

Geomatic Approach to Modelling Urban-Fire-Risk-Susceptibility in Akure, Ondo State, Nigeria

Tukka, Apollos Audu

Lecturer, Department of Surveying and Geoinformatics, Federal University of Technology, Akure, Nigeria

Email: aatukka@futa.edu.ng

Abstract - Urban fire occurs primarily in cities or towns with a high potential of destroying homes, schools, commercial buildings, and vehicles. Cases of fire disasters in Nigerian cities have been experienced in the last decade with increasing frequency and severity with properties worth millions of naira destroyed in fire accidents nationwide. This study attempts to integrate a global positioning system (GPS) and geographical information system (GIS) to model areas vulnerable to fire hazards within the study area. The procedural methodology adopted consisted of spatial data acquisition, pre-processing (geo-reference), post-processing, and analysis. Here High-Resolution Google Earth image was used for dereferencing and digitization within the ArcGIS 10.3 version, Google Earth Pro, and AutoCAD 2007 software. Three- features- analysis (Fire Incidences Scenes, Fire Stations and Road Network) in terms of coverage and service-area-delivery was performed. Findings of the study revealed that the year 2016 had the highest percentage (29%) of fire causes and occurrences; from 2016 to 2019, with Bush fire consisting of 25 (19.5%) Gas explosion 2 (1.56%), undergrowth wood-burn 13 (10.16%), Electric fault 21 (16.41%), Car burning 7 (5.47%) and unknown engulfed 60 (46.9%); while the year 2019 had the lowest, with 20.09%. The results reveal Monthly fire-occurrences from January 2016 to September 2019 and fire-occurrence-response-rate from Airport Fire station, Akure metropolitan fire station, and UBA-FUT-Akure fire stations. Hence, this study presents a knowledge-based approach to modeling urban fire- Susceptibility, with the view to managing such incidences by the State, ensuring an increase in the ratio of fire professionals per population of 1:1000 to march global tactics.

Keywords: Susceptibility, GPS, GIS, Modelling, Fire, Hazards, ArcGIS 10.3.

I. INTRODUCTION

The rapid combination of naturally occurring elements such as Oxygen and Heat alongside Fuel-substances result in the production of heat and light. Before fire can occur, there

must be presence of the three basic element or ingredient of fire, which is referred to as fire's own Eternal triangle.

The major causes of fire which often times could be due to failure of occupant of building or the community to follow necessary safety precaution against fire outbreaks, the fire from some of these sources starts from a point and continue to spread around the building if not quickly controlled. These causes of fire resulting from carelessness of occupants in building could include careless handling and indiscriminate disposal of cigarette-stump by smokers resulting to fire hazard as well causing damage or total loss of properties and pollution to the environment out which very few o may prove in-fatal and can lead to death. From the forgoing, it can be said that fire-accident is anything that happens unexpectedly which result in shock, injury, damage to life and property. Fires resulting from electrical equipment like fan, air-conditioner, lighting fittings/power fittings often cause fire outbreak in buildings, when occupants do not follow all necessary safety precaution in handling electrical equipment and faulty wiring system, fire outbreaks is always imminent

Meanwhile in the northern east part of Nigeria where suicide bombers would detonate a bomb in a building or other places, the aftermath often result in fire outbreak. We could recall similar situation in the USA September 11 attack on the world trade center in New York, this also resulted in fire outbreak which later led to the collapse of the twin tower in 2001. Fire spreads from adjacent buildings and affected another structure. Indiscriminate burning of bushes or debris could likely cause fire outbreak especially where t wooden electric poles are involved. These poles could ignite and burn the 415v power lines, which could cause more harm than good. Fire also spread in the bushy area during the dry season; therefore, people should be given orientation that uncontrolled burning of bushes is not a good practice. The visualization of risk due to fire-hazards which this study intends to provide can be helpful in identifying optimal routes to evacuate occurrence-site seamlessly and without panic. Therefore, guided crowd evacuation approach which requires the identification of highest risk areas (to be avoided; during evacuation when / where possible) to the lowest risk areas is

hereby attempted for recommendation within the study area herein considered to be susceptible to Urban-fire-risk.

From the review of previous work, it was insightful to note that, the extent of fire damage in an environment could be linked to lack of an effective and an appropriate rate-of-response that enhances fire safety, which is a necessity. The common problem is that the late or no response of Akure North, UBA FUTA and Airport Fire Stations when called upon; in addition, difficulties faced by fire fighter in accessing the place on fire and distanced need to cover before getting to scene. According to(VANGUARD NEWSDec. 2014) a gas explosion razed 42 shops and houses in Arakale area of Akure. Hence, here is every likelihood that Akure faces fire hazards due to probably a lack of an automated database system that could alert and improve response-rate among people and the fire authorities on/before the need arises (Tukka 2019).

This study attempts to identifies direct vulnerability factors and solution to fire hazards in Akure metropolis Using Global Positioning System (GPS) and Geographical Information System (GIS) technique known as Geomatic approach as a tool, where empirical review of past fire hazard occurrence in Akure metropolis, and study of geospatial similarities between variables; Digitization of spatial distribution of firefighting agencies and road network of buildings via satellite imagery of Akure will be used in the geospatial modeling of fire hazard vulnerabilities; It was detected that earlier quoted literature did not focus on the operational rheostat and management to lessen the extent of fire damage in Akure metropolis, Ondo – Nigeria. Therefore, it is necessary and justifiable to employ mapping and design of fire incident scene of existing fire stations with view of evaluating by measurement, the coverage areas using driving time associated with rate-of-response of Urban -fire- Hazards.

