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Geospatial Decision Support System for Fire Emergency Response in Rivers State, Nigeria

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ABSTRACT

Effective and efficient emergency management and response requires having the right information within the shortest possible time frame in order to save lives and property, this also involves the free flow of the right information in the right format, to the right person, in the right time to make the right decision. Information required to deal with an emergency event is of spatial origin and Geoinformatics have been known since its inception in the early 60s to handle time related spatial information. Emergency management is a national concern, at the most basic level it is the responsibility of the state emergency management agencies to respond effectively and efficient to any emergency situation. The aim of this research is to evaluate benefits of the use of Geoinformatics technology in emergency management to assist in planning and acting as a decision support system to Fire emergency managers.

In this research, Rivers state fire stations were evaluated as units of emergency delivery system, the research examined the role of Geoinformatics in evaluating the performance of emergency fire service delivery based on response time and fire station distribution. Using ArcGIS Network analysis and an annual fire incident record from the year 2000-2012, the study revealed that the functional fire stations operating in Rivers state were unable to cover the entire populated regions within 5 minutes response time. In the case of this research the primary question that was addressed was; "Does everyone have access to rescue services within five minutes of travel time?" The GIS location-allocation and Network analysis tools were deployed to address these issues, and by doing so the technology was used to address issues of equity framed by the values of efficiency and effectiveness. Using the ArcGIS Network analysis tools the research was able to evaluate and assess the nature and performance of the Rivers State fire emergency services.

One vital discovery was that fire service coverage analysis within 5-minutes response in the study area generated many gaps depriving the populated region of the state 5-minutes response coverage thus making such region highly vulnerable to loss of lives and properties in event of a fire inccident. The research concluded by proposing the location of three fire stations using location allocation tool to help reduce the burden of other fire station and ensured ninety five percent (95%) wider coverage and reduced response time. This research also recommended that more efforts should be channeled towards curbing the practice of illegal and crude ways of refining petroleum products in the state; hence the result of the partial correlation of the variables associated with causes of fire incidents in Rivers State indicates a huge influence of kerosene explosion on fire incidents in Rivers state.

Key words;

1.0: INTRODUCTION

The recent growth of population densities and economic expansion has created greater concentrations of residential and commercial risks within the urban areas which result in frequent emergency and disasters situation that can lead to loss of life and valuable properties. Consequently there is a need for proper emergency planning and responds system. Emergency planning and management is a dynamic process of mitigating, preparing, responding, and recovering from any form of emergency situation. It’s a critical segment of the society where governments, stakeholders’ planners, managers and even the general public play a vital role in saving lives and property.

Whether an environmental analyst is assessing the likely impact of a hazard, or an emergency manager is identifying the quickest and shortest evacuation routes during a disaster, or a fire, police and paramedic team is been called to a fire, crime and life threaten situation, or a civil engineer is carrying out a rebuilding attempt after a disaster, all of these individuals tasks involves spatial component as well as relevant spatial-related data and this data are conventionally handled with the help of Geographical Information Systems (GIS). GIS allow access to different layers of Spatial referenced data (SRD) such as transportation network, postal addresses index, highways, land use, etc. GIS aids quick and accurate decision making by facilitating the integration, storage, querying, analysis, modelling, reporting, and mapping of this data. Prior to the introduction of GIS, emergency response decisions were mostly based on a manager's perception and work experience instead of current information on the incident that requires emergency responds. Whether responding to a severe weather event or anthropogenic hazard, emergency management personnel require accurate information presented in a format that can be quickly comprehended. Such information containing data describing population structure, infrastructure, physical geography, political boundaries, Land use and other vital aspects of an area comes from many sources, moreover the speed of which most emergency events occur does not allow managers enough time to gather these resources hence wrong decision are made resulting to loss of lives and properties. But with the advent of Information Technology, a common GIS based framework makes data produced and held by different agencies readily available and accessible so that current, timely and accurate information can be brought to aid emergency management during any emergency situation. GIS has a modelling ability that allows user to make adjustments to data and scenarios for adequate planning and predicting result as support for decision that requires knowledge about population demography, best route, closest facility, coverage area, weather events, roads, buildings etc. GIS broaden the capabilities of conventional database systems by enclosing spatially- referenced information (cartographic grids , layers, etc.) as well as textual data (attributes and spatial data) thereby making them potent tools for complex modelling, planning and designing, and imaging abilities for spatial analysis (Chrisman, 1997).

1.1: AIM AND OBJECTIVES

This research is aimed at creating a geospatial database infrastructure which demonstrates capacity for effective planning, response and management of fire disaster in Rivers state.

To achieve the stated aim, the following objectives were employed;

1. Acquiring geometric and attribute data including aerial photo imagery of the study area.
2. Designing a suitable database for the study area
3. Analyzing collated geospatial data for patterns, distribution, relationships, vulnerability, trends and spatial component.
4. Identifying service coverage gaps or deficiency within the study area and closing the identified gaps.
5. Determining the desired emergency routes, response time, new service area, closest facilities and new location allocation using arcGIS network analyst.
6. Recommending relevant proactive and mitigation measures to enhance effective management of fire disaster in Rivers State.

1.2: THE STUDY AREA

The study area is Rivers state, Niger delta region of Nigeria. It is located between latitude 4, 28,39N and longitude 6, 10,12E. It is bordered in the north by Imo and Delta states, Bayelsa state in the west, Abia state in the east, the gulf of guinea and the Atlantic Ocean in the south.

It covers a landmass of about 1,077km2 with an estimated population of about 5,689,087 people (National Population Commission, 2006)

Geology: Rivers State lies on the recent coastal plain of the eastern Niger Delta. Its surface geology consists of fluvial sediments which includes the recent sediments transported by Niger River distributaries and other rivers, such as Andoni, Bonny and New Calabar. These materials deposited as regolith overburden of 30m thickness are clays, peat, silts, sands and gravels.

The depositional sequence exhibits massive continental sand stones overlying an alternation of sandstones and clays of marginally marine origin, but eventually grading downwards into marine clays. Sands, by far form the largest group of rock types in Rivers State, while mud constitutes all the polluted brackish waters of the riverine areas. However, peat constitutes the various vegetal and animal remains that lie in bogs and shallow pits. The gravel and pebbles form the last unit of the subsurface rock type, and are usually found at the base of the river channels.

Relief: The land surface of Rivers State can be grouped into three main divisions: the fresh water, the mangrove swamps of Akuku Toru, Abua/Odual, Asari Toru, Degema, Okrika, Ogu/Bolo, Bonny, Andoni and Opobo Local Government Areas; and the Coastal Sand ridge zone. The freshwater zone is the plain that extends north wards from the mangrove swamps. This land surface is generally less than 20m above sea level.

This lower Niger floodplain has a greater silt and clay foundation and is more susceptible to perennial inundation by river floods. The value of the mean thickness appreciates upward to about 45 m in the northeast and over 9m in the beach ridge barrier zones to the southwest. The flood plain is a homoclinal geomorphic structure whose trends west wards and southwards are broken in many places by small hogback ridges and shallow swamp basins (Aisuebeogun, 1995). The southern part is affected by great tidal influence.

Most water channels in the freshwater zone are bordered by natural levees, which are of great topographical interest and of great economic importance to the local people for settlements and crop cultivation. The upland is undulating to the hinterland and sandwiched with NWSE and EWW direction ridges and attains a maximum height of 30m above sea level at Okubie, to the southwest. The narrow strip of sandy ridges and beach ridges lie very close to the open sea. The soils of the sandy ridges are mostly sandy or sandy loams and supports crops like coconut, oil palm, raffia palm and cocoyam. Fourteen of the twenty three LGAs of the State are located on the upland with varying heights between thirteen to 45m above sea level. These include Ogoni, lkwerre LGAs, Ahoada, Abual/Odual, 0gba/ Egbema/Ndoni LGAs and Port Harcourt LGAs. The drier upland area of Rivers State covers about sixty one percent while riverine area, with a relief range of 2m to 5m, covers about thirty nine per cent of the State. The entire topography of the State is also characterized by a maze of effluents, rivers, lakes, creeks, lagoons and swamps crisscrossing the lowlying plains in varying dimensions.

Drainage: Drainage is poor being low-lying with much surface water and a high rainfall of between 3,420 mm and 7,300 mm. Thus, almost all riverine LGAs are under water at one time of the year or another.

2.0: MATERIALS AND METHODS

ArcGIS Software. ArcGIS is one of ESRI software product developed to provide GIS solution to numerous spatial related problems. The ESRI ArcGIS product comes in various packages such as ArcGIS for Desktop, ArcGIS for Mobile, ArcGIS for Server and ArcGIS Online, this study made use of ArcGIS Desktop. ArcGIS Desktop is a comprehensive, integrated and scalable system designed to perform various GIS analysis ranging from simple to complex analysis such as mapping, data management, geographic data analysis, editing and geoprocessing functions. ArcGIS Desktop software suite is made up of three applications that work together to give ArcGIS Desktop its powerful analytical capability. These three applications are;

1. ArcMap- use for mapping and data manipulation.
2. ArcCatalog- for data management.
3. Arctoolbox- for data conversion, modelling, and spatial analysis.

ArcGIS Extensions: Esri GIS software provides an extensive variety of optional extensions that significantly increases the Analysis, Productivity and solution–based capabilities of ArcGIS. Most of these extensions are available on the ArcGIS desktop having flexible and user friendly graphical interface to solve a numerous environmental, economic and social problems. ArcGIS Extensions uses ArcGIS 3D Analyst for powerful and advanced visualization, analysis and surface generation tools that manage and analyze data in 3D realistic perspective ArcGIS Spatial Analyst. Used as a spatial modelling and analysis tool that query maps to derive new information, create maps and analyze raster and vector data set. ArcGIS Network Analyst provides solution to transportation and service location problems. ArcGIS Schematics help to Visualize and manage linear physical and logical (economic and social) network through an automated schematic representation of geodatabases. ArcGIS Tracking Analyst is for space and time based visualization analysis. ArcGIS Geostatistical Analyst serves as a tool for statistical modelling, data exploration and probabilistic mapping which Serves as a tool to create a valid statistical prediction of event.

Table 2.1: GIS Desktop Extensions

S/N	**ArcGIS Extensions**	**Uses**
1.	ArcGIS 3D Analyst	For powerful and advanced visualization, analysis and surface generation tools that manage and analyze data in 3D realistic perspective
2.	ArcGIS Spatial Analyst.	Used as a spatial modelling and analysis tool that query maps to derive new information, create maps and analyze raster and vector data set.
3.	ArcGIS Network Analyst.	Provides solution to transportation and service location problems.
4.	ArcGIS Schematics.	Help to Visualize and manage linear physical and logical (economic and social) network through an automated schematic representation of geodatabases.
5.	ArcGIS Tracking Analyst.	For space and time based visualization analysis
6.	ArcGIS Geostatistical Analyst	As a tool for statistical modelling, data exploration and probabilistic mapping. Serves as a tool to create a valid statistical prediction of event

2.1. Data acquisition and source

Map of study area: The map of Rivers state, the study area with its local government Area population was produced Esri shape file from image data of Rivers state surveys department.

Fire incident data: The study made use of primary fire incidents and the data used was acquired from the Rivers state fire service statistics report for 2000-2012. The primary fire incidents for Port-Harcourt and greater Port-Harcourt region of Rivers state was digitized from the entire Rivers state fire service primary fire incident statistics report, (2000- 2012).

