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SPATIAL DISTRIBUTION PATTERNS OF URBAN ENERGY INSTALLATIONS IN PORT HARCOURT METROPOLIS, NIGERIA

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Abstract

In the location of private and public energy installations in urban areas, the major factors that stakeholders and policymakers consider are accessibility to transportation and telecommunication networks, raw materials, market, security of earnings, attitude of government, community and ultimately profit generation with little or no recourse for the safety implication for lives, properties and the environment. The study examined the spatial distribution pattern of an energy installation, Liquefied Petroleum Gas stations in Port Harcourt metropolis, using a cross-sectional design for 79 licensed stations. The dataset was subjected to cartographic analysis within the ArcGIS environment to examine the spatial distribution of Gas stations. Weighted standard distance was computed to measure the compactness or degree of concentration around the geometric mean Centre. Weighted and Standard Deviational Ellipses (SDE) were also computed to represent the directional distribution of Liquefied Petroleum Gas stations to measure the directional trend. The study found that the metropolis has a clustered pattern tending towards the developing North-West and North-East end in Obio-Akpor and Ikwerre axis, while being randomly placed in the Port Harcourt, Eleme, and Oyigbo ends. The paper therefore recommends that hazardous energy installations should not be located close to individuals, households, and communities, but be relocated to areas with less population, considering safe distances and buffer zones in the design and scoping stages of hazardous facilities installation by planners. The paper further recommends that continuous research should be carried out by the government through the regulatory agency, research bodies, and academia on ways of reducing the impact of hazardous energy installations on the population and environment to foster sustainable development.

Keywords: Spatial distribution, Hazardous Energy Installation, Energy infrastructure, Urban planning, and Risk Assessment.

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1.0 Introduction

Urban growth is a complex process that is a result of a combination of manifold factors which include geographical location, natural population growth, rural-to-urban migration, infrastructural development, national policies, corporate strategies, and other major political, social and economic forces, including globalization (Ogoro, Eze, & Dollah, 2020). The process of urbanization is described as the movement of population from rural areas to urban areas with a proportional gradual increase in of urban dwellers (Haralanova & Menabde, 2005; Davis, 2006). Globally, it is estimated that by 2030, 60% of the population will live in urban areas and cities as the urban population have increased from 13% in 1900 to 29% in 1950 and 49% in 2005 (UN, 2015). Of this projected growth, Latin America, Asia and Africa account for almost all of the growth with Asia and Africa particularly urbanizing faster and projected to become 56% and 64% urban respectively by 2050. India, China and Nigeria are expected to account for 37% of the projected growth of the world's population between 2014 and 2050 (Aliyu & Amadu, 2017; Mohammed, (2014). In Nigeria, 43.3% of the country's population lived in urban centers in the year 2000, with an expected increase to 58.3% in the year 2020 (Aliyu & Amadu, 2017). This implies that at present, more than half of the Nigerian population lives in urban centers. However, the process of urbanization is not devoid of problems. One of such problem is hazardous distribution of energy installations resulting in frequent explosions of energy installations resulting in loss of lives thereby increasing urban insecurity and vulnerability. With the demand for energy growing very fast with cities responsible for the 67% of the world energy demand and over 60% urban dwellers, it has become necessary to examine the urban distribution and location patterns of energy installations, especially in urban areas (IEA, 2015; Aliyu & Amadu, 2017).

In locating private and public installations, the common objective of policy-makers is either to maximize utility or to minimize costs. However, public and private decision-makers differ in their definition of utility and cost. Since the major goal of shareholders or owners of private facilities is to maximize their profits, private locational decisions are necessarily profit-oriented. For all private enterprises, the ultimate basis of choice of location is the rate of earnings (wages, profits, or interests) obtainable at different locations, the regularity, security of earnings and access to installation by population (Omole, 2001, Smieszek, 2019). Bello Pintado and Contín-Pilart, (2010) found that the influential factors in location decision in biofuel installations were the availability, quality and reliability of transport modes, telecommunications' quality, production system capability, marketplace location, the number of nearby competitors and population density. A study by Hilmola, Saranen and Padilha, (2010) concluded that the influential factors in biofuel plant location were raw material availability, oil price, product price and transport costs. Espejo, Ortega-Blu, Muñoz-Lagos, González-Platteau, & Biocombustibles, (2019) found that factors responsible for biofuel plant location in Colombia were security and criminality, local government attitude towards a project, quality and reliability of utilities, quality of transport infrastructure, community attitude towards a project and the region's social impact and agricultural capacity. Also, according to Smieszek, (2019), the spatial distribution of solar radiation stations is determined by numerous elements such as terrain, atmosphere, air pollutants, water and aerosol in the atmosphere, and cloud cover. He further opined that the key problem is the real solar radiation incident on a regional scale, i.e. urban area. In that case, the major factors modifying the distribution of the radiation are the cloud cover, terrain, air pollutants and also important is the local shadowing effect of the terrain. Kavumah, Sandoval and Dieu, (2022) in the analysis of power generating plants and substations for increased Uganda's electricity grid access found that most large power plants are located far from load centres such as cities or urban areas while stating that road network was an important factor in substation