1.1 Study Area

Akure metropolis is one of the fast-growing cities in Southwestern Nigeria. Akure became the administrative capital of Ondo State in 1976. It is located between latitudes 7°3'40" N - 7°26'38" N and longitudes 5°5'11" E - 5°29'39" E. According to 1991 and 2006 census, the provisional population was estimated at about 316,925 and 484,798 respectively. The metropolis occupies an area of about 530Km². It is made up of two Local Government Areas (LGA) these are Akure North and Akure South. Akure is situated within the rain forest belt of Nigeria with the climate of the wet season spanning from April to October and dry season between November and March. The town experiences the hottest weather from February to March and experiences the cold-dry wind (harmattan) from December to February. It lies within the zone of the moderate annual rainfall of about 1,300

to 1,700 mm while humidity is relatively high during the wet season and low during the dry season with temperatures varying between 22°C and 31°C throughout the year (Iloeje, 1981). The topography of the Basement Complex terrain of Akure is generally undulating with a virtually rugged terrain consisting of hills and valleys with field recorded elevations varying between 330m above mean sea level in the southwestern flank and 399m in the northeastern flank (Michael, and Franklin, 2016).

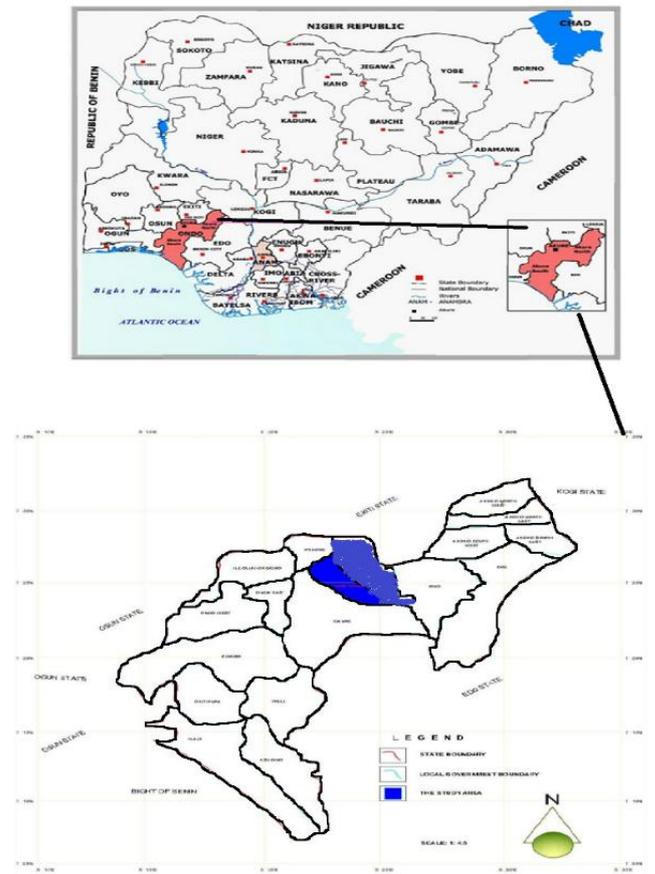


Figure 1: Map showing study area in a National and State setting (Source: Adopted and modified from Tukka, 2018)



Figure 2: Typical Urban fire scene at Oja-Oba Market Akure (Source: Daily Post Sahara Reporters, 2018)

II. MATERIAL AND METHODS

The general procedures and process adopted are data acquisition, pre-processing (geo-reference), and analysis of results with the view to achieve the designed objectives. Reconnaissance is the first step in all Geomatics approach towards obtaining reliable data for the required result and it's consist of two aspects, office and field reconnaissance.

