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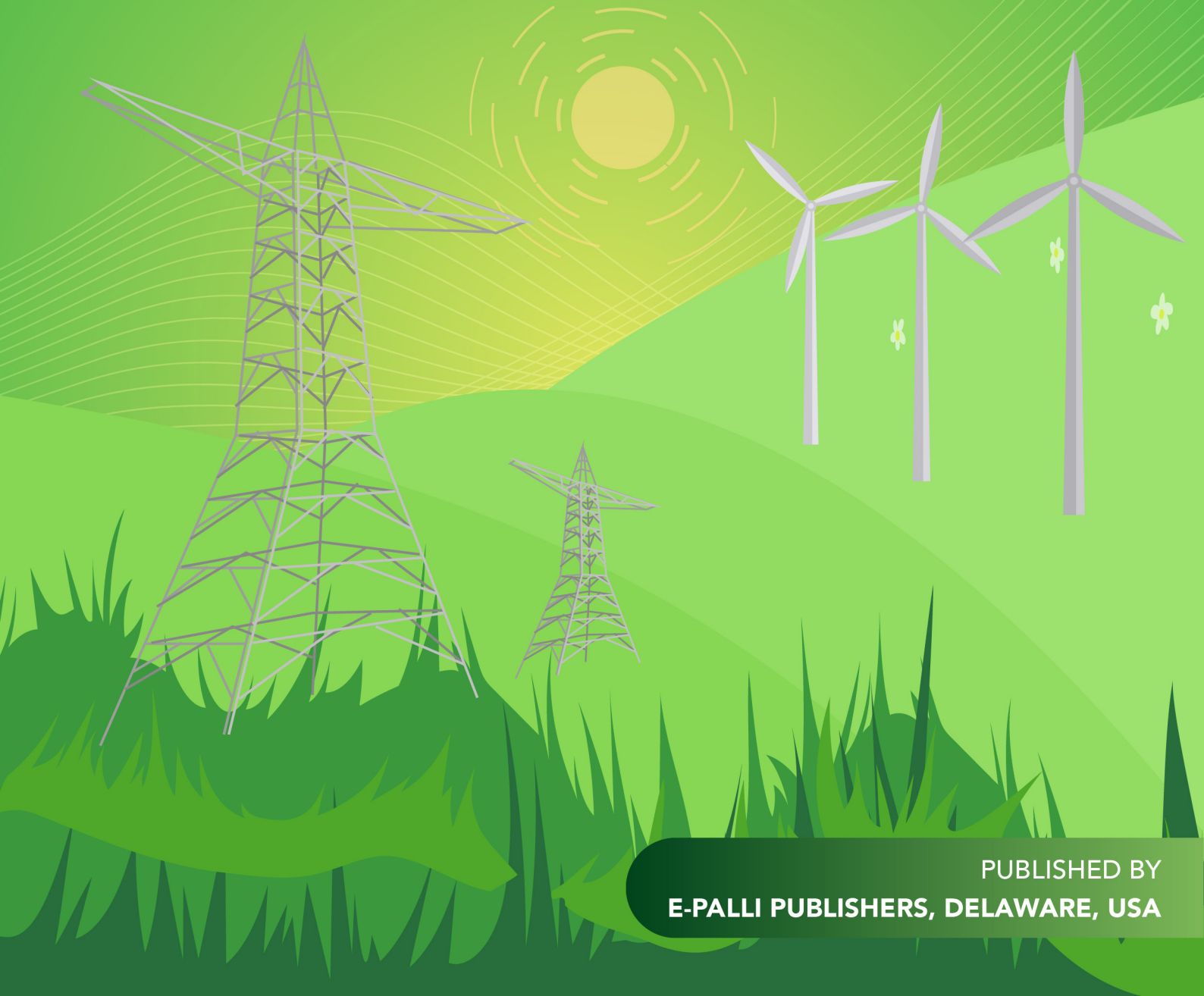

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Spatial Analysis of Petroleum Filling Stations' Compliance to Regulatory Standards in Bauchi Metropolis, Nigeria

