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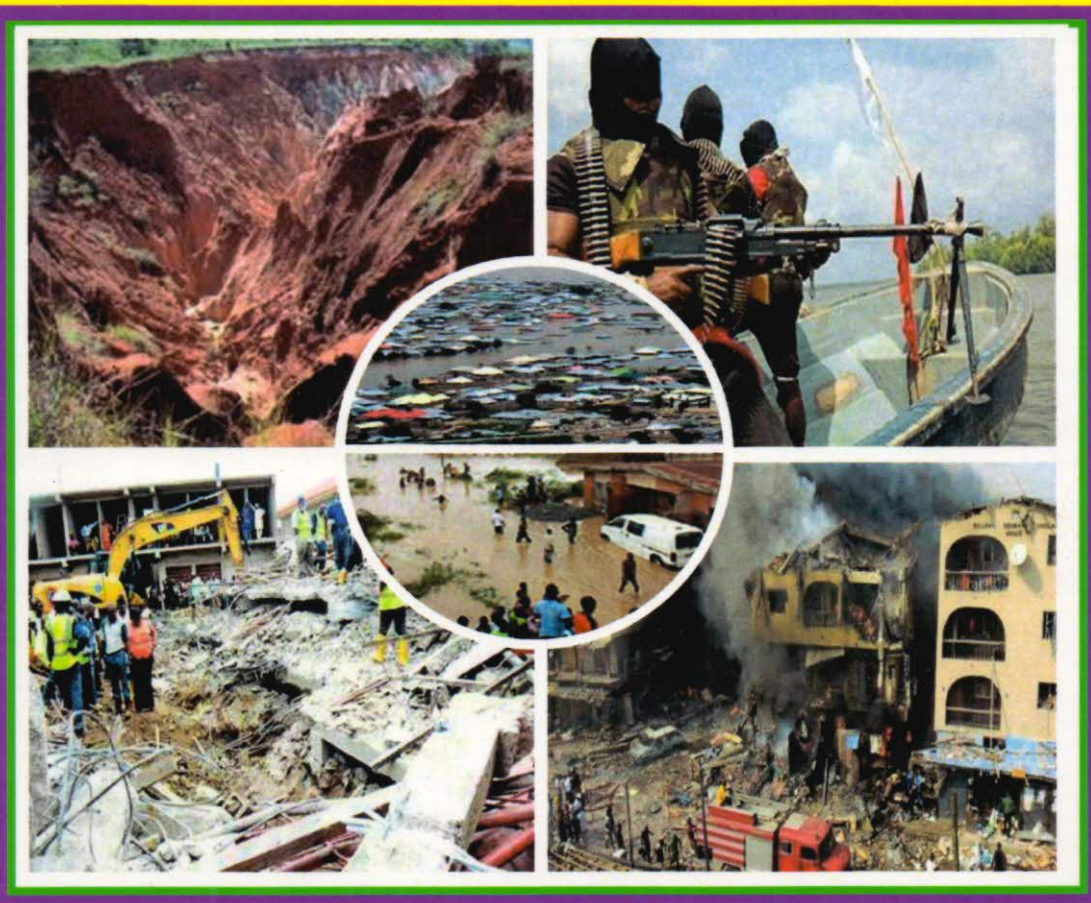

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Geospatial Assisted Road Network Routing for Fire Service Disaster Response in Ibadan Nigeria

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Abstract

This study showcased a key shortfall in the efficient and effective execution of fire service activities in Ibadan North Local Government Area (LGA) in Oyo state, Nigeria. The objectives of the study include finding the fastest routes (streets) through which fire service vehicles from Agbowo fire station can reach fire incident sites within the Local Government Area (LGA), the route (streets) fire vehicles should follow during traffic peak hours when roads are congested; draw out the implications of the response time analysis of Agbowo fire station the best route according to previous studies in the area. The data from field visit, on-line Google earth imagery and government agency where compiled for spatial operations. Geographic routing with ARCGIS network analyst extensions, geo spatial measurement and overlay analysis were carried out. The shortest and alternative distances to the fire incidence used as case study (in Montana Street) were 3.70km and 4.82km respectively. The study reveals that routing disturbance will elongate fire disaster response operation within and outside response/service area jurisdictions thus leading to inefficient response time. It also reveals that for efficient response, the fire fighters are expected to route through Fadeyi Street to Oyo road to Ondo Street to Oshuntokun Avenue to connect Bodija road at Foodco supermarket junction. From the study, a 1km routing extension was geo-spatialized. The study concluded that adequate funding for routing planning exigencies and even densification of fire stations should be embraced in order to avert the possible losses that routing delay cause in case of fire disaster.