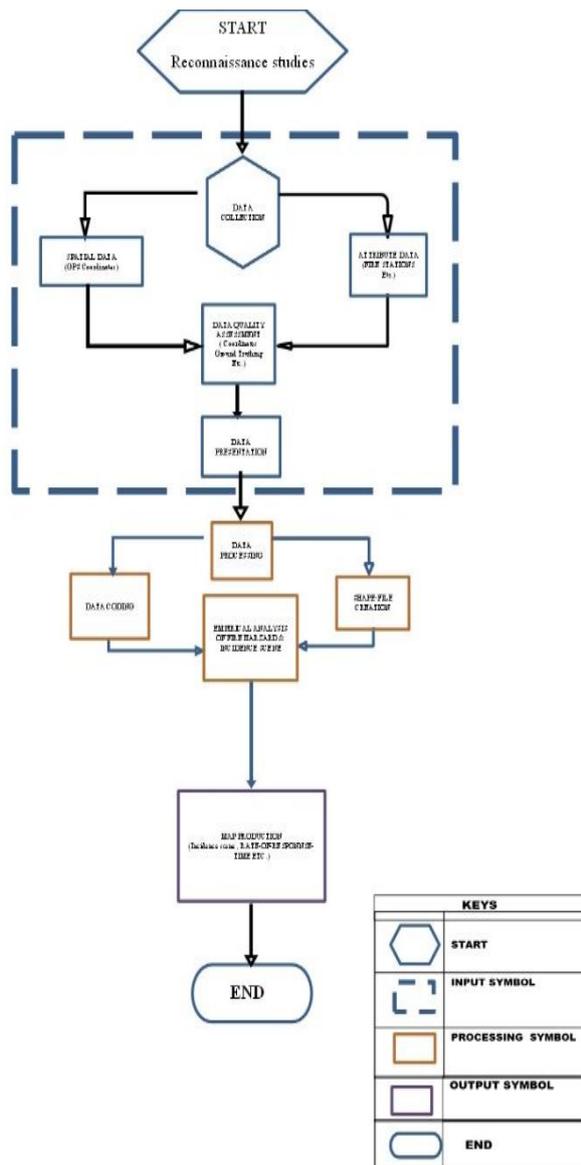


Figure 3: Flowchart of research methodology (Source: Authors Research work)

The Identification and empirical analysis of fire hazards, existing fire station and reported fire incidents was adopted within the study area. This was done within the Microsoft excel were table of details on fire incidents was collected for the period of 4 years consecutively (2016 -2019). This was used to analyzed and check the frequency of fire damage occurrences in Akure as reported by each fire station. The

analysis was based on the number of occurrences in each month, causes of fire, frequency of occurrence over the years.

Spatial distribution of existing fire station and analysis of fire incidents scenes. The “average nearest neighbor analysis” tool in ArcGIS 10.3 was employed as a methodology towards the evaluation of the spatial distribution pattern of fire stations and fire incidents pattern in the study area. This affords us with the concept of fitting a way to explore the spatial distribution of features. Meanwhile, from the returned values in the “average nearest neighbor analysis” tool provided by ArcGIS 10.3, the z-score and p-value results were all measures of statistical significance which tells you whether we should accept or reject the null hypothesis we set at the beginning. If the NNI is less than 1, the distribution pattern of the fire stations in the study area is categorized as clustering; if the index is more than 1, the trend is toward dispersion.

Investigation on if the existing fire stations can serve effectively was considered and activated, using the Network analyst (Service Area) tool in ArcGIS 10.3.1. Service area analysis was done considering the driving time of 5, and 10 minutes respectively. Which run from the fire stations toward every direction along the road network and the spread terminate with respect to the driving time specified. Buffering was equally done to justify the efficiency of the network area analysis.

Finally map production of fire incident pattern and fire service stations was attempted using ArcGIS 10.3.1. From the details of fire station and reported fire incident scenes recorded on spreadsheet (Microsoft Excel), the spatial and attribute data of the features was integrated into the GIS tool (ArcGIS) to aid in the design and production of various maps.

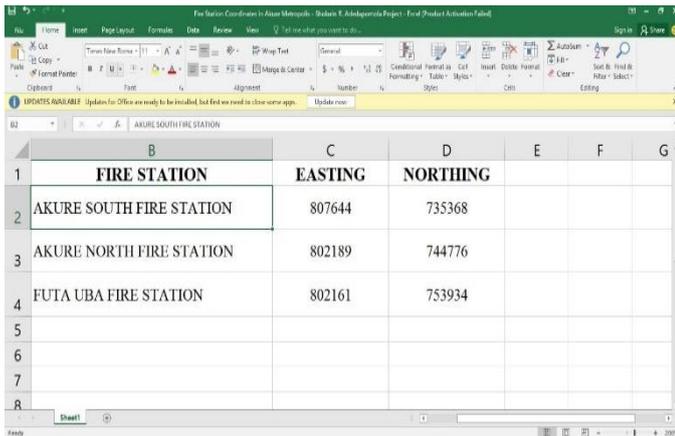
III. RESULTS AND DISCUSSIONS

The variables analyzed include details (coordinates, name, and forms of ownership) of each fire station, reported fire incidence causes of fire, monthly/ yearly occurrences of in the study area. Table 1 contain the various form fire station ownership, while figure 4 to 11 gives us the first impression associated with each result

Table 1: The forms of ownership of fire stations in Akure metropolis

FIRE STATIONS OWNERSHIP		
FORMS OWNERSHIP	UNITS	PERCENTAGE
PRIVATE	2	67%
PUBLIC	1	33%

Table 2: Showing Information about Fire Stations within Study Area



	B	C	D	E	F	G
1	FIRE STATION	EASTING	NORTHING			
2	AKURE SOUTH FIRE STATION	807644	735368			
3	AKURE NORTH FIRE STATION	802189	744776			
4	FUTA UBA FIRE STATION	802161	753934			
5						
6						
7						
8						

Table 3: Showing Information about Fire Incidences within Study Area

June	6	3	7	10	26
July	5	8	1	6	20
August	8	3	5	7	23
September	2	7	11	3	23
October	6	8	4	0	18
November	5	4	9	0	18
December	12	4	23	0	39
TOTAL	105	109	105	86	429

