SITE SUITABILITY ANALYSIS AND RISK ASSESSMENT OF PETROLEUM FILLING STATIONS IN UMUAHIA METROPOLIS INUMUAHIA NORTH L.G.A USING GIS TECHNIQUE

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ABSTRACT

The rapid growth in urbanization has produced greater demand of vehicles, which results in morefuel consumption. A petrol filling station is a facility catering for need of vehicles and home appliances. The location of petrol filling station is important as it poses a potential risk to the environment and humans. The study aimed at performing a site suitability analysis and risk assessment of petroleum filling stations in Umuahia metropolis in Umuahia north LGA using GIS and Remote Sensing techniques. The aim was achieved through the following objectives: to investigate the factors for suitability analysis of petrol filling station based on physical planning standards of Department of Petroleum Resources (DPR); to carry out the site suitability analysis of petrol filling stations; to assess the factual condition of petrol filling stations distribution based on suitability analysis results and to produce a site suitability map of petrol filling stations in the study area. The methodology involved the acquisition of Landsat 8 satellite imagery and coordinatepoints of petrol filling stations. Features were extracted from the satellite imagery; spatial distribution analysis and suitability analysis were carried out in ArcGIS 10.2 software. The proximity tool in Arcmap was used to carry out the suitability analysis using buffer distance stipulated by DPR's physical planning standards. The results revealed that there are 33 petrol filling stations located along the 12 roads in the study area. There is 61.5% compliance of petrol filling stations in the study against the physical planning standards. 42% of petrol filling stations satisfied the minimum requirement of 15metres distance from the road. Equally 100% of the fillingstations met the minimum distance of 100meters from the health care facilities. However 24.2% ofpetrol filling stations met the criteria of 400meters minimum distance to other stations where located on same road side and when not separated by any road or street, while about 88% of petrol filling stations met with the criteria of 100meters from schools. The study and results achieved is important and beneficial; and is recommended as a decision support system in town planning scheme for future development and policy formulation.

KEYWORDS: Petrol filling stations, GIS, Location and Physical Planning Standards

1. Introduction

In recent years, the rapid growth in urbanization has produced greater demand of vehicles, which results in more fuel consumption. This fuel need is catered by the place named a Petrol Filling station (PFS). It has been evident from different studies that petrol filling station has the high potential hazards to the site and the surroundings (Khahro, *et al.*, 2013).The rapid increase in population and urbanization in Umuahia, has also brought an increase in the number of automobilesand therefore the need to fuel these automobiles. Petrol Stations are constructed around Umuahia metropolis to meet up with the fuelling services of these automobiles and other house hold equipment that uses petrol. These petrol filling stations are often found, not to conform to basic standard in safety, health and risk control as approved by regulatory agencies such as the

Department of Petroleum Resources (DPR). The location of petrol filling station (PFS) is important as it poses potential hazards not just to the site but also to the environment at large. There are also hazards affecting the workers in the petrol stations and such hazards may include: dizziness, anger, depression, reduced performance and even hypothermia. The hazards which may affect the environment may include: Fire outbreak, leakage of Underground Storage Tank (UST), static electricity, traffic congestion due to vehicle queue to access the PFS and air pollution as a result of concentration of aromatic compound (Khahro, *et al.*, 2013).

In Umuahia metropolis, there is an indiscriminate sitting of petrol filling stations and they do not conform to basic standard in safety, health and risk control as approved by regulatory agencies such as the Department of Petroleum Resources (DPR). This therefore may lead to potential hazards which may affect the environment, human resources and the economy. Petrol filling stations are sited close to schools, markets, residential areas and very close to roads as against as against the basic standard in safety, health and risk control.

Geographic Information System have been found to provide high efficiency in spatial analysis as it has greater flexibility and accuracy for handling digital spatial data especially in suitability analysis. Many researchers have applied GIS in carrying out site suitability analysis of Petrol filling Stations. This study aims at using GIS and Remote sensing techniques to analysing the suitability of Petrol Filling Stations in Umuahia Metropolis according to DPR (2007) physical planning standards.

