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Application of GIS technology to geospatial location of Lagos State fire stations, Nigeria

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Abstract: The number of lives and properties lost to fire outbreak has heightened the need for evaluating the efficiency of fire stations within Lagos State, Nigeria. In 2016, over 16 billion naira was lost to fire in the State. This research examined the application of GIS technology to geospatial location of Lagos State fire stations and their efficiencies. The aim of this research is to evaluate fire station distributions in relation to population and economic level within Lagos State using GIS technology. This evaluation provides various analyses to support efficient planning of fire services and identify areas that are less serviced within Lagos State. To accomplish this aim, graphical representation, Euclidean buffers, and network analyst, closest to facility mapping tool were used. The main data used were; Lagos State base map, XY coordinates of commercial/industrial buildings, thirty-four fire stations, (Federal, state and privately owned), and road network of Lagos State. The study revealed that within 1km coverage area, these thirty-four (34) fire stations owned by Lagos State (14 fire stations), Federal (8 fire stations) and Privately owned (18 fire stations) are insufficient for efficient service in the populated areas of Lagos state. The paper recommends need for more geospatially located fire stations in the populated areas of Lagos State for enhancing and achieving better and safe environments.

Keyword: Lives, Properties, Outbreak, Fire Station, Lagos State, GIS technology, Efficiencies,

1. Introduction

The mission of the fire service is to protect life, property, and natural resources from fire and other emergencies. With increasing demands, the fire service must utilize the best tools, techniques, and training methods to meet public expectations (ESRI, 2007 and 2012). Currently, the fire management team and information technology professionals are innovating modern and creative ways to apply this new technology to solve ever increasing fire service demands (Thomas, 2011; Ayodele, 2011 and Bukowski, 2008).

Due to increasing community's population growth, it has become necessary to upgrade, replace or relocate existing stations or build more fire stations to cope with the rise of public demands for emergency services (Conweh, 2012). With this urbanization rate and consequent heavy traffic congestion, the location of new fire stations is becoming a huge problem in urban planning and development (Stewart, 2004). The fire service requires tools to help identify the origin of any emergency, determine the shortest and quickest route to the incident and develop a more efficient approach to combat the fire via new station location. ESRI, 2012 and Badran, 1997 attributed causes of fire hazards to overcrowding in houses and work places, rapid expansion of production and commercial activities in industrial zones of newly developed areas which frequently lack adequate measures to counter fire hazards (Shikoli, 2015). Fire stations are one of the important and vital land uses in urban areas, needed to guarantee the safety of life and properties of urban residents.

The increase in urbanization has put population growth of urban areas in developing countries at the risk of imminent hazardous fire (Habibi et al 2008). According to Habibi et al (2008), the main criteria for fire station location are distance among the stations; level of fire risk in different parts of a city; accessibility; coverage area; population, and directions of city expansion. Studies like this, with existing stations must begin with an assessment of the effective response coverage area for each of those stations, usually by using time or distance limits. Most researchers chose to create the response area as a straight-line or Euclidean buffer rather than a network buffer because of computation time (Liu et al. 2006) or because the necessary network data was unavailable (Murray and Tong 2009).

2. Study area

Lagos State is a prominent place in Africa and the World, with its adjoining conurbation, having a population estimate of over twenty-one million in 2015 and it's rated the largest population/second largest city after Egypt, Cairo in Africa (National Wildlife Coordinating Group, 2014)

Lagos State, just like most urban area, is in a developing country Nigeria with a fast population growth rate. Her population according to the Lagos State Bureau of Statistics (LBS) is put at over 22,583,305 Million (Lagos State Estimate, 2014), and a population annual growth rate of 3.2 % (Annual abstract of statistics, 2012). The United Nations estimated that the city population by year 2015 will have risen to about 24.5 million at a growth rate of 6-8% per annum making Lagos State the 3rd Largest Mega city in the world (Lagos Bureau of statistics, 2016; Lagos state Fire service, 2017).

2.1 Lagos population

Within the last ten years, Lagos State Population has grown drastically. This growth is quite significant in all parts, including the suburbs (GISGeography, 2017). For instance, Epe increased from 181,000 to above 200,000, (Table 1) and figures 1 and 2 showed this increase clearly. With this population increase, it can be said that

there will be high risk of fire outbreak in these suburb areas (Burrough and McDonnell, 1998). As increase in population may give rise to imminent fire outbreak, Fire Stations facility must be increased to address any subsequent future fire outbreak (Mohammed, 2014 and Monsuru, 2015).

Figure 1 shows that Lagos State population is concentrated within the metropolis, as these areas have companies and industries (Map is prepared using UTM projection and represents Zone 31N). There is always an influx of people to a city's central business district. As a result of this, Public facilities like Fire Stations are majorly situated in this region. It can be said that economic level within the metropolis is higher than that of the suburbs.

3. Methodology

Figure 3 describe the steps and methods adopted in achieving the aim and objective of this study.

his study uses both spatial and non-spatial data, such as:

a) Lagos State population data (Table 1), acquired from Annual Abstract of Statistics, Nigeria (2012, Lagos Bureau of statistics web and National Population Commission web (2017);

b) Nigeria and Lagos State digital maps which comprises: Lagos state shapefile in Geographic coordinate system (GCS_WGS_1984: WKID: 4326 Authority: EPSG) showing local government boundaries. Source: Guinea Current Large Marine Ecosystem/Unilag Centre for Environmental Information and Decision Support Systems (EIMS).

c) Road network map shapefile of the state (GCS_WGS_1984: WKID: 4326 Authority: EPSG) Source: Open Street Map (OSM) https://www.openstreetmap.org/relation/301633.

d) XY Coordinates of Commercial/Industrial buildings, Lagos state Fire service and Federal Fire service was acquired from Google earth and Fatai and Olusegun (2016). Ground truthing was done for these sites.