2.2: Database design

Database design constitutes one of the basic tasks in developing any GIS application. The first thing to do here is to carry out users requirement studies. Database design involves the process by which the real world entities and their relationships are analyzed and modelled in order to derive maximum benefits while using a minimum amount of data (Kufoniyi, 1998). This process consists of two phases. These are:-

1. The design phase
2. The construction or implementation phase

The design phase however consists of the view of reality together with three other steps, namely

1. Conceptual design
2. Logical design
3. Physical design
4. View of reality

Reality refers to the phenomena as they actually exist, including all aspects which may and may not be perceived by individuals. The view of reality is the mental abstraction of the reality for a particular application or group of applications (Kufoniyi, 1998). The view of reality in this study refers to the Roads, Police stations, the Rapid Response Squads, Hospitals, Federal Road Safety Commission office and the FRSC operating locations, as well as Rivers State Fire Service station.

Fig. 2.1: Database design and construction schema

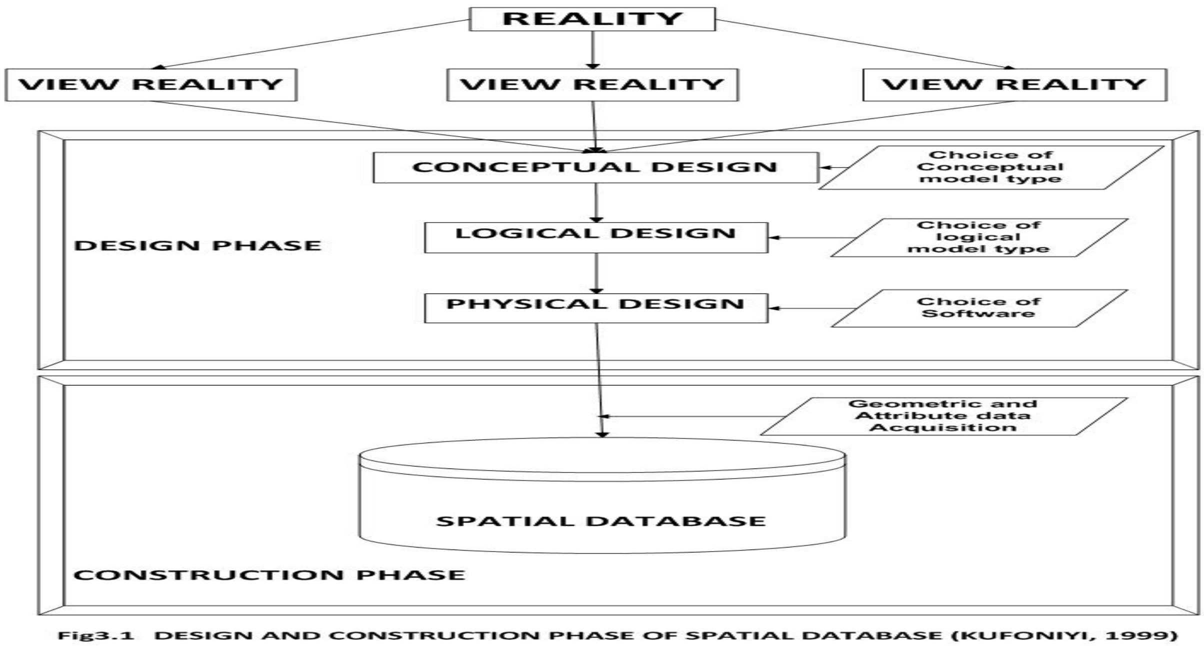

Fig. 2.2: Entity Relationship diagram for Fire Facilities

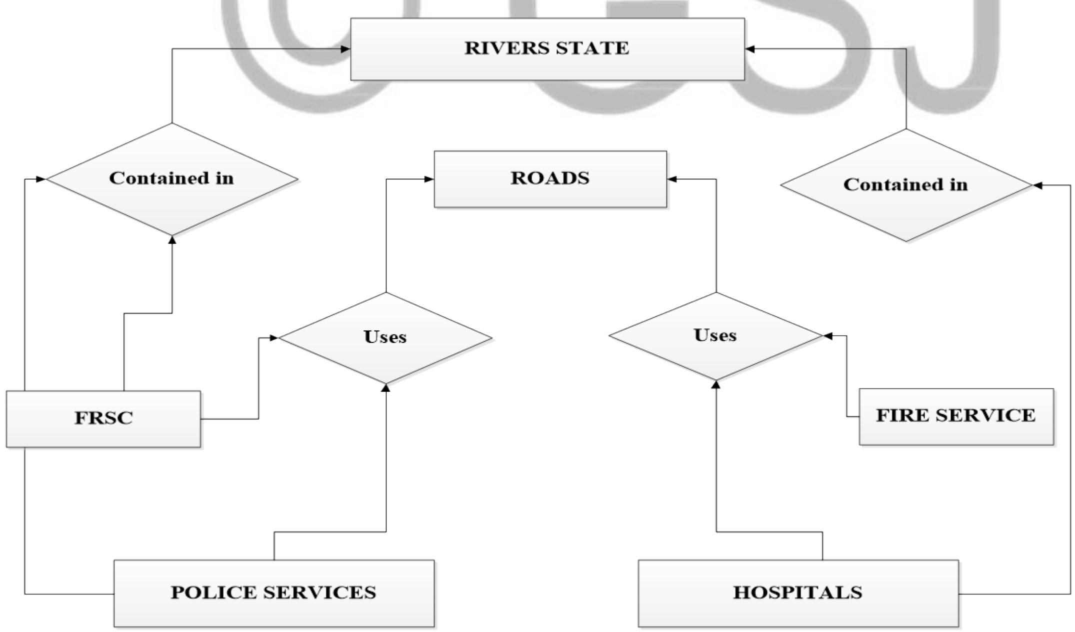

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Fig. 2.3: Entities and Attribute data schema

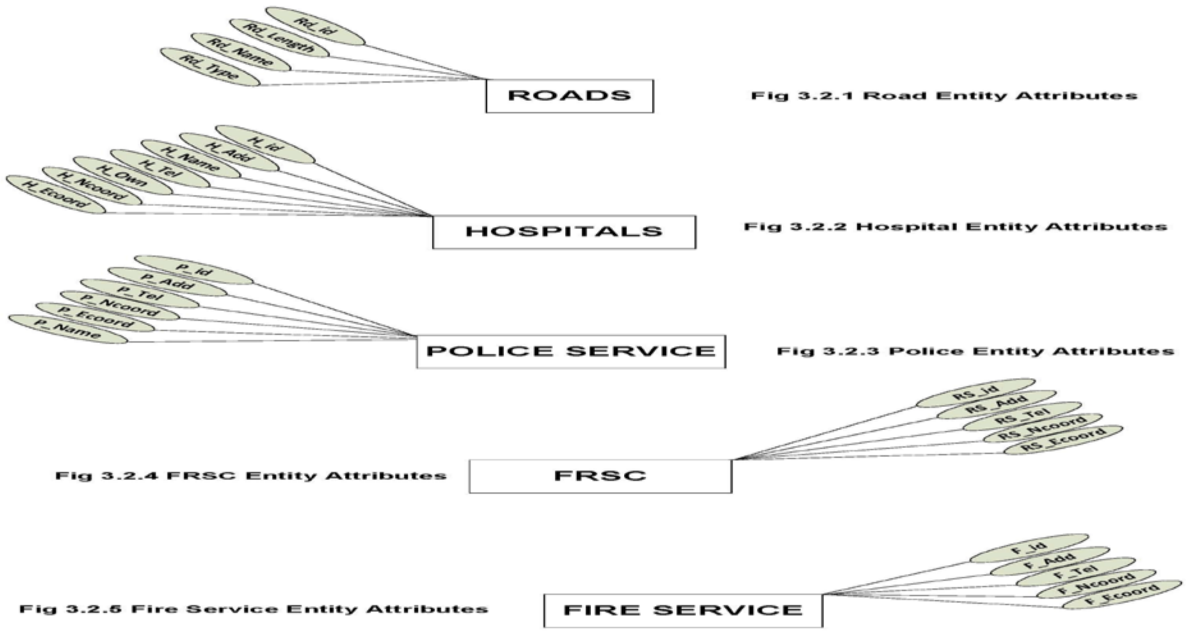


Fig. 2.4: bar chat of fire incidence in Rivers state

Fig. 2.4: Rivers State primary Fire Incidents bar graph

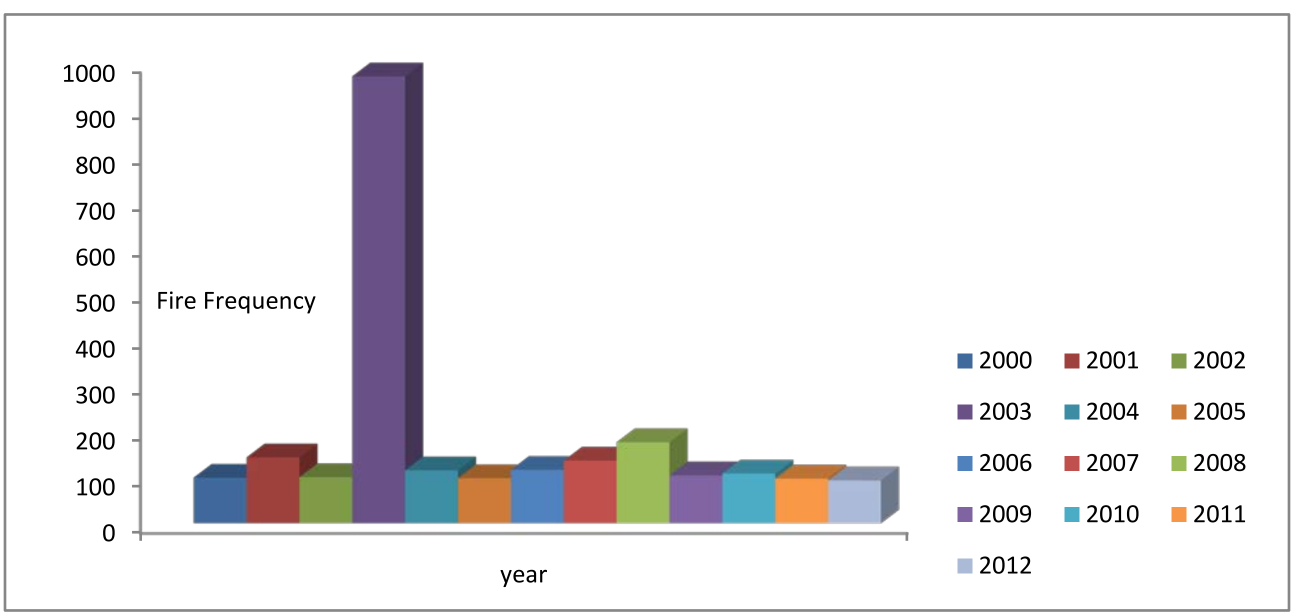
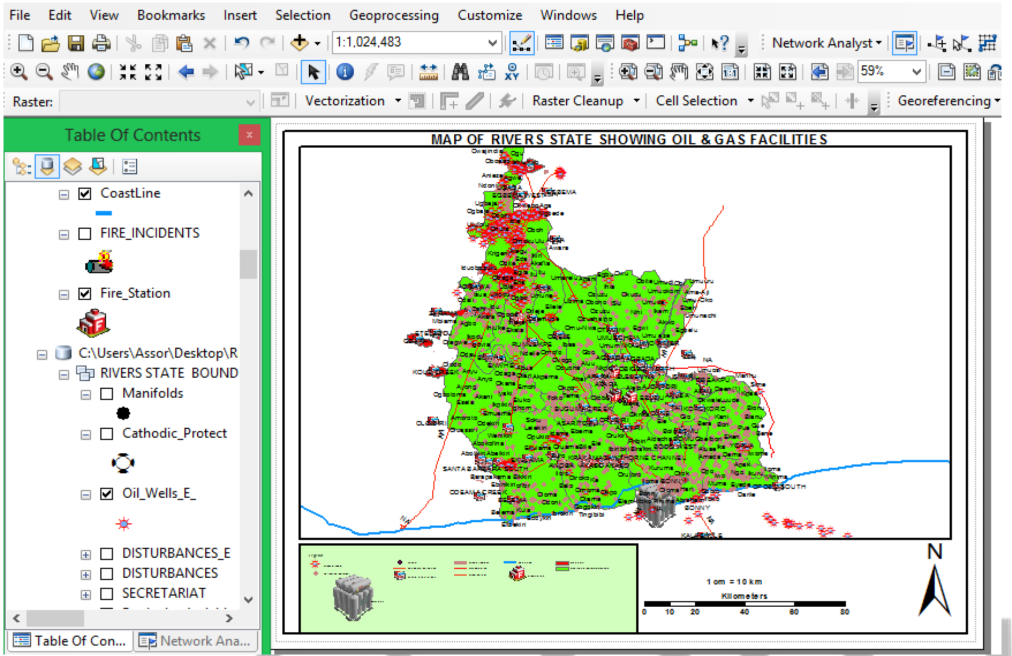