2. MATERIALS AND METHODS

2.1 Study Area

The study area, Umuahia North is a local government area in Umuahia town. Its headquarters are in the city of Umuahia. It is located along the railroad that lies between Port Harcourt to its south and Enugu city to its north. The region lies between Latitudes 7°19' 21''and 7°37'29" North, and Longitudes 5°23'18"and 5°45'31" East. It is 155m over sea level. It covers a total area of 245 square kilometres. According to the national census 2006, the total population of Umuahia North is stated to be 220, 660 persons. The climate of Umuahia North is classified as tropical. There is significant rainfall during most of the year and short period of dry season. The climate is classified as Am by the Koppen-Geiger system. The average annual temperature of Umuahia is 26.0 degrees Celsius and average precipitation is 2153 mm. Figure 1 is the map of the study area.

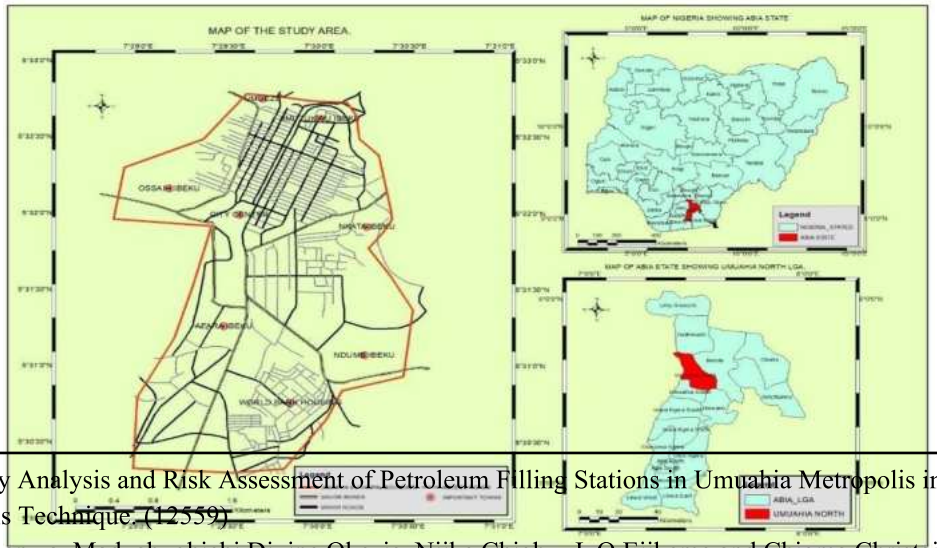


Fig. 1 Map of the Study Area

2.2 Methodology

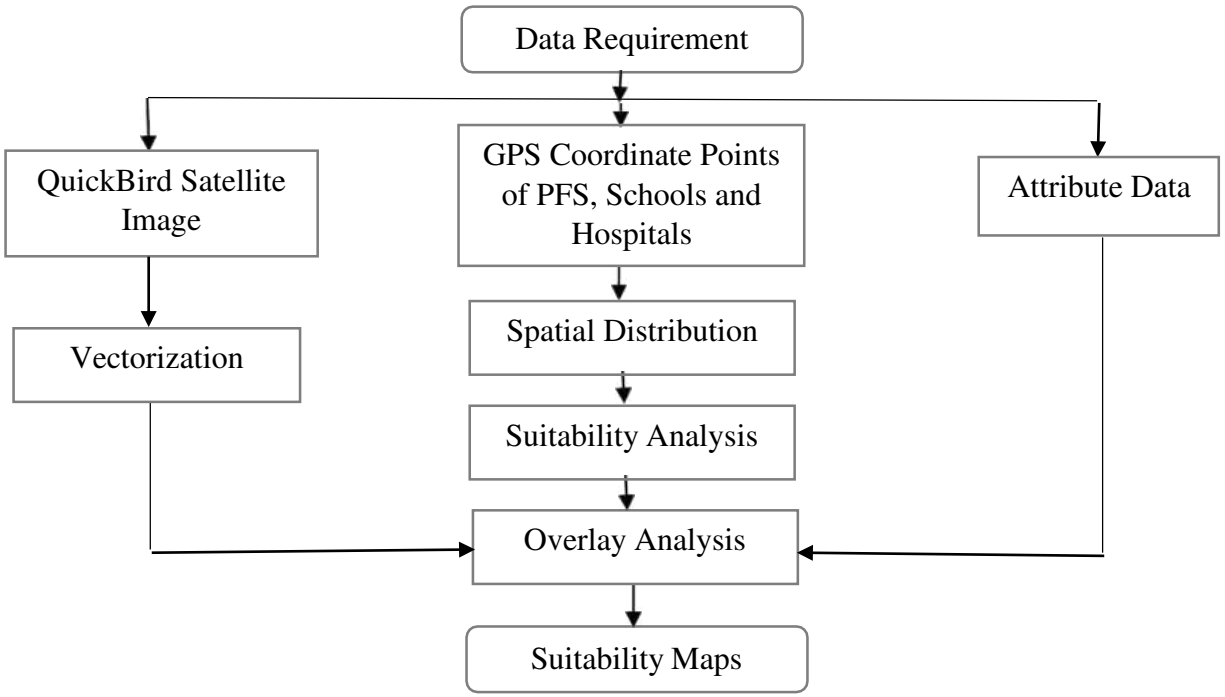


Fig. 2. Flowchart of methodology for the study

To analyse the site suitability and risk assessment of petrol filling station in Umuahia Metropolis, the existing PFS were checked against the DPR the physical planning standards. Table 2.0 shows the criteria for petrol filling station sites as stipulated by DPR:

Table 2.0 Buffer Zones of Entities

S/N	Layers	Buffer (m)
1	Major Roads	15
2	Existing Petrol Filling Stations	400
3	Educational Institutions	100
4	Health Facilities	100