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ABSTRACT

Nigeria is the most populous country in the Organization of Petroleum Exporting Countries (OPEC) with a population of about 250 million people. Bauchi metropolis has witnessed great changes in recent years, in terms of population growth and rapid urbanization. This study aims to assess the level of compliance of petrol filling stations in Bauchi metropolis to the standards of the Department of Petroleum Resources [DPR] (2007) and Bauchi State Development Board [BSDB] (2012) guidelines. Field survey, Grid3 portal and Global positioning system (GPS) were the research instruments used for the study. ArcGIS 10.8 was used to carry out the analysis using the Buffer and Near analyses. The results indicated that the distribution pattern of the filling stations is clustered. The study found out that only 33.63% of the stations violated the criterion of a 15-meter minimum distance from the road while the rest fulfilled that requirement. However, 11.81% of the stations met a minimum distance of 400 meters from their nearest neighbors, while 88.18% failed to achieve the minimum distance of 400 meters. The study also revealed that only 3.63% met the requirement of not more than four stations within a 2 Km radius. Based on the findings of this research, the study recommends that the DPR and the BSUDB should create a database for filling stations in Bauchi Metropolis.

INTRODUCTION

The growth in the global population has posed a major challenge to both state and national governments in providing the masses with the requisite infrastructure and imposing guidelines as well as regulations on the people, a trend that will continue with most of the world's population living in cities (World Health Organization [WHO], 2010). Currently, 55% of the world's population lives in cities, which is predicted to rise to 68% by 2050 (Rai, 2020). Urbanization or the steady movement in human population from rural to urban regions, combined with global population increase, may add another 2.5 billion people to metropolitan areas by 2050; according to World Health Organization's projections, Asia and Africa will account for over 90% of this growth (United Nations, 2018). Nigeria holds a significant position in the world economic history as virtue of its immense natural resources, which include crude oil and natural gas, water supplies, stretches of productive agricultural land, and substantial forest resources (Ukpong *et al.*, 2013). Bachi state is one of the six states in Northeastern Nigeria. Furthermore, insecurity in neighboring cities such as Damaturu and Potiskum in Yobe State, Jos in Plateau, and Gombe, and Borno States, respectively, results in a huge influx of people into Bauchi; these are indicators that the population of the city will double. Independent marketers own more than a third (59.09%) of the filling stations in the area.

Petrol Filling Station (PFS) is a business outlet that sells vehicle fuels and lubricants, including Premium Motor Spirit, Liquefied Natural gas, Kerosene, Dual Purpose Kerosene (DPK) and Aircraft Turbine Kerosene (Randall and Warren, 2020). Observing a set of rules, such as a policy, specification, standard or legislation, is referred to as compliance. Regulatory compliance is the goal that institutions aim to achieve when it comes to ensuring that they are aware of and comply with relevant laws, rules, and regulations (Tom, 2016). Compliance initiatives may take a wide range of ways, including instructions, regulatory regulations, civil judicial regulation, and criminal enforcement, to constrain, enable, or encourage behaviors (Crane and Matten, 2007). According to the requirements of the Department of Petroleum Resources (DPR), the distance between the road's edge and the closest pump shall not be less than 15 meters and the Euclidean distance between two petroleum filling stations should not be less than 400m. Fires at petrol stations are mostly caused by failures in human behavior, attitude, and procedures, according to the Department of Petroleum Resources (DPR) (2007). Petroleum filling stations should be situated at least 100m away from schools, hospitals, and heavily inhabited areas in the urban environment (Mshelia *et al.*, 2015).

Regulations and criteria for obtaining clearance for the building and operation of a petrol station; are in accordance with Petroleum Amendment decree no. 37 of 1977 safety rules and regulations. They are as follows: The distance between the road's edge and the nearest pump will be not less than 15m. There should be not more than four petrol stations along a two-kilometer stretch of road on both sides of the road, including the one under consideration, and the station under review should not be less than 400M

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away from the near-by station (DPR, 2007).

The distance between any petroleum filling station and any public area shall not be less than 100 meters; the site's drainage shall not flow into a body of water; and the site's drainage will not flow into a stream or river. A letter of approval from the Federal Highway is necessary in some cases where the location is found along the highway (Department of Petroleum Resources [DPR], 2007). Proof of land ownership, development permission, detailed building plans (mechanical and civil engineering drawings), and locational/zoning clearance is among the criteria, according to the Bauchi state Urban Development Board guidelines [BSUDB] (2012). The BSUDB must first issue a development permit before the applicant can approaches the DPR for final clearance. The BSUDB also adopted the DPR's locational guidelines for locating the petroleum filling stations.

