Original Research Article

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

ABSTRACT

Recently, there is a rapid development in road transportation network in the city of Ibadan. This arises due to the number of vehicle on the road that keeps increasing year by year. Improper maintenance of such roads will increase the possibility of danger to the road users if not properly maintained. Therefore in order to keep the road in safe condition, there must be adequate maintenance and proper monitoring. This study assesses the road conditions with the aim of analyzing the effectiveness and efficiency of the road network system of major roads connecting Ojoo/University of Ibadan-Sango, University of Ibadan-Bodija, Sango-Eleyele and Sango-Mokola route, while the minor roads connecting University of Ibadan-Agbowo, Sango-Housing/Awolowo, Sango/Eleyele-Mechanic/Samonda, The Polytechnic Ibadan, and Agbaje/Ijokodo/Apete road in Ibadan, Oyo State, Nigeria. The major objectives of the study is to locate and identify the road networks within the study area, evaluate the road conditions such as 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) instrument was used in acquiring (x, y) coordinate data and a steel tape was used for linear measurement of potholes and cracks. 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 to two lanes for easy passage and flow of vehicle in order to avoid constant traffic congestions. Therefore, proper monitoring should be done by State and local government agency in charge of road construction/maintenance in order to avoid 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 physical and economic development of towns and cities all over the world. Road tends to increase in areas with expanding transportation networks, and increase less rapidly in areas without such improvements. Rapid and continued rise in roads networks are 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 [3], 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 measure of traffic density and congestion rather than overall speed of the journey [5]. Road network consists of large number of interwoven roads exhibiting many patterns ranging from stars like to grid like with irregular patterns becoming recognized [6]. According to [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 [8].

Developments of various transportation modes have become pivotal to physical and economic developments. Such modes include human porterage, rail ways, 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 [10], [11]. Urban areas have tendency to develop at modal points in transport network and places with good road network. Urban location with such retrieve advantages are found where different transport routes converge with high degree of compactness, connectivity, density, length and accessibility exhibited within the intra-and inter-urban road networks as stated by [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 a number of 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 [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 monitored place as opined by [23]. Their (proposed) system makes use of the powerful functions of GIS to realize real-time monitoring and recording road conditions on 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 monitoring of transportation generally as stated by [24].

Therefore, there has been no information regarding road condition of major and minor roads in part of Ibadan metropolis especially the area under the study, Oyo State, Nigeria most importantly to show how efficient and effective the road network around the area is. Various agencies that are 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. So as a result of these challenges, there is need to create information about road network conditions and the actual position of each potholes and cracks to minimize the damages such road causes to road transportation means within the study area.

2. MATERIAL 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 market environment. It falls in the urban core area of Ibadan metropolis. It is located approximately between latitude 7^0 23' 4" N to 7^0 23' 35" N and longitude 3^0 55' 56" E to 3^0 56' 48" E. It consists of many infrastructural amenities such as; Banks, higher institution of learning, Filling stations, Motor parks/garages, Police station, restaurant etc.

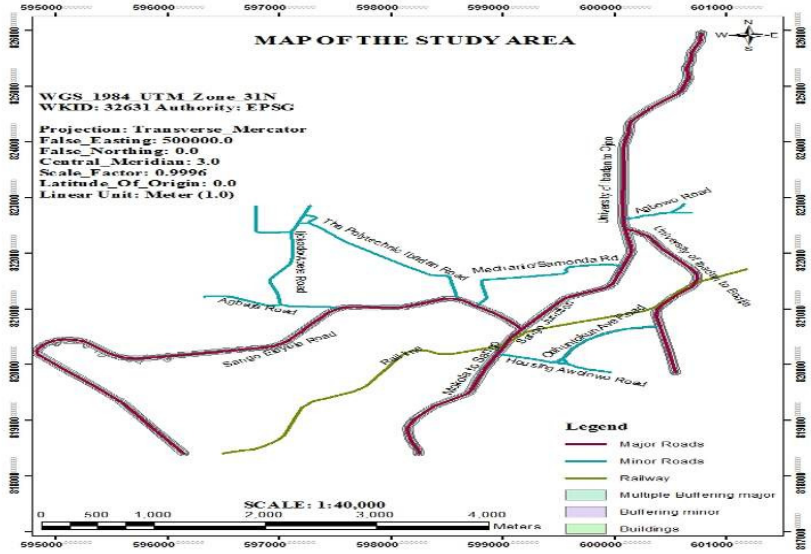


Fig. 1. Showing the Map of the Study Area.