5	Public/ Semi-public Buildings	100
6	Built-up (Residential)	50
7	Fire Station	Nil

Data Source: DPR (2007)

The Quickbird satellite image of the study area was acquired from the Digital Globe platform and the satellite was used to extract the features of interest (Road networks, schools, hospitals etc.). The Extrex10 handheld GPS receiver was used to acquire the coordinate points of filling stations,

schools and hospitals in the study area. Table 2.1 shows the petrol filling stations, its coordinate points and location within the study area.

Table 3.1. List of PFS in Umuahia Metropolis

S/N	EASTING	NORTHING	PFS NAME	LOCATION
1	333116.769	611260.684	TOTAL	Aba Road
2	333115.205	611222.178	OANDO	Aba Road
3	333105.765	611087.066	FORTE OIL	Aba Road
4	333095.341	610985.261	MASTERS ENERGY	Aba Road
5	333102.868	610864.811	OANDO	Aba Road
6	332820.065	609695.804	MOBIL	Aba Road
7	332782.275	609626.854	OANDO	Aba Road
8	332648.831	609262.377	CITY BASE	Aba Road
9	332652.791	609228.375	TOTAL	Aba Road
10	332623.999	609188.513	HUMAR	Aba Road
11	332506.320	608819.735	MAJOR & CRYSTAL	Aba Road
12	332471.592	608655.743	JUHEL	Aba Road
13	332788.384	611634.482	FORTE OIL	Club Road
14	332605.981	611757.486	SDON OIL	Mission Hill
15	332339.049	611931.656	EZE YAM	Mission Hill
16	332291.591	611947.053	SINADY OIL	Mission Hill
17	332124.880	612011.881	TONIMAS	Mission Hill
18	332018.124	612034.020	NNPC	Mission Hill
19	331819.528	611930.932	TOTAL	Mission Hill
20	332329.234	611918.746	VILLA ROY	Mission Hill
21	333334.663	612672.989	SDON OIL	Uzuakoli Rd