LITERATURE REVIEW

Geographic Information System (GIS) is a sophisticated computer-based application. Bringing together different data sets that may be separated across space (Karen, 2008). With the use of GIS, users can comprehend spatial patterns, correlations, and trends by visualizing, challenging, analyzing, and interpreting data. Numerous industries, including public health, transportation, urban planning, and environmental management, heavily rely on this technology (Longley *et al.*, 2023). Geographic information systems (GIS) and Global Positioning Systems (GPS) have been used in previous studies like Adekunle, A. (2020), Oladipo *et al.*, (2018), El Faleet (2017) and Uba, (2015) and they have proved to be very effective tools in studying the locations of filling stations. This study's goals are akin to those of Yusuf *et al.*, (2022), who examined COVID-19 vaccine and testing center locations in Nigeria using GIS and web mapping technologies to boost access and public education. Both investigations emphasize the pivotal role of spatial data and modern technology in enhancing access to crucial services.

Oladipo *et al.*, (2018) analysed filling stations in Abuja using a GIS, paying particular attention to how close they were to residential areas and important infrastructure. The investigation found that several stations were too close to hospitals and schools, in violation of DPR rules. These violations could be visually represented thanks to GIS mapping, which made it easier to enforce regulations and make plans for safer areas. According to the study's findings, dangers related to filling station location might be considerably decreased by incorporating GIS into urban planning procedures. Adekunle (2020) conducted research in Ibadan using GIS to evaluate filling stations' adherence to safety and environmental regulations. Unauthorized stations and those without adequate safety precautions were among the problems brought to light by the research. These stations were identified with the use of GIS tools, which also suggested appropriate steps to guarantee compliance. The study showed how GIS may improve both regulatory compliance and urban safety. Ayodele (2011) did similar research in Kaduna North Local government, with the goal of determining the capability of GIS-based technology for identifying filling stations. His research shows that 69.5% of the filling stations in Kaduna did not obey the planning requirements using GIS; however, the research did not clarify the technique use or which of the standards were not fulfilled. According to Mshelia *et al.*, (2015), most petrol stations in Maiduguri have not followed the guidelines for siting petrol stations, posing a serious threat to residents living near them, despite the fact that some of these petrol stations were built much earlier than the residential houses nearby. The majority (98%) of the petrol stations in Kano metropolis, as found by Mohammed, Musa, and Jeb (2014), met the requirement of being at least 400 meters away from healthcare facilities. Just a few stations (2%) were unable to meet the requirements. Yau *et al.*, (2022) uses GIS tools to analyze the spatial distribution of health care facilities in Dass Local Government Area, Bauchi State, revealing a dispersed pattern likely due to the limited number of facilities, and recommends closer placement to improve utilization.

This study is prompted by the fact that there are many filling stations in Bauchi Metropolis that may not be located according to standards, some of the stations seem to be located within residential areas. Some of the consequences of the improper location of the petroleum filling stations include traffic congestion, fire risk, and inconveniences (El Faleet, 2017). According to DPR 15 filling stations in Bauchi metropolis had been sanctioned for refusing to adhere to safety rules in 2020 (DPR, 2020). In addition, there was a fire incident at NNPC Mega filling station along Jos Road in Bauchi metropolis (The Eagle online, 2013). This necessitates the study to be carried out to know the level of compliance by the filling stations in the study area.

MATERIALS AND METHODS

Study Area

Bauchi has a tropical savanna climate, type "Aw," according to Koppen's Climatic classification scheme. The study area experiences two main seasons: wet season and dry season. (UBRDA) 1987-1994 Yearbook). The wet season is from April to October, with humidity ranging from around 37% to 68%. Bauchi gets about 85.87 millimetres (3.38 inches) of rain per year. The rainfall often begins in May, whereas its ends in October. Bauchi Metropolis receives a mean annual rainfall of up to 1091.4 mm. Its wettest Month is August while the hottest month is normally April, while the coldest months are December and January. The temperature generally fluctuates throughout the year from 13.89°C to 37.78°C and is rarely below 10.56°C or above 39.45°C (Britannica, 2020). Throughout the year, radiation is consistent (Cointreau, 1996).

The population of Bauchi was put at 493,810 in 2006 based on the census figures of 2006 with a growth

rate of 3.0% per annum. It is projected to increase to 730,839 people in 2022. The population of the town of Bauchi includes many ethnic groups, the main ones being *Gerawa, Sayawa, Jarawa, Bolawa, Fulani* and *Hausa* (United Nations High Commission on Refugee Statistical Yearbook, 2006).