2.2 Methods of Data Acquisition

Geographic location values (x, y) of points of road defects such as potholes and cracks of the major and minor routes of the study area were determined. Using the static mode of operation, a Hi-target differential Global positioning (DGPS) receiver was used to determine the spatial data (x, y) coordinates of each pothole and cracks along both the major and minor routes. The major routes consists of Ojoo/University of Ibadan-Sango, Sango/Eleyele, 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 base and the other as rover. The first one which was used as 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 [30]. [31] Have also worked on patches; however their method can't tell the difference between a patch and a pothole. [32] Utilized texture information for differentiating potholes from cracks.

[33] Did the same along with using shape information for detecting potholes in asphalt images. [34] Extended this work for detecting potholes in video data. [35] Worked one level deeper to measure the properties of potholes. 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 falls within the specified right of way and those that are out of specification. The steel tape was used in taking the width and length of each pothole. The minimum and maximum diameters of 0.50-9.50metres and length of 1.00m to 147.00metres was observed on the four major roads. 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 reconstructing the surface with the aid of multiple video cameras. The applicability of such a technique for the purpose of road reconstruction was experimented by [36] and [37].

Additionally, [38] and [39] used it in a study for enhancing a method for highway condition assessment. [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. The distance between pothole to pothole and crack to crack was determined using the coordinate x, y of potholes and cracks. Also the setback for each feature along the routes was recorded using steel tape. The width of the major road measured was 14metres with 7metres measured from the Centre of the road to the edge of the road on both sides respectively. 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 falls within the specified right of way and those that are out of specification of right of way. The specification for the right of way of major roads (Trunk A) from the Centre of the road is 45.72metres (150ft).

Table 1. Shows the (x, y and z) coordinate of the control point.

Point identify	Northing	Easting	Height
YZN 364	820651.379	599156.600	243.144

2.3 Specification Design

Setback, width for major and minor roads, potholes and cracks specifications are listed in the table below. The Federal highway specification is the same all over the country except those of major roads and minor roads differ in each state with a little difference in figure. A setback is the minimum distance which a building or other structures must be set back from a street, or road, river or other stream, 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 30m 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 24m, 18m, 15m, 12m that is 12m, 9m, 7.5m, 6m from the Centre of the road and that of rail line was a minimum distance of 21m between the property and the railway lines and 60m between property and unmanned railway crossing level [44]. For this study, (Table 2) described the specification used.

Table 2. Specification for Oyo State major and minor routes

S/N	Features	Type	Width in (metres)	Setback from the Centre of the road in (metres)
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

2.4 Data Processing

The acquired data was downloaded from the Hi-target DGPS receiver using (HGO) Hi-target Geomatics Office and the data was processed with the same software which convert it to rinex data. Also, Global Navigation Satellite System (GNSS) solution software was used to convert the rinex data to a coordinate system data fig 2 and 3.

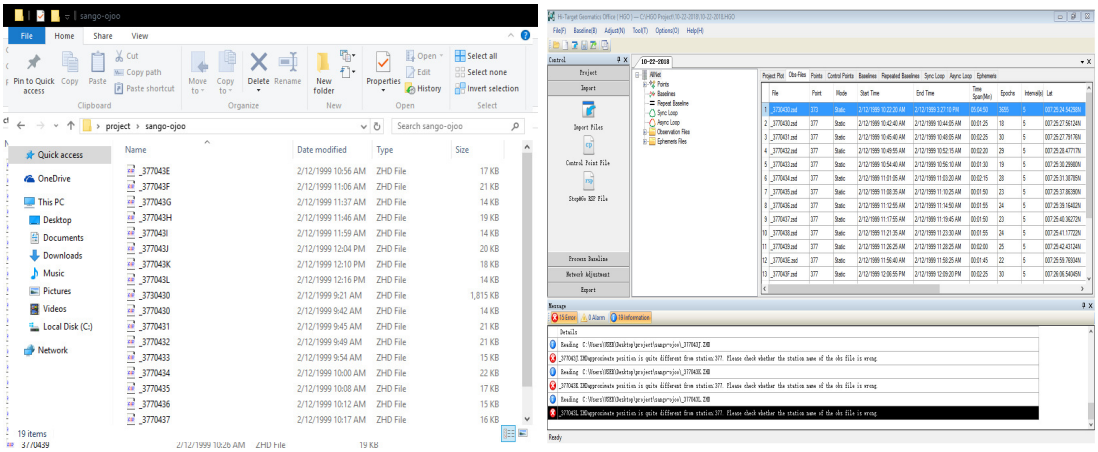


Fig. 2. Raw data downloaded from Hi-target DGPS receiver and Hi-target geomatics office (HGO) software used to convert to rinex data