22	333205.358	613142.456	CITY BASE	Ugwunchara Road
23	333044.726	613231.454	LAWKEN OIL	Ugwunchara Road
24	333436.285	612472.657	EASY ON	Umuwaya Road
25	333385.841	612348.617	HANPET	Umuwaya Road
26	334256.922	611851.338	DONJUSTUS	Bende Road
27	334313.842	611872.367	HANPET	Bende Road
28	334453.712	611988.289	BAWAS	Bende Road
29	334517.47	612041.973	SDON OIL	Bende Road
30	334630.801	612157.659	BENNY ARIS	Bende Road
31	333842.516	610088.226	SUPERLATIVE WINNERS OIL	Ikot-Ekpene Road
32	333901.055	609884.441	NGOZI FILLING STATION	Ikot-Ekpene Road
33	333904.561	609807.183	ORPET PETROL STATION	Ikot-Ekpene Road

Data Source: (Field Data)

The ArcGIS 10.2 software package was utilized in development of GIS data and GIS analysis of site suitability of PFS in the area using the DPR physical planning standards. The proximity analysis tool supported by the ArcGIS software was used to carry out the suitability analysis.

The following are the summary of the GIS tasks performed for the study:

i. Vectorization: This operation involves conversion of raster image to vector data used for the research.
ii. Database design and creation to support the suitability analysis.
iii. Spatial analysis (buffer analysis).
iv. Overlay of restricted (buffer) areas to analyse suitable sites

3. RESULTS AND DISCUSSIONS

3.1 Spatial distribution of Filling Stations

The study revealed that the thirty three (33) existing PFS in the study area are distributed along the eight (8) roads in the study area and these filling stations are not equally distributed between the roads. However, Aba road has the highest number of station (12) followed by Mission with (7) and these two roads account for more than one-third of the PFS in the area. This result is not surprising because the two roads are the major roads in the metropolis and it also shows that PFS are not built in town centers but rather on exit roads of the metropolis.

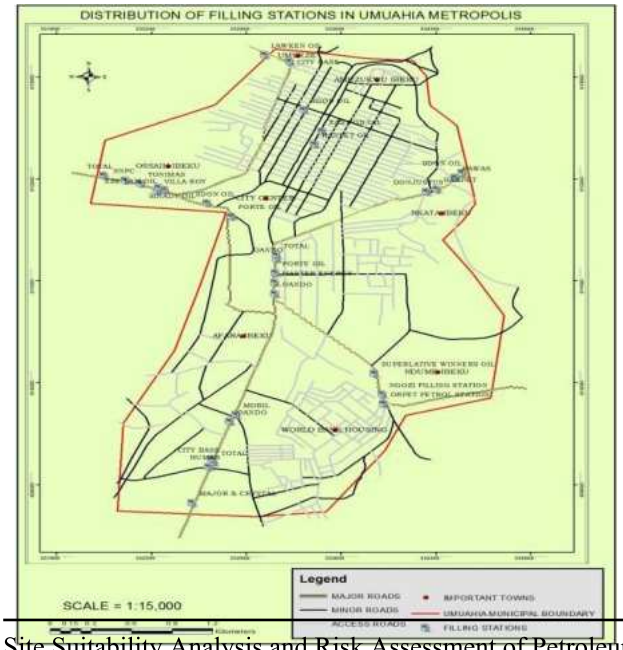
Table 3 shows the distribution of filling stations by road and figure 3.0 is the map showing the

distribution of filling station by road.

Table 3.1: Distribution of Filling Stations by Road

S/N	Road	Road Type	No. of stations	Percentage (%)
1	Aba Road	Major	12	36.4
2	Bende Road	Minor	4	12.1
3	Club Road	Access	1	3.0
4	Ikot-Ekpene Road	Major	3	9.1
5	Mission HilL Road	Major	7	21.2
6	Ugwunchara Road	Minor	3	9.1
7	Umuwaya Road	Minor	2	6.1
8	Uzuakoli Road	Minor	1	3.0
			Total = 33	Total = 100

(Source: Field Data)