distribution. The research further opined that almost all the Ugandan medium voltage network lines follow the roads; to allow access to the network and the substations during installation and incase of maintenance or repair as materials are heavy hence the installation is best suited where vehicles can access and takes lesser time in acquiring way leaves. Also, according to Levin and Thomas, (2012) Uganda is less suited for decentralized electrification due to higher population density. Power is a major infrastructure required as a key demand in urban areas for businesses e.g., shops, hotels, factories, offices etc. In a similar work in DR Congo irregular distribution of electrical cabins was observed and electricity was opined to be a factor for rapid urban growth (Banza, Flory, & Bouillard, 2016). Mahmood, Shaban, and Numan, (2015) in their work Optimal Spatial Distribution of Gasoline Stations in Baghdad Province Utilizing GIS Techniques found that the distribution pattern was random for gasoline. According to a study by Ogunyemi et al, (2017); analysis for the spatial pattern of petrol service stations in Sango Ota metropolis revealed three major spatial distributions. The spatial pattern from Iju to Iyana and Iyana to Ojuore showed dispersed pattern, Abeokuta highway showed random pattern, while Sango Ota showed clustered pattern. (Ogundahunsi, 2014) in his study of the locational pattern of fuel stations in Ilesa, Osun state, revealed that the distribution of pattern of the fuel stations was tending towards clustering which is not an ideal situation for such a facility in view of the safety implications. In a study carried out by Oloko-oba, et al., (2016) in Ilorin, Kwara state, the result reveals that the spatial pattern of distribution of filling stations in the study area shows a clustered pattern. Olapeju, (2017) in his study of petrol stations in Ilaro Ogun state revealed that the locational pattern of petrol filling station tends towards clustering. Ayodele, (2011) examined the spatial distribution of filling stations in Kaduna North study identified the pattern and distribution problem in the area. Similarly, a study was carried out in Agege Local government Area of Lagos State by Abdullahi, (2002), the study observed that filling stations were randomly distributed in the area. The study observed due to land shortage people build station wherever the land is available. In his work Spatial Analysis of the Locational Pattern of Filling Stations in Oyo West Local Government Area Adedeji, (2018) revealed that the locational pattern of filling stations exhibits a cluster pattern with factors such as influence cheap land value, proximity to market, and profitable location influencing the location of filling stations in Oyo West local government with profitable location 51 (54.8%) of the filling stations being the most important factor. The temporal distribution of filling stations in the LGA also revealed that the number of filling stations in the LGA is growing tremendously over time with an increasing trend of growth of filling stations witnessed from 2010 till date. The analysis of the spatial distribution of filling stations in the Obio/Akpor Local Government Area of Rivers State by Samuel, Ogoro, and Amanoritsewo (2015) revealed that of the 153 petrol filling stations in the region 118 (77%) did not conform to the 400m required distance from one another only 35 (23%) conformed while on the conformity of petrol filling stations' to the required 15m distance from the road the study revealed that 103 (67%) petrol filling stations did not with only 50 (33%) petrol filling stations conforming. The study further reveals clustering of petrol stations along roads. According to studies by Olapeju, (2017) and Ulakpa, Ulakpa, Eyankware and Egwunyenga, (2022) Petroleum Filling Stations have been found to be abundant near roadways and residential buildings and that the locational pattern of nearby petrol filling stations has a propensity to cluster in a specific zone. The study recommended that petrol stations be closed or restricted in and around the town's-built road flight path and strictly designated residential zones. Alimah and Mellawati, (2018) opined that at the screening stage before any LPG station is located, if the source of the hazardous fluid falls within a distance of more than 5 km from residential buildings then it is not necessary to analyze. This is because if there is release of the hazardous fluid at a distance of more than 5 km, the air will reduce and disperse the gas to a tolerable level before reaching the site. Also,

