Geospatial Distribution and Locational Impacts of Filling Stations in Minna Metropolis

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Abstract

This research analyzed the geo-spatial distribution of filling stations outlets in Minna Metropolis using Global Positioning System (GPS) receiver; Garmin 76X to determine their spatial locations. The updated georeferenced street shape file of the study area was sourced from the Niger State Geographical Information System (NGIS) and imported to ArcGIS environment with data integration and transformation of the geographical coordinate of the filling stations. Standard of planning by Department of Petroleum Resource (DPR) was adapted by Environmental Guidelines Standard was also used as a standard for the study. The study discovered 83 filling stations located along the 10 roads in the study area, of which 73.973% belong to indigenous marketers, 20.55% belong to multinational marketers and 4.82% belong to NNPC. Correlation exist between hierarchy of road and filling stations, Bosso, Western by-pass, Eastern by-pass, Bida, Kpakungun and Paiko road (all major roads) have the highest number of filling stations whereas minor roads like Shehu Musa and Shehu Kangiwa roads have low density of filling stations. The locational pattern of the filling stations is clustered with significant difference between the pattern and random pattern at both 95 and 99% level of significance. The major factors governing the location of filling stations are the traffic flow, exit site from the city and closeness to Motor Park. 83.13% of the filling stations met 15 meter distance to the road as standard. However, 60% of the stations met distance of 100 metre to the utilities but with side by side closeness to built-up. Thus, many stations does not meet the standard of 400 metre distance to nearby stations but were located without separation. The research recommended that agencies in charge of regulation should ensure that filling stations operators comply with standards through enforcements.

Keywords: ArcGIS, ArcMap, Coordinate System, Department of Petroleum Resources, Filling station, Geo-referencing, Global positioning system.

1. Introduction

Petroleum products are highly inflammable and hazardous, their explorations, transportation and citing of filling stations must not be taken with levity like other products but handle with cares as they are capable of life and properties destructions. According to World Health Organization (2016), millions of lives with more than billions of properties were lost to fire outbreaks due to mishandling of petroleum product.

Minna as the capital city of Niger state is one of highly populated settlements in Niger state and by implication with high transportation system (National Population Commission 2006, Niger State Bureau of Statistics 2012). The demand for petroleum becomes more very high as a result of

shortfall in supply of electricity from the national Grid. The petroleum filling stations become lucrative as a result leading to concentration of filling stations in the strategic places of Minna especially along major and main road, cited with unconformity with Department of Petroleum Resources Guidelines.

In Nigeria, Department of Petroleum Resources Environmental Act amended Decree no 37 of I997 serve as safety rules and guide in protection of environment from potential hazard of close proximity of filling stations to build up area. However, Nigeria Department of Petroleum Resources (DPR) under ministry of petroleum and Environmental Guidelines and Standards (EGAS) of 1991 serve as comprehensive working documents with serious consideration for preservation and protection of Niger Delta region and by extension the Nigeria environment (Department of Petroleum Resources, 2016).

Recently, number of filling stations in metropolis of Minna has increased tremulously; best reason for such unprecedented increased includes the growing number of people that brought about increase in the number of vehicles. The profit attractive of petroleum both at black and control market makes more people to ventures; marketers take advantage of this and build petroleum filling stations randomly without considering the certain environmental effects of such location. Because petroleum are highly in flammable and a times center of district business in most built up areas. Therefore environmental impacts assessment of Petroleum filling station distribution should not be neglected but ascertained.

2. Literature Review

The largest industry in Nigeria nation economy is the petroleum industry or sector as opined by Baghebo and Atima (2013) which provides approximately 90% of foreign exchange earnings of the country with about 80 percent of Federal revenue and a major determinant to the rate of growth of Gross domestic product of the nation.

Petroleum industry in Nigeria is distinguished by type of actors that is otherwise known as sector (Ehinomen and Adeleke, 2012). They further itemized that the actors in the Nigeria industry or petroleum economy consisting both private and public organizations. The public actors are the government functionaries and agents such as the Nigerian National Petroleum Corporation (NNPC) and its subsidiaries, the Petroleum Products Pricing Regulatory Authority (PPPRA), the Department of Petroleum Resources (DPR), among many others. The private segments on the other hand consist of both indigenous and foreign actors that own oil block. The indigenous actors are the private marketers which numbered about 2000 in 1983, after the act which established them was formulated , private investors increased to 7988 in 2012 with much more competition with the major marketers who are foreign and multinational marketers that includes Conoil Public Limited Company, Oando Nigeria Public Limited Company., African Petroleum Public Limited Company, Mobil Oil Nigeria Public Limited Company, MRS Nigeria Public Limited Company, and Total Nigeria Public Limited Company among many other company.

Mshelia, Abdullahi and Dawha (2015) study revealed that the standards for citing petroleum stations have not been adhered by most of the petroleum outlets and this is thereby posing serious dangers on residents living in close proximity to petroleum filling stations in Maiduguri and Jero. The hazards causing to their study includes injury to aquatic life, harmful effects to human's health and environmental pollution from generating plant exhaust.

Hazards are harmful physical environmental elements to man that can be caused by forces that are extraneous to him. These hazards are also seen as threat to future source of danger having the potential to cause harm to people such as death, injury, disease and stress among others; harm to human activities including economic development, educational activities and sustainable development; harm to property damage and economic loss and environmental harm loss of plant and animal, aquatic organism and its biodiversity, pollution and loss of amenities. Mshelia, Abdullahi and Dawha (2015) further suggested that government in partnership with all the petrol stations should constantly be mounting public enlightenment campaign using bill boards, posters and media houses to enlighten the public at large on the hazards associated with petroleum products mishandlings with respect to human health and the environment so as to discourage residing close to petrol stations as mitigation control measures.