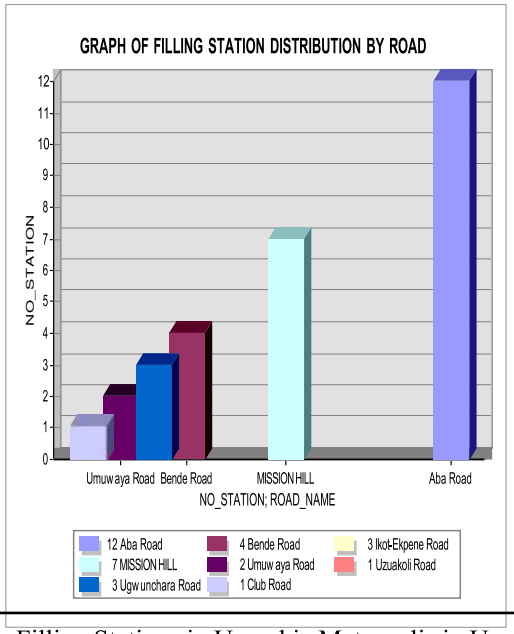


Fig. 3.1: Distribution of Filling Stations in Umuahia Metropolis.

3.2 Suitability Analysis

For the purpose of this study, the method of suitability analysis was by Physical Planning Standards

of the Department of Petroleum Resources. The standards set by the DPR were used to analyse the compliance of filling stations to these physical standards which will limit health and environmental challenges in the society. The proximity analysis tool in ArcGIS software package was used for the suitability analysis.

3.2.1 Distance of PFS Pumps to the Road

According to the physical planning Standards set by DPR (2007), the distance from the road to PFS pump should not be less than 15meter. Since PFS were represented as point features and road as line features, a buffer of 15m was created on the road and data query by location was made in ArcGIS. The query assisted with "selecting all locations that are completely within 15meter road buffer.''. The result of the buffer query of 15m of filling stations rom road is presented in figure 3.2.1

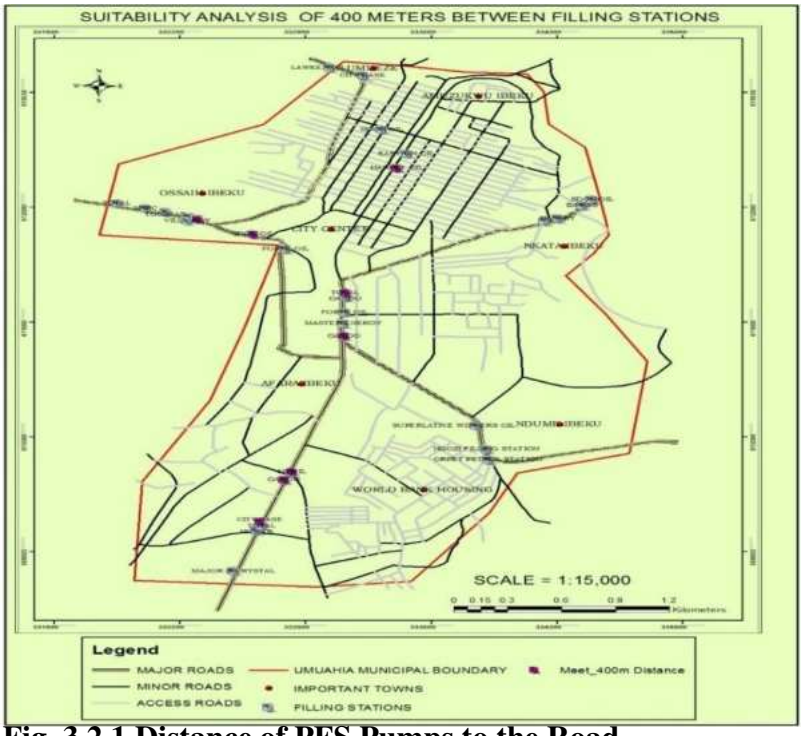


Fig. 3.2.1 Distance of PFS Pumps to the Road

From the result in Fig. 3.2.1, it was observed that fourteen (14) stations which make up of (42%) did not meet the criteria of 15m minimum distance from road. These stations include some PFS along the following roads (Aba, Bende and Uzuakoli Road). Nineteen (19) stations which is 58% were observed to meet up this 15m criteria and these PFS are along Mission Hill and Ikot-Ekpene Road meet this criterion.