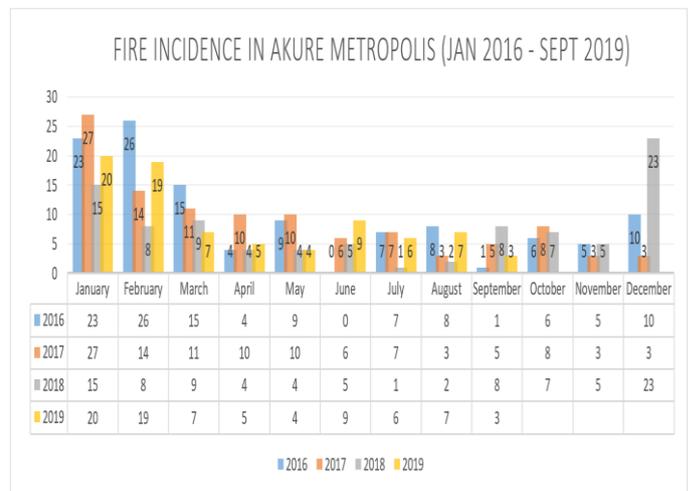
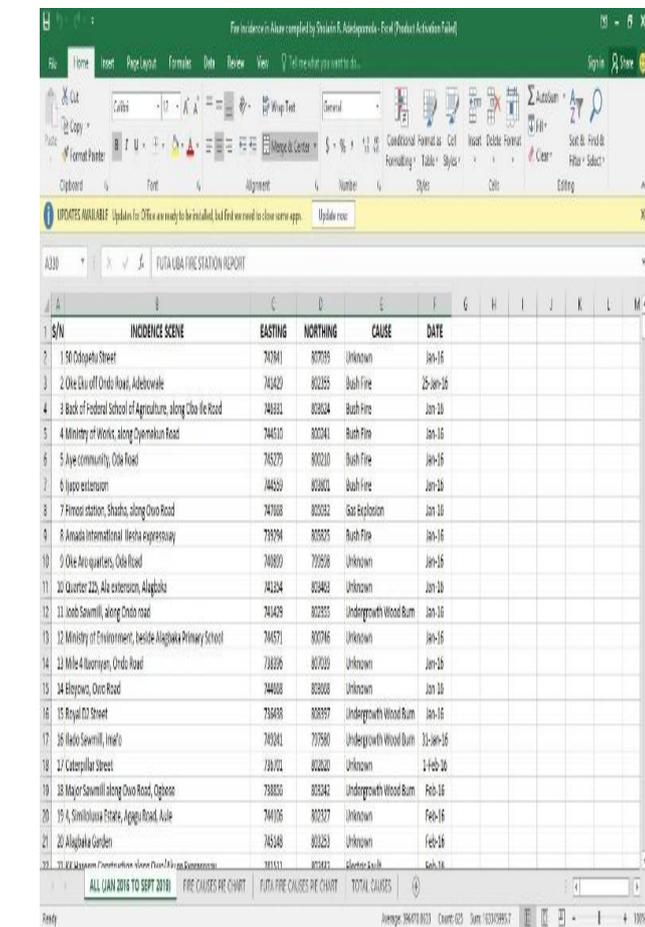


Figure 4: Bar chart of the causes of total reported fire incident in Akure metropolis for 4 years



S/N	INCIDENCE SCENE	EASTING	NORTHING	CAUSE	DATE
1	50 Odogbe Street	743611	807839	Unknown	Jan-16
2	Oke Olu off Ondo Road, Aledokole	743423	802255	Bush Fire	25-Jan-16
3	Back of Federal School of Agriculture, along Oke Olu Road	744321	803634	Bush Fire	Jan-16
4	Ministry of Works, along Oyeemokun Road	744510	803241	Bush Fire	Jan-16
5	Aye community, Oke Road	745279	800210	Bush Fire	Jan-16
6	Isupe extension	744529	803801	Bush Fire	Jan-16
7	Pinno station, Shaaba, along Oke Road	747008	803082	Gas Explosion	Jan-16
8	Amash International Iksha expressway	739394	803825	Bush Fire	Jan-16
9	Oke Awo quarters, Oke Road	740800	799226	Unknown	Jan-16
10	Quarter 22, Ake extension, Alagboko	741234	803463	Unknown	Jan-16
11	Jobe Sawmill, along Oke road	741429	803835	Undergrowth Wood Burn	Jan-16
12	Ministry of Environment, beside Alagboko Primary School	744571	803716	Unknown	Jan-16
13	Mile 4 Ilorin, Oke Road	738326	807209	Unknown	Jan-16
14	Elayere, Oke Road	744408	803608	Unknown	Jan-16
15	Royal D2 Street	739498	808997	Undergrowth Wood Burn	Jan-16
16	Welo Sawmill, Welo	740341	797580	Undergrowth Wood Burn	11-Jan-16
17	Caterpillar Street	739101	802820	Unknown	2-Feb-16
18	Major Sawmill along Oke Road, Okebo	738856	803342	Undergrowth Wood Burn	Feb-16
19	Similoluwa Estate, Agogo Road, Ake	744116	803327	Unknown	Feb-16
20	Alagboko Garden	745348	803283	Unknown	Feb-16
21	Major Sawmill Extension along Oke Road, Okebo	741111	803482	Undergrowth Wood Burn	Feb-16

Table 4: Fire Monthly Occurrence in Akure Metropolis (Jan 2016 - Sept 2019)

MONTH	2016	2017	2018	2019	TOTAL
January	23	29	16	21	89
February	31	14	10	19	74
March	15	11	9	9	44
April	5	10	6	6	27
May	11	8	4	5	28