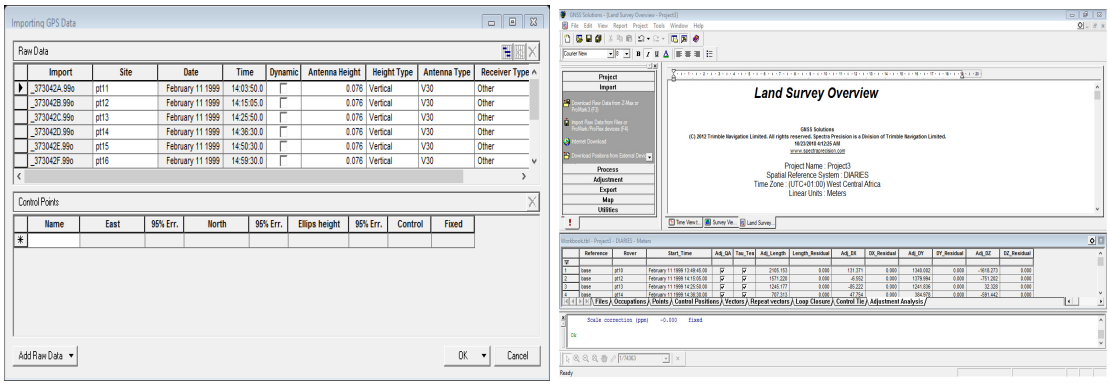


Fig. 3. Showing the GNSS solution displaying the rinex data and the control point space with the land survey overview report in coordinate format.

3. RESULTS AND DISCUSSION

The results and analysis in this study was as a result of field observations and measurements on the study area road conditions such as road defects resulted in potholes and cracks and features such as potholes, cracks and building setback. 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 which fall into different categories of road type, that is, some were collected on the highway road, some on the main road and some on the minor road. Fig. 4 below described the relationship between roads and features within the study area. The table below describes further the analyses of the field work of the study area. The total length of the major roads from Ojoo/University-Sango-Mokola was 8.425kilometres in which Ojoo-University/Bodija Junction covers 3.742km, University of Ibadan-Sango Junction covers 2.117km, Sango-Mokola covers 2.567km. Sango-Eleyele covers 5.037km and University of Ibadan to Bodija covers 2.946km. For the minor roads, the distance from University of Ibadan to Agbowo road clipped was 508.761m, Sango to Housing road was 1.713km, Housing Rounabout to Oshuntokun Avenue Bodija was 1.149km, Mechanic–Samonda was 1.726km, The Polytechnic Ibadan road covers 2.014km, Sango Eleyele road to Agbaje cover 458.371m, Sango Eleyele to Apete covers 1.050km and Sango Eleyele to Ijokodo covers 2.502km.

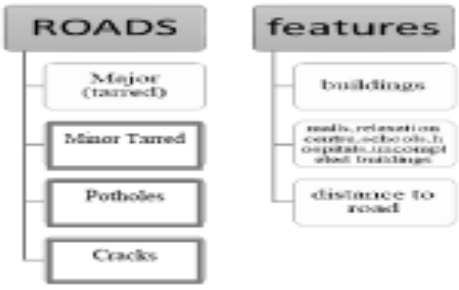


Fig. 4. Showing the relationship between roads and features within the study area.

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 below described the locations, the road types and the number of defects types

Table 3. Showing the locations of potholes and cracks on major and minor road of the study area

S/N	Road Name	Road Type	No. of Pothole	No of Cracks
1	Ojoo/University of Ibadan-Sango	Major/Trunk A Road	16	4
2	Sango-Mokola	Major/ Trunk A Road	11	1
3	Sango-Eleyele	Major/ Trunk A Road	6	4
4	University of Ibadan-Bodija	Major/ Trunk A 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**

From the table 3 above, 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 and can also be attributed to the material used by the road construction companies such as the soil type, road alignment/level etc.