Keywords: Fire Disaster, Fire Service, Geospatial, Routing, Road Routing Response

1. Introduction

The geography of movement is an indispensable subject in earth's study that focuses on the mobility of human, goods, services and resources over travelable distances (NCGE and AAG, 1984). The insights from the advancement of geographic mobility have enhanced its application in different issues that are movement associated. The development of some specialized geospatial technologies, tools and extensions can be traced to geographic understanding of movement. According to Mitchell (1999) and Okabe *et al.* (2006), the Network applications of most Geographic Information System (GIS) packages are based on the geography of movement given the ability of the Network modules to give a true and dynamic model of reality in space and time (ESRI, 2010). The Network modules incorporate an advanced connectivity model that can represent

complex scenarios, such as multimodal transportation networks. The Network modules also allow for analytical and computational tools to be used in conjunction with detailed representations of the local geography, allowing analysis and problem-solving to be tailored to the local context (Miller and Shaw, 2001). This account for their wider application in several transportation networks analysis problem.

Routing consideration is an integral part of most geospatial technologies (network analytic tools) that highlights and expedites movement direction paths from destinations to various sources as it concerns specific subject matter. Apart from aiding spatial mobility, routing analysis also enhances the management, coordination and the accessibility to all kind of facilities and services. It maximizes cost of mobility especially when special consideration and resources are expended on building effective network structures. Therefore, routing structures and configurations are especially important for routing effectively (Ogunbodede, 2006). Road routing is the most extensively used routing structure in several cities. It is diverse and sometimes complex especially for those cities that are being or have not been upgraded, planned or renewed in accordance with modern model. Road's positive conditions and decent connectivity aids various activities and stimulate the delivery of numerous services. Globally and locally, road system and fitness cannot be undermined in the delivery of various ground based goods and services (Popoola *et al.*, 2013).

In Nigeria, road network routing is the major mode of transport system it carries more than 90% of cargo and passenger traffic (RAMP, 2007). In 2004, road transport routing activities accounted for nearly 86% of the countries transport sector output for GDP (World Bank, 2007). The Federal Government in recognition of the essential role of road routing for national development has consistently found the nations developmental plans around it while spending huge amount on road transport infrastructures (Ogunbodede 2006; Adedeji, *et al.*, 2014). In Ibadan, South Western Nigeria, poor road condition and network routing like in other parts of the country has posed serious challenges on the mobility of goods, services and people from place to place (Ogunsanya 2002; National Transport Policy for Nigeria, 2010; Moses, 2011). The uncontrolled expansion of cities has led to exceeded capacity of infrastructures (Egunjobi, 1999; IFPRI, 2002; Helaakoshi, and Merilainen, 2001) including road infrastructure (Ogunbodede 2006). Which lead to a corresponding development of roads route which government hardly ever envisaged. In many cases poorly routed roads are developed which substantiates the fact that inadequate planning as result of unexpected city expansion leads to poor road network development which will also affect road transport dependent goods and services. Although, recent literatures abound on traffic routing situations and delay in majors cites in Nigeria (Ogunsanya 2002; Onokala 2008; Bashiru and Waziri 2008; Agbonika 2011; Aworemi *et al.*, 2009; Aderamo and Atomode 2011). Few have emphasized on how it affects routing for salient disaster (fire) response using a geospatial approach particularly the level of service provided by disaster managers.

Firefighting is a social service activity aimed at safeguarding lives and properties confronted with fire and other emergencies thrive with effective road network aiding its operations. The quality of service which may be justified by response speed and travel time, freedom to maneuver, convenience and comfort of operation route as well as traffic interruptions and safety to fire scene. Investigations have it that apart from fire service area delineation, problem encountered by fire service in Ibadan, include delays associated with the movement and maneuvering of the fire fighting vehicles to the fire sites (Adenle *et al.,* 2016). The main problem is determining the best and shortest path to fire sites so as to minimize the response time. There are cases of delay in response of fire services there are also events in which the response team missed their route to fire sites resulting into destruction worth million. This is with the aim of reducing the response time by reasonable amount. This amplifies the need to plan network routes for fire service disaster response in Ibadan. Without effective road network routing losses due to fire incidence will be aggravated (ESRI, 1999; ESRI 2000; Warfield, 2008; Adenle *et al.,* 2016).