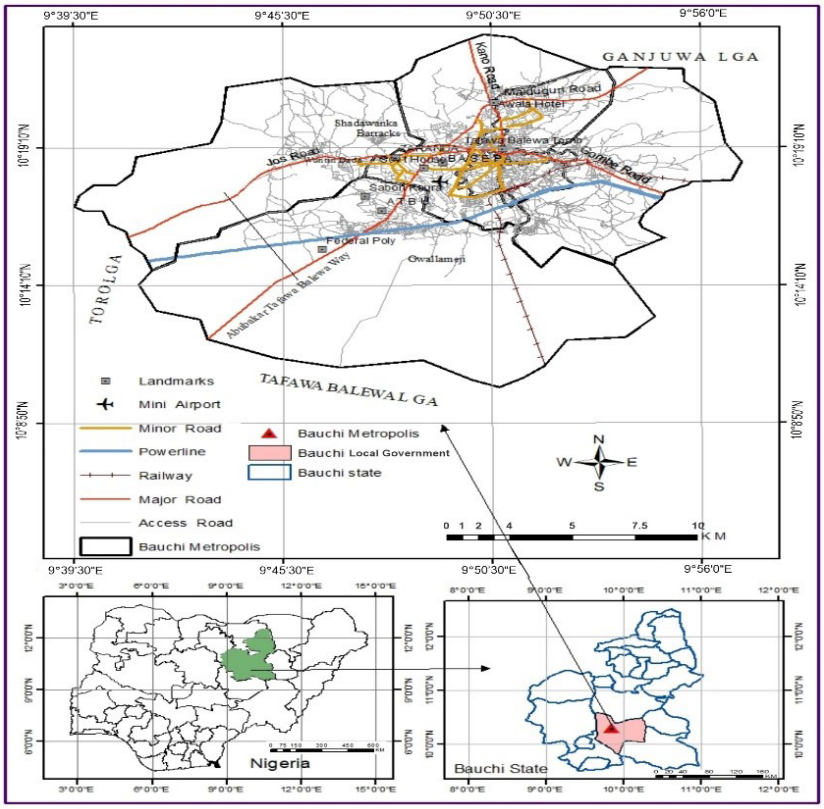

Figure 1: Map of Bauchi Metropolis
Source: Adapted from the Administration Map of Bauchi, 2023

Types and Sources of Data

The types and sources of data required for this study are indicated in Table 1.

Table 1: Types and Sources of Data

S/N	Type of Data	Sources	Purpose
1.	Base Map of Bauchi Metropolis	Bauchi State Development Board	This was used to overlay the Coordinates of the Petrol Service Stations.
2.	Inventory of Petroleum Filling Stations	Department of Petroleum Resources, Bauchi Field office.	This was used to get the total number of filling stations for the extraction of coordinates.
3.	Coordinates of the petroleum stations	Fieldwork using Hand-Held GPS Receiver (GARMIN 78SC)	The Coordinates were Overlaid on the Base Map of Bauchi Metropolis.
4.	Coordinates public places (schools, hospitals, places of worship and commercial areas).	Fieldwork using Hand-Held GPS Receiver (GARMIN 78SC) and GRID3 portal.	It was used to determine the level of compliance and to obtain spatial patterns of the filling stations in the study area.
5.	DPR/BSUDB Guidelines	DPR portal and BSUDB office	It was used to assess the level of compliance by the filling stations.
6.	Open Street Map of Bauchi Metropolis	Open street map website	The street map was used together with Base map obtained from BSDB for overlay and to create buffer to observe compliance.

Source: Author's Compilation, 2023

Garmin GPS Data Accuracy

Accuracy and precision are terms that are frequently used to describe how a competent GPS receiver acquires its position. Accuracy is the degree to which an estimate is near to its genuine value. GPS satellites transmit their signals in orbit with some precision, but what you receive is determined by other factors such as satellite geometry, signal blockage, atmospheric conditions, and receiver design features/quality. Garmin Handheld GPS has a maximum accuracy of 3 meters and a spatial accuracy of 95%, which is acceptable. In terms of accuracy and dependability, Garmin GPS is at the top of its field. Positional errors can be more than ten times greater under forest canopy than when operating in the open sky (Sigrist *et al.*, 1990). Garmin GPS has a barometric altimeter, which detects changes in pressure to determine the user's precise height. The altimeter also allows the user to track barometric pressure over time, which can aid in the observation of changing weather conditions.

It also offers the best visual and aural directions, as well as a variety of useful navigational features. Furthermore, it has a powerful quad-helix antenna and connects to more satellite networks with greater precision than most other versions. Garmin includes a 3-axis, tilt-compensated electronic compass that displays the user's heading even when standing stationary, regardless of how it is positioned. The government and other relevant agencies should work together to have a comprehensive dataset of the locations of all public facilities in the study area.