3. Methodology

This section discusses the study area, data and methodology used for the study. It discusses data sources and types, data collection procedures, sampling techniques and methods of data analysis. Thus, the primary data used for this study includes collection of geographical coordinates, field survey, interview and the secondary data includes land use and road map of the study area.

The criteria used in siting of filling stations was obtained from DPR office in Minna, Niger State, before proceeding to field to obtain geographical coordinate (x and y) of the existing filling stations in the study area. The shape files of the updated road and land use maps were also obtained from Niger State GIS office in Minna, Niger State. Checklist was drafted after detailed information on the filling stations has been sourced.

Field operation was made to acquire the geographical location (x and y) of the existing filling stations using Global Position System (Garmin 76X Model). The filling stations were categorized into three (3) for comparison and they includes multinational (major) marketers, indigenous (independent) marketers and NNPC stations.

To achieve the goal of the study, different sets of data were used. These include the filling stations data sourced from DPR and field survey, land use map and road map. These data were imported, georeferenced to the same coordinate and datum, and integrated in the ArcGIS 10.3 environment for the analysis.

3.1 The Study Area

Minna is located geographically on latitude 9^0 36' 50'' and longitude 6^0 33' 25'', with a population estimation of 304,113 (National Population Commission, 2006). It is the capital of Niger state and is connected to neighbouring cities by road with Abuja for instance being about 150km away. The city is linked to both Lagos and Ibadan in the south and to other places in the north. Minna is situated at 243 meters above the sea level, have a geological base of basement complex that consist of gneiss and magmatite that are undifferentiated. Urban development of the city is limited in the north east direction of the city due to continuous steep of granite. Figure 1 shows the map of the study area.

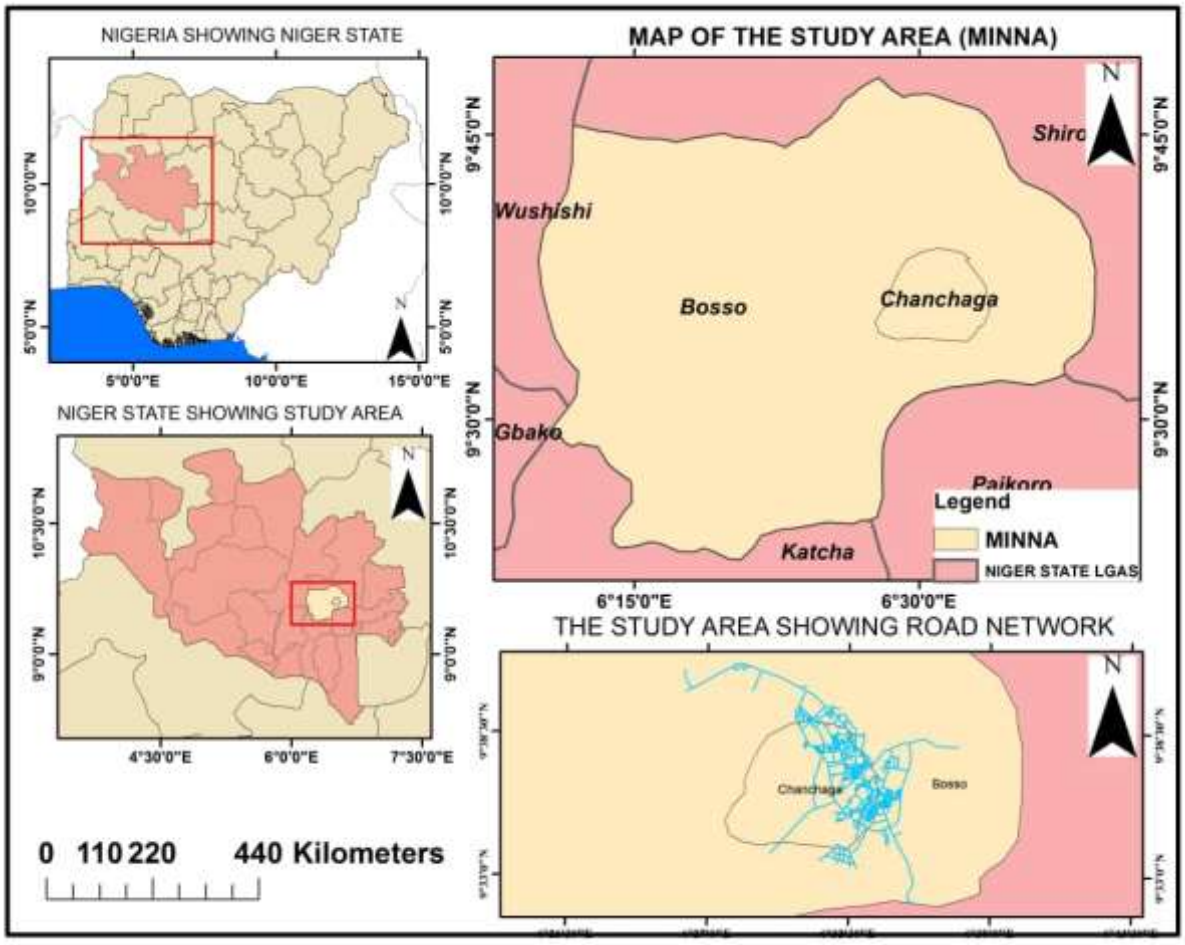

Figure 1: Map of the study area showing the road network

3.2 Geo-referencing and digitizing the map

The digitized shape files of the updated road and map obtained from Niger state GIS office was imported into Arc Map environment of ArcGIS 10.3 software. Major landmarks in the area like Mobil Round About, Federal University of Technology Bosso campus, Kpakungun Junction and Air force base in Maikunkele were used as georeferencing point of the road shape file. The shape file and the geographical coordinate were auto rectified and transformed to same coordinate system using UTM (Universal Transverse Mercator) of Global Coordinate System (GCS) projection with Minna Zone 32N being used as datum. The UTM was used in light of the fact that it is metric and has the ability to calculate distance, length and other measurement that may not be possible with geographic coordinate.