Table 2.2: Rivers state fire service primary fire incidence records (2000-2012)

Fig. 2.5: Locations of Oil and Gas facilities in Rivers State



Year	Number of fire Incidence	Number of Deaths	Number of Injuries
2000	99	12	22
2001	143	8	7
2002	100	3	7
2003	970	1	4
2004	115	7	13
2005	98	3	5
2006	116	10	7
2007	136	20	14
2008	176	17	27
2009	104	7	15
2010	108	3	7
2011	97	6	13
2012	93	148	80
	TOTAL	245	221

Fig. 2.6: Rivers State Integrated Transport Network (ITN)

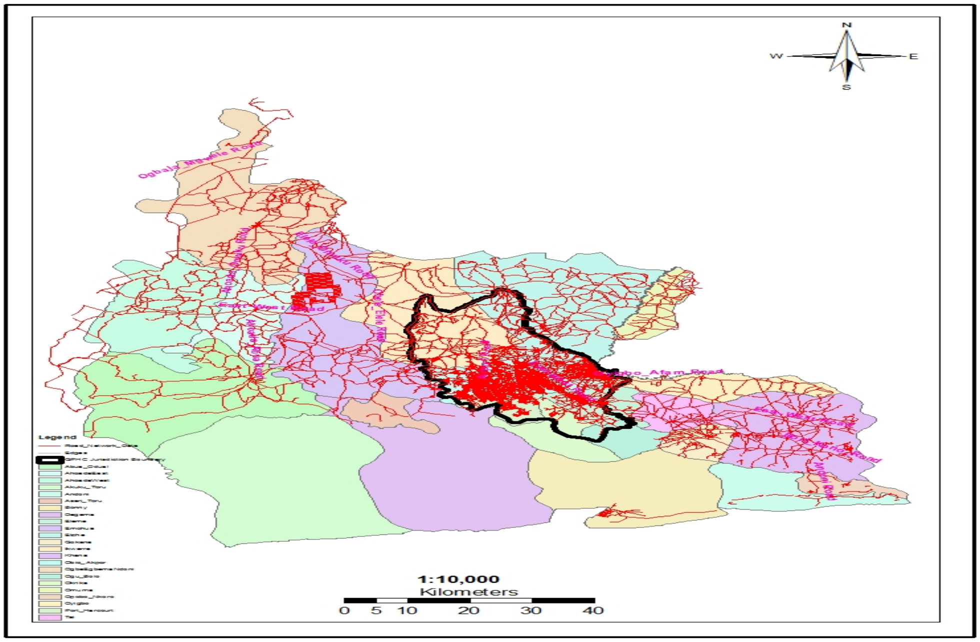


Table 2.3: Correlation Analysis of the Causes of Fire Incidents

Year	Amount of Deaths(Independent Variable)	Causes of fire incidents (Dependent Variable)		
	X1	X2	X3	X4
2000	99	32	6	26
2001	14	40	10	10
2002	10	22	20	14
2003	23	55	5	5
2004	7	64	16	12
2005	3	18	8	6
2006	10	42	12	8
2007	20	51	13	11
2008	17	69	13	13
2009	7	41	4	8
2010	3	64	15	9
2011	6	56	6	7
2012	148	51	8	21

Correlation analysis was performed using the data on the major causes of fire incidents in Rivers State include;

1. Deaths and injuries from fire Incidents (X1)
2. Spill from petroleum products (X2)
3. Electrical current sparks (X3)
4. Domestic Kerosene explosion(X4)

Total number of Deaths and Injuries from fire Incidents (X1) is the independent variable while the data on the major causes of fire incidents; spillage of petroleum products (X2), Electrical current sparks (X3) and domestic kerosene explosions (X4) were the dependent variables. The influence of these dependent variables on the independent variable (Deaths from fire incidents) was investigated through partial correlation analysis.

The inter-correlations between these variables were obtained through the Spearman's Rank relation,

$$\mathbf{rs = 1(\frac{6\Sigma d^2}{n^3 - n})}$$

Where;

r12.34 = 0.40, r13.24 = 0.55, r14.23 = 0.50, r23.14 = 0.40, r24.13 = 0.11, r3412 = 0.33.

The partial correlation analyses between the independent and dependent variables are as follows;

r12.34 = 0.40, r13.24 = 0.55, r14.23 = 0.50, r23.14 = 0.40, r24.13 = 0.11, r34.12 = 0.33.

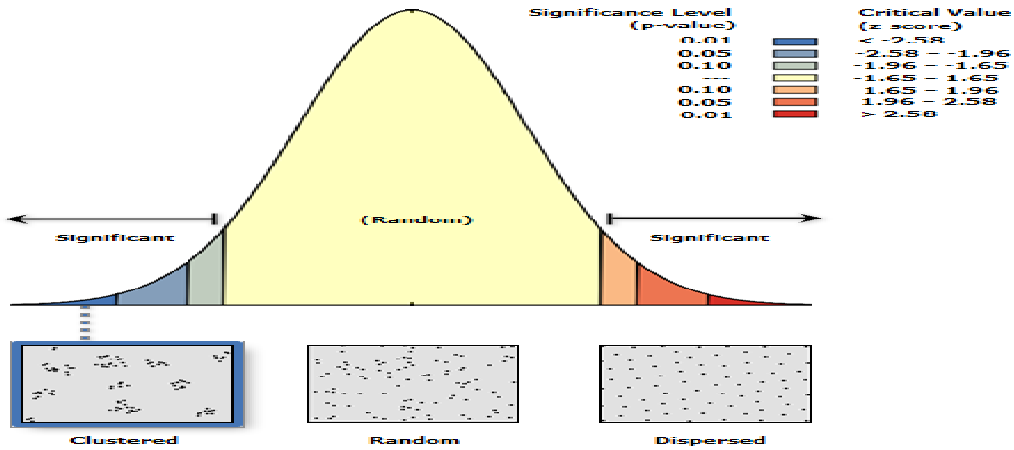
The multiple correlation analyses between the independent and dependent variables using the multiple correlation coefficients expressed in terms of partial correlation coefficient for the variables using the expression;

1- **R1. 234^2 = (1-r1. 12^2) (1-r1. 234^2) (1-r1. 132^2) (1-r1. 1423^2)**

R = 0.81

The nearest neigbour index **(RN) of 0.59** for Hospital and **1.17** for Police Station indicates a clustered and regular distribution of health and security facilities in Rivers State. A test for the significance of the result at **0.05%** confidence level confirmed a significant difference between the distribution of health and security facilities and a random pattern.

Hospital



Average Nearest Neighbor Summary

Observed Mean Distance: 483.303249 Meters

Expected Mean Distance: 812.700117 Meters

Nearest Neighbor Ratio: 0.594688

z-score: -9.899513

p-value: 0.000000

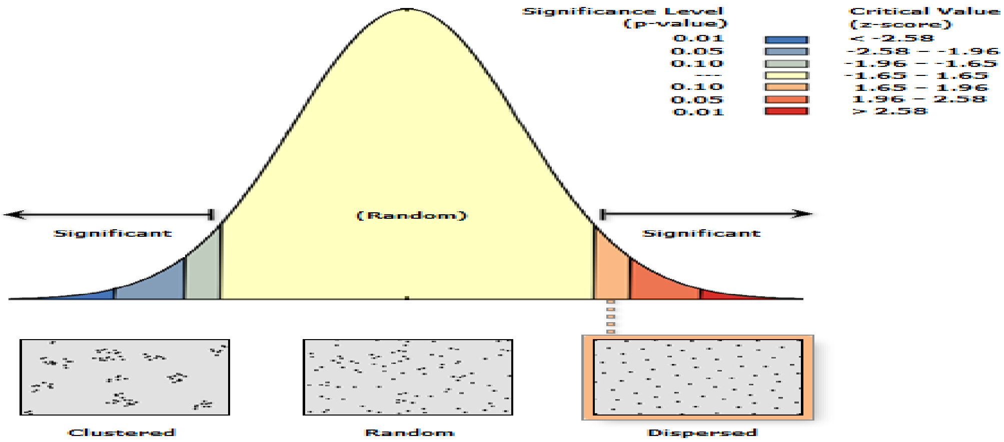
Dataset Information

Input Feature Class: HOSPITAL

Distance Method: EUCLIDEAN

Given the z-score of -9.90, there is less than 1% likelihood that this clustered pattern could be the result of random chance.

Police Station



Average Nearest Neighbor Summary

Observed Mean Distance: 1765.339249 Meters

Expected Mean Distance: 1498.737755 Meters

Nearest Neighbor Ratio: 1.177884

z-score: 1.894736

p-value: 0.058127

Dataset Information

Input Feature Class: POLICE_STATION

Distance Method: EUCLIDEAN

Given the z-score of 1.89, there is less than 10% likelihood that this dispersed pattern could be the result of random chance.

Graph indices such as Connectivity, Alpha, and Cyclomatic Ratios where obtained from road network data of Rivers State using the expression;

Cyclomatic Index (μ) = e – v + g

Connectivity Index (c) = $\frac{e}{1/2(v-1)}$

Alpha Index (α) = $\frac{e-v+g}{2v-5}$

Where;

Connectivity Index (c) = 0.3, Cyclomatic Index (μ) = 3, Alpha Index (α) = 0.8

3.4. Spatial Analysis

The ArcGIS spatial analyst extension provides a wide range of powerful spatial modelling and analysing tool which can be used to derive new information from existing data set, query maps, and analyze cell- based raster data. One of the spatial analyst techniques used for this study is the density analysis technique. Density analysis is used to measure the quantity of an input data set (line or point) that is distributed throughout a geographical space. It shows where point and line features are more concentrated within a specific area of study.

2.3 Network Analysis

ArcGIS Network Analyst extension is a powerful and sophisticated GIS tool that manages and analyse network-based spatial data in order to solve routing problem ranging from classic point-to-point routing to advanced time-based delivery problems across thousands of spatial attributes. ArcGIS Network Analyst offers a Flexible and friendly graphical user interface operating environment and tools alongside its powerful functionality accessible in the geo-processing environment which can be used for modelling and scripting in other to solve problems such as:

1. Finding the shortest routes to and fro facilities.
2. Determine service area coverage of a service or facilities based on distance and travel time.
3. Optimum location of services and facilities.
4. Create a travel cost matrix from a facility or service to all destinations.
5. Find the closest facilities within a given area.
6. Create a route direction for fleet of vehicles.
7. Perform Point-to-Point transportation Routing

ArcGIS Network Analyst can be used by a wide range of industries such as; transportation and logistics, emergency service delivery (fire, public safety and healthcare), education, utilities and services providers, business and government etc.