METHODOLOGY

The determination of the level of compliance was achieved by querying the database created to observe which petroleum filling stations violate the set standards, it was achieved by using buffer and near analyses in ArcGIS 10.8 environment to measure the distance between the stations and from the other public places to observe the stations which meet or violated the DPR standards of 400m apart from other stations and 100m away from any other public places. The near analysis was employed also to see the exert distances in meters between the petrol stations and the places of interests. A different symbology was used for all the different data types which are filling stations, schools, places of worship, commercial areas, and hospitals.

RESULTS AND DISCUSSION

Identification and Mapping of the Filling Station

A total of one hundred and ten (110) filling stations were identified during the field survey and data collection. They are mainly located along ten (10) major and minor roads within the study area as shown in Table 2. The results in Table 2 show the locational pattern of the filling stations. As observed, most of the filling stations are located along major and minor roads, this is hardly unexpected given that the major roads are more efficient for traffic flow and can carry more vehicles, being the longest and connecting Bauchi to Nigeria's main cities. The result is consistent with those of Samuel, Ogoro, and Amanoritsewo (2015), in their study in Obio Akpor Local government in Rivers state Nigeria, revealed that filling stations are largely clustered along major routes. In addition, Dogara (2017) also observed that filling stations in Kaduna Metropolis, Kaduna state Nigeria are located on exit routes rather than city centers. Nnamdi Azikwe Expressway alone has 83 (37%) filling stations out of the two hundred and twenty-seven (227) stations in the study area followed by Sabon Tasha/Kachia road 32 (14%) and Zaria/Kaduna Expressway with 7% stations. The spatial location of the filling stations in the study area is shown in Figure 2.

Table 2: Location of Filling Stations in the Study Area

S/N (%)	Road Name	Road Type	Number of Stations	Percentage
1	Jos Road	Major Road	26	23.6
2	Maiduguri Road	Major Road	26	23.6
3	Abubakar Tafawa Balewa Way	Major Road	15	13.7
4	Gombe Road	Major Road	14	12.7
5	Muda Lawan Road	Minor Road	12	10.9
6	Kano Road	Major Road	7	6.4
7	Muda Lawan Road	Minor Road	5	4.6
8	Ahmadu Bello Way	Major Road	2	1.8
9	Ran Road	Minor Road	2	1.8
10	Yandoka Road	Minor Road	1	0.9
	Total		**110**	**100**

Source: Field Survey (2023)

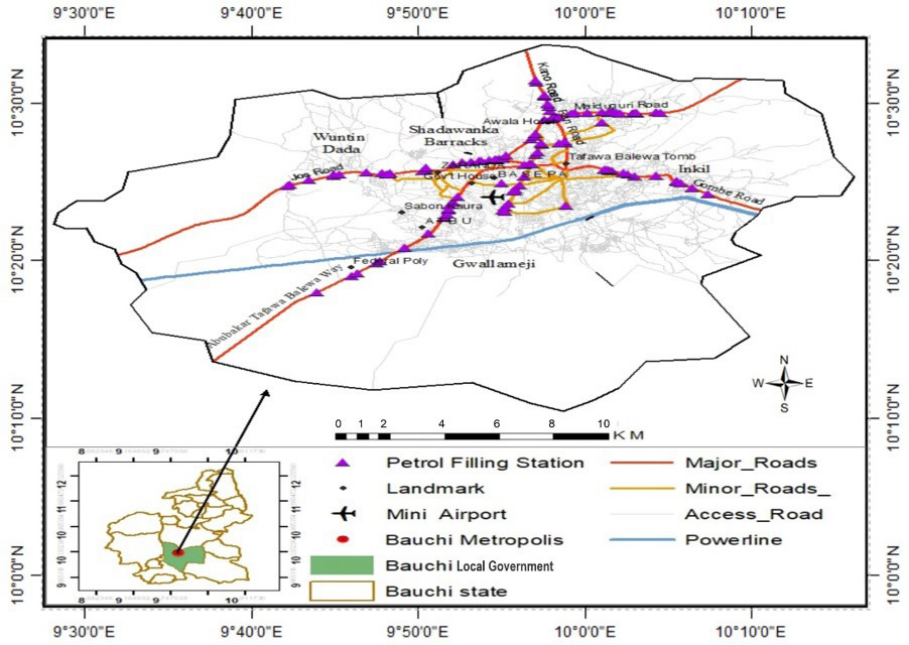

Figure 2: Spatial Location of Filling Stations in Bauchi Metropolis
Source: Author's Analysis (2023)