3.3 Data processing

The geographical coordinates of the existing filling stations were entered into Excel Microsoft application software to create database. Information on the existing filling stations which includes company name, address and road location, latitude and longitude coordinates was stored with column and row. The data were saved in the folder created in C drive and exported it to ArcGIS environment to show spatial pattern and arrangements using map with further analysis. In order to achieve the objective of mapping out filling stations in the study area. Pattern analysis was carried out using spatial statistics tools in ArcMap environment to identify the location pattern by using nearest neighbour index (NNI) and the Z-score value to determine the pattern of distributions.

The nearest neighbour index (Rn) according to Muritala (2015) is the ratio between the observed and expected values that varies from zero (when all points are in one location and distance between each point and its neighbour is equal to zero) and (for a perfect uniform or symmetrical point pattern spread out on an indefinite large area). A values of $Rn = 1$ indicate a random pattern since the observed distance between neighbours is equal to the one expected for random distribution. The nearest neighbour formula is given as:

$$\boldsymbol{Rn = 2 đ \sqrt{n / A}} \qquad (1.1)$$

where,

Rn = description of the distribution

d = the mean distance between the nearest neighbours (km)

n = the number of the points in the study area

A = the area under study (km^2)

The Z-score is the number of standard deviation from mean of data point which is technical way of measuring deviation below or above mean population and apply to compare result from test analysis

to normal population distribution, the Z-score formula for a sample is given as:

$$z = (x - \mu) / \sigma \quad (1.3)$$

where,

X = value of the element

μ = population mean

σ = standard deviation

3.4 Filling station and physical planning standards

Filling station business is regulated by DPR, a department under the Ministry of Petroleum Resources saddled with responsibility to register and regulate the downstream petroleum sector. In addition, there exists Niger State Urban Planning Department Agency (NSUPDA) whose duty is to regulate all development within the metropolitan of Minna. In order to achieve the second objective which is comparing location of the filling stations with standards of DPR and EGAS, proximity analysis (buffering) was used. This was achieved using buffering analysis tools available in ArcGIS 10.3 software.

3.4.1 Distance to road

The physical planning Standards by DPR (2016) grant of approvals to construct and operation of petrol station, the distance from the road to station must not less to fifteen (15) meter. Because filling station is a point location and road being a line feature, a buffering of 15 metres was created on the road and data query was made in ArcMap environment (Figure 4). To avoid the clustering of the road buffering result of 15 meters distance standard of filling to road, filling stations that does not conform to the standard was extracted and presented in map and table for easy visual interpretations.

3.4.2 Proximity of filling stations to utilities

The various utilities considered for this study include churches, mosques hospital, schools and other places of gathering merged together as layer to obtain their proximity to filling stations for vulnerability assessment. 100 metres buffering was created on the filing stations and query of data was created by location in ArcMap environment to determine possible associated hazard of proximity. The selections of locations that are within 100 meters distance to the utilities were identified by the query.

3.5 Factors that determine filling stations distribution in Minna Metropolis

Filling station business exists in a geographic space and has spatial dimensions of which such place for this business has to possess. The DPR is responsible for issuance of license to operators and ensure standards are complied with, marketers consider some factors in business location choice.

The result of the interview conducted by IPMAN official in Minna revealed that the following are the factors the operators take into consideration in selecting site for building filling station.

1. Traffic flow: This is one of the most paramount factors operators considered in citing filling station. Marketers build station along main roads that have continues and heavy traffic flow because they attract more customers. In other words the more the heavy traffic flow the more the demand of fuel.

2. Exit roads**:** Filling stations were usually built along the exit roads that link the city (Minna) to other neighbouring cities. Example of such roads like Paiko, Bida/Kpakungu, Eastern bye-pass, Bosso and Western bye pass road have the greater number of station compare to other roads partly because they are the exit road from Minna to all parts of the country. Petroleum had been compare to food as such anyone driving out of the town has to full his tank (with fuel). In fact finding showed that most filling stations are built on the exit road where customers will find it easier to enter filling station and fuel their motor vehicle. In addition, the marketers assumed that vehicle driving-in the town (Minna Town) had already fuel their vehicle at their source/origin.

3. Closeness to Motor Park: Filling station business targets drivers, especially public transport drivers, so filling stations were built very close to motor park especially those for intercity or intra transport.

4. Convenience: This was another factor consider by marketers for choosing their business location. Though marketers are attracted by heavy traffic flow, they prefer re built-in their station in places away from traffic jam heart were the passengers may find it convenience to park and fuel their vehicle. Hence, stations are built where there is enough space for customers to maneuver the vehicle when entering or exiting after fueling.

5. Near Nodal Towns/Junctions**:** Filling stations are also built close to nodal towns or junction because nodal towns are potential markets for filling station, filling station were built along them. However, this is more applicable to peri-urban stations. Vehicles are coming from different side of the junction and therefore likely to stop and get fueled.

4. Results and Discussion

4.1 Results

This involves the presentation of results from the processed data, analysis, and discussion of results. Figure 2 shows the map of the spatial distribution of the existing filling stations in the study area while Figure 3 depicts the nearest neighbor analysis to determine the pattern distributions of the filling in the study area.