3.2.2 Distance PFS to Health Facilities

By DPR (2007) standards, PFS are not allow to operate adjacent to public institution like hospitals. In case they are to operate, the minimum distance of 100meters has to be maintained. Thus a comparison was made between the location of PFS and their distance to the hospital. The proximity analysis tool in ArcGIS was used to carry out this analysis using a buffer distance of 100 meters from the location of these filling stations to the health facilities to determine those that meet with this criteria. Figure 3.2.2 shows the result of the 100m distance of PFS to health facilities.

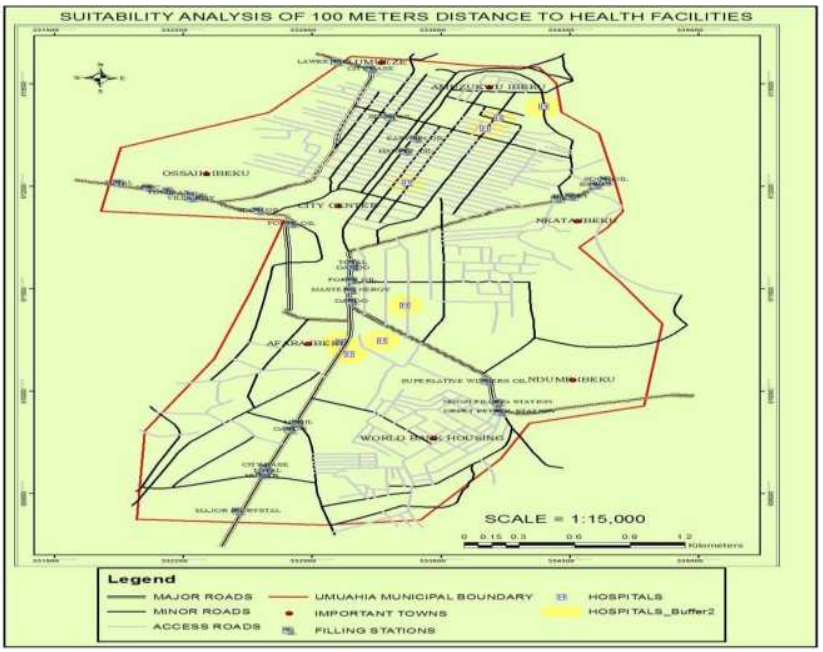


Fig. 3.2.2 Distance of PFS to Hospitals

From the result in Fig. 3.2.2, it was observed that all the filling stations meet with this criteria of 100m to health facilities.

3.2.3 Distance of PFS to Schools

According to the criteria set by DPR, PFS are not allowed to operate adjacent to public institutions like schools and if they must operate, then a minimum distance of 100meters must be adhered to before sitting such PFS. The proximity analysis tool in ArcGIS was used to carry out this analysis using a buffer distance of 100 meters from the location of these filling stations to the schools to determine those that meet with this criteria. Figure 3.2.3 shows the result of the buffer query of 100m of schools to PFS.