ArcGIS Network Analyst uses the Dijkstra’s Algorithm to solve various routing Problem and this algorithm was developed by Edgar Dijkstra in 1959. (ESRI 1992) states that “Dijkistra's algorithm is a recursive algorithm which assumes that the shortest route between any two points will be no greater than 1.25 the Euclidean distance between the two points”. Also according to Olivera (2002) the algorithm finds the best route by calculating a path which is close to the optimal path that is computationally manageable and then strikes a balance. The algorithm breaks the network into nodes and the paths between each node are represented by lines and each line has an associated cost that represents the cost (in length) of each line in order to reach a node. Stewart (2004) tries to describe the process that take place when using the Dijkstra’s Algorithm is used to find the shortest distance between points he said that “There are many possible paths between the origin and destination, but the path calculated depends on which nodes are visited and in which order it is visited. The idea is that, each time the node, to be visited next, is selected after a sequence of comparative iterations, during which, each candidate-node is compared with others in terms of cost”.

GIS Network applications are based upon the concept of geography of movement (Mitchell 1995). The movement of people, goods and services occurs through specific network systems this makes network Analysis the backbone for an effective Emergency service Planning because it has the ability to dynamically model real life network situation at different impedance such as (traffic conditions, turn restrictions, speed limits, height restrictions, and day and night conditions) in order to determine and efficient drive path and travel sequence. The Network Analyst Dijkstra's Algorithm generates routes based on two criteria; Distance and time criteria.

Distance Criteria: The route is generated by taking only into account the location of the fire incident. The volume of traffic, speed and road characteristics is not considered in this case.

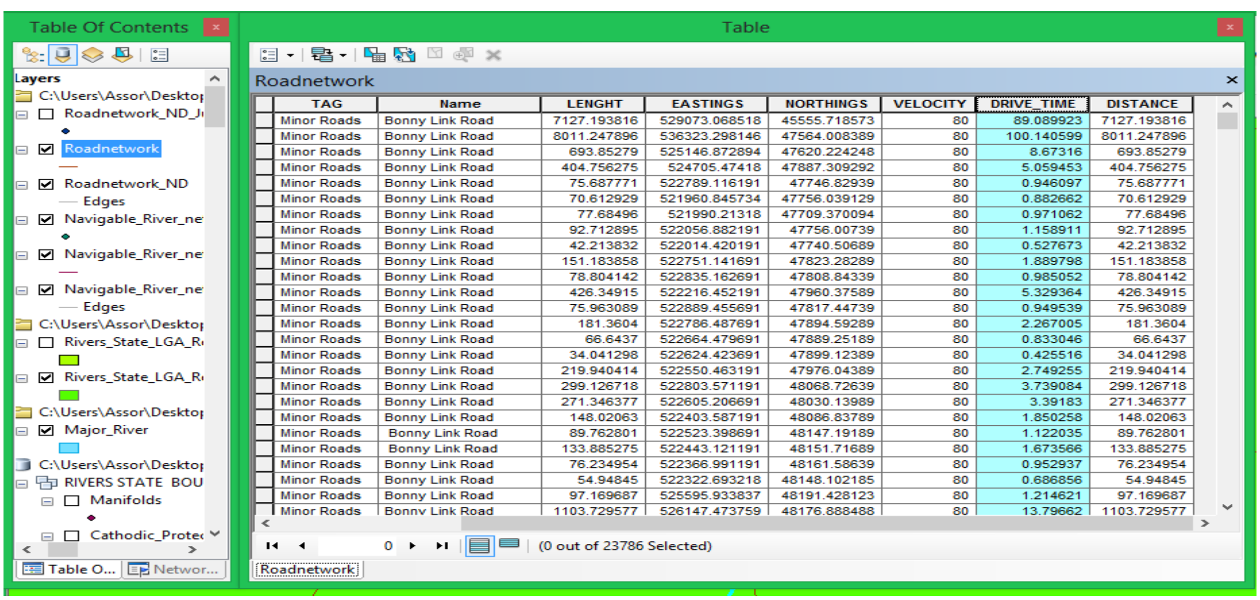
Time Criteria: The total drive time and speed in each road section is considered here and it is given as (The total reflex time (time between convey and actual fire fighting)

The paramount goal of an emergency delivery service is to provide quick response to any emergency call hence the measure of its effectiveness and efficiency is based on its response time. The ArcGIS network analysis is equipped with various tools to help study and solve service coverage and response time related problems.

This study made use of the following Network Analysis tools.

1. New Closest facility analysis.
2. New Service (Drive-time analysis).
3. New Location- Allocation.

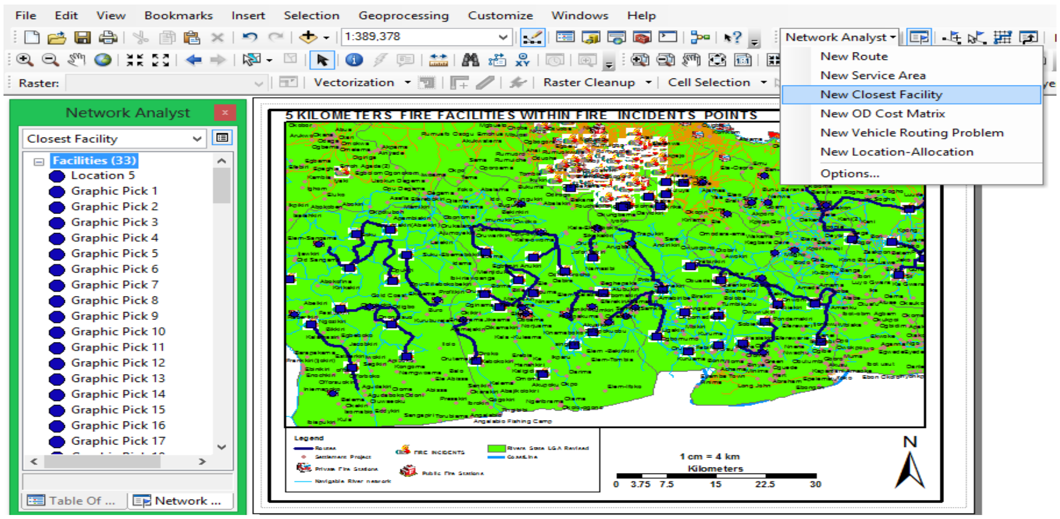
Table 2.4: Attributes of Road network data



TAG	Name	LENGHT	EASTINGS	NORTHINGS	VELOCITY	DRIVE_TIME	DISTANCE
Minor Roads	Bonny Link Road	7127.193816	529073.068518	45555.718573	80	89.089923	7127.193816
Minor Roads	Bonny Link Road	8011.247896	536323.298146	47564.008389	80	100.140599	8011.247896
Minor Roads	Bonny Link Road	693.85279	525146.872894	47620.224248	80	8.67316	693.85279
Minor Roads	Bonny Link Road	404.756275	524705.47418	47887.309292	80	5.059453	404.756275
Minor Roads	Bonny Link Road	75.687771	522789.116191	47746.82939	80	0.946097	75.687771
Minor Roads	Bonny Link Road	70.612929	521960.845734	47756.039129	80	0.882662	70.612929
Minor Roads	Bonny Link Road	77.68496	521990.21318	47709.370094	80	0.971062	77.68496
Minor Roads	Bonny Link Road	92.712895	522056.882191	47756.00739	80	1.158911	92.712895
Minor Roads	Bonny Link Road	42.213832	522014.420191	47740.50689	80	0.527673	42.213832
Minor Roads	Bonny Link Road	151.183858	522751.141691	47823.28289	80	1.889798	151.183858
Minor Roads	Bonny Link Road	78.804142	522835.162691	47808.84339	80	0.985052	78.804142
Minor Roads	Bonny Link Road	426.34915	522216.452191	47960.37589	80	5.329364	426.34915
Minor Roads	Bonny Link Road	75.963089	522889.455691	47817.44739	80	0.949539	75.963089
Minor Roads	Bonny Link Road	181.3604	522786.487691	47894.59289	80	2.267005	181.3604
Minor Roads	Bonny Link Road	66.6437	522664.479691	47889.25189	80	0.833046	66.6437
Minor Roads	Bonny Link Road	34.041298	522624.423691	47899.12389	80	0.425516	34.041298
Minor Roads	Bonny Link Road	219.940414	522550.463191	47976.04389	80	2.749255	219.940414
Minor Roads	Bonny Link Road	299.126718	522803.571191	48068.72639	80	3.739084	299.126718
Minor Roads	Bonny Link Road	271.346377	522605.206691	48030.13989	80	3.39183	271.346377
Minor Roads	Bonny Link Road	148.02063	522403.587191	48086.83789	80	1.850258	148.02063
Minor Roads	Bonny Link Road	89.762801	522523.398691	48147.19189	80	1.122035	89.762801
Minor Roads	Bonny Link Road	133.885275	522443.121191	48151.71689	80	1.673566	133.885275
Minor Roads	Bonny Link Road	76.234954	522366.991191	48161.58639	80	0.952937	76.234954
Minor Roads	Bonny Link Road	54.94845	522322.693218	48148.102185	80	0.686856	54.94845
Minor Roads	Bonny Link Road	97.169687	525595.933837	48191.428123	80	1.214621	97.169687
Minor Roads	Bonny Link Road	1103.729577	526147.473759	48176.888488	80	13.79662	1103.729577

Closest fire Facility: This is performed in order to determine the closest fire station to recorded fire incident given a 5 and 10 min response time.

Fig. 2.7: Closest fire Facilities within 5 kilometers to incident points



Service area. This technique was used to determine the street visualization and area coverage extent of fire station within the study area using drive time polygons.

Fig. 2.8: Rivers State population concentrations showing fire service demand points.

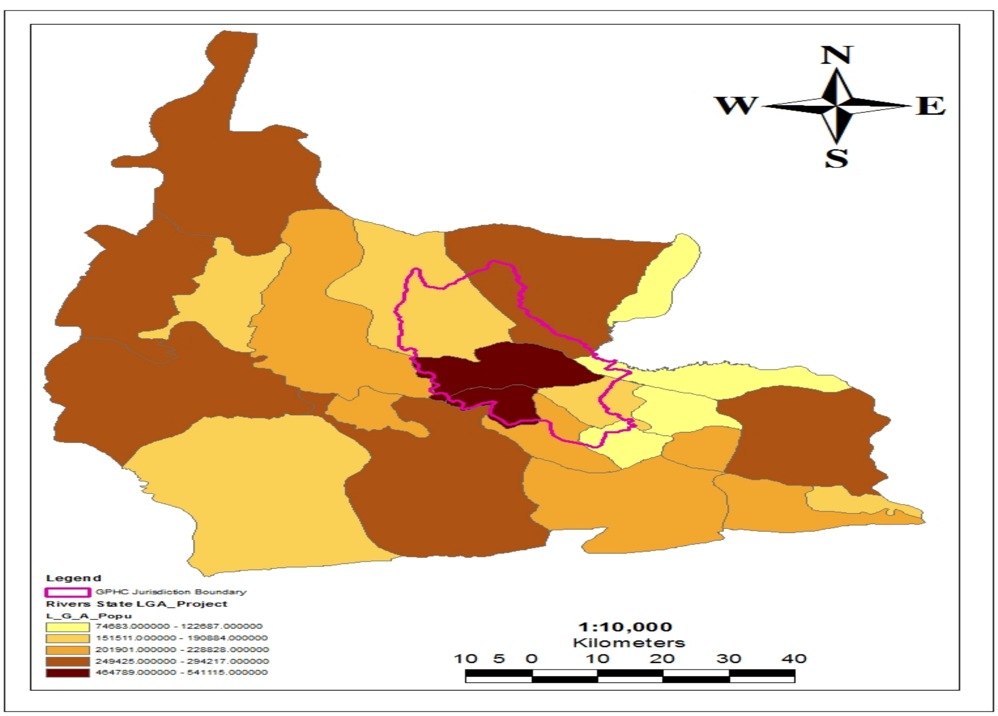
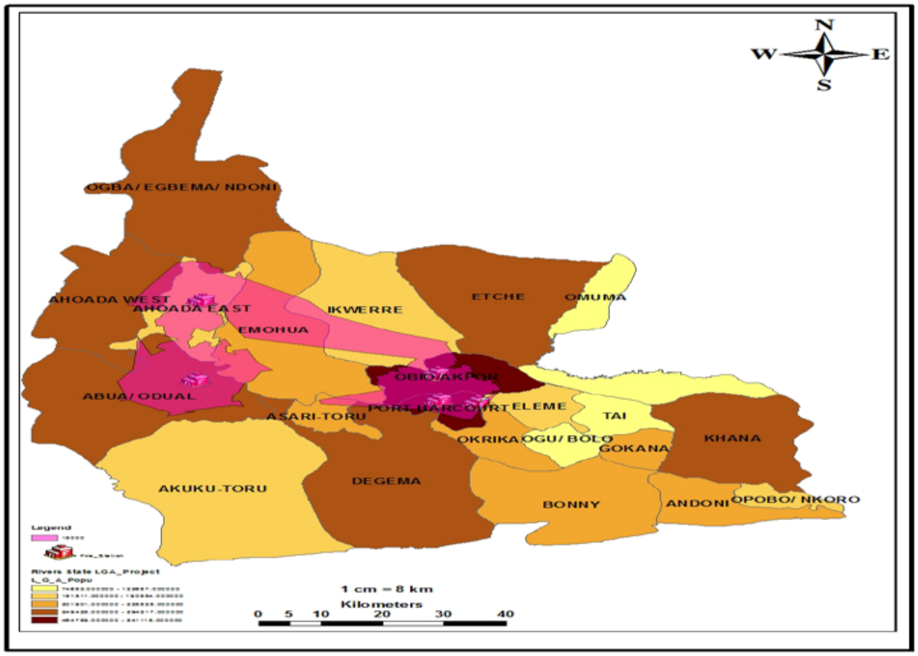


