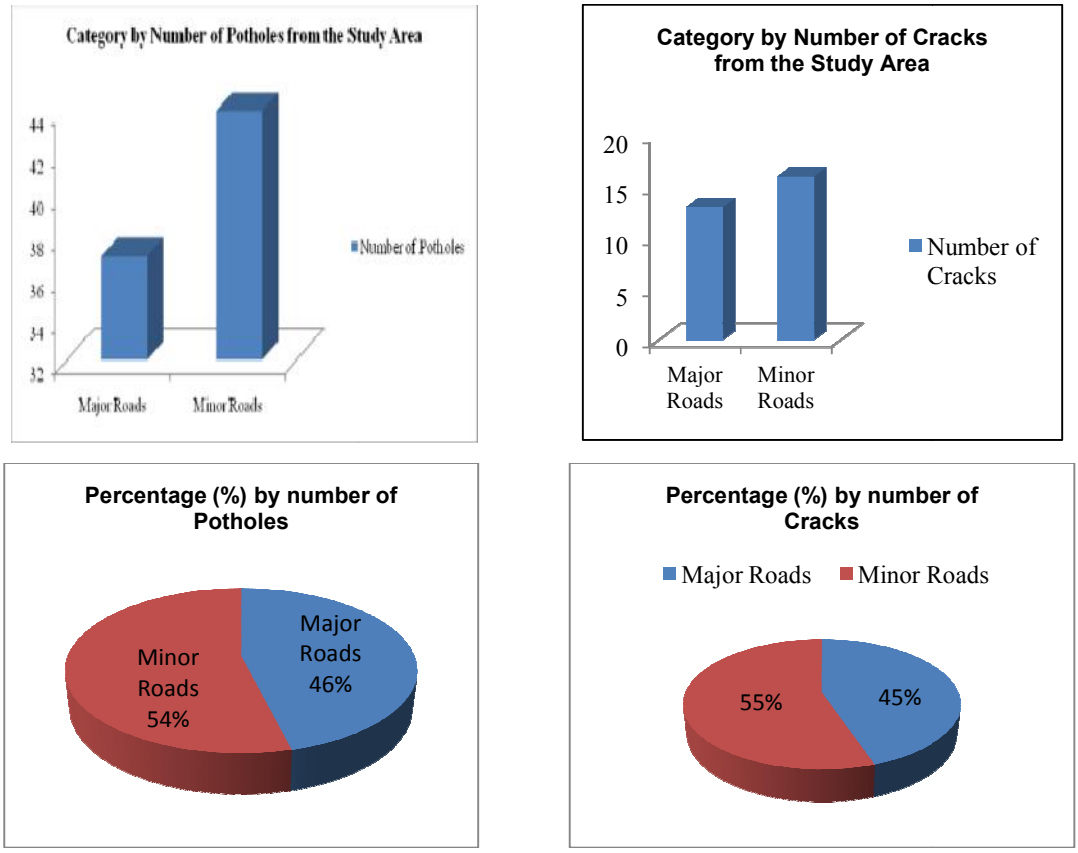



**Fig. 5. Shows different road classes and the percentage of potholes**

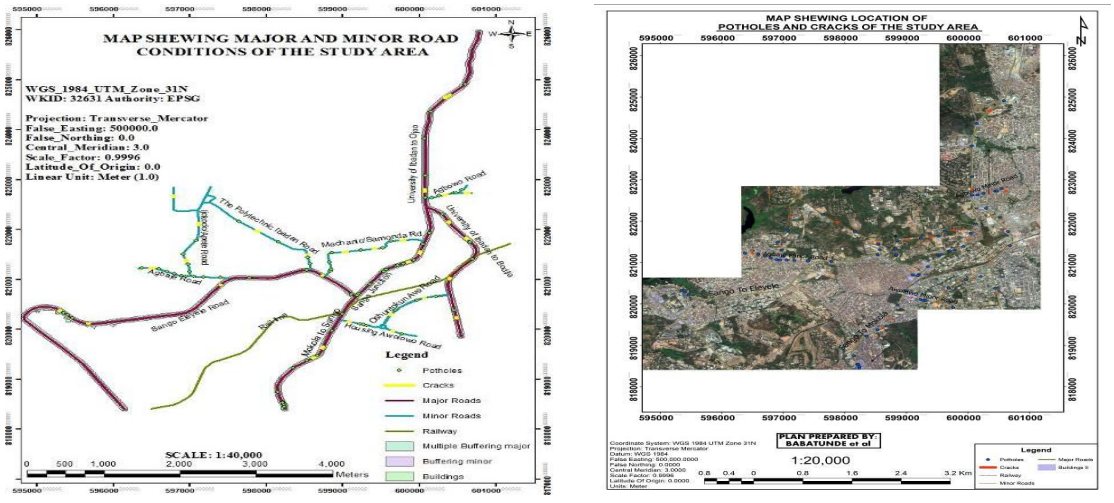