Douti, Abanyie, Ampofo, and Amuah, (2019) in the research spatial distribution and operations of petrol stations in the Kassena-Nankana district (Ghana) found that the distribution pattern was haphazard with stations located close to residential buildings, public places, roads and other petrol stations. In a similar study carried out in Port Harcourt City Local Government Area, Orupabo and York, (2018) observed thatthere was a total of 53 petrol stations within the study area sited close to each other, along minor and major roads and were located in the midst of residential houses or sharing walls with residential buildings. In locating petrol stations Odeh, (2017) opined that it is important to take some precautionary measures like locating them at a required distance from buildings; places of public assembly such as markets, hospitals and schools and areas of high traffic congestions and residential buildings. This should be in accordance with the guidelines provided by the Department of Petroleum Resources DPR, (2007). In another work by Muhammad and Wali, (2020) it was observed that the spatial distribution of the seventy-three filling stations in Bauchi Town is clustered along the out bound roads. For more than half of them, the requirement for a minimum distance of 400 m between neighboring stations was violated. Odeh, (2017) in his work Spatial analysis of the petrol stations in Khan-Younis city using geographic information system (GIS) techniques found that petrol stations were located close to public places like schools, hospitals and wedding halls, the horizontal distance between the station boundaries and the electricity high tension lines was less than 10 m, petrol stations were less than 10ms from open flames like welding shops.

Nowadays, the demand for energy is growing very fast, but at the same time global energy resources are running out. Energy demands are the biggest in cities where most people live; that is the reason why energy in cities is one of the biggest challenges for this era. The transformation of industrial areas into residential areas due to disaster risk drivers such as increasing population density and urbanization coupled with the location of many energy installations near highly populated residential areas for proximity to customers to gain competitive market advantage while ignoring the risks of the energy installations leading to disasters and increasing the severity of impact is now the norm in most cities globally. As the global population grows more and more people are settling in urban areas worldwide.

In Africa, urbanization recently has gained additional momentum due to climate change and armed riot in rural areas. Africa in particular displays the highest urban growth rates in the whole world, growing by 3.4% each year. The (UN) forecasted that African's population will double over the next 40 years and attain a total population of 2 billion persons in 2050. This figure is expected to be centred within the urban areas resulting to a projection of 720 million cities dwellers during this period (Ogoro, Eze, & Dollah, 2020). This situation is expected to be more pronounced in Nigeria as the most populated nation in Africa with a land area of 923,000 sq km and 193,392,517 million people as at 2016 (NPC, 2007). The land use and vegetation map of the study area drawn from satellite imagery in 1976 shows that the total anthropogenic altered/built-up area/space of the city and its environment was only 16.25 Km2 by 1995, an updated edition of same map showed that the anthropogenic/built-up area of the region had increased to 282.25 Km2, indicating that the size of the city has increased by seventeen times in two decades (Oyegun& Adeyemo , 1999, Ogoro, Eze, & Dollah, 2020). The demand of land from the expansion of urban centres or cities is growing higher than the available suitable land, leading to haphazard urban sprawl and deliberately locating settlements near highly hazardous chemical plants. When disasters strike in densely populated urban areas the economic and social impact is very high. According to Perrow, (2008) increased population density and urbanization increases the vulnerability to disasters. Generally, many cities develop without any recourse for development planning let alone

paying attention to the location of key infrastructures like LPG stations and the risks they pose to inhabitants of the city. Locating LPG stations far from residential areas of the city and the relocation of affected settlement is the most reliable prevention measure to reduce casualties and economic losses. As cities expand with development, the residential area has more chance to be next to hazardous sites, such as LPG filling stations, which once were remote from residential areas to comply with regulations, nearness to road and market and customers. It's not simple for a regulatory agency to force the station to move away from residential or commercial area to satisfy safety criteria. Instead, they recommend reasonable measures to mitigate and reduce the corresponding risk by the use of proper safeguards (Park, 2017). Conclusively, According to Khatsu, (2005) urban hazards are potentially damaging phenomenon that threatens a city, its population and socioeconomic activities. The definition of reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of disaster risk. Nevertheless, with knowledge of the distribution of prevailing energy installations patterns, population and socioeconomic development, risks can be assessed, mapped and control measures proffered to reduce public insecurity. This research was funded by the Petroleum Technology Development Fund.