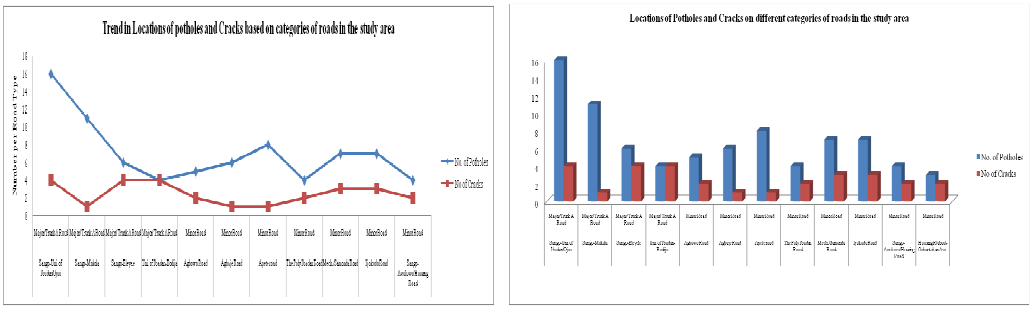
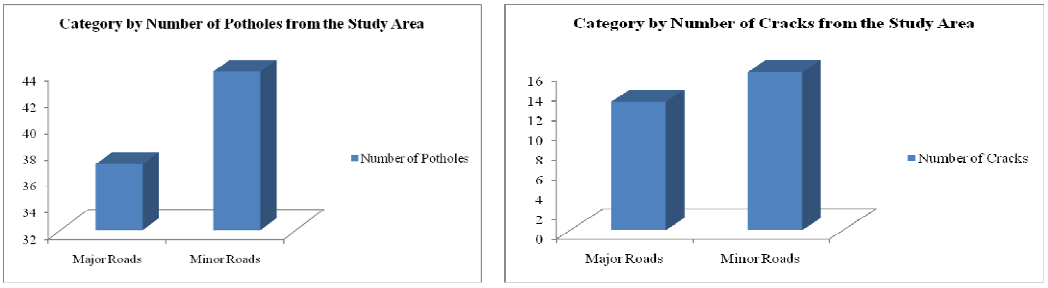


Fig. 5. Location of Potholes and Cracks in the study area



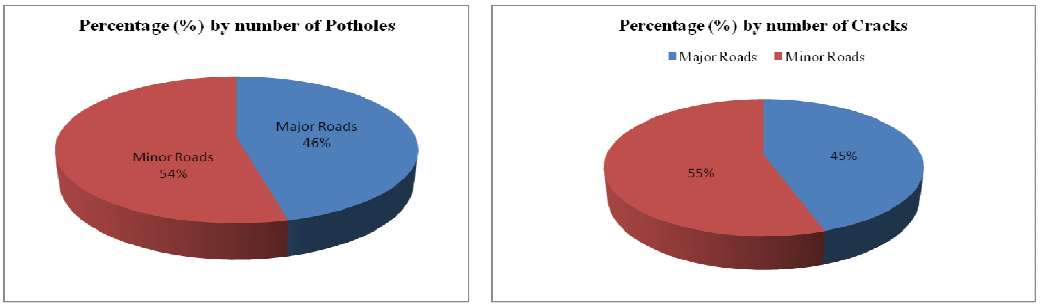


Fig 6. Shows different road classes and percentage of potholes.

From figures 6 above, it shows that minor roads is besieged with large number of potholes and cracks, follow by minor roads. However, the reasons for this may be attributed to the type of construction firm, compartment of the under laid soil before putting asphalt, poor drainage system, low quality material during construction and failure to repair the road at specified period of time.

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

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

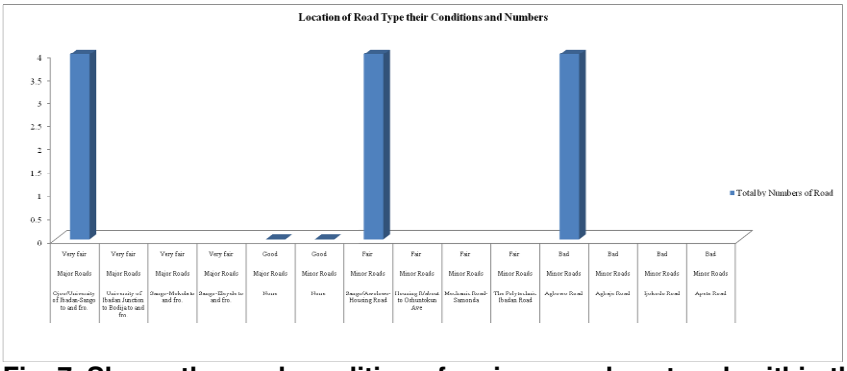


Fig. 7. Shows the road condition of various roads network within the study area.

Fig. 7 above showed that most of the major roads are very fair in condition i.e. Ojoo/University-Sango road, University of Ibadan to Bodija road, Sango-Mokola road, and Eleyele Sango road. 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 road maintenance agency as well as the local government authority in charge of road construction/renovation. The result generally showed that none of the major and minor roads in the study area are of good quality. A good road is road which meets its best purpose and what makes a good road are; long life span without requiring major repairs, no potholes, bumps, reflective cracking, smooth movement of vehicles, save during winter, solid foundation during reconstruction, water resistance, compactment of soils well, best soil use, investment protection, keeping good record, road design for traffic loads and volumes etc.