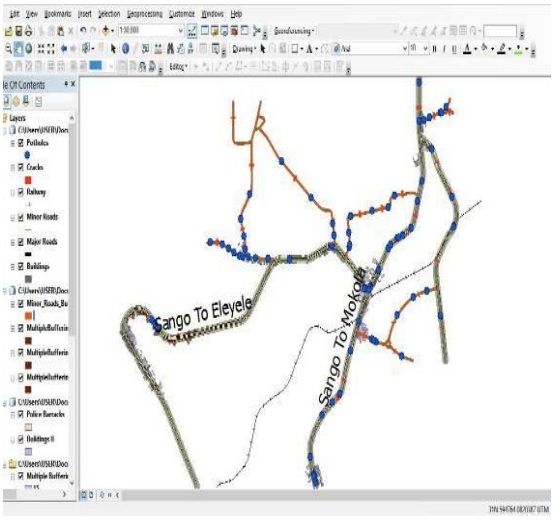
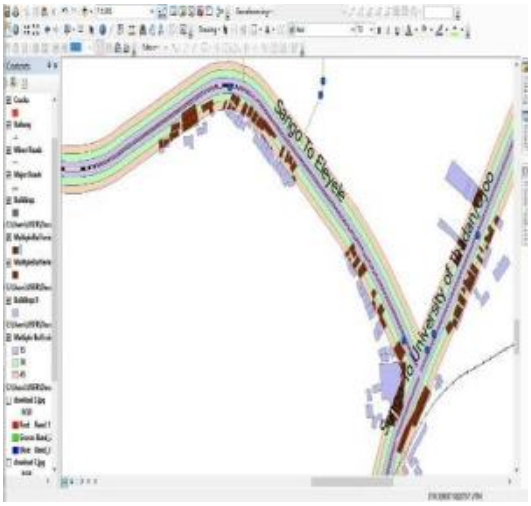
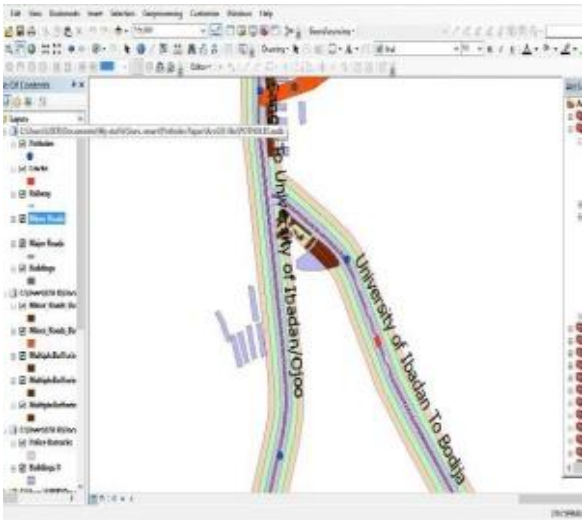