The GIS technology is useful in addressing transportation problems related to safety and emergencies. According to Miller and Shaw (2001), Geographic Information System for transportation (GIS-T) are useful in taking transportation decisions by allowing a wide-range of information to be integrated based on the location by giving a holistic view. The versatile capabilities of the technology in mapping and carrying out spatial analysis while harnessing geographically referenced data is a much needed tool for planning purposes and to assist road network routing for fire service disaster response. The GIS network analyst is employed in this research to analyse the stated problems of road routing for fire response and to aid in making decisions as regards solving the problem. The study is to corroborate or otherwise the previous fire disaster location and one of the fire stations (Agbowo fire station) in Ibadan North LGA. Therefore, this study embraced the use of widely used mode of transportation in Nigeria and the conditions of the road while responding to fire disaster and how movement can be made. The size of the ancient city of Ibadan south western Nigeria as well as the limited number of fire stations within the city makes this research to focus on Ibadan North Local Government Area (LGA). The objectives include, to find the fastest routes (streets) through which fire fighting vehicles from Agbowo fire station can reach fire incident sites within Ibadan North Local Government Area (LGA); to identify the streets fire fighting vehicles should travel during peak hours when roads are congested; to assess the implication of the response time analysis of Agbowo fire station (with the (6min) most coverage to) the route best according to Adenle *et al.* (2016).

2. Study area

Ibadan North Local Government Area is the seat of power and is one of the nucleuses making up the hub of Ibadan. It has two fire stations among the 7 (seven) fire stations scattered round the city; including the head quarter of the state fire station which is located within the state secretariat, Agodi, in Ibadan. It lies approximately within latitudes 7° 15' and 7° 30' north of the Equator and longitudes 3° 45' and 4° 00' East of Greenwich meridian. The land area is

about 27km square (16.45%) of the Ibadan metropolis. According to national population census of 2006 about 306,795 people which is expected to have grown to 766, 987 in 2015 dwell in the LGA. The extreme level of urbanization and diversity such as ethnicity, amenities, educational facilities, Income, land use and social welfare is a unique attribute of the LGA (Office Website, Oyo State Government, 2014) Figure 1 shows the map of the study area. The Google earth satellite imagery (online) covering the study area shows that more than 70% of the landed areas within the local government are built-up with about 33,100 buildings foot prints (Figure 2).

2.1 Ibadan North L. G. A. Fire Stations

Ibadan North Local Government Area is serviced by two fire stations. The first which is the headquarters is located within the State Secretariat in Agodi area, while the other is located within Agbowo shopping complex, Agbowo. Table 1 and Figure 3 shows their respective coordinates and their locations in the study area at Agbowo fire station.

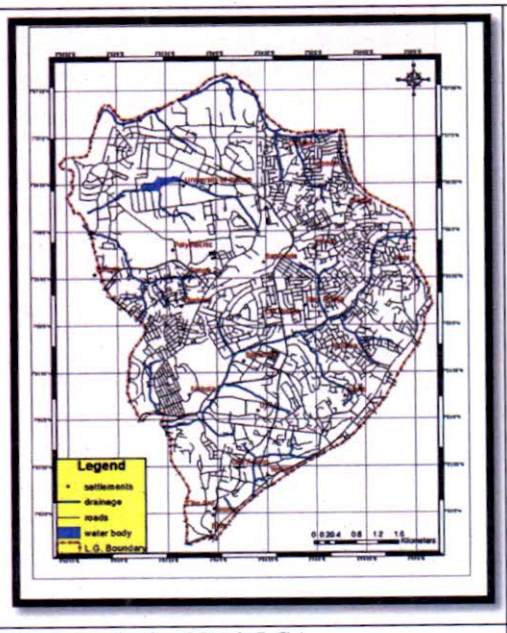

Figure. 1 Ibadan North LGA.
Source: Authors' Design, (2015)