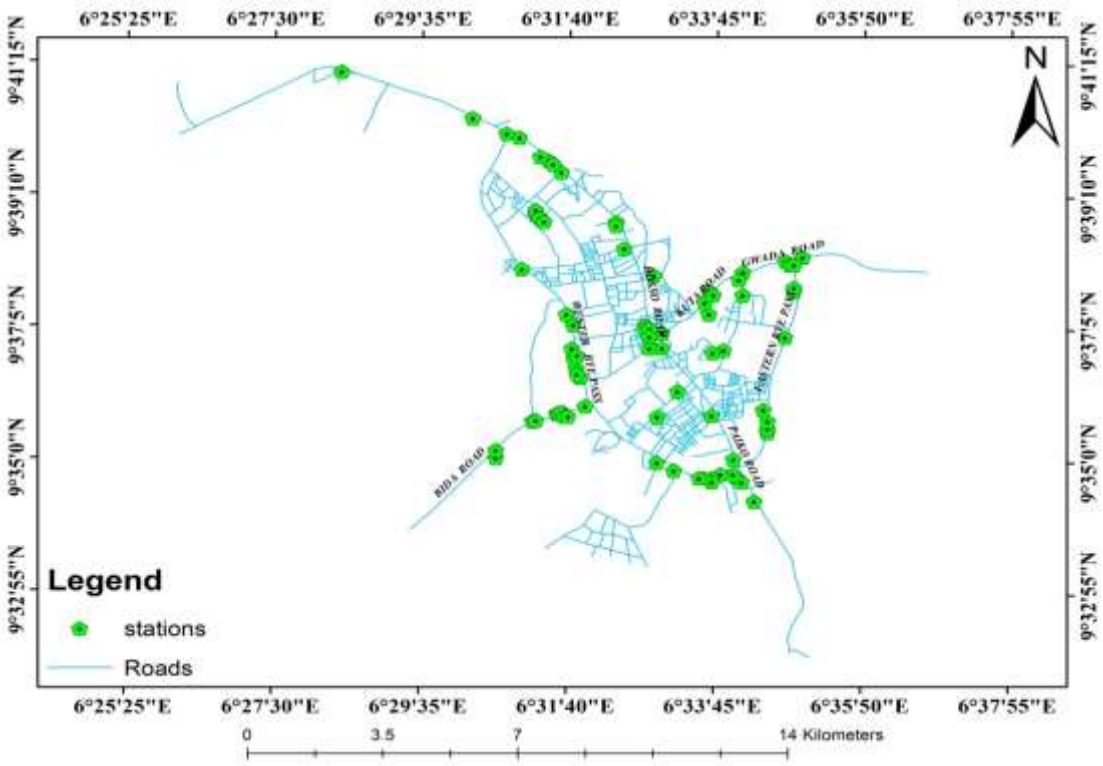

Figure 2: Existing filling stations spatial distribution in Minna Metropolis

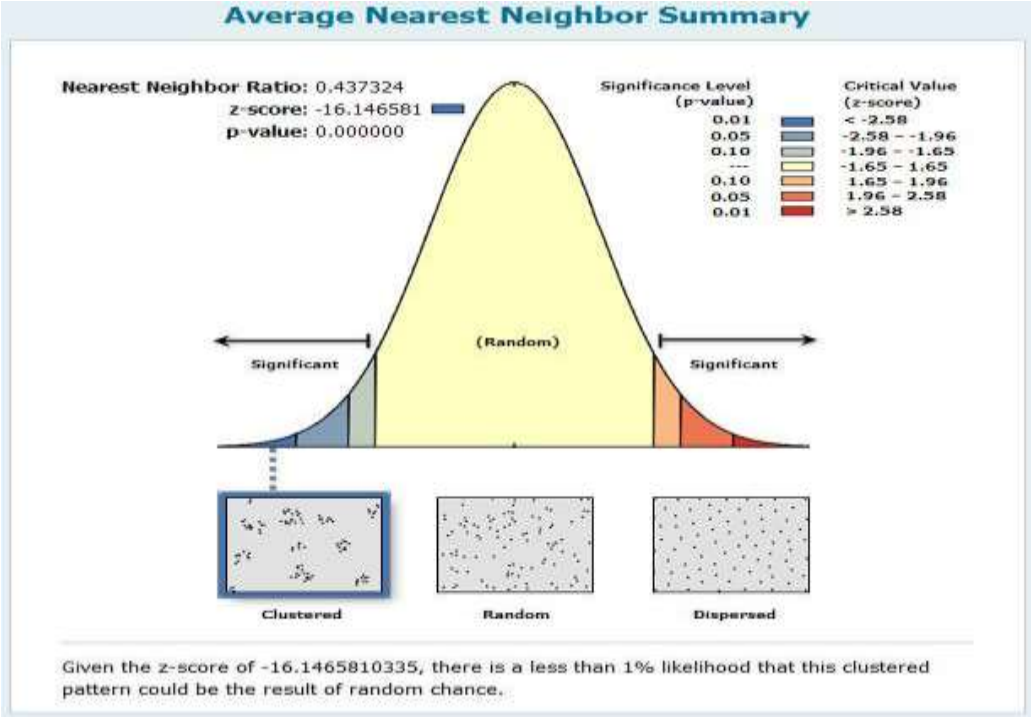

Figure 3: Nearest neighbor analysis of filling station

Table 1 shows the percentage location of filling stations in Minna metropolis. Figure 4 shows the 15meters distance road buffer used on the existing filling stations while Figure 5 is the map of the filling stations that does not meet the 15 metres distance to road in the study area.