Compliance with 15m Distance from Road

The distance from the road to the filling station pump shall not be less than 15 meters, according to DPR (2007) guidelines for granting permission to construct and operate a fuel products retail outlet. The distances of the filling stations from the roads were calculated using the proximity analysis (Near) under analysis tools in the ArcMap environment. Only 33.63% failed to fulfill the criterion of a 15-meter minimum distance from the road, according to the findings (Figure 3). These stations include stations on minor roads (such as Murtala Muhammad Road and New Road) as well as a handful on major highways (Kano Road and Maiduguri Roads). This result agrees with that of Oloko-oba *et al.*, (2016) in their study in Ilorin Kwara state, who found that 71.6% of the filling stations met the criterion of being less than 15 meters from the road's edge, while 28.4% do not.

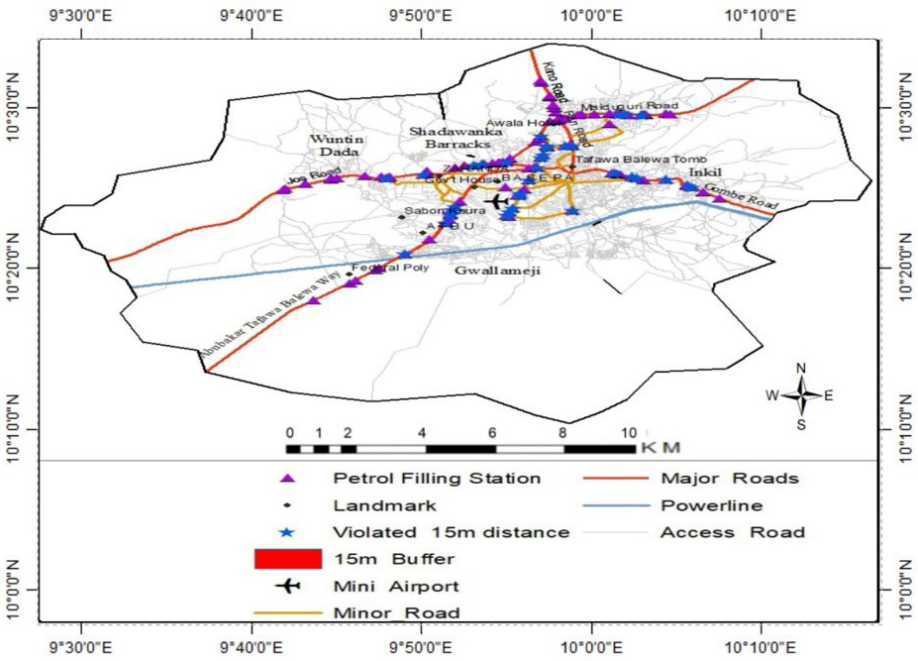

Figure 3: Filling Stations that Violated 15m from Road's Edge
Source: Field Survey (2023)

Compliance to 400m Distance between Filling Stations

According to DPR's (2007) physical planning standards, the distance between any two filling stations, including the one under consideration, should not be less than 400m. The longest distance between two filling stations was discovered to be 2,231 meters, which was discovered between Sarinawa Petroleum and another filling station under construction on Railway Road, both on Murtala Muhammad Way. Aside from the two indicated, the average distance between filling stations was around 244.94 meters. Along Abubakar Tafawa Balewa Way, the shortest distance was 46 meters between Launi Petroleum and AKY Makama Petroleum (see Palate I). The distance between two AIB-owned stations and Company Nig Ltd is 53.86 meters, while the distance between A. A Kunya Petroleum and Matrix Petroleum Nigeria Ltd along Gombe Road is 55.72 meters.

The study observed that majority of the filling stations are not within 400 meters of their neighbours. However, only 11.81% meet the required distance of 400 meters from their nearest neighbours, while 88.18% failed to achieve the minimum distance of 400 meters. The findings are consistent with those of Oloko-oba *et al.*, (2016) in their study in Ilorin, Kwara State, who found out that 97.3% of filling stations do not meet the 400-meter distance requirement from the nearest station, while just 2.7% meet the distance requirement. Figure 4 shows the filling stations that violated 400m distance from their nearest neighbours.

Figure 4: Launi and AKY Makama Petroleum along Abubakar Tafawa Balewa Way

The filling stations that did not meet this criterion are located along almost every road. The highest number of stations failing to fulfill the minimal distance between filling station locations of 400 meters are found on the Jos and Maiduguri roads, which connect Bauchi to other major Nigerian towns. The probable reason behind this situation is the high demand for petroleum products in these areas. Additionally, regulatory authorities may be inclined to grant leniency to filling stations in busy locations regarding adherence to certain criteria.