Figure.2 Imagery of the study area
Source :Google Earth, 2015

Table 1: Coordinates of the Fire Stations and Fire Incident at Motola Street

Station	Eastings	Northings
Fire Service Headquarters, State Secretariat, Agodi. Ibadan North L. G. A.	3.9033	7.4073
Fire Service Station, Agbowo Shopping Complex, Agbowo, Ibadan North L. G. A	3.9078	7.4402
Fire Incident on Motola street	3. 9230	7.4275

Source: Author field study, 2015

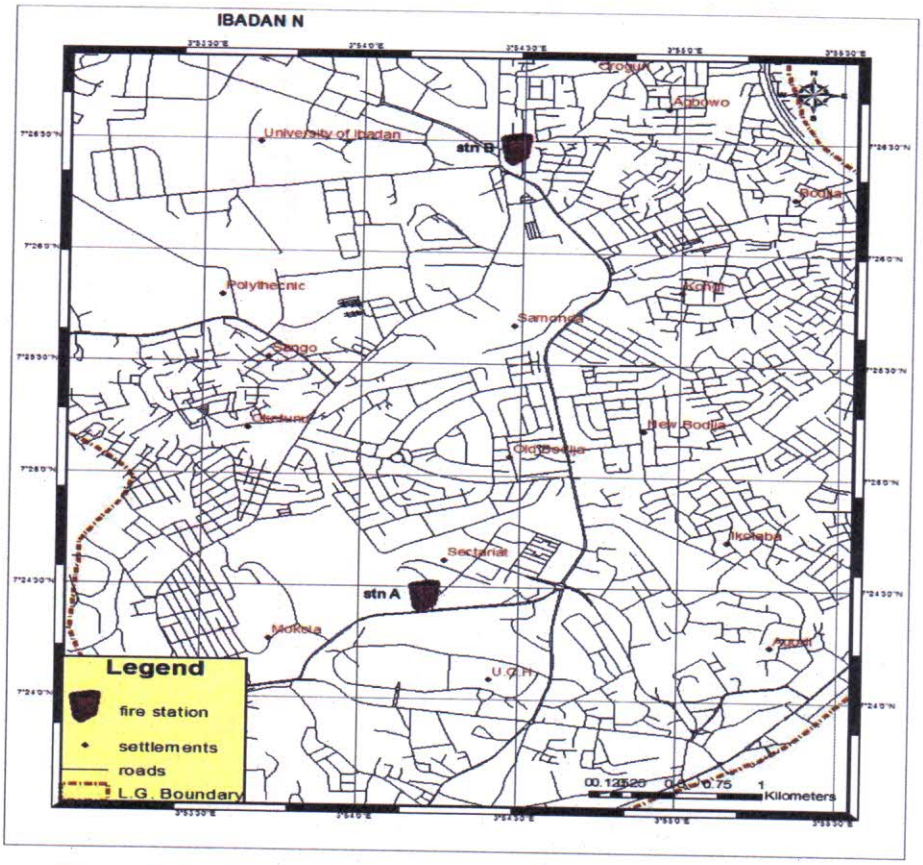

Figure 3: Ibadan north showing fire station locations and road routing
Source: Author Data Analysis, 2015

3. Materials and Methods

3.1 Data Sources and Types

The data sources were from field visit, online, and government agency. Coordinates of the two fire stations and the fire incident at Motola Street were captured using Geographic Positioning Systems receiver devices. Road map of Ibadan was acquired from the office of the Surveyor General (OSGOF) under the Ministry of Lands and Housing, Ibadan, Oyo state. The on-line google earth imagery, covering the area was acquired to update the information provided by other sources Graphical User Interface for Panorama tool (PTGUI) was used for Photo stitching of the Google earth image along the functionality of the map puzzle software. Standard digital data creation and pre-processing operations involving scanning, geo-referencing, image downloading for mosaicking, digitizing of buildings and road layer were carried out. ARCGIS 9.3, and excel packages were useful. Coding and conversion of the geographical coordinates of the fire stations were downloaded from the GPS into Microsoft excel environment before being imported and plotted into ARCGIS as a layer. A suitable projected coordinate system of Universal Transverse Mercator (UTM) was

adopted for all the spatial operations in the area.