3.2 Identification of Features Along the Major Roads

Right of way according to [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. Larger percentage of the features is very close to the road side which indicates that rules and regulation governing right of way are not observed. The distance of the features from the road side are observed and recorded. One hundred and forty-five (145) features were observed. The table below describes the different features and their distance to road.

Table 5. Shows the 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 in (metres)**	**Features Identify**	**Distance to Road in (metres)**
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 in (metres)**	**Features Identify**	**Distance to Road in (metres)**
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 in (metres)**	**Features Identify**	**Distance to Road in (metres)**
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

From the table 5 above, it shows that none of the feature was within the specified distance therefore; none of them observe the specification of right of ways. The minimum and maximum distance observed from the Centre of the road to the features ranges from 0.62-30.45m. Since the distance of features to the Centre of the road either to the left of right of the road is 45.27m (150ft) and that of the study area is 30m, then it showed that and only one comply with the specification with a distance of 30.45m. 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 so as to ease the constant occurrence of traffic delay along the three major routes.

3.3 Potholes and Cracks Along the Major and Minor Roads

Pavement deterioration and degradation arises 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 adversely affects the traffic flow. Highways and road maintenance is a way of preserving and keeping different categories of roadway, road side 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 road side maintenance, bridges constructed maintenance, traffic service and road surface maintenance leading to potholes and cracks. Potholes are caused by 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 thin surface course [46]. Cracks are formed by many factors such as water accumulation on road, oil spill, stripping, drying shrinkage etc. [46]. Table 6 below described the spatial location values (x, y) coordinates, length and width of the major and minor roads in the study area.

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

Potholes Along Sango-University of Ibadan/Ojoo Major road							
X Coordinate(m)	**Y Coordinate(m)**	**Length (m)**	**Width (m)**	**X Coordinate(m)**	**Y Coordinate (m)**	**Length (m)**	**Width (m)**
599185.142	820684.266	1.05	0.20	599930.871	821393.007	0.06	0.30
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
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
Potholes Along Sango-Eleyele Major road							
X Coordinate(m)	**Y Coordinate(m)**	**Length (m)**	**Width (m)**	**X Coordinate(m)**	**Y Coordinate (m)**	**Length (m)**	**Width (m)**
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
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
Potholes Along Sango-Mokola Major road							
X Coordinate(m)	**Y Coordinate(m)**	**Length (m)**	**Width (m)**	**X Coordinate(m)**	**Y Coordinate(m)**	**Length (m)**	**Width (m)**
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				
Cracks Along Sango-Mokola Road							
598607.159	819428.101	0.50	0.25	598733.342	819623.159	0.62	0.47
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
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
Potholes Along Agbaje Minor Road							
596945.184	821064.661	0.54	0.84	596593.681	821205.835	0.49	0.45
596890.832	821069.435	0.65	0.67	596375.975	821227.753	0.69	0.52
596793.916	821109.286	0.62	0.88	**Cracks Along Agbaje Minor Road**			
596703.746	821155.155	0.71	0.78	596479.354	821229.556	0.63	0.81

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	**Cracks Along Apete Minor Road**			
595937.310	823566.310	0.69	1.20	595121.900	823437.870	0.65	0.44
Potholes Along Mechanic-Samonda Minor Road							
598833.531	821169.588	0.30	0.54	599634.373	821769.473	0.71	0.49
598842.130	821196.046	0.52	0.76	**Cracks Along Mechanic-Samonda Minor Road**			
598826.447	821342.689	0.82	0.58	599005.949	821552.769	0.56	0.51
598859.515	821533.002	0.44	0.62	599756.115	821784.696	0.62	0.70
599238.252	821591.386	0.56	0.44	599398.328	821617.434	0.43	0.35
599523.080	821637.273	0.48	0.56				
Potholes Along Ijokodo Minor road							
597402.597	821035.049	0.81	0.35	597075.952	821785.320	0.41	0.21
597180.423	821049.240	0.66	0.52	**Cracks Along Ijokodo Minor Road**			
597052.761	821061.740	0.58	0.28	596950.622	821370.171	0.55	0.32
596994.147	821151.939	0.49	0.55	597108.492	822098.696	0.64	0.41
596973.033	821304.134	0.74	0.61	596780.657	822654.616	0.70	0.64
596911.733	821501.951	0.68	0.52				
Potholes Along Awolowo-Housing Minor Road							
599230.657	820110.991	0.47	0.36	599315.271	820080.035	0.36	0.22
599272.250	820094.163	0.38	0.46	**Cracks Along Awolowo-Housing Minor Road**			
599762.191	819912.765	0.71	0.29	599073.327	820160.270	0.77	0.45
599687.088	820388.328	0.56	0.36	599637.896	819973.810	0.50	0.34
599968.624	820589.814	0.47	0.47	599619.577	820294.227	0.42	0.63
600211.001	820664.232	0.55	0.62	600052.632	820627.781	0.56	0.29
Potholes Along Agbowo Minor Road							
600161.651	822638.233	0.44	0.35	600548.085	822791.300		
600254.521	822674.773	0.64	0.61	**Cracks Along Agbowo Minor Road**			
600443.676	822727.555	0.52	0.52	600316.844	822688.795	0.44	0.39
600471.654	822730.353	0.37	0.58	600589.989	822737.170	0.57	0.66
Potholes Along The Polytechnic Ibadan							
598567.865	821311..048	0.66	0.55	**Cracks Along The Polytechnic Ibadan Minor Road**			
598545.377	821440.234	0.82	0.49	598538.885	821477.529	0.88	0.48
598162.374	821774.276	0.47	0.58	597892.919	821958.961	0.60	0.69
597639.338	822163.873	0.74	0.77				