Fig. 2.9: 5 Kilometer Fire service coverage for public Fire facilities in Rivers State.



3.6.3: Location-Allocation. Criteria used in selection of candidate site for a new fire station. The role of GIS in Fire station Location studied in the literature section of this work reviewed international standards and various case studies regarding the process and spatial requirements of sitting a new fire. It looked at the rational approaches as well as quantitative and qualitative methods of fire station location such as multi-criteria evaluations, performance evaluation and mathematical models. It was established that the most vital aspect of these evaluation and location models reviewed are response time and coverage area. Thus fire station should be strategically located not only that maximum area can be served but also to help minimize the response time. The criteria used for selecting candidate site for a new fire station location within the scope of this thesis are;

1. Population density (Demand point).
2. The coverage area extent.(Maximum coverage)
3. Incident density of the area.
4. Accessibility to (and egress from) road networks.
5. Targeted response time value.
6. Distance to existing fire stations (the distance between fire stations should be 1 to 9km [5.6miles]) (Liu et al., 2006).
7. Availability of land space or lettings within the demand area.

The availability of land space or letting for a new fire station location within the demand area was determined by charting vacant sites through the Rivers State land information system (LIM).

The following three (3) potential candidate sites were selected to perform optimum location- allocation analysis see table below.

Table 2.5 (a): Chosen location for new fire station and population demand points

Candidate Location	**Site Name**	**Site Address**
Location 1	Vacant site located at Kpokpori,	Ogba/Egbeme/Ndoni L.G.A
Location 2	Vacant site located Onne Eleme	Eleme L.G.A
Location 3	Vacant site located at Finima, Bonny	Bonny L.G.A.

Running the location Allocation analysis based on the above listed criteria, using the road junction from the (ITN data set) as demand points which is known to be directly proportional to population concentration in an urban area.

The following results were obtained as shown in table 4.6 below;

Table 2.5 (b): Chosen location for new fire station and population demand points

Candidate Location	**Site Name**	**Site Address**	**Eastings**	**Northings**
Location 1	Vacant site located at Kpokpori, north of Omoku.	Ogba/Egbeme/Ndoni L.G.A	2401110.988	598972.516
Location 2	Vacant site located Onne Eleme	Eleme L.G.A	294898.133	522615.371
Location 3	Vacant site located at Finima, Bonny	Bonny L.G.A.	293387.36	487855.408

Table 2.5 (c): Chosen location for new fire station and population demand points.

Candidate Location	Site Name	Site Address	No of Demand Points
Location 1	Vacant site located at Kpokpori, north of Omoku.	Ogba/Egbeme/Ndoni L.G.A	325
Location 2	Vacant site located Onne Eleme	Eleme L.G.A	586
Location 3	Vacant site located at Finima, Bonny	Bonny L.G.A.	244

The major purpose of this site selection analysis is to maximise coverage area in other to reach as many demand point as possible.

In order to determine the area of improvement in response time and coverage extent, the new fire station is added to the four (5) existing ones.

New service area

Fig. 2.10: 5 minutes Fire service coverage area gap of existing fire station.

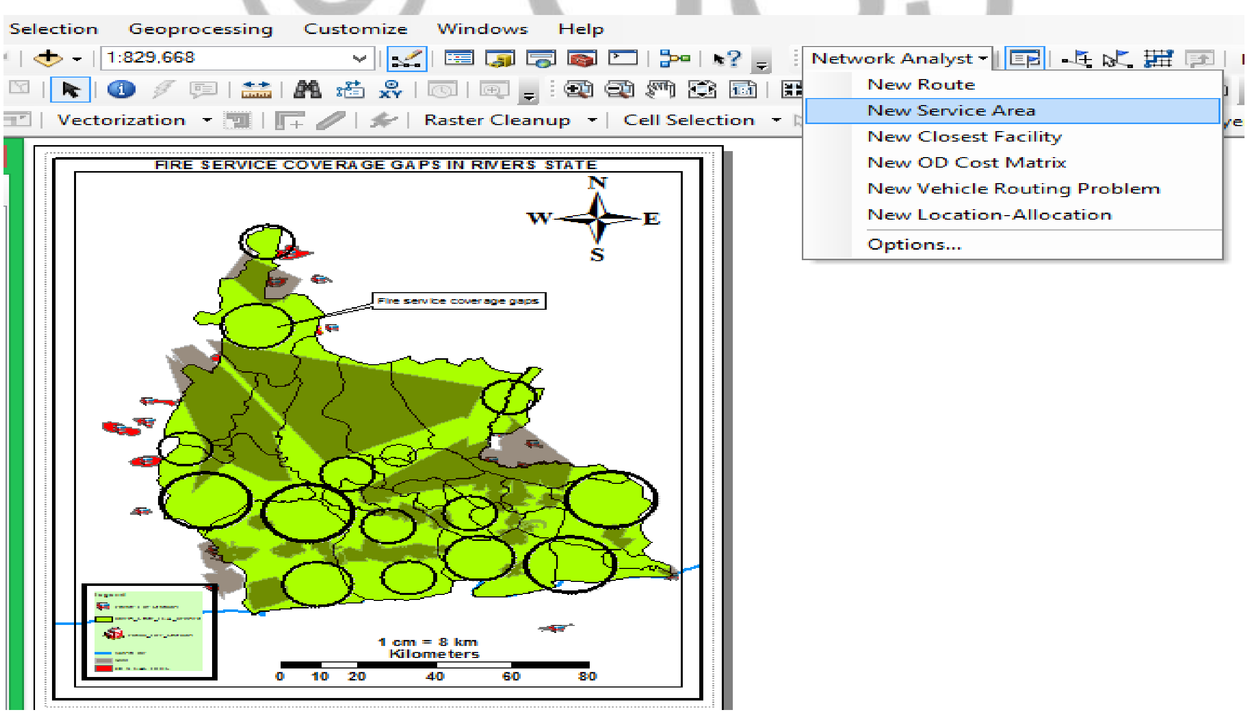


Fig. 2.11: Comparing the 5 minutes fire service coverage and population demand points