3.2 Network Analysis (NA)

The network layer of the updated road shape file was generated with the help of the created network and 'build' tools in the network analyst toolbox of Arc tool box. The vertices (nodes) and links (edges) are defined and were attributed as road type, distance, and travel speeds (miles or kilometers per hour). The guiding assumptions of network analysis that crossroads are significant vertices and road tracks whose endpoints are closer to each other beyond the defined tolerance setting are coincident and constitute a valid network vertex. This facilitated the operationalizing of useful spatial activities like identification of points (station locations), specify a travel time, and to run a network analysis. Time was the attribute used for optimal route the calculations for creating the network dataset which have been previously used in determining the service area delineation by a network (Adenle *et al.,* 2016)

The route analysis methods out of the four (4) methods of data analysis for Network Analyst (NA) was adopted (Figure 4). The analysis uses both spatial and attributes data for the creation of a Network dataset in the routing analysis. The road network data requires attribute like name, length, speed limits and travel time to perform the network analysis. Hence the fields 'name' 'length', 'speed limit' and 'travel time' were added to the road attribute table. An average speed of 40km/hr. was adopted for all roads and the travel time for each road was calculated in minute using the field calculator in the attribute table, entries was [length]*(60/ [speed, limit]) (Adenle *et al.,* 2016). The field readings of the Agbowo fire station were imported on the created network to assist in the routing from the firefighting station to the fire incident within Ibadan North Local Government Area.

3.3 Route Analysis

The route solver, in ArcGIS was employed for determining routes from location to another i.e between the specified start point and end point. The Agbowo fire station was considered as the starting point while the fire incident at Motola Street was picked as the end point. The different layers used included; Stop feature layer (fire stations, fire sites), Barrier feature layer (congested areas where fire vehicles cannot travel), Route feature layer (generated route from fire stations to fire sites. Time also was specified as the impedance to enable routing of the fastest/best routes through which fire vehicles can reach fire sites within the Local Government Area (LGA) and how fire vehicles should travel during peak hours when roads are congested. Barrier(s) were placed on the computed route, to represent a road block which helps in computing the alternative route during the peak periods, in relating the response time analysis with most coverage to the best route, to get the effect of response time on the location of fire sites with respect to existing fire stations is further analysed. An overlay of the best route was done with six minutes (6) service area.

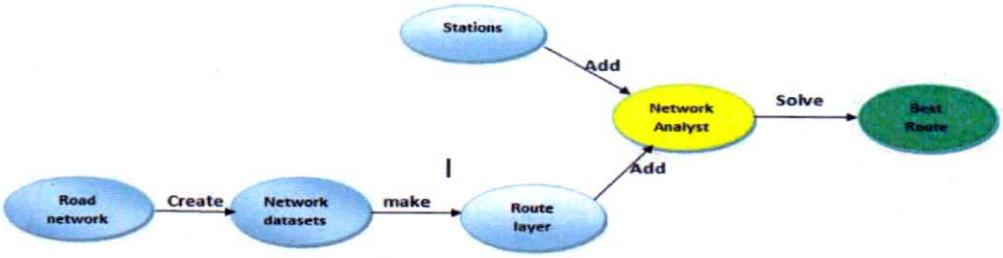

Figure 4: Cartographical model for the route analysis.
Source: Adapted from Okabe *et. al.*, 2016