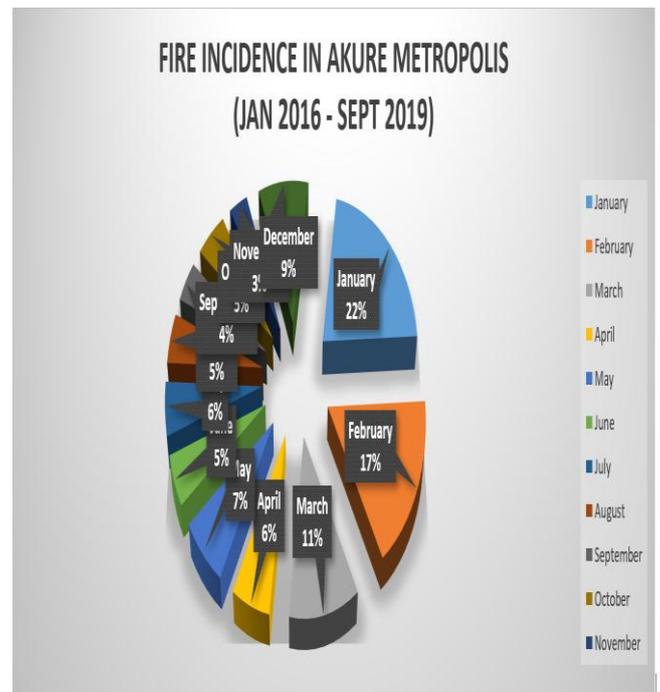


Figure 5: Pie-chart of percentage the total monthly reported fire incident in Akure metropolis for 4 years

Table 5: Statistics of Fire Causes Respect with Occurrence from Jan 2016 till September 2019

FIRE CAUSE	IN 2016	IN 2017	IN 2018	IN 2019	TOTAL OCCURRENCE
Bush Fire	25	22	22	14	83
Gas Explosion	2	1	1	1	5
Undergrowth Wood Burn	13	6	1	1	21
Unknown	60	60	71	51	242
Electric Fault	21	16	8	18	63
Car Burning	7	3	3	1	14
GRAND TOTAL	128	108	106	86	428

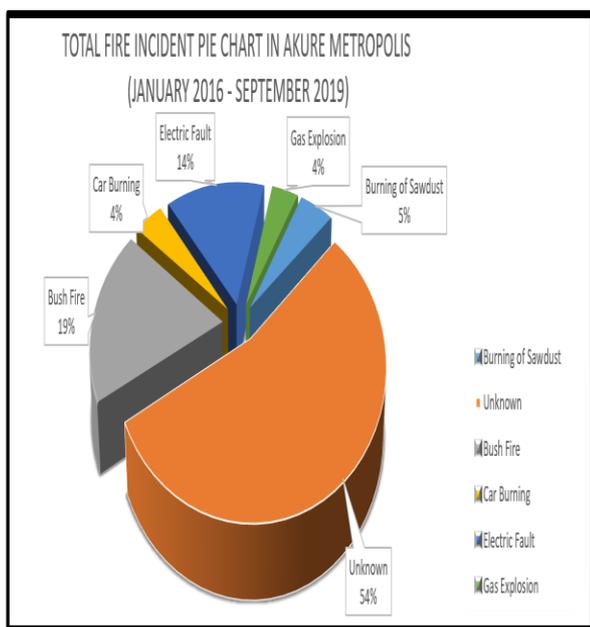


Figure 6: Pie-chart of percentage the total causes of fire incident in Akure metropolis for 4 years

3.1 Buffer Statistical Results

Table 6 below reveals the outcomes from this statistical analysis in respect to buffer distance and incidence scenes which fell within fire scenes.

Table 6: Buffer Distance in respect to Akure Incidence Scenes (Jan 2016 - Sept 2019)

FIRE STATION	BUFFER DISTANCE (M)	SCENES WITHIN
AKURE NORTH	1000	37
	2000	95
	3000	158
UBA FUTA	1000	110
	2000	102
	3000	110

3.2 Service Area Statistical Results

Meanwhile, Table 7 with its corresponding figure reveals the result of service area statistical analysis in respect to time of alert plus driving distance coverage to incidence scenes which fell within fire serviceable route in specified minutes, as presented below:

Table 7: Fire Stations Serviceable Route in Specified Minutes in Akure Metropolis

FIRE STATION	SERVICE AREA (MINS)	SCENES WITHIN
AKURE NORTH	5	204
	10	289
UBA FUTA	5	115
	10	156

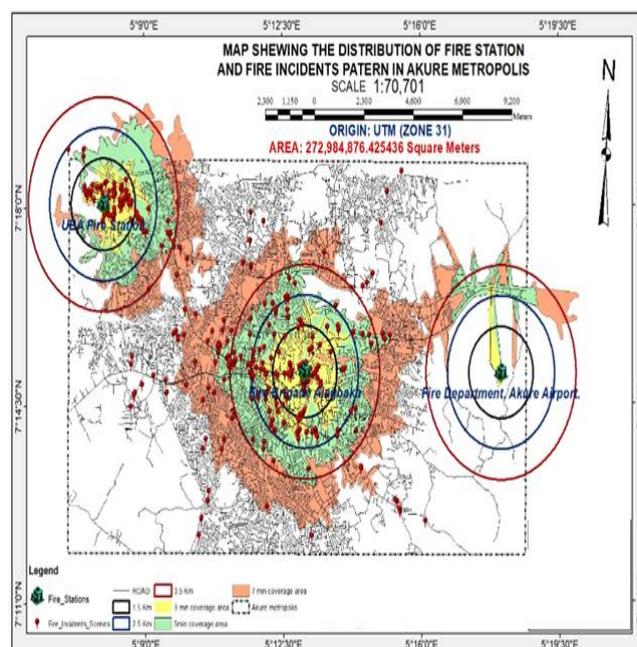


Figure 7: Network Analysis (Service area)