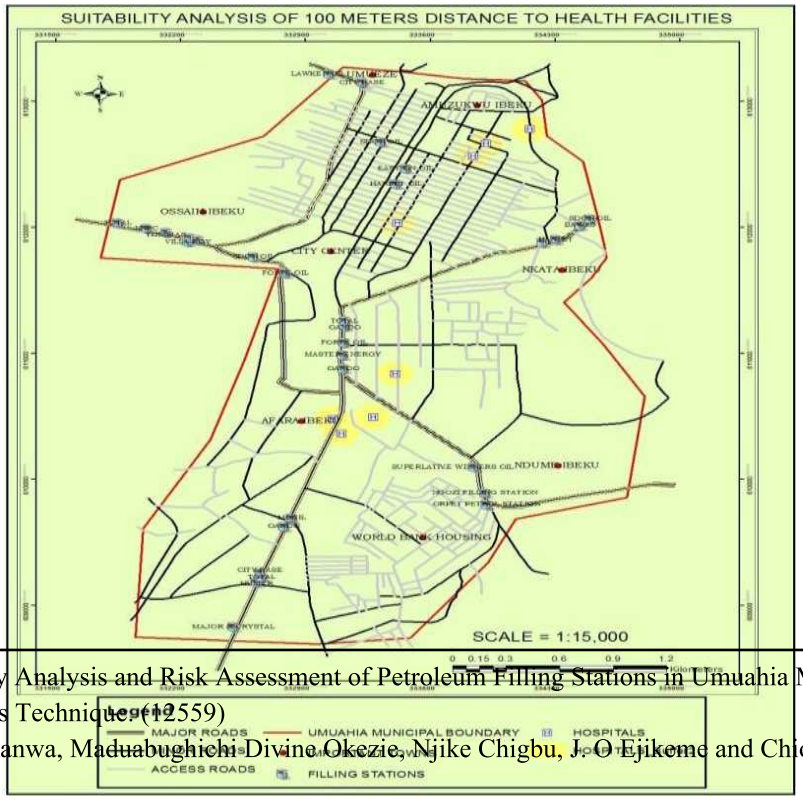


Fig. 3.2.3: Distance of PFS to Schools

The result in Fig. 3.2.3, shows that twenty eight (29) PFS comprising of 88% meet up with this criteria while about four (4) PFS do not which comprises of 12%.

3.2.4 Distance Between two PFS

According to the DPR (2007) standard, the distance between two PFS should not be less than 400m. This criteria was checked against the existing PFS in the study area using the proximity analyst tool in ArcGIS. The result of the analysis is shown in Fig. 3.2.4.

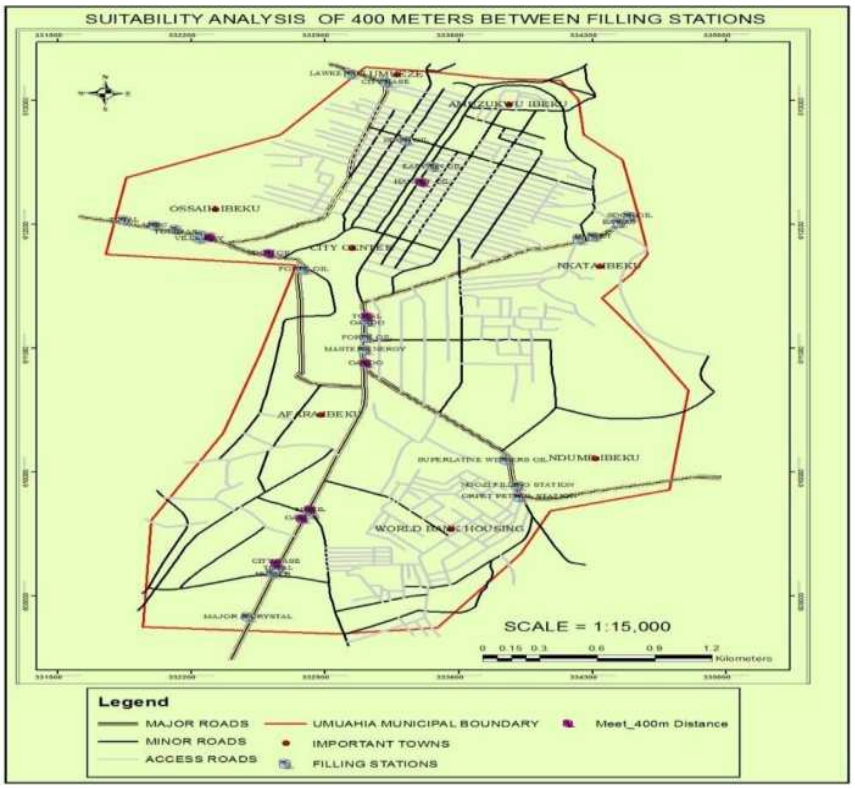


Fig. 3.2.4: Distance between two PFS

The result in Fig. 3.2.4 above revealed that 8 filling stations (24.2%) meet up with these criteria of 400m apart as stipulated by DPR. The longest distance between PFS is between Oando and Mobil filling station along Umuwaya-Aba Road having a distance of about 1,222.670 meters while the second station with highest distance apart is between Hanpet and Total which is also along Umuwaya-Aba Road having a distance of about 1,159.436 meters apart. The following stations Oando and City Base along Aba and SDON and Eze Yam filling stations are having 412.378 meters and 401.236 meters respectively.