4. Results and Discussions

4.1 Route analysis

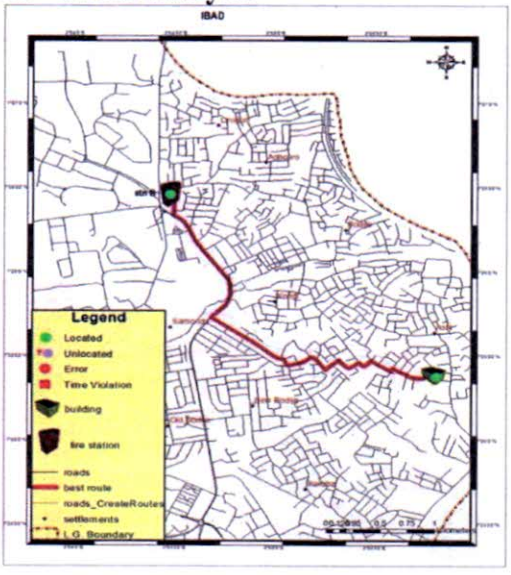

Figure 5: Fastest route to the fire site
Source: Author's Data Analysis, 2015

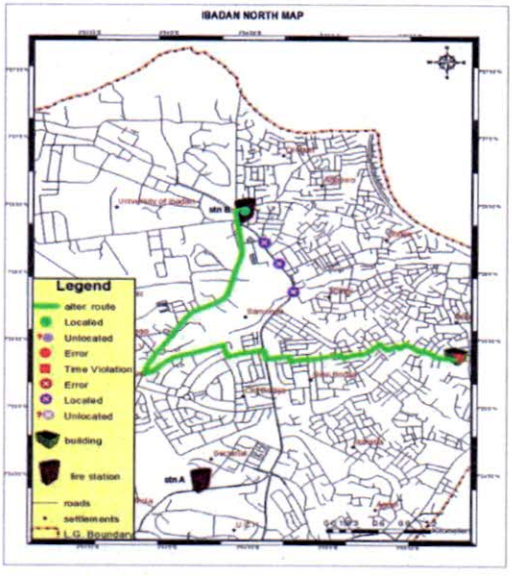

Figure 6: Alternative route to the fire site during peak periods
Source: Author's Data Analysis, 2015

4.2 The fastest routes through which fire vehicles can reach fire sites

Figure 5 shows the fastest route to the fire site between one of the two stations and the 2012 fire incidents in Agbowo. Stop 1 refers to the location of the fire station in Agbowo area while stop 2 refers to location of a fire incidence in Motola Street, Ashi area. The direction window associated with the network analyst displays the total distance covered by the route analysis as 3.70km. According to the results of the fastest route analysis (Figure 5), The fire fighters are expected to route through the following streets and roads (Red line): Fadeyi street- Bodija road- crossing the railway -Adenuga street- Mofolasade Bolarinwa drive- Adebajo road- Olalere tokun street- Labanji Ayoola street-Aina Afolayan street- A linking street off Bamigbola avenue to join - Unity road- Motola street. Table 2 presents the

approximate breakup of distances covered between the streets.

Table 2: Approximate Breakup Distance Travelled Between Streets When Road Route Are Not Congested (Fastest Route)

S/N	From	To	Estimate Time (Minute)	Distance between Street (km)	Rank
1	Fadeyi street	Bodija Road	0.102	0.1534	4
2	Bodija road	Adenuga street	0.656	0.9846	10
3	Adenuga street	Mofolasade Bolarinwa drive	0.499	0.7488	9
4	Mofolasade Bolarinwa drive	Adebajo road	0.055	0.0824	1
5	Adebajo road	Olalere tokun street	0.126	0.1891	5
6	Olalere tokun street	Labanji Ayoola street	0.096	0.1439	2
7	Labanji Ayoola street	Aina Afolayan street	0.1	0.1495	3
8	Aina Afolayan street	Bamigbola avenue	0.308	0.4615	7
9	Bamigbola avenue	Unity road	0.32	0.4807	8
10	Unity road	Motola street	0.193	0.2888	6
		Total	**2.455**	**3.6827**	

Source: Author field work, 2015

From Table 2, the shortest distances will be covered by the firefighting vehicle in few times between Mofolasade Bolarinwa drive- Adebajo road (Ranked 1, Estimated Time 0.055inute) Olalere tokun street- Labanji Ayoola street (Ranked 2 , Estimated Time 0.096 Minute); Labanji Ayoola street-Aina Afolayan street (Ranked 3 , Estimated Time 0.0100 Minute); and Fadeyi street-Bodija road(Ranked 4 , Estimated Time 0.0102 Minute); Shorter distances will be cover between Adebajo road- Olalere tokun street (Ranked 5 , Estimated Time 0.0126 Minute) Unity road- Motola street(Ranked 6, Estimated Time 0.193 Minute) while short distances are expected between Labanji Ayoola street-Aina Afolayan street (Ranked 7, Estimated Time 0.308 Minute) Bamigbola avenue to Unity road (Ranked 8, Estimated Time 0.32 Minute) and Adenuga street- Mofolasade Bolarinwa drive (Ranked 9, Estimated Time 0.499 Minute) as well as Bodija road- Adenuga street (Ranked 10, Estimated Time 0.656 Minute). The distances on Table 2 are only considered when the road routes are not congested but this is not the idea situation in reality because road problems like bad road, road structure and congestion are characteristics of most Nigerian roads (Ogunbodede, 2006; Popoola *et al.*, 2013). Hence, a shorter urban road may not be an idea from routing for fire disaster response. The tragedy still remains that most urban centres in Nigeria are lacking vital data for managing urban processes (Mabogunje, 1990).