3.3 Akure Metropolis Urban-Fire-Risk Assessments

The scene of burning activities was observed as latent sources of fire outbreak in sawmills and schools (undergrowth wood burn and bush burning respectively). This presents a high risk of fire hazard given that small particles of wood (sawdust) dry weed can ignite fires when not well controlled.

It was also discovered that, the form of electrical connection within buildings in most of these locations has exposed how vulnerability most of the edifices are to fire hazards. Open wiring systems where electricity cables are run on wall surfaces and ceilings present a direct hazard. This could be a source of fire outbreak, particularly when

connections have been tampered with overtime with wires crisscrossing and joined together dangerously.

The results shown in figures below help to visualize the extent and nature of fire risk assessment in Akure metropolis. From January 2016 to September 2019, the density of fire occurrence mainly covered the center of the map.

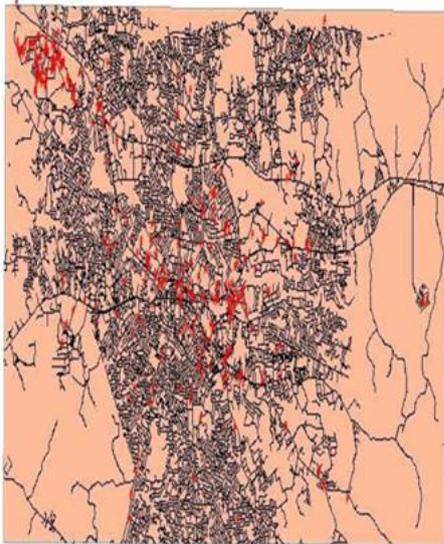


Figure 8: Density of Fire Occurrences in Akure Metropolis

The construction of UBA FUTA and Airport Fire Stations at the north-western and mid-eastern part of the metropolis was another notable factor that plays a prominent role in the extinguishing fire under their jurisdiction.

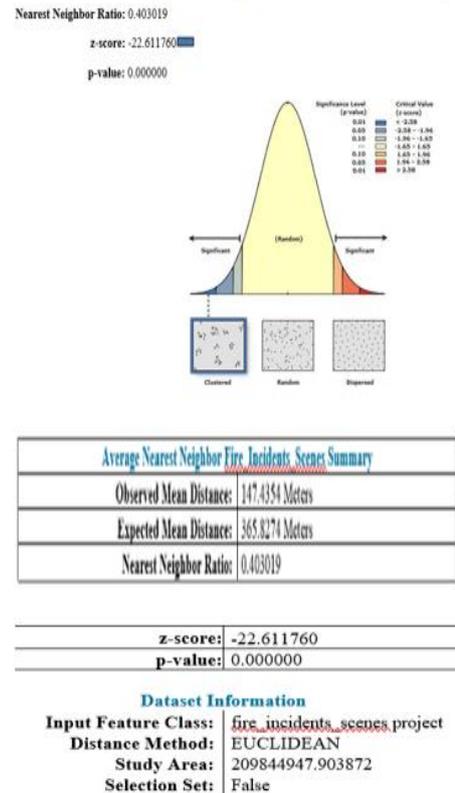
Feasibility studies reveal that, in 2016, the spread in fire incidence was diffused in all directions. This was due to bush burning in congestion with electric and usage of electronic equipment and which does not favor harsh atmosphere condition of the metropolis. As shown in Table 9, larger part of known observation made up 25 which totaled 35.94% of the whole study area. Gas explosion 2 (1.56%), undergrowth wood burn 13 (10.16%), electric fault 21 (35.94%), car burning 7 (5.47%); unknown is 60 (46.88%).

In 2017, the extent of fire occurrence reduced noticeably to 8.47%. Gas explosion 1 (0.93%), undergrowth wood burn 6 (5.55%), electric fault 16 (14.81%), car burning 3 (2.78%); unknown is 60 (55.56%).

3.4 Spatial Distribution Analysis

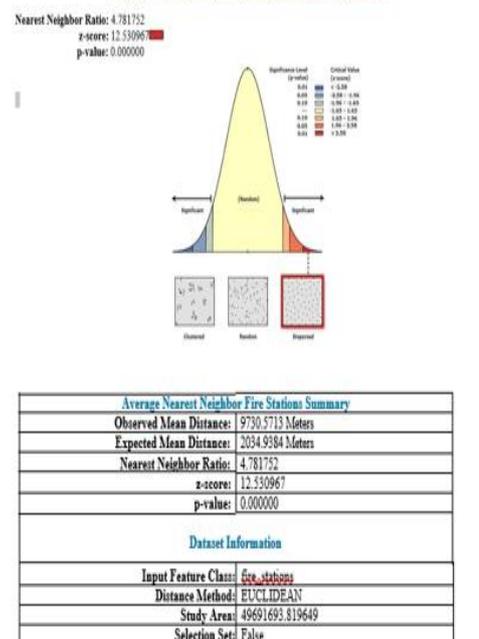
For this study, the nearest neighbor analysis was used to examine the distances between each point and the closest point to it, and then compares these two expected values for a random sample of points from a complete spatial randomness pattern. It is used for spatial geography.