Table 1: Location of filling stations by road in Minna Metropolis

S.N	Road	Type	F	Percentage
1.	Bida Kpakungun	Major	10	12
2.	Bosso	Major	9	11
3.	David Mark	Major	3	4
4.	Eastern byepass	Major	10	12
5.	Western byepass	Major	20	24
6.	Ibo	Major	4	4.8
7.	Kuta Gwada	Minor	8	9.64
8.	Paiko	Major	7	8.43
9.	Shehu Musa	Minor	3	3.61
10.	Bala Shamaki	minor	4	4.8
11.	Shehu Kangiwa	Minor	5	6.24
Total			**83**	**100**

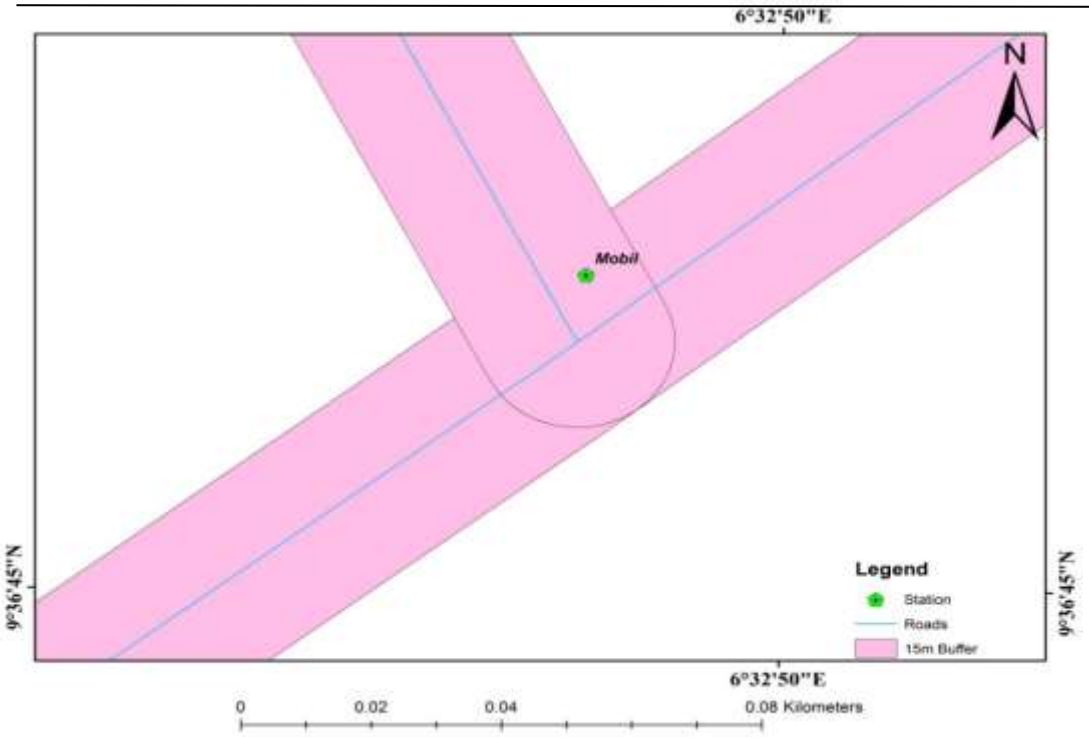

Figure 4: Filling stations and 15 metres distance road buffering

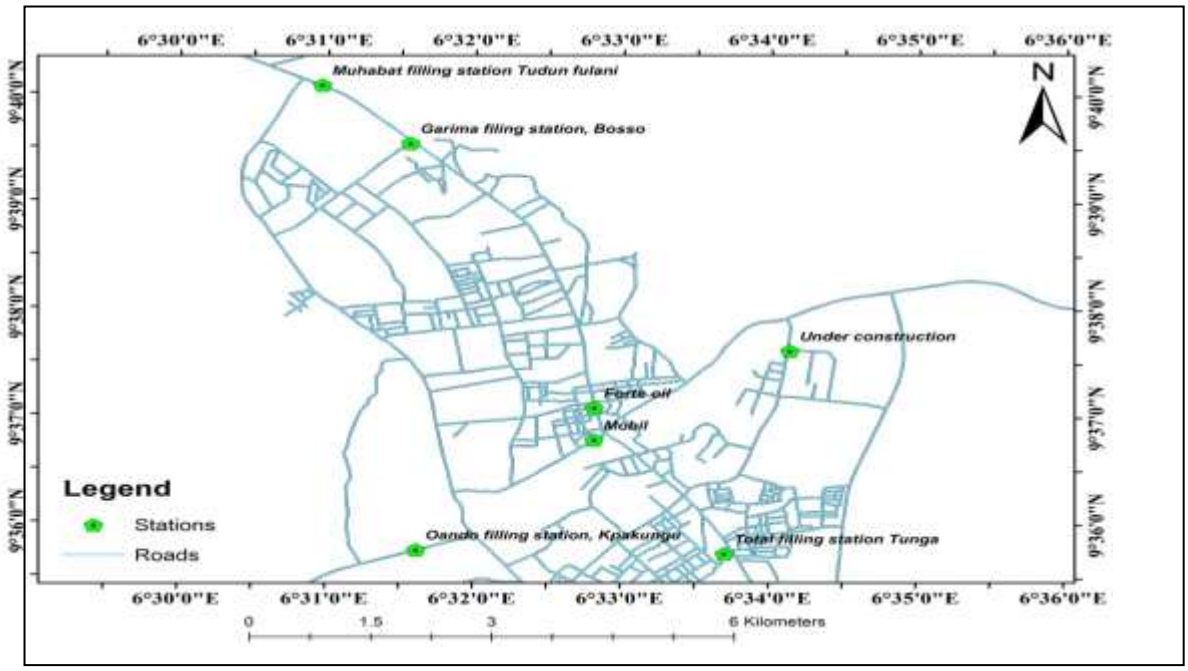

Figure 5: Filling Stations not meeting 15 metres distance to road in Minna Metropolis