Table 1: Lagos state five years interval projected population data with reference to 2006

	1991	**Census 2006**	**Projected population 2011**	**Projected population 2016**
Total	5,725,116	9,113,605	10,694,900	22,745,200
Agege	417,981	461,743	541,860	1,371,700
Ajeromi-Ifelodun	593,561	687,316	806,570	1,905,700
Alimosho	430,890	1,319,571	1,548,530	2,717,900
Amuwo-Odofin	225,823	328,975	386,060	697,000
Apapa	154,477	222,986	261,680	693,600
Badagry	119,267	237,731	278,980	316,400
Epe	101,464	181,734	213,270	241,900
Eti-Osa	157,387	283,791	333,030	1,305,900
Ibeju/Lekki	24,937	117,793	138,230	156,800
Ifako-Ijaye	233,341	427,737	501,950	988,300
Ikeja	203,383	317,614	372,720	861,300
Ikorodu	184,674	527,917	619,520	706,100
Kosofe	412,407	682,772	801,240	1,240,900
Lagos island	165,996	212,700	249,610	1,141,700
Lagos Mainland	273,079	326,700	383,390	835,800
Mushin	539,783	631,857	741,490	1,754,600
Ojo	215,837	609,173	714,870	1,250,100
Oshodi-Isolo	449,781	629,061	738,210	1,506,400
Shomolu	358,787	403,569	473,590	1,361,100
Surulere	462,261	502,865	590,120	1,692,000

Source: Lagos Bureau of statistics (2016)

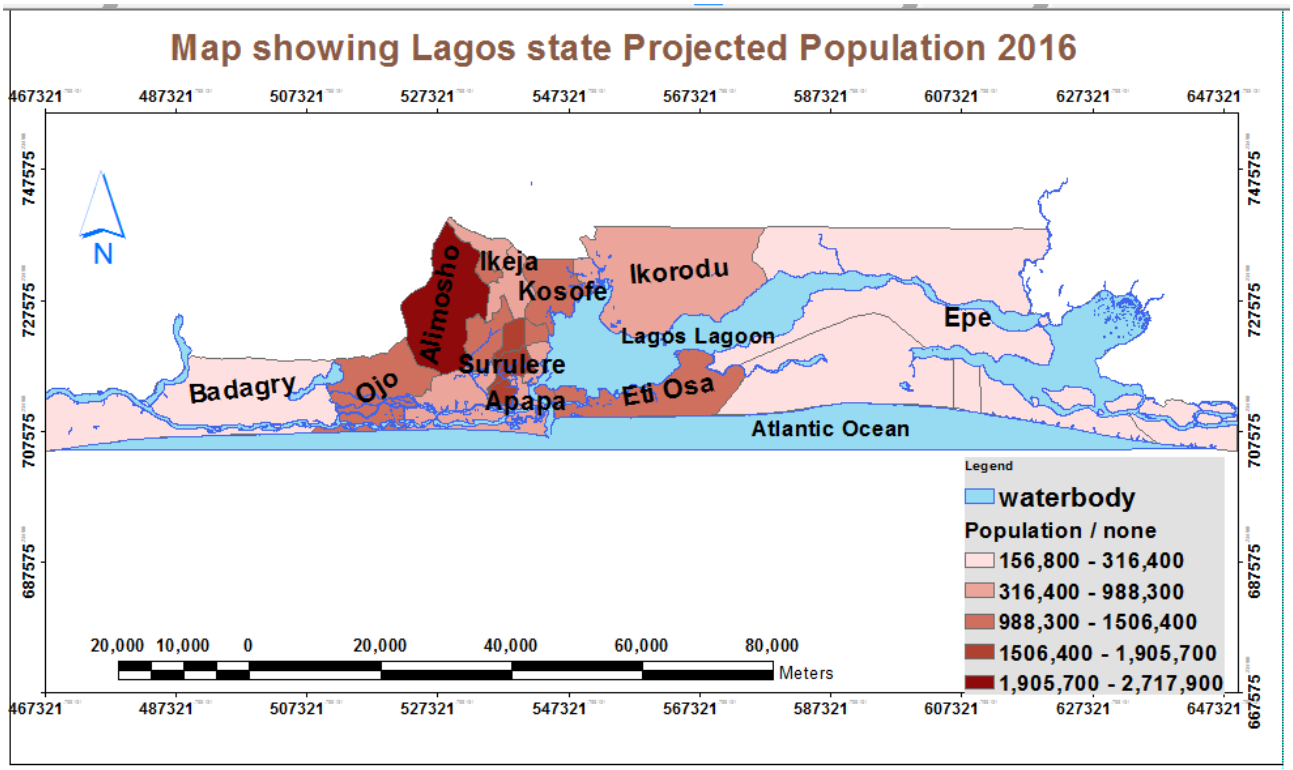

Figure 1: Map showing Lagos state projected population and water-body in 2016. (Source: Lagos Bureau of Statistics, 2016)