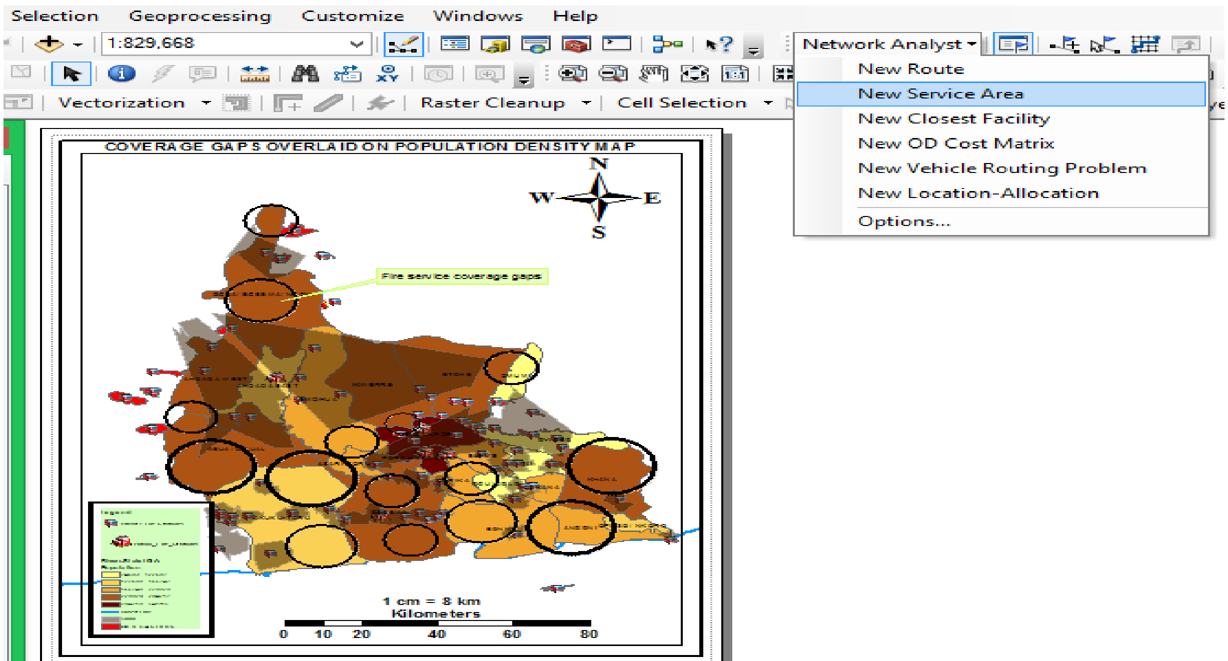


Fig. 2.12: Locations of Three (3) proposed fire Facility sites in Rivers State

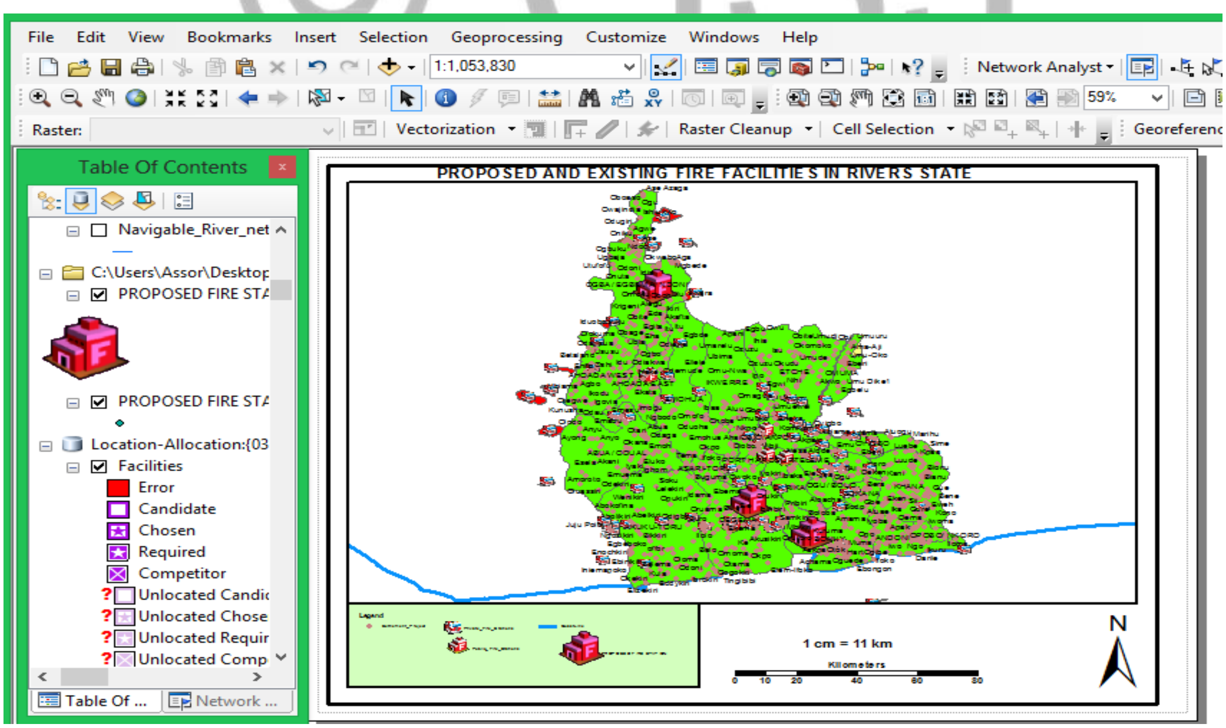
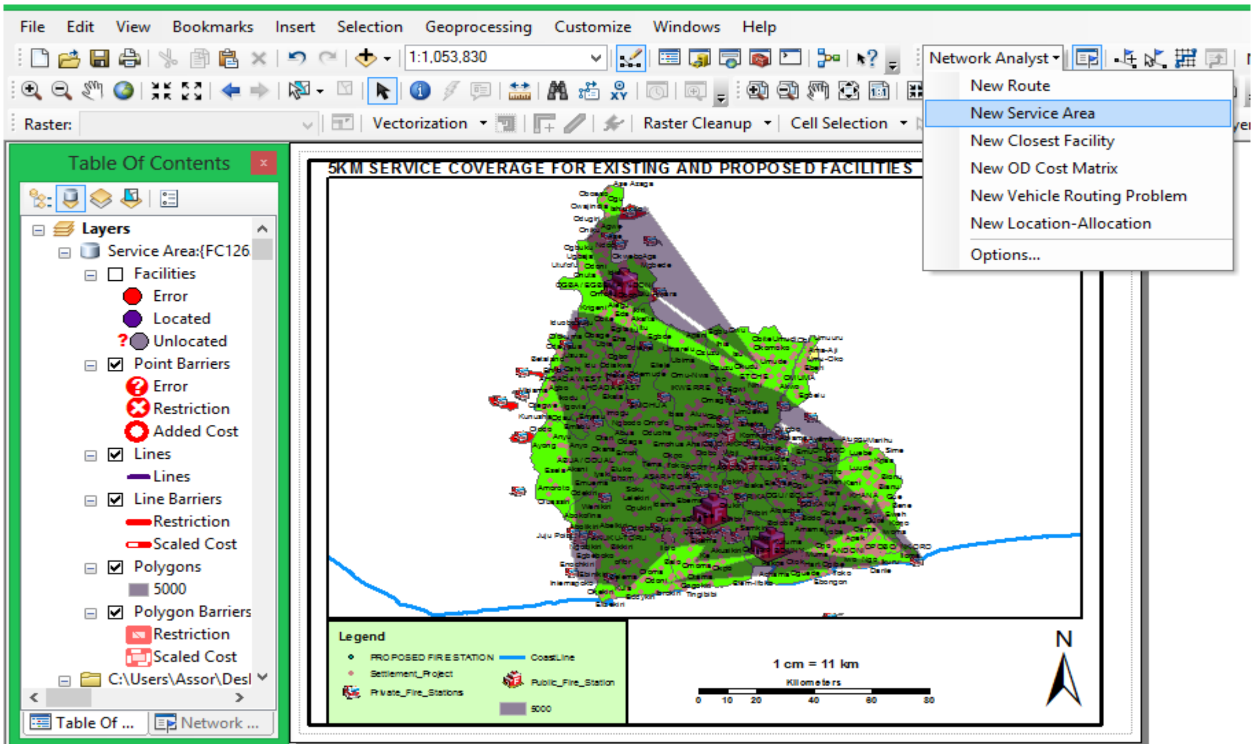


Fig. 2.13: New service area created from the proposed Fire Facility sites in Rivers State.



3.0: RESULT AND DISCUSSION

The multiple correlation analyses between the independent and dependent variables using the multiple correlation coefficients expressed in terms of partial correlation coefficient for the variables using the expression;

$$\mathbf{1\text{-}R1.\,234^2 = (1\text{-}r1.\,12^2)\,(1\text{-}r1.\,234^2)\,(1\text{-}r1.\,132^2)}$$

$$\mathbf{(1\text{-}r1.\,1423^2) \qquad R = 0.81}$$

This result indicates a very huge influence of kerosene explosion, spillage of petroleum products and electric current sparks on the frequency of fire incidents in Rivers State, **(X1, X2, X3, and X4).**

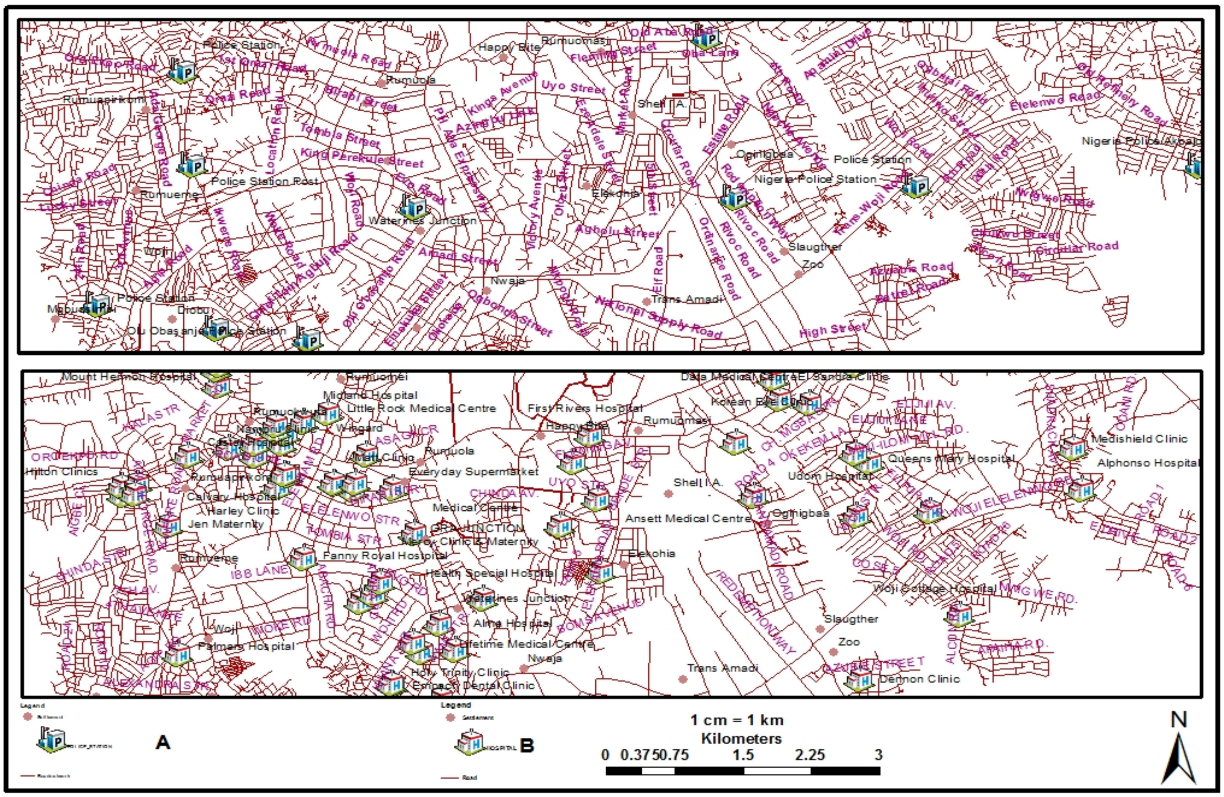
The partial correlation analyses between the independent and dependent variables of **r12.34 = 0.40, r13.24 = 0.55, r14.23 = 0.50, r23.14 = 0.40, r24.13 = 0.11, r34.12 = 0.33.** A partial correlation coefficient of **r13.24 = 0.55, r14.23 = 0.50**, indicates a huge influence of both kerosene explosion and spillage of petroleum products on the frequency and deaths associated with fire incidents.

The nearest neigbour index (RN) of 0.59 for Hospital and 1.17 for Police Station indicates a clustered and regular distribution of health and security facilities in Rivers State. A test for the significance of the result at 0.05%

confidence level confirmed a significant difference between the distribution of health and security facilities and a random pattern.

The Connectivity, Alpha, and Cyclomatic Graph indices where obtained from road network as 0.3, 3, 0.8 respectively showing a maximally connected network of roads.

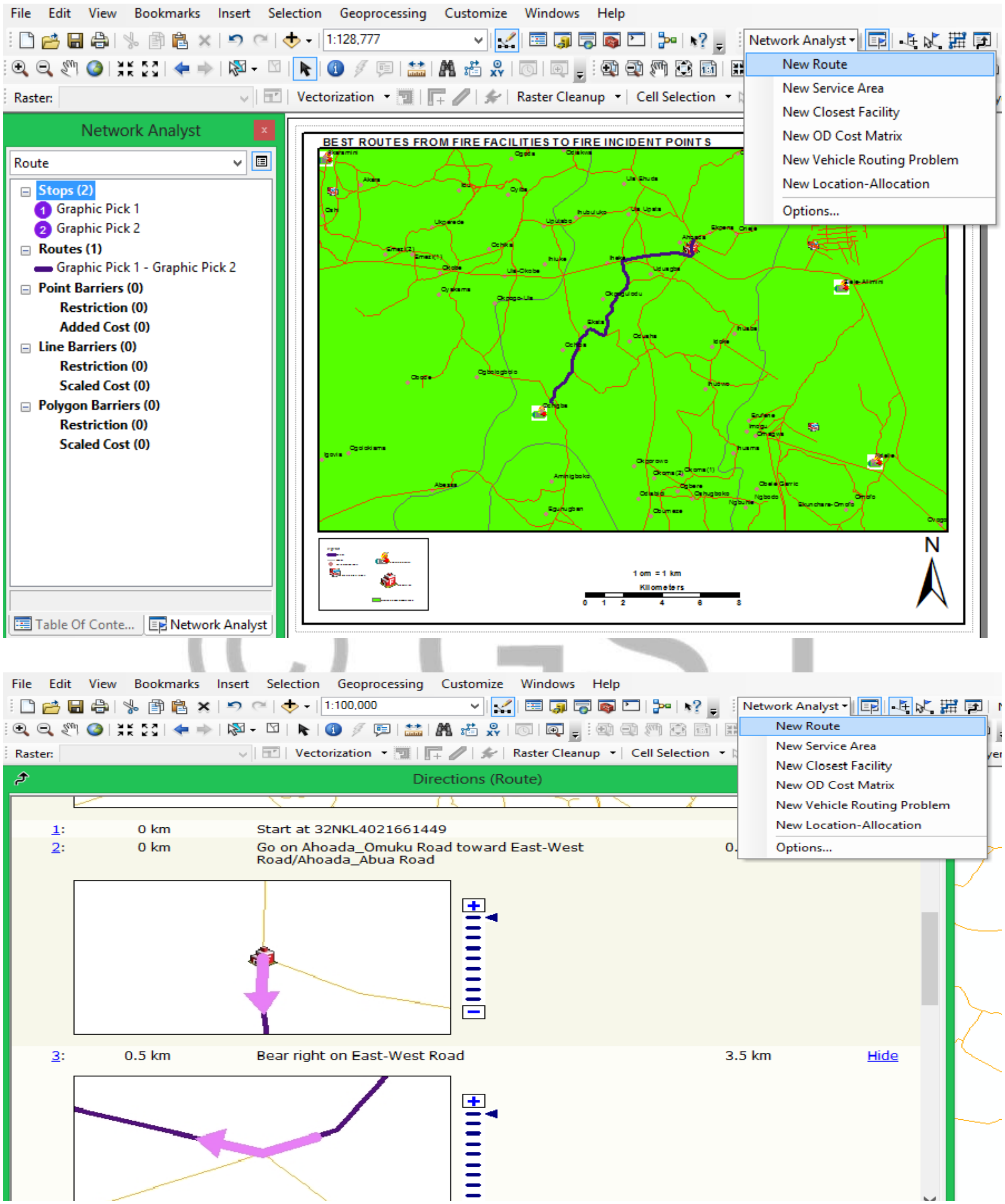
Fig 3.1: Distribution of Hospitals and Police Stations in Rivers State.