Thus, Table 2 shows the filling stations that are not conforming to the 15 meters standard because the distance from the road to station must not less to fifteen (15) meter. Figure 6 depicts the map of the existing filling Stations in the study area in relation to 400 meter distance buffered to each other. Figure 7 is the map the shows the spatial distribution of filling stations in relation to utilities. Figure 8 is the map of the filling stations and 100 metre distance buffered from utilities while Figure 9 depicts the filling stations and 100 metres buffered distance to the utilities in the study area.

Table 2: Filling stations not conforming to 15 meter standard

SN	Distance (m)	Filling Stations
1	5.00	Oando filling station, Kpakungu
2	9.00	Total filling station Tunga
3	18.00	Garima filing station, Bosso
4	37.00	Muhabat filling station, Tudun Fulani
5	79.00	Forte oil, Kuta round about
6	81.00	Mobil filling station, Mobil round about
7	83.00	Under construction

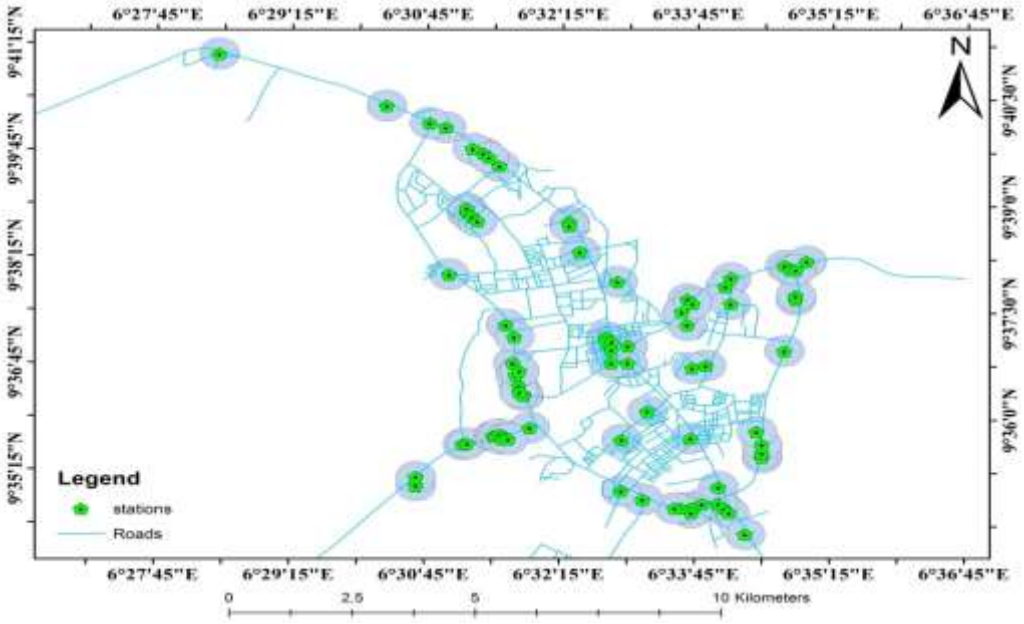

Figure 6: Filling Stations in Relation to 400 meter Distance to each other

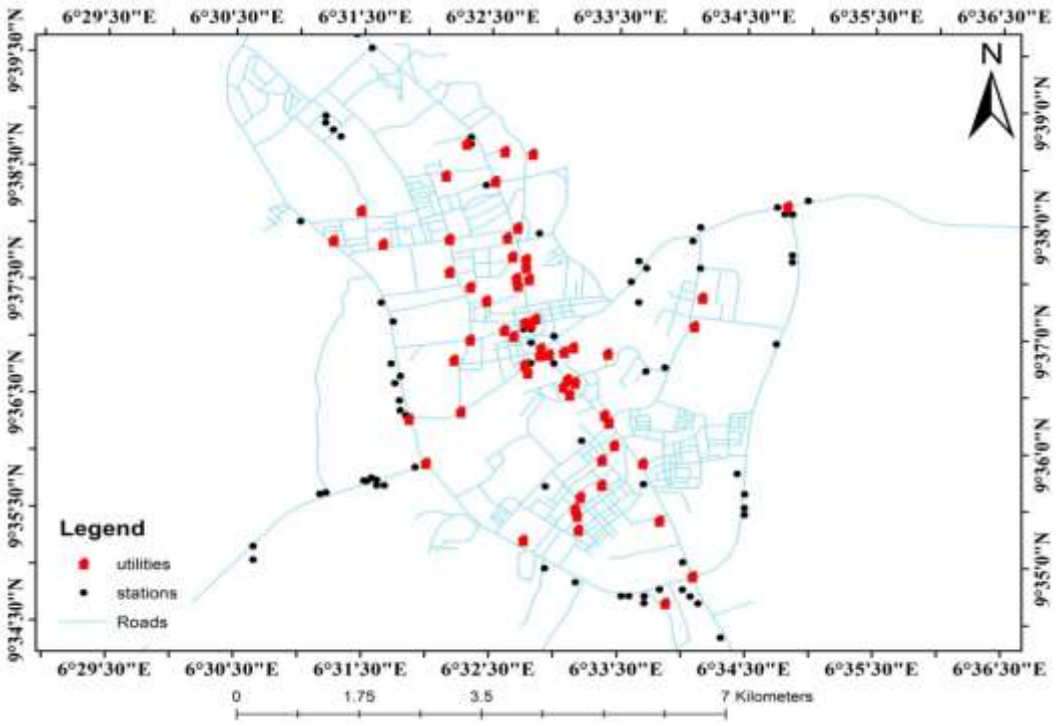

Figure 7: Spatial distribution of filling stations in relation to utilities