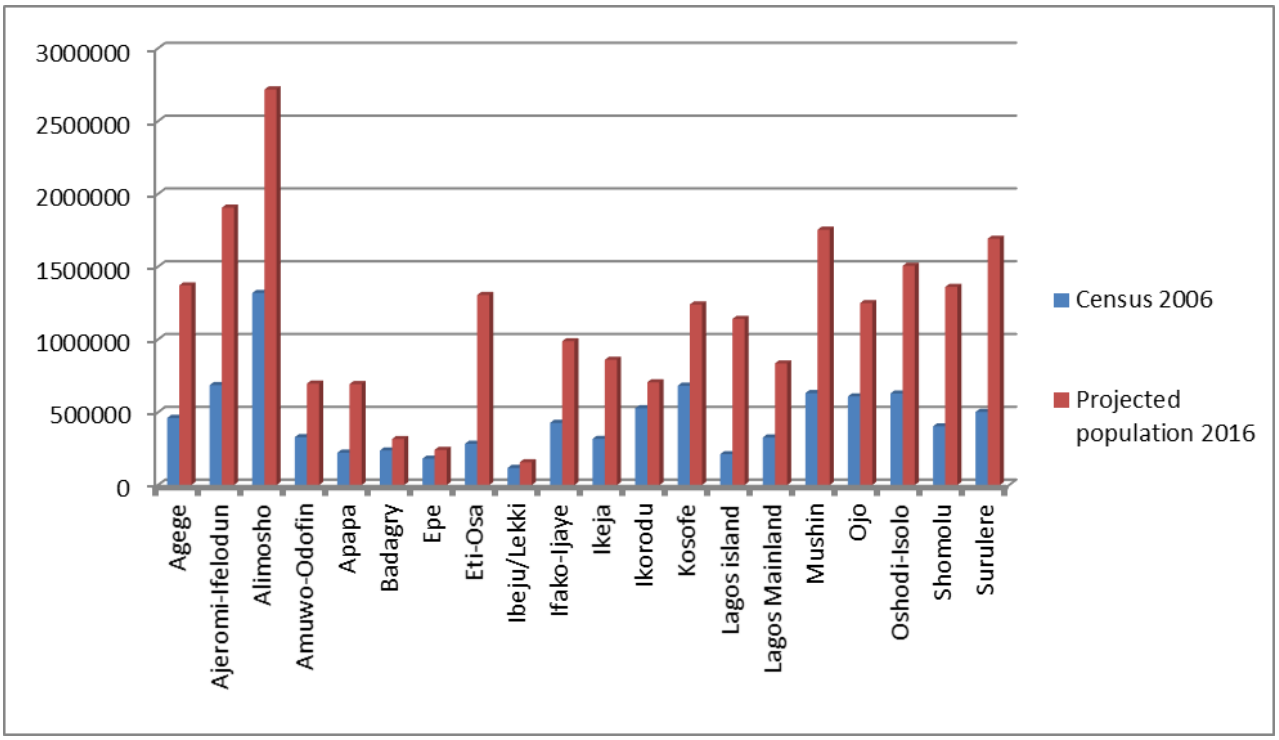

Figure 2: Graph showing Lagos population change between 2006 and 2016

4. Results

4.1 Evaluation of Fire Service in Lagos State and its population

Comparing Lagos population with number of available fire stations, it can be seen from figure 4 and table 2 that the available fire stations are concentrated within the Metropolis, while the Suburb regions like Alimosho, Ojo, Mushin, Ikorodu, and Kosofe, each, has one fire station. Therefore, area like Alimosho which have high population or increasing industries is under-served.

From the map in figure 5, and figure 6 it can be seen that both fire stations and fire hydrants are concentrated

within the metropolis, leaving the suburbs with just one fire station and no hydrants, while commercial buildings, are growing in the suburbs as seen in figure 7.