From the table 6 above, the minimum and maximum length and width of pothole ranges from 0.03-1.60m and 0.05-0.96m which implies that the road are still in good condition but still requires adequate monitoring and all the affected areas should be renovated.

Table 7: Distance of pothole to pothole, crack to crack on major and minor roads of the study area

Pothole to pothole Along the Major Roads (m)	Crack to Crack Along the Major Roads (m)	Pothole to pothole Along the Minor Roads (m)	Distance of Crack to Crack Along the Minor Roads (m)

Ojoo-University of Ibadan/Agbowo Road	Ojoo-University of Ibadan/Agbowo Road	Housing-Awolowo Minor Road	Housing-Awolowo Minor Road
445.453	1898.823	44.868	594.563
745.482	3131.992	45.282	320.940
546.698	234.476	477.196	546.621
703.915	Nil	Nil	Nil
		Mechanic Road-Samonda	
University of Ibadan-Bodija	**University of Ibadan-Bodija**	27.821	785.200
661.392	405.724	148.472	394.953
345.115	824.253	192.180	Nil
1056.278	784.034	383.210	Nil
354.963	Nil	288.501	Nil
262.843	Nil	172.809	Nil
University of Ibadan-Sango	**University of Ibadan-Sango**	**Agbowo Minor Road**	
240.664	Nil	99.800	277.396
351.899	Nil	196.381	Nil
376.216	Nil	28.117	Nil
537.775	Nil	97.756	Nil
Sango-Mokola	**Sango-Mokola**		
169.837	232.314		
235.194		**The Polytechnic Ibadan Minor Rd**	
522.856	Nil	131.128	805.636
211.554	Nil	489.012	Nil
17.579	Nil	670.543	Nil
15.609	Nil	Nil	Nil
20.563	Nil	**Agbaje Road**	
18.584	Nil	222.627	Nil
35.720	Nil	128.272	Nil
		107.617	Nil
Sango-Eleyele		54.561	Nil
749.697	464.435	104.789	Nil
770.422	1892.542	101.161	Nil
2455.877	1343.561	121.172	Nil
89.104	Nil	218.807	Nil
67.945	Nil		
		Apete Minor Road	
Ijokodo Minor Road		319.982	Nil
222.627 745.434	Nil	57.156	Nil
128.273 645.386	Nil	103.296	Nil
107.571	Nil	162.321	Nil
153.653	Nil	145.122	Nil
207.097	Nil	213.241	Nil
327.515	Nil	239.021	Nil