Average Nearest Neighbor Fire Incidents Scenes Summary



Given the z-score of -22.6117604393, there is less than 1% likelihood that this clustered pattern could be the result of random chance.

Average Nearest Neighbor Fire Stations Summary



Given the z-score of 12.530966605, there is less than 1% likelihood that this dispersed pattern could be the result of random chance. The Nearest Neighbor Index (NNI) tool used

in this project to measure the spatial distribution of fire incident scenes is clustered pattern due to the value of Z-value -22.612, while fire stations pattern is dispersed because Z is 12.531. In order to certainly assert if objects are regularly dispersed, randomly dispersed, or clustered.

3.5 Response Rate

Observations revealed that some of fire stations in the Akure metropolis do not have paved roads to aid the access of emergency response during fire outbreaks as seen figures below after the consideration of traffic congestion, speed limits and breakers. The situation is worsened during rainy seasons when these roads greatly reduce speed of vehicles. The implication of this in the event of a fire hazard is that there may not be quick fire extinguishes means, which may lead to a higher number of casualties than if the roads were more accessible.

The below Figures 9, 10 , and 11 below indicate the driving-time-distance and proximity of UBA FUTA, Akure and Airport fire stations in Akure metropolis within the distance of 1km – 3km buffer distance and serviceable area of 5– 10 minutes driving distance respectively. The major criterion considered for this analysis is the speed limit recommended for majority of the minor roads of Akure metropolis is 40m/s. The result obtained demonstrates that in space of 5minutes the fire stations arrived approximately 200 (46.62%) incidence scenes in the past.

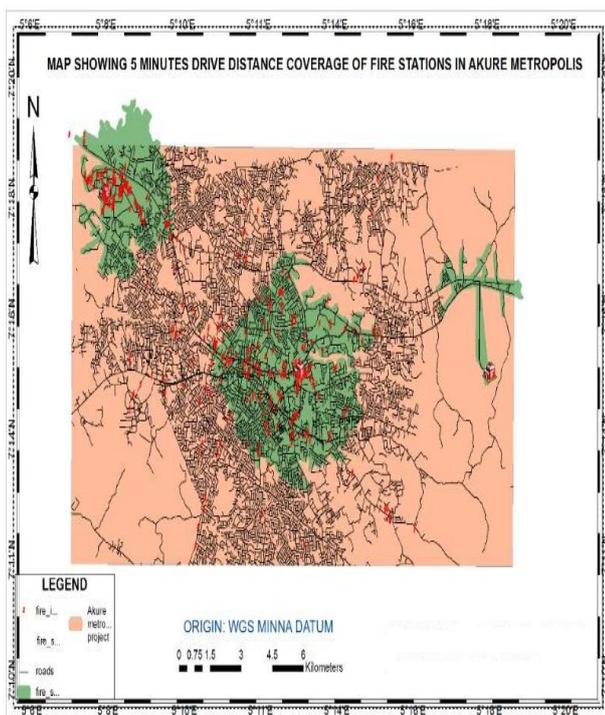


Figure 9: Map showing 5 Minutes Drive Distance Coverage of ALL Fire Stations in Akure Metropolis

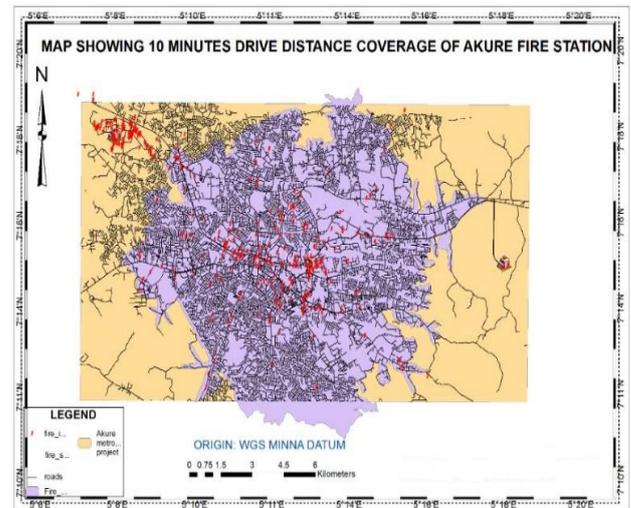


Figure 10: Map Showing 10 Minutes' Drive Distance Coverage FROM Akure Metropolis Fire Stations