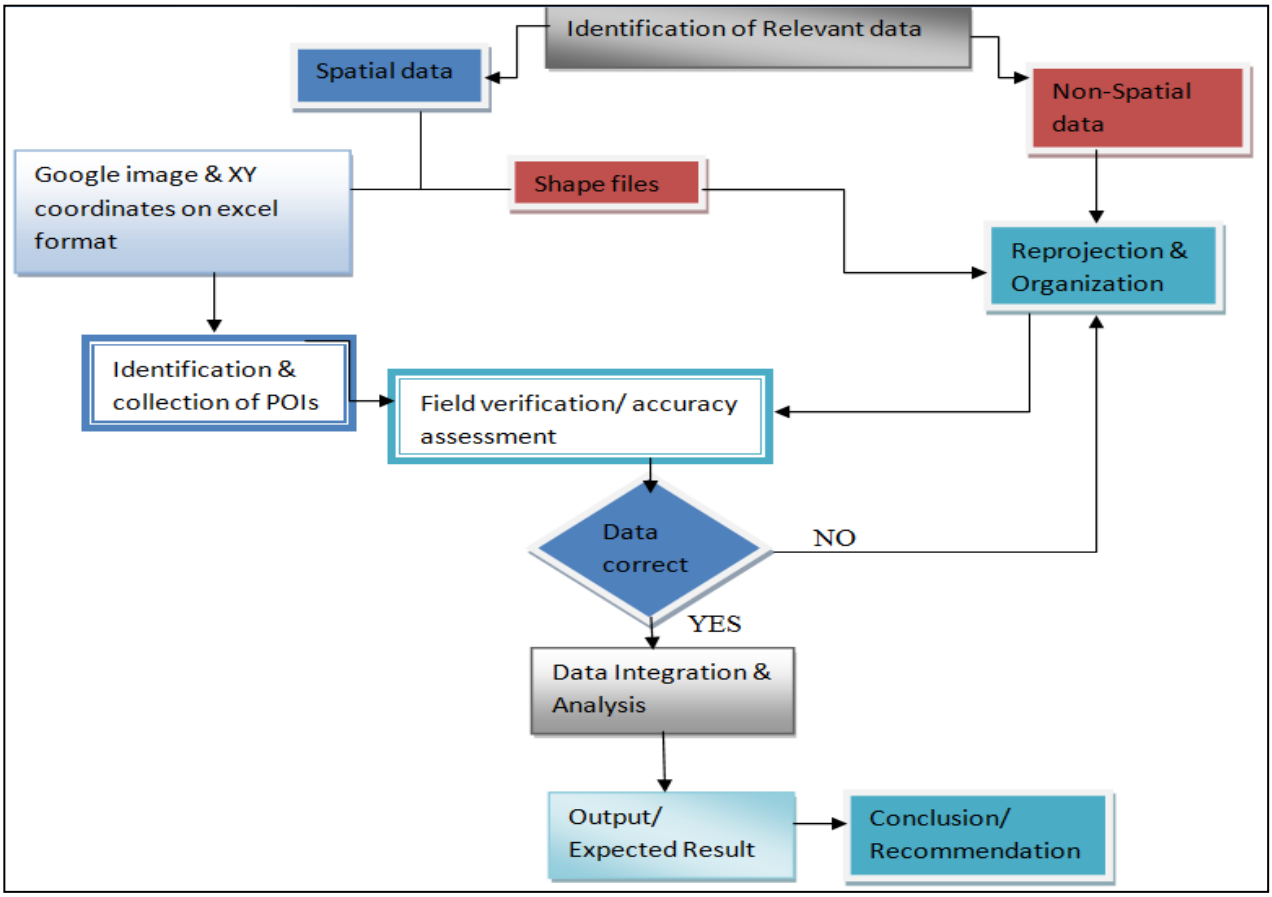

Figure 3: Flow chart of methodology

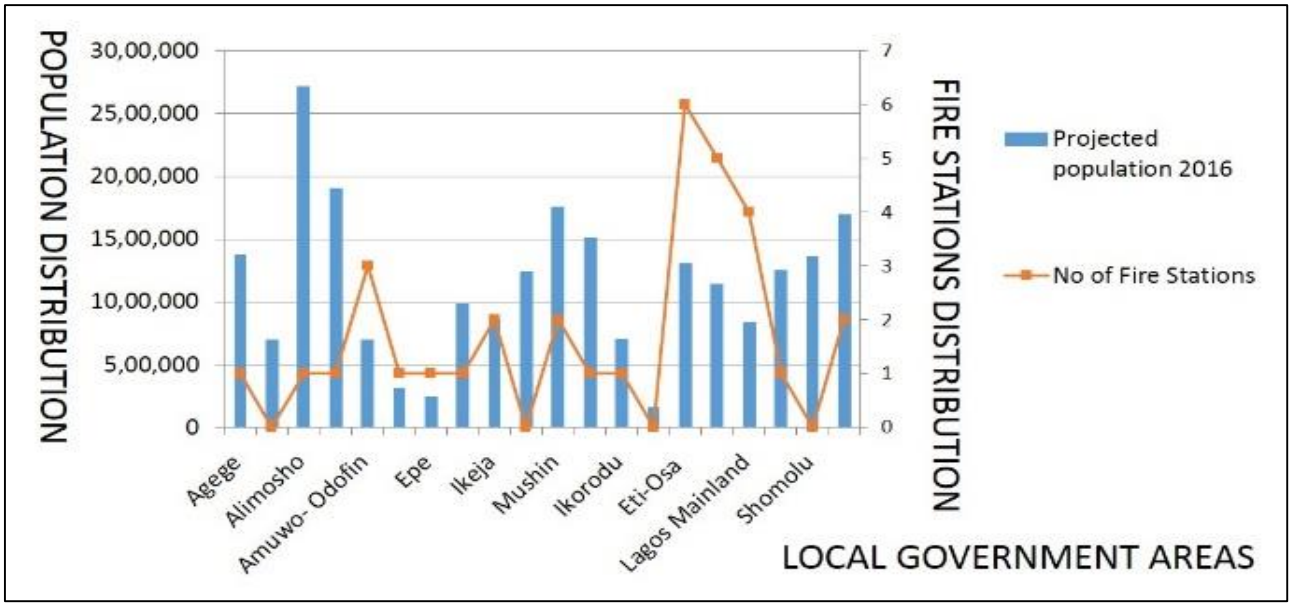

Figure 4: Graph of population distributions against number of fire stations in some Local government areas of Lagos state