4.3 Fire vehicle travel during peak hours when roads are congested

Fig. 6 is the alternative route to the fire site during peak periods due to traffic congestions or any other traffic barrier that hinders fire vehicle from travelling on the best route. However, the fire fighting vehicle has to travel more distance and consequently more time, through the best alternative route based on minimum travel time. The result shows that a total distance of 4.82km will be covered. The fire fighters are expected to route through the following alternative streets and roads (Green line);

Fadeyi street -Oyo road- Ondo street – Oshuntokun avenue to connect Bodija road at Foodco supermarket junction – Are road–Okunlola Abass street- Aladuni Ayandipo street - Mofolasade Bolarinwa drive- Labanji Ayoola street- Aina Afolayan street- A linking street off Bamigbola avenue to join - Unity road- Motola street. Table 3 gives the approximate breakup of distances covered between the streets.

Given the distances of the alternative route path to the fire incidence, (Table 3) the various breakups path will have different distances and routing time. Shortest distances are found between Bodija road at Foodco supermarket (Ranked 1, Estimated Time 0.087 Minute); Are road - Okunlola Abass street (Ranked 2, Estimated Time 0.092 Minute); Fadeyi street -Oyo road (Ranked 3, Estimated Time 0.116 Minute) while shorter distance will be experienced between Okunlola Abass street- Aladuni Ayandipo street (Ranked 4, Estimated Time 0.176 Minute); Foodco supermarket junction –Are road (Ranked 5, Estimated Time 0.181 Minute); Unity road- Motola street (Ranked 6, Estimated Time 0.193 Minute); Mofolasade bolarinwa drive- Labanji Ayoola street (Ranked 7, Estimated Time 0.255 Minute); Oshuntokun avenue to connect Bodija road (Ranked 8, Estimated Time 0.281 Minute); Aladuni Ayandipo street - Mofolasade bolarinwa drive(Ranked 9, Estimated Time 0.290 Minute).The short route include off Bamigbola avenue to join - Unity road (Ranked 10, Estimated Time 0.321 Minute); Ondo street – Oshuntokun avenue (Ranked 11, Estimated Time 0.359 Minute); Labanji Ayoola street- A Bamigbola (Ranked 12, Estimated Time 0.408 Minute); Oyo road- Ondo street (Ranked 13, Estimated Time 0.448 Minute). The same poor road condition identified by Ogunbodede (2006) and Popoola *et al.* (2013) are still factors be referenced.

4.4 Implication of the six-minute Service Area/Response Time Analysis with Best Route

Figure 7 depicts the coverage and intersection of the two stations service for six minute thereby confirming that the response time for each of the stations were the same for the areas like Sango, New and Old Bodija; the management of fire incidents within the overlap will receive better response compared to other areas with less response time (1 and 3minutes); few areas are prone to risk of fire outbreak (Adenle *et al.*, 2016). Figure 8 relates the Agbowo fire station six minutes' drive time polygon with the best route to Motola fire incident.

Table 3 Approximate breakup distance travelled between streets when roads are congested (peak period)

S/N	From	To	Estimate Time (Minute)	Distance between Streets (km)	Rank
1	Fadeyi street	Oyo road	0.116	0.1736	3
2	Oyo road	Ondo street	0.448	0.6719	13
3	Ondo street	Oshuntokun avenue	0.359	0.5391	11
4	Oshuntokun avenue	Bodija road	0.281	0.4215	8
5	Bodija road	Foodco supermarket junction	0.087	0.1302	1
6	Foodco supermarket junction	Aare road	0.181	0.2708	5
7	Are road	okunlola Abass street	0.092	0.1488	2
8	okunlola Abass street	Aladuni Ayandipo street	0.176	0.2647	4
9	Aladuni Ayandipo street	Mofolasade bolarinwa drive	0.290	0.4343	9
10	Mofolasade bolarinwa drive	labanji ayoola street	0.255	0.3819	7
11	labanji ayoola street	Bamigbola street	0.408	0.6121	12
12	Bamigbola avenue	Unity road	0.321	0.4807	10
13	Unity road	Motola street	0.193	0.2888	6
		Total	**3.205**	**4.8184**	