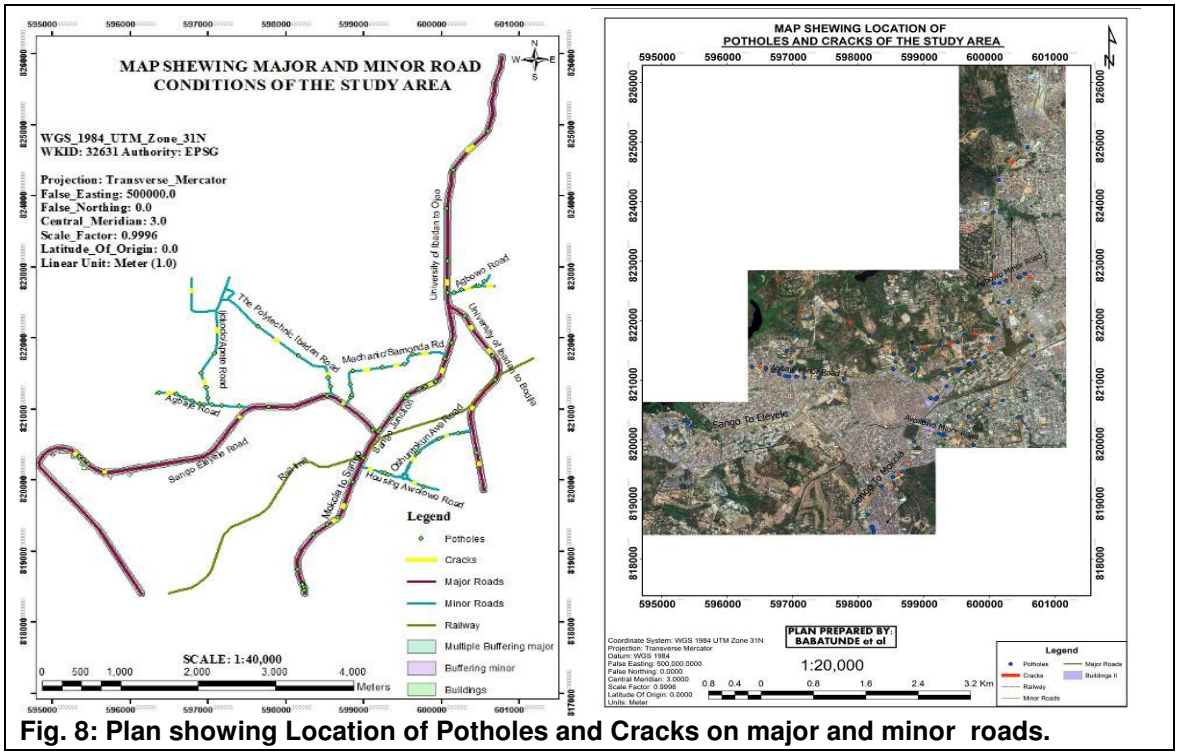
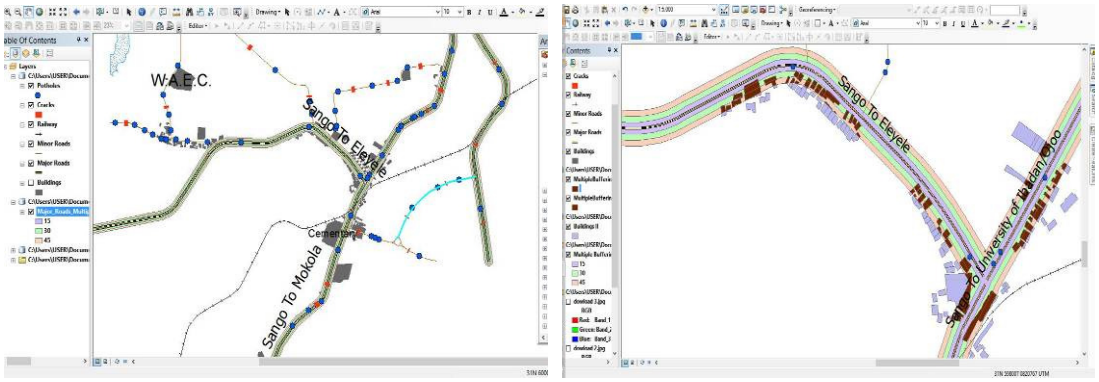
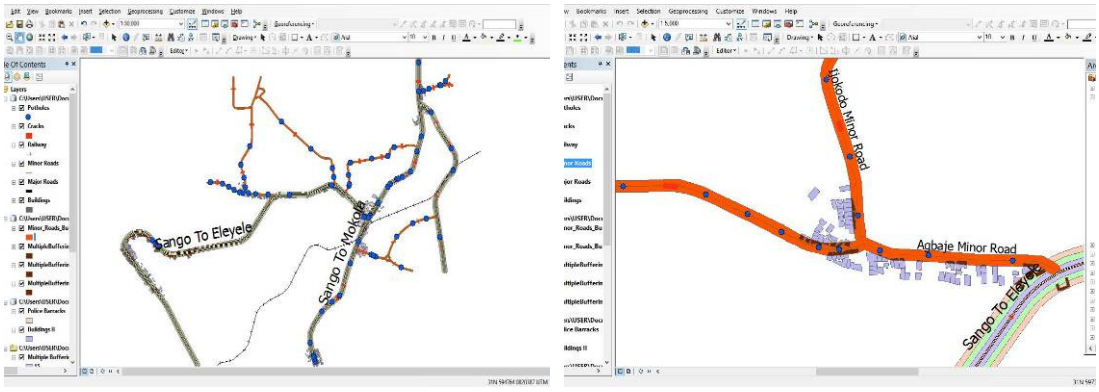


Fig. 8: Plan showing Location of Potholes and Cracks on major and minor roads.