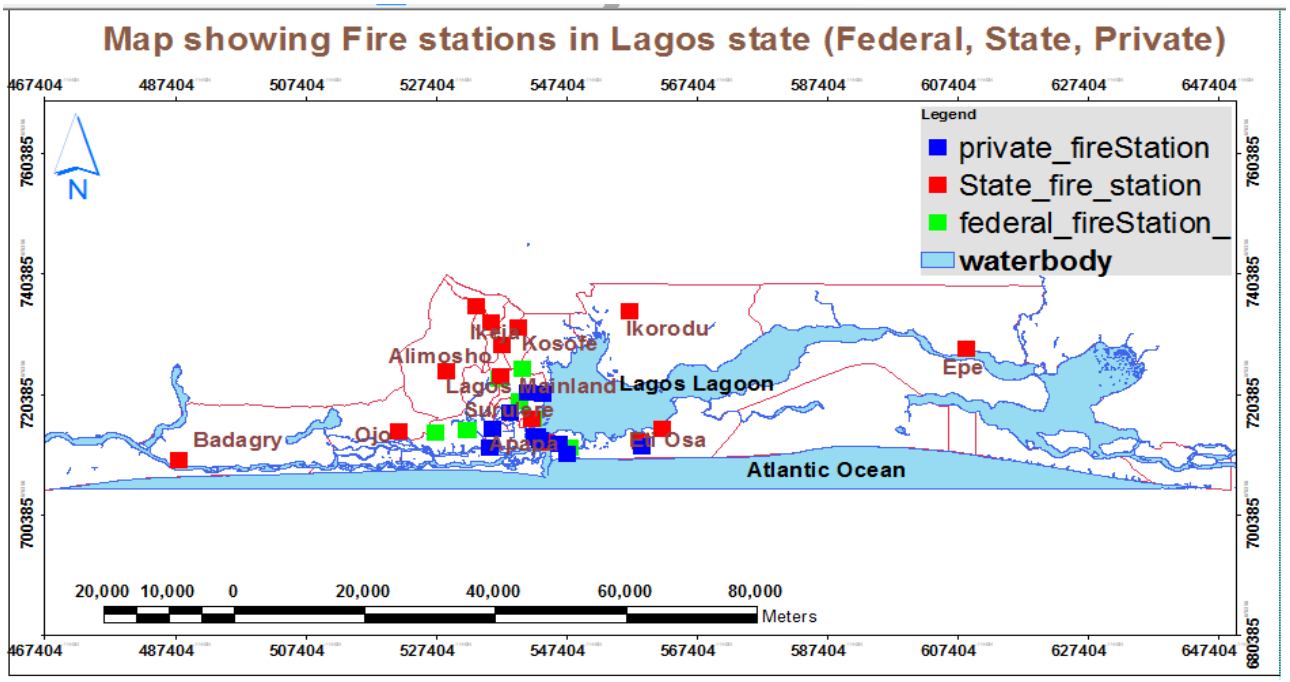

Figure 5: Federal, State and Privately owned fire stations and waterbody distributions within Local government area of Lagos state

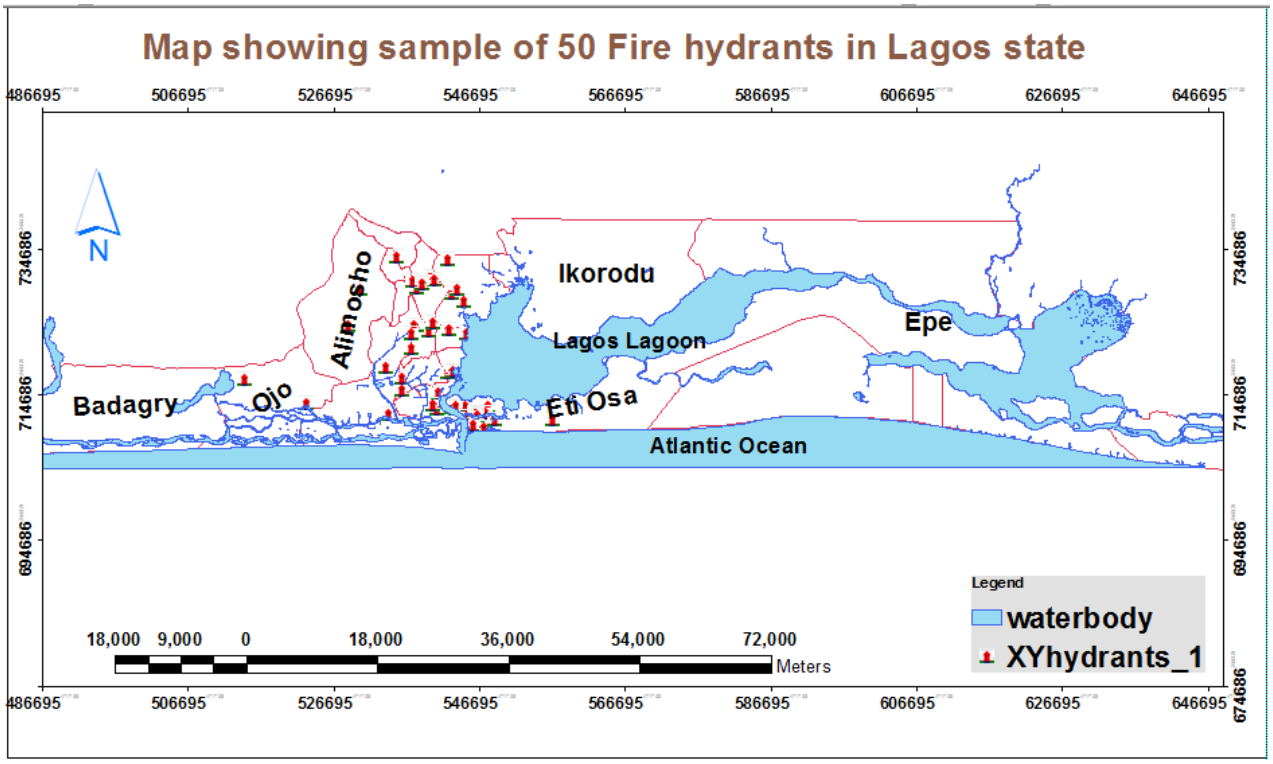

Figure 6: Map showing 50 locations of fire hydrants and water-body in Lagos state