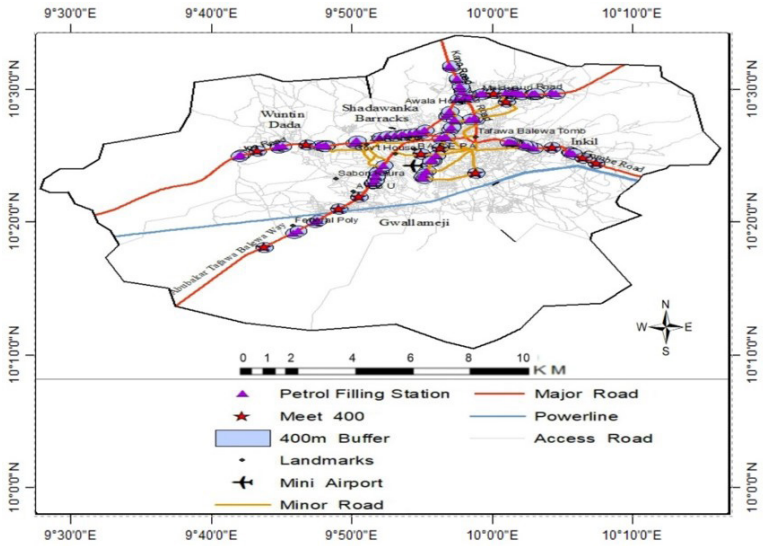

Figure 5: Filling Stations that Violated 400m Distance between them
Source: Field Survey (2023)

Compliance with a Total Number of Petrol Stations within 2 Km Radius

The study also revealed that only four stations (3.63%) obeyed this criterion of having not more than four filling stations within a 2km radius of any filling station as stated in the DPR (2007) guidelines. These stations are Bushirika Petroleum, Hakson Petroleum, and Basfrost Petroleum located along Abubakar Tafawa Balewa Way, and another new filling station located at the end of Murtala Muhammad Way. This result is similar to the findings of Oloko-oba *et al.*, (2016), who found that only 1.3% of the population met the minimum of four petrol stations along a two-kilometer stretch on both sides of the road, while 98.7% of the population violates the standards because there are more than four filling stations every two kilometers along the roads. Figure 5 shows stations that are not more than four within a 2km radius. Similarly, Yunus (2019) also observed that 90% of the stations in Dutse metropolis, Nigeria contradict the standard of 4 stations within 2 Km distance.

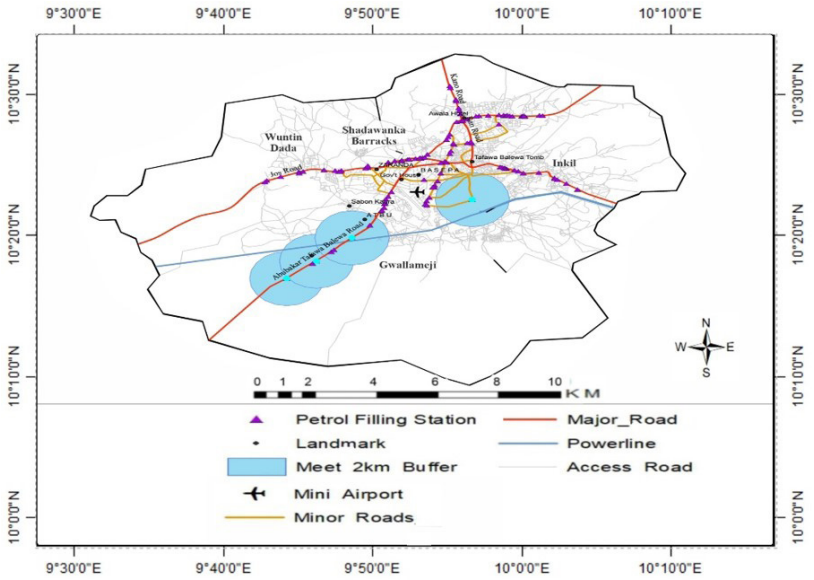

Figure 6: Filling Stations that are not more than four within 2 KM
Source: Field Survey (2023)

Compliance with 100m Distance from Filling Stations to Markets

It is recommended that every market be at least 100 meters away from the nearest filling station. Table 3 below shows the distances between the marketplaces and the nearest filling stations.