Rivers State public fire and rescue service is made up of 5 unitary authorities and 97 privately owned stations. Rivers State was chosen as a case study because of its strategic location as the hub of oil and gas activities in the Niger-Delta region of Nigeria and importantly the economic heartbeat of Nigeria which consequently accounts for the current urban sprawl resulting to high level of fire risk from high rise buildings, shopping malls and high density population around urban center see Fig 3.7.

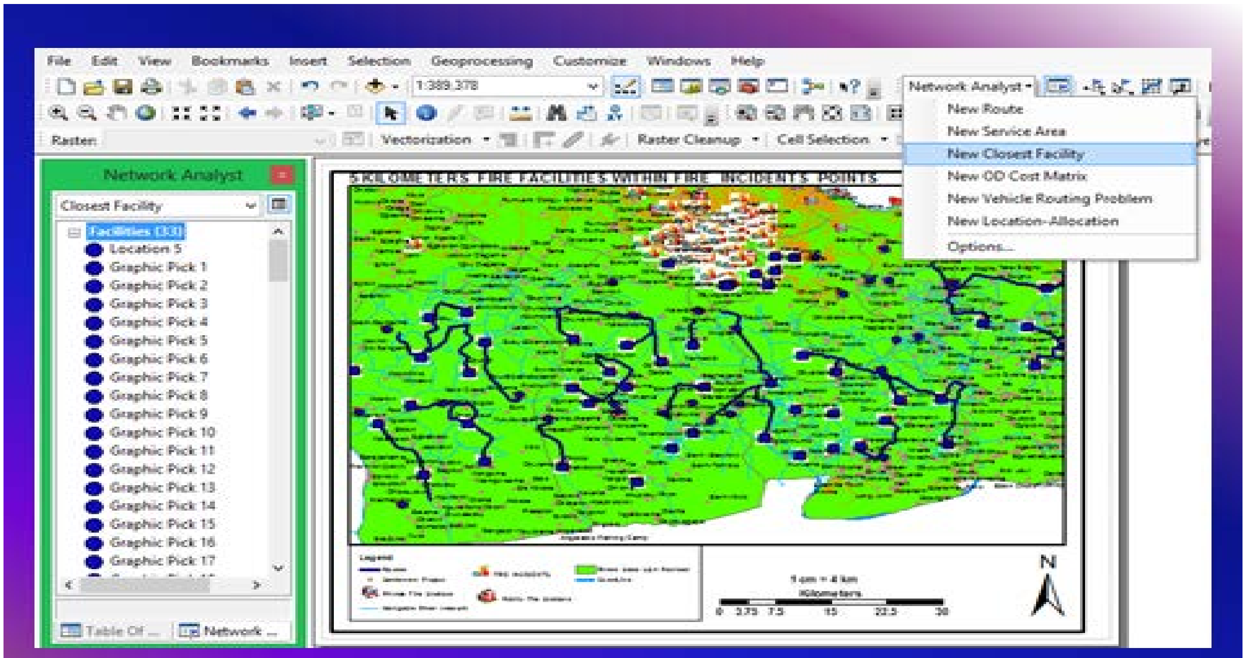
Time is an important factor in fire fighting; the travel time a fire engine takes to get to fire incident from a fire station can be transformed to the shortest path between these two points. Here, the shortest path can show the shortest drive time between fire station and fire incident which is very significant to this study and this was calculated using ArcGIS 10 Network analysis.

Fig 3.2: Best route between the fire station and fire incidents spots.



The closest facility analysis shows that the four fire and rescue stations operating in Rivers State where only able to respond to 82 within 5 minutes response time out of 103 fire incident recorded in year 2010 with a minimum and maximum distance of 0.6 and 4.2 miles respectively.

Fig 3.3: Closest fire facilities to fire incidents spots within 5 minutes response time.



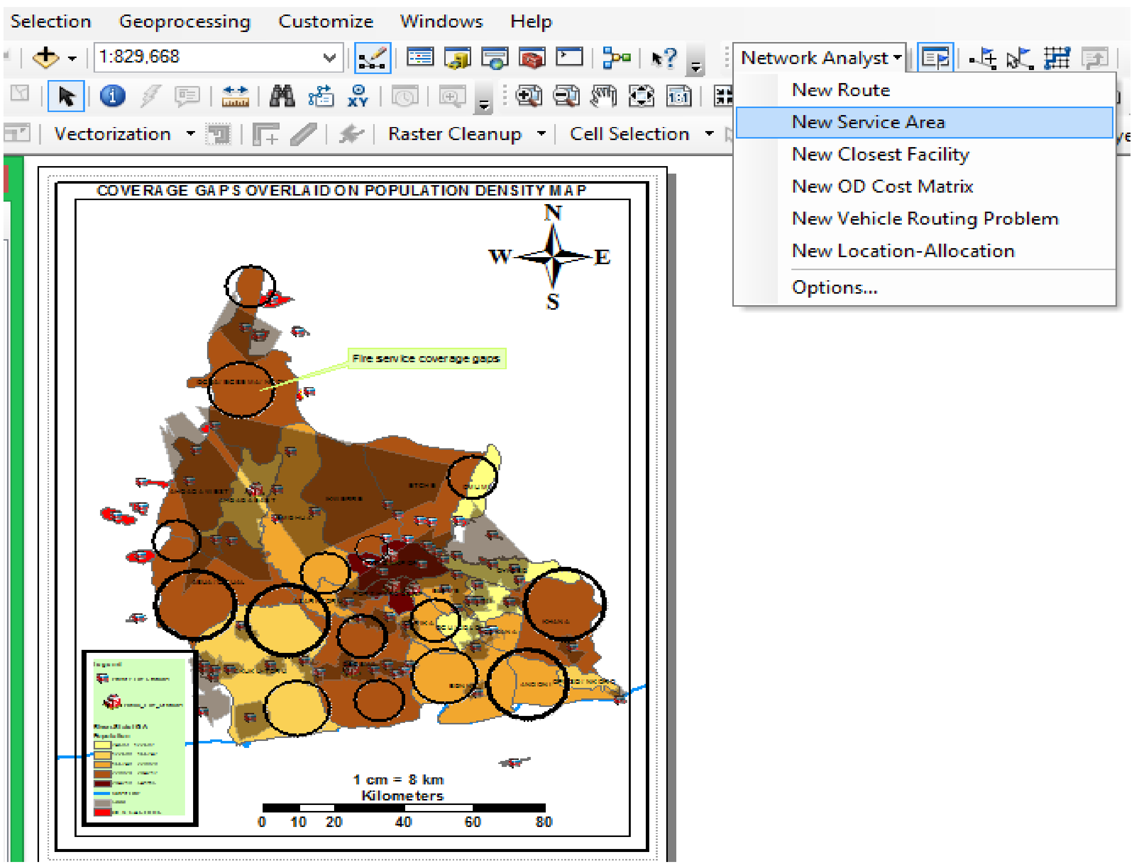
The service area analysis was used to reveal the extent of service coverage using drive time polygons given a stipulated response time. The service area analysis produced three overlapping drive time polygons that show the region covered by each fire station. Fig 3.13 reveals the area coverage of individual fire stations in Rivers State within a drive time cut-off value of 5 minutes.

No driving restrictions was used because when an emergency service is responding to a Life-threat situation (fire and medical) which is known as a CODE 3 responds, Lights and siren are used to bypass all traffic lights and driving restrictions.

The result as shown in fig.3.13 reveals that majority of the fire service coverage area within 5 minute's drive time was at the city center reasons for this can be seen in fig 3.7 indicating that it will take more than 5 min to cover the city periphery as shown in fig 3.14 and 3.15. The 5 min responds service coverage map was then overlaid upon the population of the study area to identify areas of incomplete coverage and weak performance by the rescue units. The population concentration map show that there are 23 Local government areas in Rivers State out of which 8 have a relative high population of between 200,000 and 500,000 people. (fig 3.16), the result of the overlay reveal that 2 out of this high population L.G.As have 60 percent fire service coverage of 5 minutes while the remaining six populated L.G.As have no fire service coverage at all. Fire and rescue service is at the forefront of emergency because the amount of lives and economic property loss from fire incident is usual very high. The number of lives lost and property damaged is directly proportional to the response time of the fire fighters. Any response time of more than 5 min for highly populated area will result in more loss of lives and economic property in a case of fire breakout.

The populated L.G.As of Khana, Etche, and Degema located at the north east and east side of the city respectively fall off the project 5 min response time coverage. The eighty public and private fire rescue facilities in Rivers State where unable to cover this populated region within 5 min thus creating a risk of increase loss of lives and property in event of a fire break out. The closest facility analysis also identified this gap by revealing that Mile 1, Borokiri, and Rumuodomanya fire station within Port-Harcourt and greater Port-Harcourt where only able to respond to 62 of recorded fire incident within 5 minutes out of 103 fire incident that occur within that region.

Fig.3.4: Fire service coverage gap



Closing the identified gap

The most important components of these models and evaluations include response time and coverage area; these are the criteria on which the scope of this research is based. Ertugay, (2003) explains that the sitting of new fire station in an urban area is aimed at maintaining and improving the existing service levels and response times. The problem of determining coverage area has two main components which are demand points and travel distances. To solve the problem of 5 minutes coverage deficiency ArcGIS location – allocation network analysis tool was used with the aim to select an optimum location for placing a new fire station in order to attain the highest maximum coverage of demand points around the deficiency region. Three potential sites where chosen base on the criteria of population density (demand points), incident rate, accessibility to road network, coverage area, targeted response time and most importantly availability of free or open space within the region to be covered. The sites include;

A). Vacant site located at Kpokpori, north of Omoku in Ogba/Egbema/Ndoni L.G.A (Location 1)

B). Vacant site located at Onne in Eleme L.G.A (Location 2)

C). Vacant site located at Finiema Bonny L.G.A. (Location 3)

Fig. 3.5 (a): Demand point reached by the proposed candidate location at Kpokpori.