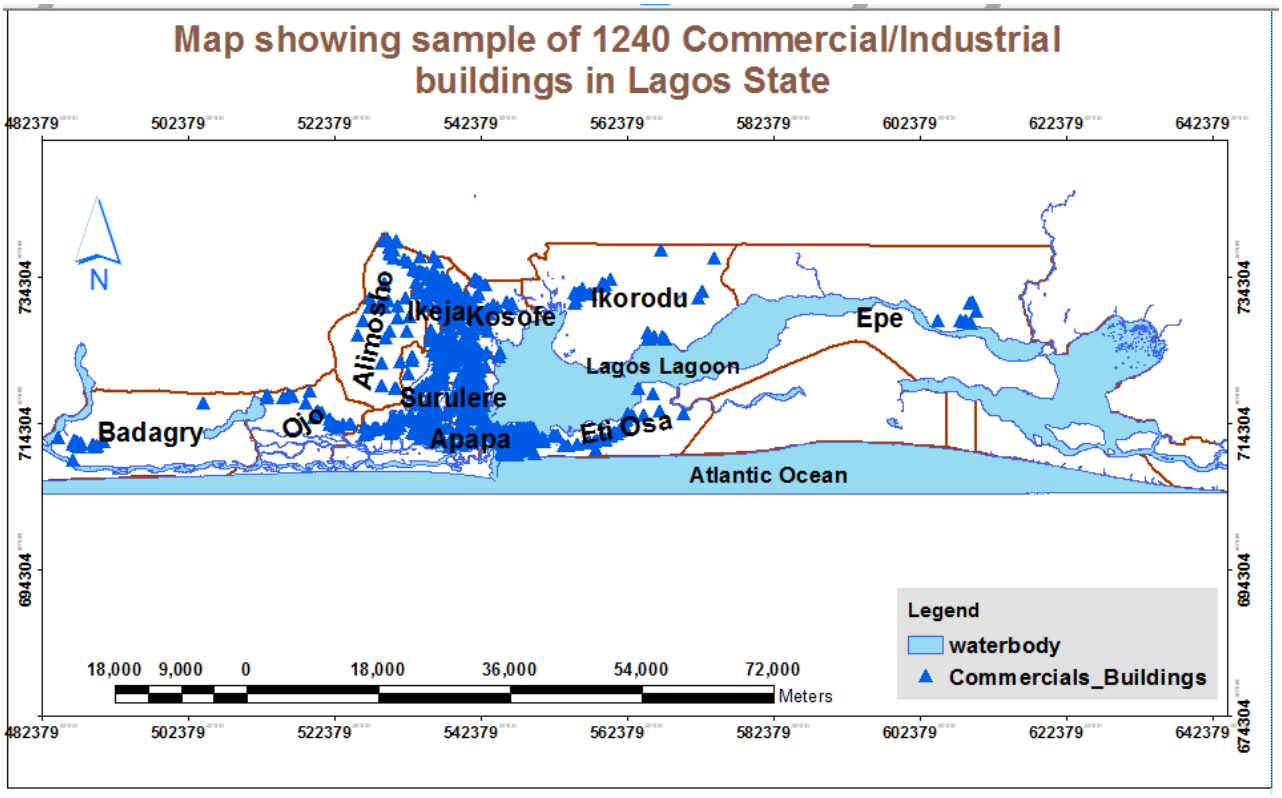

Figure 7: Map showing 1240 samples of commercials buildings distributions within Local government area of Lagos state

Table 2: Population distribution/Number of Fire stations in the twenty Local government areas of Lagos state

LGA	Population	Number of Fire Stations
Agege	461,743	1
Ajeromi-Ifelodun	687,316	1
Alimosho	1,319,571	1
Amuwo-Odofin	328,975	3
Apapa	222,986	0
Badagry	237,731	1
Epe	181,734	1
Eti-Osa	283,791	1
Ibeju/Lekki	117,793	6
Ifako-Ijaye	427,737	1
Ikeja	317,614	3
Ikorodu	527,917	2
Kosofe	682,772	0
Lagos island	212,700	5
Lagos Mainland	326,700	4
Mushin	631,857	0
Ojo	609,173	1
Oshodi-Isolo	629,061	1
Shomolu	403,569	0
Surulere	502,865	2

4.2 Closest facility mapping query

Network analyst closest to facility mapping was carried out on commercial buildings, it was used to locate the closest specific Fire station to a Commercial/Industrial building. This is seen in figure 8 and 9.

The closest facility map in figure 8 shows that closest distance of Fire Station to a shopping complex is more than 4.7 km and closest Fire Station to Ikeja secretariat is 620 meters, although other Fire Stations are 4.07 km and 4.4 km distance to the secretariat which seems quite far. As in some cases the closest Fire Station may require assistance from other Fire Station.