Source: Author field work, 2015

The dark green background is the service area while red line is the best route to the fire site. The segment encircled red at the left side of the result indicated that an approximate distance of 3.7km cannot be reached by fire vehicles from either of the station. This explains the inadequacy of fire stations distribution in the study area particularly under an idea condition of six minute and best route. Locating more fire stations in close proximity will definitely reduce the response time to fire sites within the area, thereby enabling more fire engines from more stations to coordinate effectively at a particular fire site. The traffic congestion within the Ibadan metropolis particularly, along the best route and service will exacerbate fire disaster losses because alternative response routing will be longer (see table total Table 3 and 4); sometimes requiring routing extending outside the stations service area (Figure 6). The response timing along the alternative is also expected to be more, this will also increase the overhead cost of fire response because fire service department will have to seek alternatives route to reach the fire disaster scene. This further intensifies the need to fund fire service departments to be able to route without the constraints of routing cost and logistics (Adenle *et al.*, 2016).

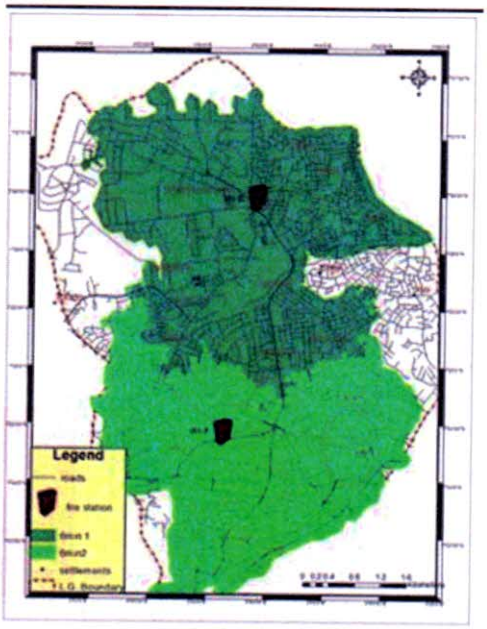

Figure: 7 A Six minutes' interception of service area

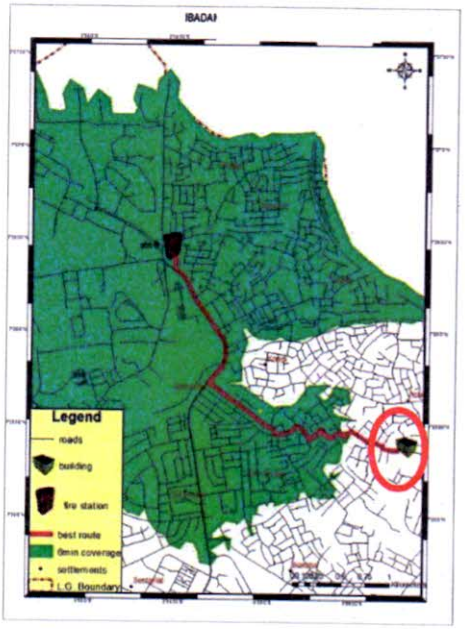

Figure.8 Overlay of the analyzed best route layer on six (6) minute drive time polygon

Source: Author's Data Analysis, 2015

5 Conclusion and Recommendations

This study has showcased the shortfall in the efficient and effective execution of fire service activities in one of the largest LGA in Ibadan Western, Nigeria. Routing disturbance which will elongate response operation was identified. The work built on previous researches on traffic congestion and delay in major cities with an effect on road routing for high level disaster service delivery in Ibadan. The following recommendations are made on the basis of the findings.

I. The fire service should be better funded and equipped to plan for unexpected routing exigencies particular alternative routing.

II. The even densification of stations is study area in recommended to cater for traffic congestion and alternative routing cost.

III. Preferential attention should be given to fire fighting vehicles during traffic control, in view of their emergency response status

IV. Municipal development plan should exercise restrains in granting building approval permits like putting stations in area which lies outside good coverage of the firefighting service.

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