Table 3: Distance of Filling Stations to Nearest Markets

ID	Market	Nearest filling Station	Distance (m)
1	Kasuwan Bayara	Alkabir Petroleum	3,996
2	Kasuwan Dan Dango	Hakson Petroleum	6,735
3	Kasuwan Gwallameji	Lawsat	608
4	Kasuwan Yelwan Tudu	AYM Tafawa Balewa Road	235
5	Kasuwan Gudum	BA Bello	2,719
6	Zango Market	Alkabir Global	1,192
7	Wunti Market	Total Yandoka Road	209
8	Kids Pawan Market	AIB Ran Road	241
9	Bakin Kasuwan Shanu	Himma Gombe Road	558
10	Kasuwan Tirwun	NNPC Maiduguri Road	246

Source: Field Survey (2023)

As shown in Table 3, the furthest distance between a filling station and a market is between Kasuwan Dan Dango and Hakson Petroleum (6735.839 m), while the shortest distance is from Wunti Market to Total Yandoka Road (209.9502m), indicating complete compliance with the DPR's (2007) standard of a minimum of 100m from any filling station to the nearest market. Previous studies like Emakoji (2019), Oloko-oba *et al.*, (2016), and Mohammed, Musa, and Jeb (2014) did not compare the locations of filling stations with markets because of a lack of data on the markets.

Compliance with 100m distance from Filling Stations to Worship Places

The worship places comprise Mosques and churches within the study area. Only 7.27% of the 110 filling stations failed to comply with the requirement of being 100 meters away from places of worship, while the remaining 92.73% do fulfill the requirement. The eight stations are; OandO, NNPC Soroman, and Arms along Maiduguri Road; Gyangyan Petroleum Gombe Road; OandO Ahmadu Bello Way; AYM Muda Road and Pinnacle located along Kano Road.

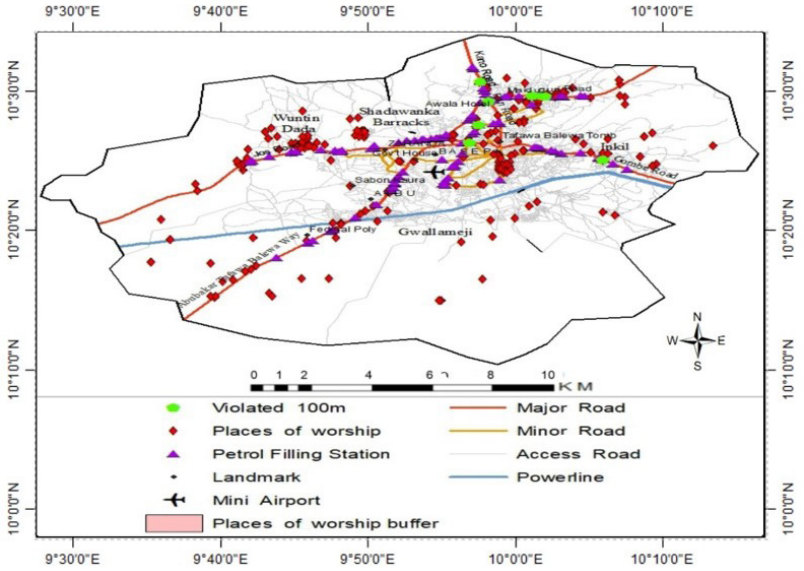

Figure 7: Stations that Violated the Minimum of 100m Distance from Places of Worship
Source: Field Survey (2023)

Avoid extensive citations and discussion of published literature only; instead discuss recent literature for comparing your work to highlight the novelty of the work in view of recent development and challenges in the field.

CONCLUSION

The filling stations in Bauchi metropolitan are not evenly distributed; rather, they are clustered along major roads (highways), particularly those leading to Jos, Kano, Gombe, and Maiduguri. There is a substantial correlation between the number of filling stations and the road rank. Filling station marketers are constructing highways connecting Bauchi Metropolis to major Nigerian cities such as Kano, Jos, and Maiduguri, among others. Even though main roads have the most filling stations (81.82%), secondary roads have a higher density per kilometer.

Major roadways have more than the DPR minimum of four stations per two kilometers. Independent marketers control the petroleum retail business (filling stations), which is beneficial to the economy. In addition, independent marketers were established with the purpose of economic diversification by allowing Nigerians to participate in the downstream petroleum industry and eliminating the dominance of foreign corporations in the industry. Although most filling stations comply with the standard concerning the distance from the road and public spaces, notably hospitals, many petrol stations failed to meet the 400-meter minimum distance required from other stations.

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