4.3 Euclidean distance calculation (buffer zones) The buffers zone of 1km also butress the point earlier made that demand points and historic incident points are not properly covered by any Fire station service coverage of 1 kilometer. Buffer zones are also a type of visualized coverage area, of the facility which is buffered. The map in figure 9 shows that some Commercial/Industrial buildings are left out from the 1km and 2km buffer of Fire Stations.

5. Conclusion

A major concern of any country or society is security, fire as a threat ought to be controlled at all cost. In this age of computer technology, the GIS technology has been proved to be a tool for enhancing efficiency in fire control services across the globe.

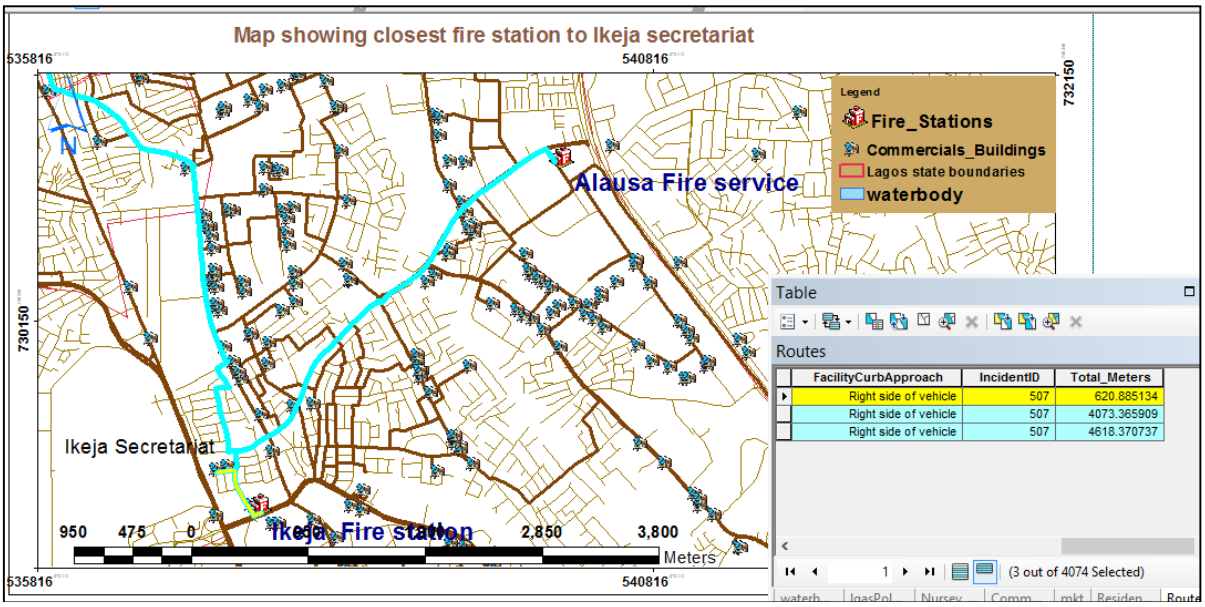

Figure 8: Closest fire station (Alausa fire station) to Ikeja secretariat

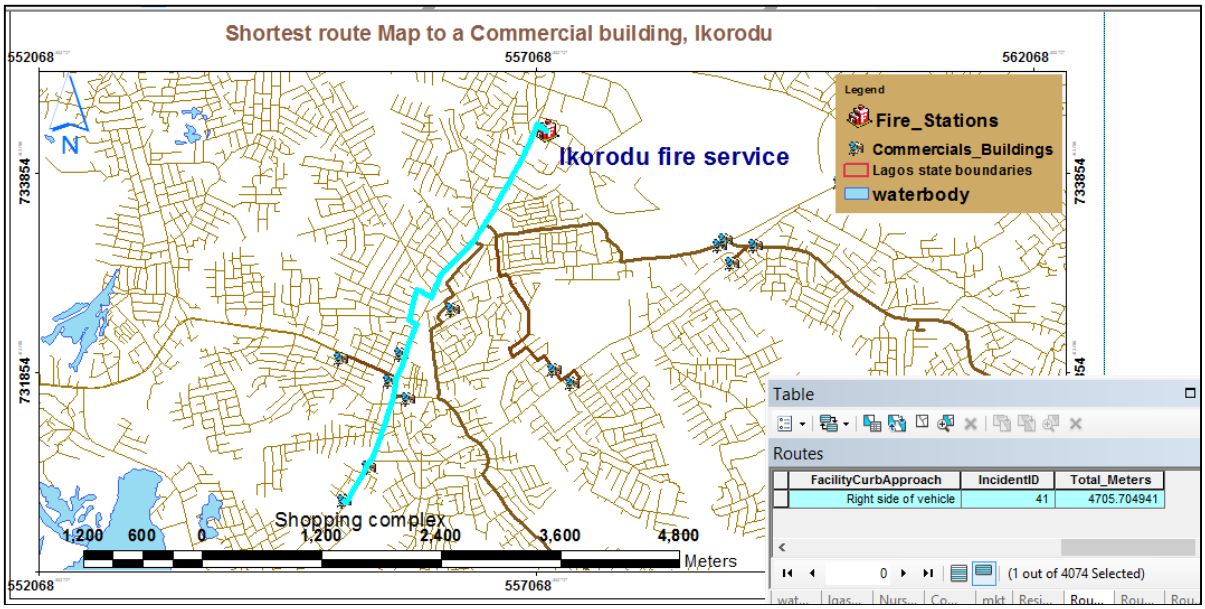

Figure 9: Map showing shortest distance from Ikorodu fire station to shopping complex

The mapping of fire facilities was achieved and the evaluation of their suitability in location as it relates to Commercial/Industrial buildings and distribution was done using Geographic Information System (GIS) technology.