3.2.5 Integration of All Suitability Analysis

The different criteria analysed for this study were integrated together to determine the general level of conformity of the PFS in the study area to the physical planning standards stipulated by the DPR. The result of the integration is shown in Fig. 3.2.5.

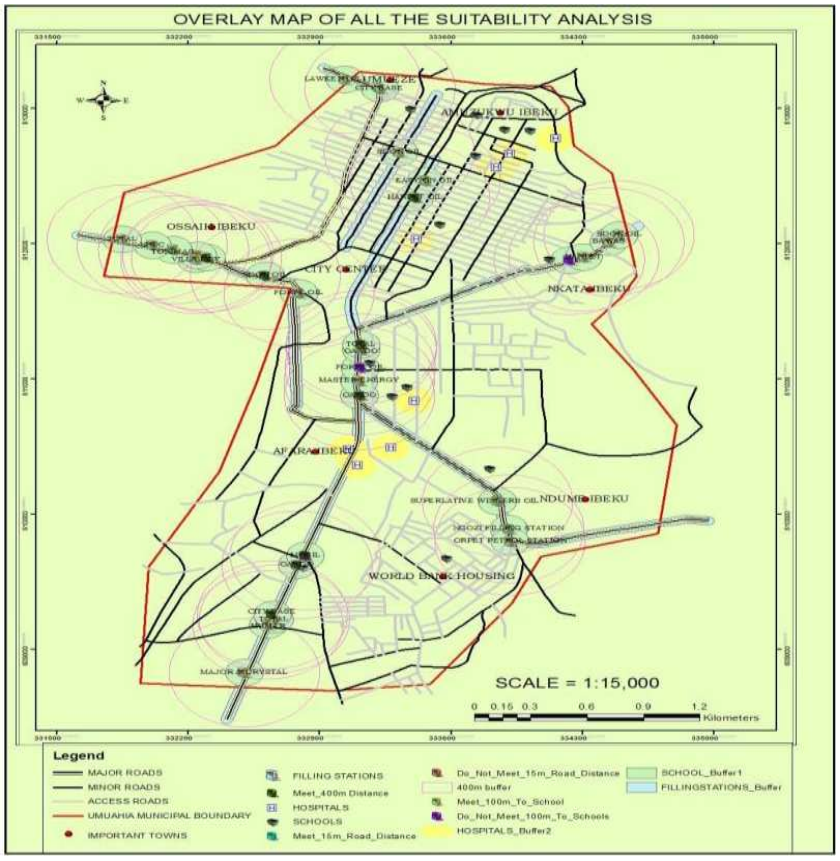


Fig. 3.2.5: Overlay Map of all Suitability Analysis of PFS

The result in Fig. 3.2.5 above shows that there is 61.5% compliance of the PFS to the physical planning standards by the DPR and most PFS in the study area were located far away from firefighting stations except Orpet, Ngozi, Superlative filling stations. Also, most of the PFS in the study area do not have adequate firefighting equipment in situation of casualties.

4. CONCLUSION

This study has demonstrated the use of GIS tools in solving spatially related pertinent problems, such as siting of PFS. From the study it was revealed that there is a high concentration of PFS within Umuahia metropolis. And these filling stations are not evenly distributed; rather they are concentrated especially along Aba Road and Mission Hill road.

The suitability analysis shows that there is 61.5% compliance of the PFS to the physical planning standards by the DPR. Most existing PFS are sited in an uncongenial environment and therefore poses threat to the lives and properties within their vicinity.

The study recommends the following:

i. That site suitability analysis of PFS be incorporated in the Town Planning scheme for future development and policy formulation.
ii. Measures should be put in place to enforce the set standards by DPR and offenders be prosecuted to bring sanity in the oil and gas industry and the environment at large.
iii. This study should be replicated in other parts of the country or be adopted for future redevelopment of the study area.

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