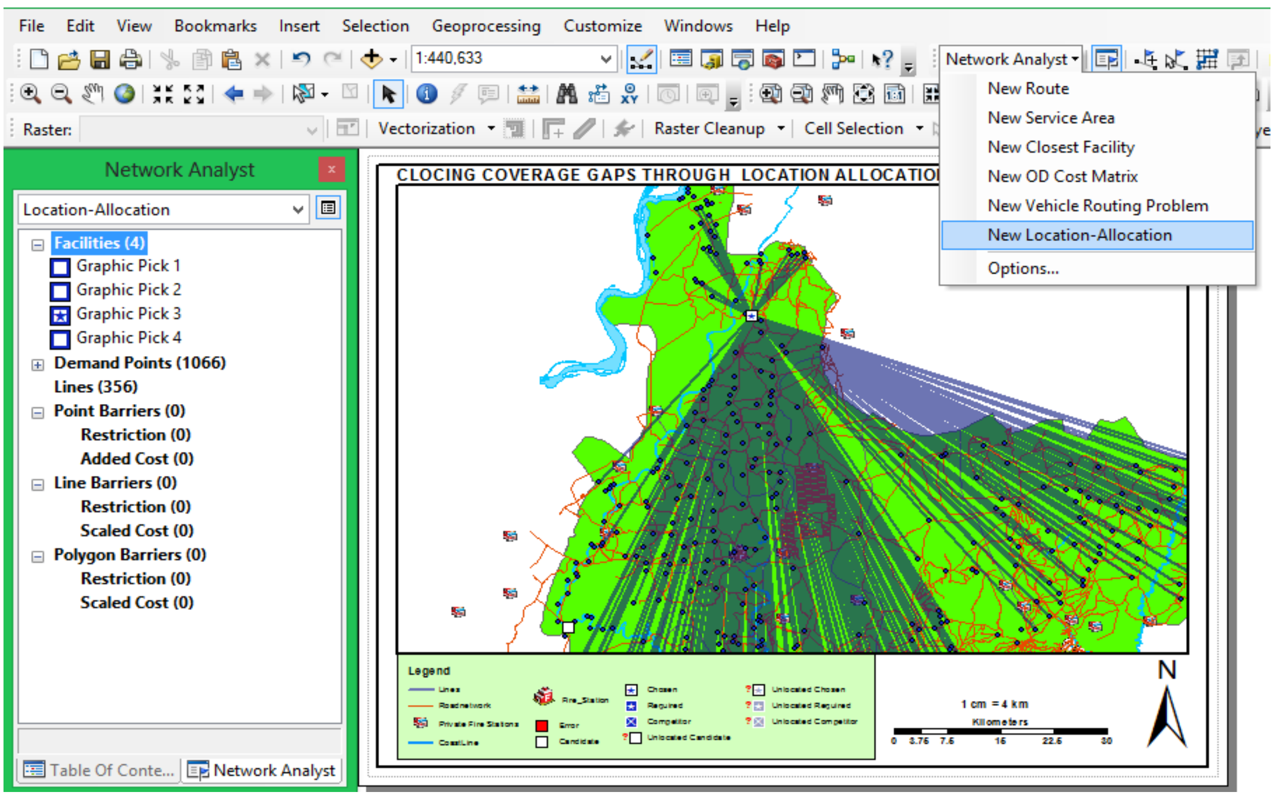


Fig. 3.5 (b): Demand point reached by the proposed candidate location at Onne in Eleme

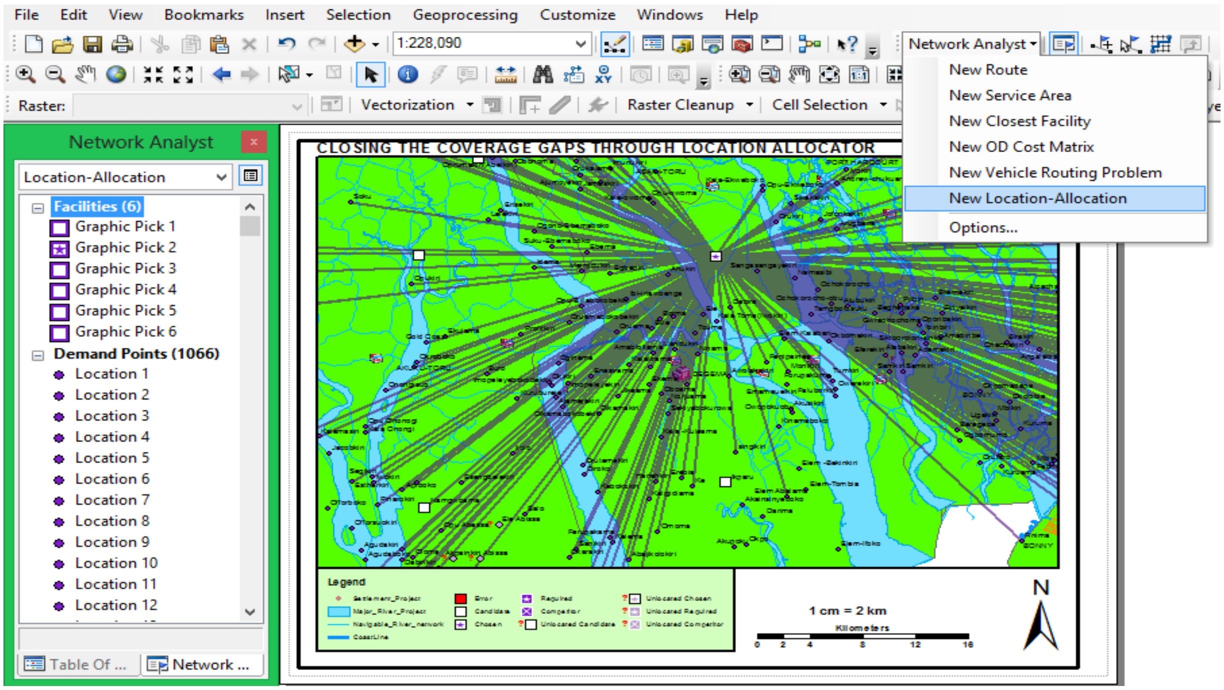
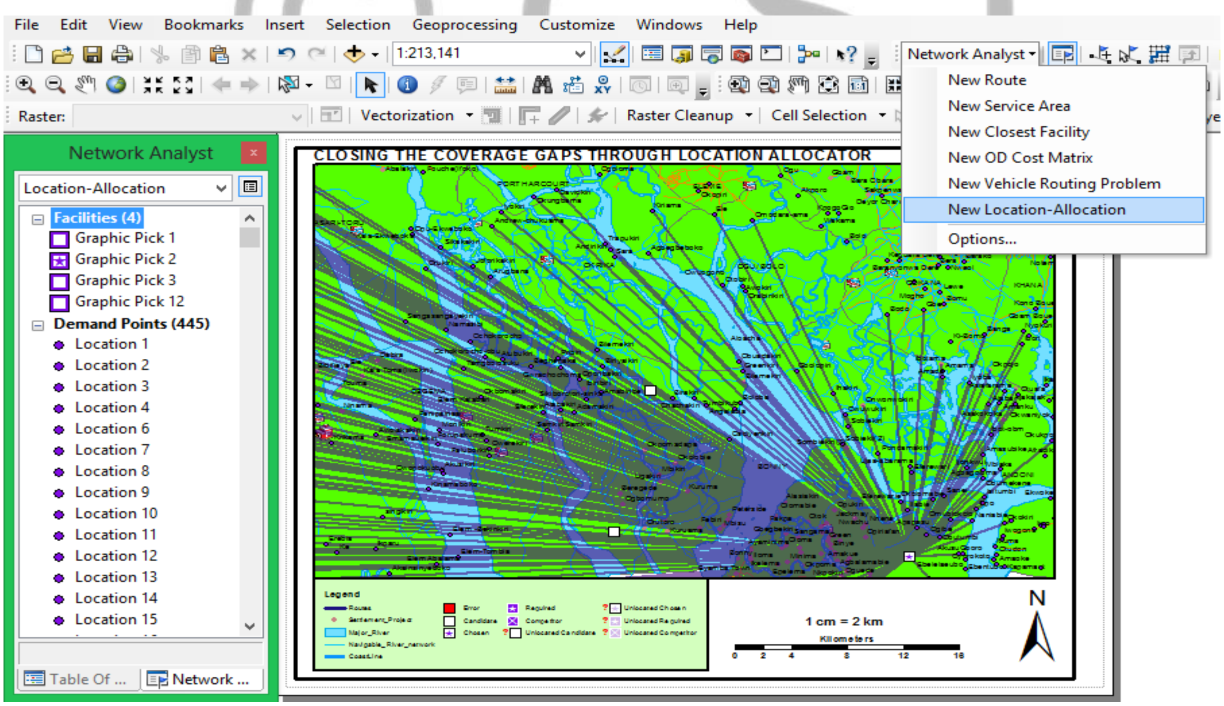


Fig. 3.5 (c): Demand point reached by the proposed candidate location at Finiema Bonny



The network road junction was used to represent population and demand point, loading the road junctions into the allocation analysis tool gave a total of 1,205 demands point for the entire study area fig. 3.20 & 3.21. The goal of the location allocation analysis tool is to choose the site that reaches more demand point within the region to be covered. Setting the analysis properties to maximise coverage, a cut-off value of 5 minutes and locating only one facility and ignoring all travel restrictions. The analysis result revealed that the open space located at Kono Bue in Khana L.G.A, (location 2) reached more demand point than the other two locations, table 4.4 below.

Table 3.1: Demand point reached by the proposed candidate location

Candidate Location	Site Name	Site Address	No of Demand Points Reached
Location 1	Vacant site located at Kpokpori, north of Omoku.	Ogba/Egbeme/Ndoni L.G.A	325
Location 2	Vacant site located Onne Eleme	Eleme L.G.A	586
Location 3	Vacant site located at Finima, Bonny	Bonny L.G.A.	244

Performing a closest facility analysis (including the proposed new fire station) the analysis result revealed that the proposed new fire station reduced the burden of public and private fire stations by assisting these fire stations to respond to more distance fire incidents within 5 kilometers that otherwise would have taken between 6 – 13 minutes to respond, thus ensuring that 80-90% of the fire incidents is reached within a maximum of 5 minutes response time.

Also, performing a new service analysis it was discovered that the proposed new fire station site was able to solve between 60- 70% of the existing 5 minutes respond time coverage deficiency.

The entire populated L.G.As of Khana, Ogba-Egbema, Etche and Ahoada-West were covered with 5 minutes responds time by the proposed fire station. However the proposed new fire station was not able to completely cover some parts of Emohua and Ikwerre L.G.As as the gaps previously seen still exist. This is due to the fact that most of these areas are uninhabited as seen from the imagery used for this study.

The Reason for the Service coverage gap seen in Degema L.G.A was as a result of the geography of the region which is predominantly riverine communities' consequently lacking access roads; see fig 4.4. The optimized fire station coverage is achieved based on real road network rather than the beeline distance, which means that optimized fire station service coverage has geographical network characteristic which is a roadway network that consist of roads and junctions of those roads. So without this road net work accessibility and service coverage will be almost impossible as in the case of this present gap in study area.

4.0 Conclusions: The significance of GIS in emergency management arises directly from the benefits derived from integrating a technology designed to support spatial decision making into a field emergency management with a strong desire to address several critical spatial decisions. Fire services, as being an emergency response unit, are different from the other public facilities; they are considered the forefront of any county emergency service delivery system because their duty sometimes requires them saving more than more lives and a lot of economic properties. Fire stations offer the essential personnel and equipment for saving life and property during a fire accident and are inevitable components of any infrastructure environment. While it is very important that fire stations are properly located, their access to good transportation network and their speed in offering services are also of substantial importance. To this end Fire stations must be strategically placed to be able to provide coverage to the greatest percentage of population and to minimize the response times to fire scenes.

Rivers State being the economic heart beat and hub of oil and gas exploitation in Nigeria requires a very effective and efficient fire emergency coverage service to cope with the growing population and urbanization. Using the ArcGIS Network analysis tools such as (closest facility, new service area and location allocation), the research was able to evaluate and assess the nature and performance of the Rivers State fire emergency service. One vital discovery was that most populated parts of the state had no access to fires service coverage area within 5-minutes response time depriving these populated regions of the stipulated 5-minutes response coverage thus making such region highly vulnerable to loss of lives and properties in event of a fire accident.

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