The main findings from this study was that Fires service coverage area within 1km, and 2km response was concentrated more at the Lagos metropolis depriving other populated region outside the metropolis of the stipulated 1km and 2km response coverage, thus making such regions highly vulnerable to loss of lives and properties in event of a fire accident. From the result of the distribution of the number of fire stations/population of each local government of the State, it was deduced that Alimosho, Apapa, Ojo, Mushin, and Ikorodu are at risk in the event of the occurrence of any fire outbreak. This is due to the ratio of the increasing population as against the few Fire stations situated in these areas.

The need for more geospatially located Fire Stations to accommodate the present gaps shown in figure 10, between the relative buffer zones of (1-3) km. in Lagos State. This would go a long way to avert/reduce loss of lives and properties that might arise in any imminent future fire outbreak. Furthermore the study showed that distance within Fire hydrants are quite far, with a minimum distance of 820 meters apart, this is higher than the NFPA regulation of 100m apart. Also, the closest fire station to a point of interest is closer within the metropolis than in the suburbs. From the research it was revealed that everyone do not have access to fire and rescue services within five minutes of travel time. It can be concluded that the present Fire stations in Lagos State cannot serve the entire population adequately.

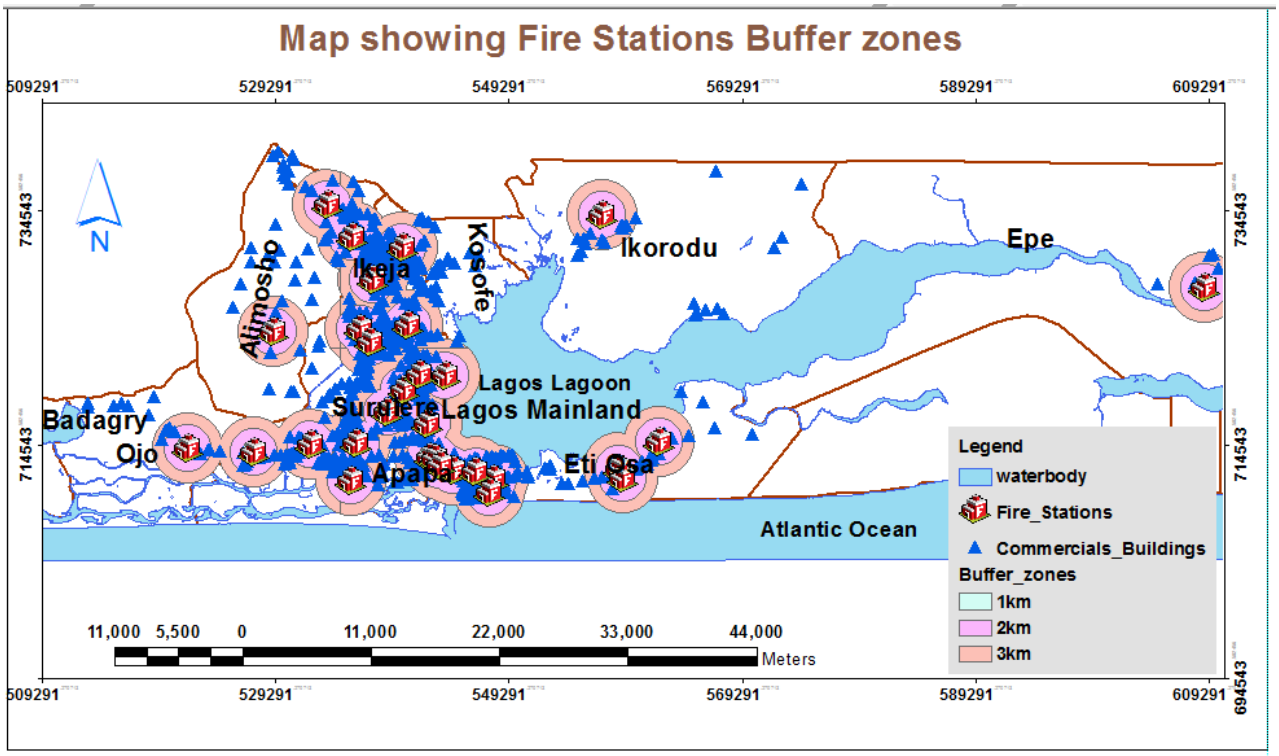

Figure 10: Fire station and Commercial/buildings buffer zones 1km-3km

6. Recommendations

New fire stations should be established using the suggested areas of short fall of fire stations. Federal government should embark on purchasing new fire trucks for federally owned stations, and Lagos state government should provide barracks to accommodate firemen officials. The present fire stations should be upgraded. Also, periodic training on safety awareness should be carried out in communities, schools, and offices regularly. State government should make it mandatory for owners of private companies and filling stations in a particular localty to jointly build fire stations as part of their "giving back to the community exercise". State government should also ensure that fire hydrants are situated within minimum distance reach in all local government areas of the state.

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