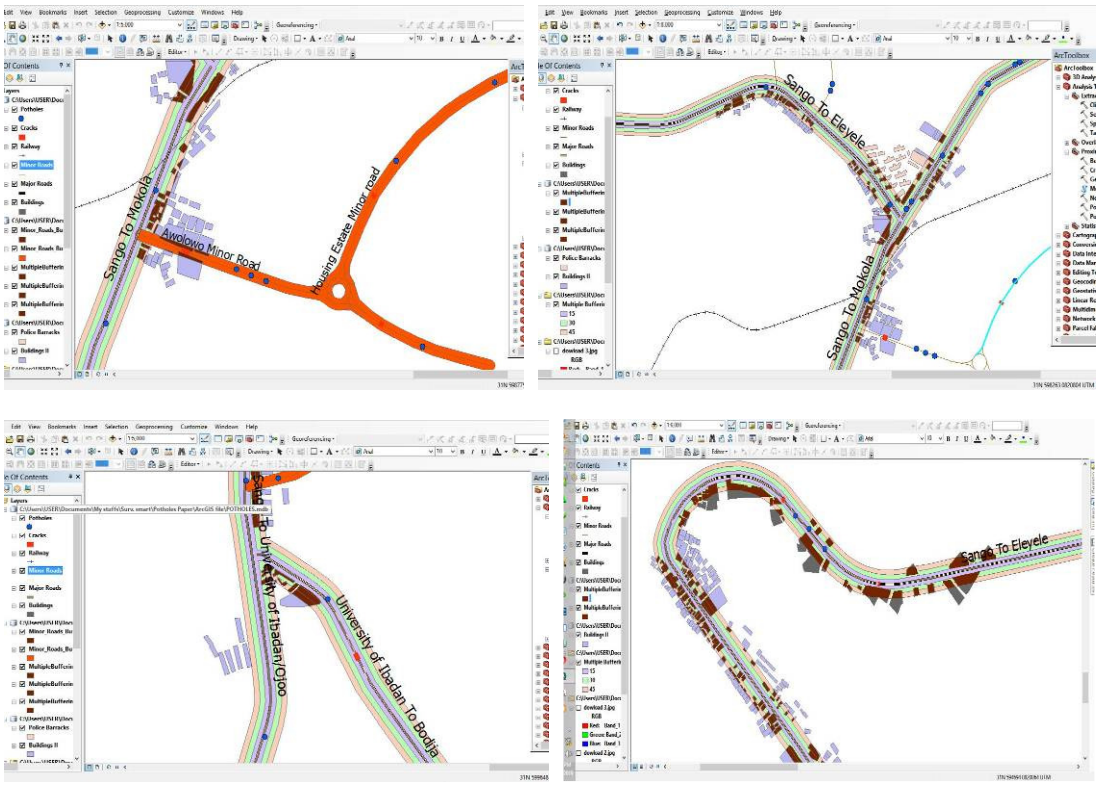


Fig. 9. Multiple buffering of major and minor roads in the study area.

Fig .9 shows single and 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 30m right of way while the area with orange accent colour are the features that are within 30m distance and non-comply with the specified right of way.

3.4 Analysis of multiple ring buffering

The features along the major roads were buffered with reference to the specified right of way which is 45.27m (150ft) standard distance from the Centre of the road. From the result in Fig 9, it showed clearly that at 45m distance, 92% of the features falls along the roads, at 30m distance which is the required specification for the setback in Oyo State, 85% of the features falls along the right of way and at 15m distance about from the Centre of the road, 95% of the features falls 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 cooperate organizations which may leads to loss of life and properties within the study area.

4. CONCLUSION

This study has examined the effectiveness and efficiency of road system in on major and minor roads in part of Ibadan metropolis, Oyo State, Nigeria using GIS application. The result from this study showed that none of the feature along the major route exceeded the specification of right of way and this was as a result that more than 90% of the features exist when all these major roads was in single lane before converting them to two lanes. The effects of the potholes and cracks in the study area may be structural failure, effect of

standards/specifications and policy, effect of traffic load and volume, properties and effect of construction conditions, effect of drainage system and ground water, aggregate properties, effect of alignment and geometry of road, flexible pavement layers thickness, and effect of pavement width which is the result of [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 [49]. This results will the study will help government to know feature that are too close to the road as well as the location of defects that is 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 so as to prevent loss of life and properties. Penalty/fine should be place on whoever disobeys the rule and regulation governing the right of way specification be it features or vehicle breakdown.

COMPETING INTERESTS

None

AUTHORS' CONTRIBUTIONS

Authors joint work make up the manuscript as All authors read and approved the final manuscript.

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