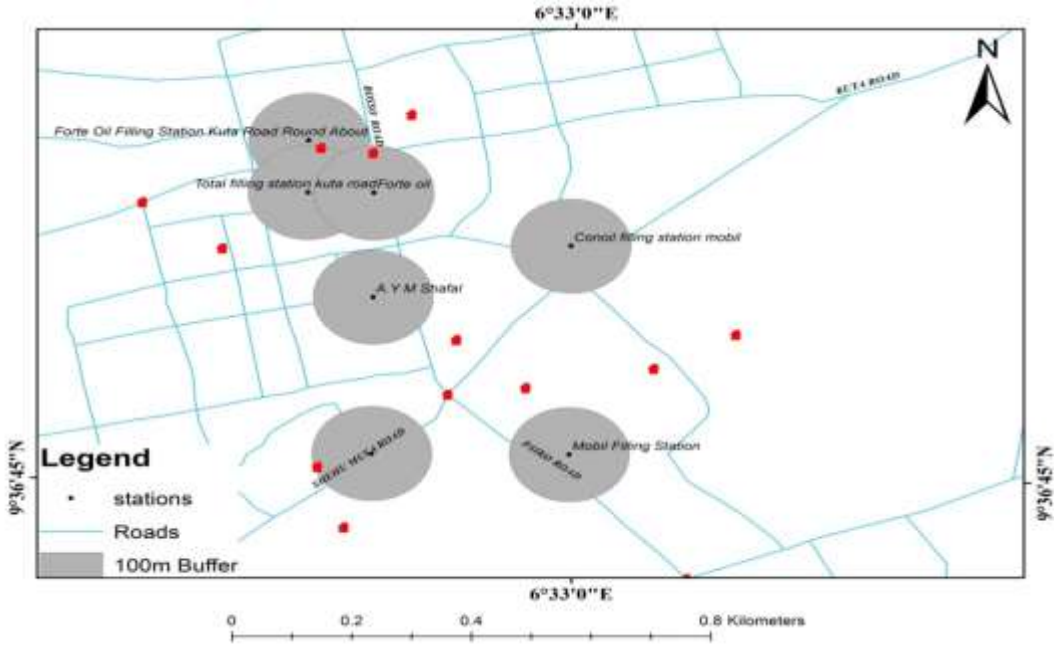

Figure 8: Filling stations and 100 metres distance from utilities

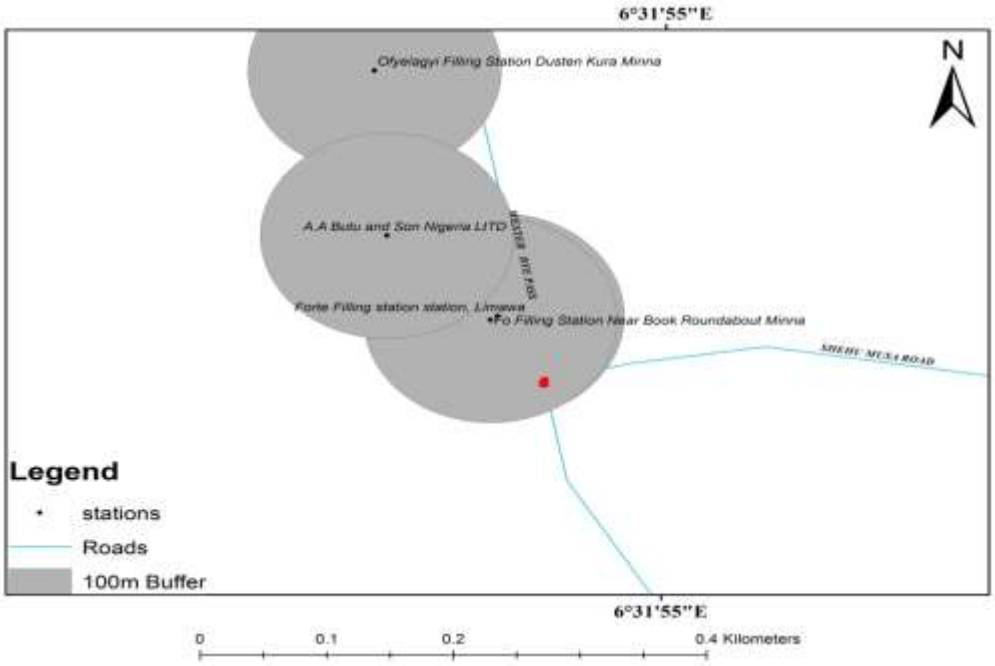

Figure 9: Filling Stations and 100 metre Distance to Utilities

4.2 Discussion of results

The finding revealed that there exist eighty three (83) filling stations at the time of this study which are distributed along eleven (11) roads in the area (Table 1). The filling stations distribution is not uniform between the roads, Western bye-pass road has the highest number of stations (20), Eastern bye pass and Bosso road have (14) and (12) each respectively. These three (3) roads account for about average of the filling stations in the area (representing about 53%). Because the roads are major roads in the metropolis, the result is not surprising; they are the longest and linked connect Minna with other neighbouring city and town. Short or access roads have least number of filling stations. This result supports that of Muritala (2012) that filling stations are mostly built in town centres rather than on the extreme exit of roads and use to be dominated on the exit side of the town.