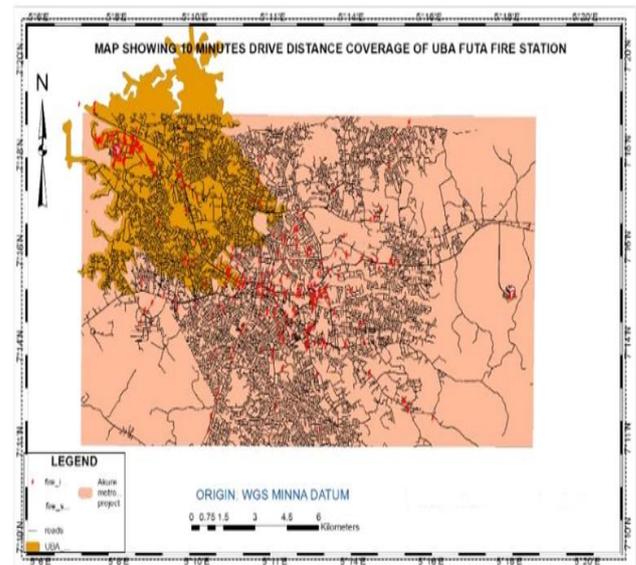


Figure 11: Map Showing 10 Minutes Drive Distance Coverage FROM UBA FUTA Fire Station

Furthermore, the study revealed the effectiveness of fire stations in the study area as shown in the figures above. queried of the processed output data acquired shows that, UBA FUTA Fire Station can effectively cover the main campus of FUTA within the space of 10minutes driving-time distance and proffer assistance in few areas such as West gate, and farthest distance to Shalom lodge at South gate, if traffic is not heavy as they always are around the hour of 8:00am and 4:00pm GMT +1. While Alagbaka Akure fire station can cover two-seventh (2/7) of the whole Akure metropolis within stipulated 10minutes driving-time distance of areas with tarred roads. These Figures further indicate the pictorial representation of service area analysis with transparent brown color, showing all fire stations arrival at incidence scenes in Akure metropolis within 10minutes if factors such as good

road, light traffic, and availability of fire extinguishing equipment are available. Thus, fire stations in Akure metropolis can effectively treat fire issues in 95% of study area and cover within the space of 10minute driving-time distance.

IV. CONCLUSION

The results and information generated from this study using data acquired from Google earth database (Geographical Information System), as well as the Global Positioning System has demonstrated the efficacy of producing Urban-fire-risk susceptibility maps using Geomatics approach, which can be a valuable tool in understanding the nature and assessment of urban activities, and their locational detail for facilitates monitoring activities. However, observing the locations of fire stations and fire incidences from January 2016 to September 2019, it was discovered that, most fires occurrences are dense at the center of Akure metropolis and the response time of Akure Fire Stations to these fires incident scenes is grossly inadequate considering the response-rate- time. Meanwhile, UBA FUTA Fire Station within University is sufficient to contain fire occurrences within its environs due to the location of fire station presence. Therefore, results of these study is hereby presented as a knowledge-based approach to modeling urban fire- Susceptibility, with the view to managing such incidences by the State, by ensuring that government should increase ratio of fire professionals per population to 1:1000 and set standards for prevention and response to fire cases using the Voluntary Fire Management Guidelines (FAO, 2006), the Global Fire Monitoring Center (GFMC), and the mechanism of the UNISDR Global Wild land Fire Network (UNISDR, 2007) to facilitate in global tactic.

ACKNOWLEDGEMENT

The author would like to acknowledge the support the members of staff of Department of Surveying and Geoinformatic, Federal University of Technology Akure, Ondo State for allowing the use of departmental equipment.

Similarly, the author thanks Oseni Ifeoluwa; and Sholarin Ridwan Adedapomola for assisting in the collection of raw spatial and attribute data.

REFERENCES

- [1] Iloeje, N.P. (1981). New geography of Nigeria. Published in Great Britain by Williams Colwes Ltd, London pp 85-120.
- [2] Tukka, A.A, (2019).“Vulnerability Mapping and Assessment of Global System for Mobile Communications (GSM) Masts in Akure South Local Government Area”, published in *International Research Journal of Innovations in Engineering and Technology (IRJIET)*, Volume 3, Issue 1, pp 14-19.
- [3] Tukka, A .A. and Odunaiya, A. K.(2018): Assessment and Determination of Spatial Distribution Pattern of Filling Stations in Akure Metropolis, Ondo State Nigeria. *Journal of Geomatics and Environmental Research, Vol. 1, No. 1, December 2018*
- [4] Michael, I.O and Franklin, I. A. (2016). Hydro geophysical Study of parts of charnockite Terrain of Akure Southwestern Nigeria. *Global Journal of Pure and Applied Sciences* Vol. 23, 2017: pp 107-121
- [5] Sahara Reporters. (2018). PHOTONEWS: 30 Shops Burnt In Akure... Fire Service Helpless Due To ‘Lack Of Fuel. *Akure*. Retrieved at: <https://saharareporters.com/photo/photonews-30-shops-burnt-akure-fire-service-helpless-due-to-lack-of-fuel>.

AUTHOR’S BIOGRAPHY



Tukka, Apollos Audu is a Registered Surveyor and a Lecturer II in the Department of Surveying and Geoinformatics, Federal University of Technology Akure, Ondo State, Nigeria.

Citation of this Article:

Tukka, Apollos Audu, “Geomatic Approach to Modelling Urban-Fire-Risk-Susceptibility in Akure, Ondo State, Nigeria”, Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 6, Issue 1, pp 102-109, January 2022. Article DOI <https://doi.org/10.47001/IRJIET/2022.601018>