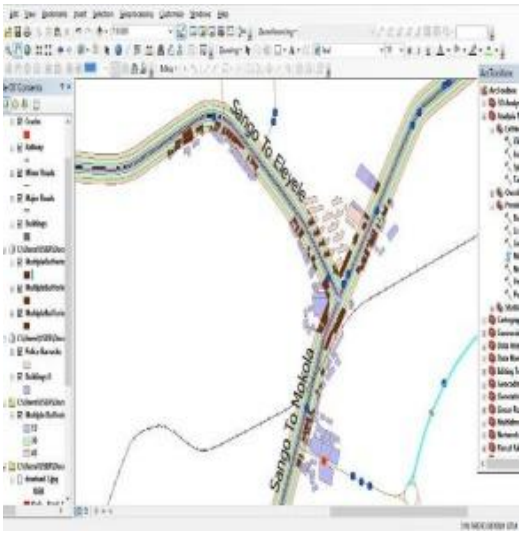

**Fig. 6. Plan showing location of potholes and cracks on major and minor roads**

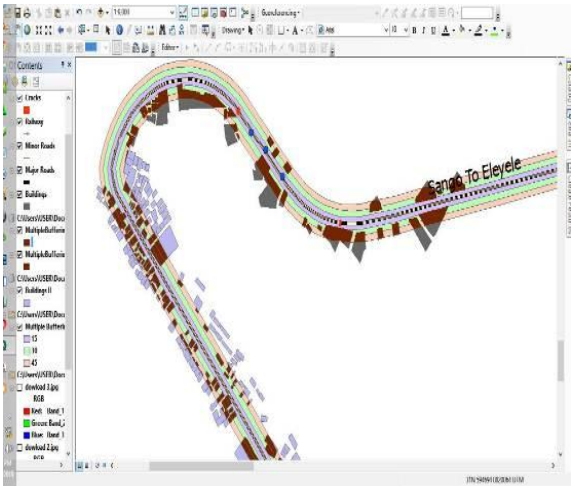
the features falls along the roads, at 30 m distance which is the required specification for the setback in oyo state, 85% of the features fall along the right of way and at 15 m distance about from the centre of the road, 95% of the features fall outside the specified right of way. From the result and analysis, it showed that the specified right of way is not strictly followed by individuals and corporate organizations which may lead to loss of life and properties within the study area.

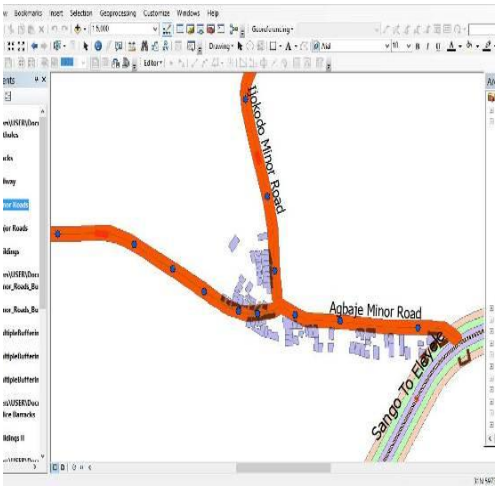

Sango To Eleyele
Sango To Mokola


Sango To Eleyele


University of Ibadan/Ojoo
University of Ibadan To Bodija


Sango To Eleyele
Sango To Mokola


Sango To Eleyele


Ilokodo Minor Road
Agbaje Minor Road
Sango To Eleyele

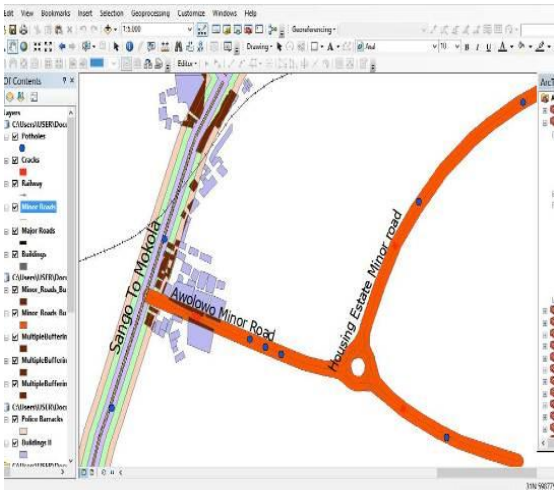



**Fig. 7. Multiple buffering of major and minor roads in the study area**

## 4. CONCLUSION

This study has examined the effectiveness and efficiency of the road system on major and minor roads in part of Ibadan metropolis, Oyo State, Nigeria using GIS application. The result from this study showed that 99% of features along the major route did not comply with the specification of the right of way and this was as a result that the features exist when all these major roads were in the single lane before converting them to two lanes. The effects of the potholes and cracks in the study area may be attributed to structural failure, standards/specifications and policy, traffic load and volume, properties and construction conditions, drainage system and groundwater, aggregate properties, alignment and geometry of road, flexible pavement layers thickness, and pavement width which is the same result of Tarawneh and Sarireh [48] while the causes of major and minor road failure may be factors such as poor design and construction, poor maintenance of already built highways, use of low quality materials in construction, poor workmanship and poor supervision of construction work and the applying of heavy traffic that were not meant for the road which is the result of Okigbo [49]. The results in this study will help the government to know features that are within and out of road specification as well as the location of defects points that are potholes and cracks and the necessary action to take on them. The Oyo State and local government road maintenance agency should go on constant monitoring to know the affected area that requires renovation in the study area as well as the entire parts of the metropolis to prevent loss of life and properties. Penalty/fine should be placed on whoever disobeys the rule and regulation governing the right of way specification be it features or vehicle breakdown.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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