For instance out of eighteen filling stations along Bosso Mobil to Tunga road, eight (44%) are built on the exit side along Minna to Suleja-Way, fourteen (52%) in Eastern and Western bye pass and Maikunkele road and three (30%) in Kpakungu road are found on exit side from Minna to Bida (Figure 2).

The study discovered that 86.31% of the filling stations are located on the major road and 13% on minor roads (Table.1). Attempt was made to see if there exist any relationship between the road rank and the number of filling station using Pearson product moment correlation and it was discovered that there is significant relationship even at alpha value of 0.00 because the p-value for

the relationship is 0.0000. In other words, the higher rank of the road the more the number of filling stations located along it.

The result shows that seven stations (8.43%) did not conform to the criteria of 15 meters distance to road (Figure 4 and 5). The stations are within major roads (e.g. Bosso and Tunga road) and none is within minor roads. This confirms that most of the filling stations meet the standard criteria of locating 15 metres distance from road because of Minna road network. Because most road networks in Minna are beautify with pedestal pathway, this constitute to factors why filling stations met the standard.

The finding discovered that 454 meters is the longest distance between neighboring filling stations; this was between solid mark filling station along Maikunkele road and Salihi filling station. Shortest distance less to metre was observed where stations lie to each other. Figure 6 show that more than one quarter of the stations does not maintain 400 meters to their neighbors. 9.64% of the stations met the minimum distance requirements of 400 meters to neighbors' as standard.

The filling stations that had not conformed to the standard were found mostly in main roads. The possible reason for the play out may be due to Bosso -Tunga road, East and Western bye-pass and Bida road that are major road that link Minna to other neighbouriing settlement, presence of market, shopping mall on these areas and the fact that regulators to does not strict to law enforcing but ignored by give waver especially in heavy traffic roads.

The study findings revealed that most filling stations meet this standard (60%) and only few of the stations could not meet the standard. Those stations that do not meet the standard are major and indigenous marketers with non-belonging to NNPC. Although, filling stations in Minna metropolis are located within built up but in particular proximity distance of filling station to utilities is one of the main standards the regulator are strictly with because of their usefulness.

4.3 Summary of findings

This research analyzed the location of filling stations in Minna Metropolis and subjected the location to the physical planning standards put in place by the regulatory agency, DPR and EGAS. The research findings discovered eighty three (83) filling stations currently operating in the study area. Among filling stations existing in the area, about 72.29% are owned by Independent marketing companies, 22.89% by six major marketers and 4.82% by NNPC. Total Nigeria plc top the major marketers with six filling stations with Mobile Nigeria have the least number among the major marketers.

The number of stations correlated significantly with road hierarchy. Major roads like Bosso Mobil Tunga, Eastern and Western byepass with Kpakungu/Bida road have higher number of filling stations. About 78% of the stations were located on the major main roads and 14% on the minor roads.

Though the filling station exhibit linear pattern because they are cited mainly on road side where drivers can easily get the product, the overall pattern off distribution is clustered with nearest neighbour value (Rn) of 0.43 (less than 1) and z-value of -16.14. There was significant different between the observed pattern and the random pattern at both 95% and 99% level of significance and its 99% likely that the pattern is cause by chance. The major factors influencing the location of the filling stations are traffic flow, exit side of the town, nearness to inter urban Motor Park, convenience and existence of nodal towns or junction. Most filling stations met the requirement of minimum 15 meter distance from the road (96%). In the same vein however, 60% of the filling stations met the minimum distance of 100 meter to utility. Many stations had not met the criteria of 400 meter minimum distance to other neighboring stations but they were located side by side without road separation.

5. Conclusion

5.1 Conclusion

The research made the following conclusions:

1. The filling stations in Minna metropolis are not equally distributed but concentrated along major roads especially Bosso road, Bida road, Eastern bye-pass and Western bye-pass road.
2. There is significant correlation between the hierarchy of the road and number of filling station. Filling station retailers prefer highways linking Minna town with other towns and cities like Suleja, Abuja, Kaduna, Bida, Kotangora among others where the people mingle all the time.
3. The independent marketers dominated the petroleum retail business (filling Station) and this is good for the economy. Indeed the independent marketers were established with intention to diversify the economy, create opportunity for Nigerian to participate in downstream petroleum sector and reduce the monopoly of multinational companies that initially dominated the sector.
5. Most Filling station complies with the standards pertaining to distance from the road due to pedestal pathways of Minna road network and from public buildings and utilities especially hospital. Many stations do not meet the 400 meter distance to other nearby stations. In fact it is common in the metropolis to see two stations lying back to back especially in the major roads.
6. This study was able to create the database for filling stations in Minna Metropolis, the DPR ,EGAS and Niger State City Development Office and Niger State GIS which are currently trying to create spatial database for the city can utilize this data. A similar study can be carried out in all states of the federation.

5.2 Recommendation

The research also made the following recommendations:

1. The regulators (DPR, EGAS, fire service and town planner) must make it mandatory for every filling station operators to include the geographic location of the site when processing license. This will aids in spatial database management updating.
2. Regulatory agencies need to look into the issue of discrepancies regarding the compliance to standards, take appropriate measures that ensured that only site that meet the minimum standards are allowed to do the business.
3. Filling stations are mostly located on some roads as found by the study, hence the need to give priority for the roads with less number of filling stations when given license to operators.
4. The vulnerability assessment shows that built up located at distance of 20 meter to filling station are in danger in case of fire outbreaks, authorities should enforce law and other to secure lives and properties from fire outbreaks.

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