2.0 Study Area

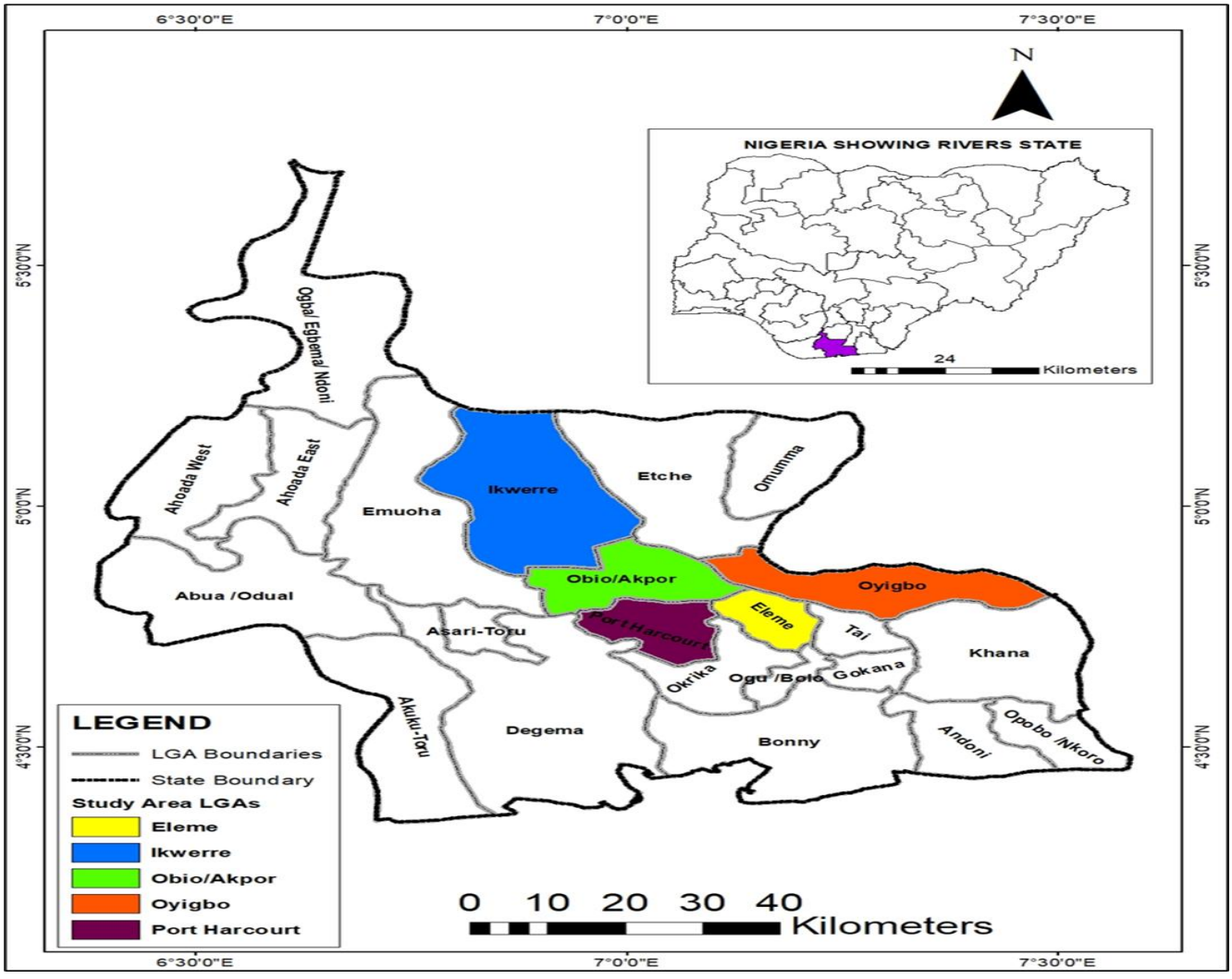


Figure 1: Rivers State indicating Study Area

Port Harcourt is positioned from Latitude 4045'N through Latitude 40 55' N, and Longitude 60 55' E through Longitude 7005' E as shown in Figure 1. The Atlantic Ocean is found at an approximate distance of 25km from it. Spatially, the study covers five local governments Areas (Obio-Akpor, Eleme, Oyigbo, Ikwerre, and Port Harcourt City Council).

Port Harcourt, one of Nigeria ‘s major cities and has been experiencing rapid urbanization since its inception in 1913. The city has grown from 5,000 persons in 1915 to 79,634 in 1953 and to 179,563 in 1963 (Ogionwo, 1979). The 1991 census gave the city ‘s population as 440,399 and in the 2006 census National Population Commission fixed it at 1,005,904. There is a considerable population growth that has led to spatial expansion, engulfing once distant communities on the urban periphery, to the extent that they can no longer be seen as distinct communities but have become part of the urban fabric extending into Local Government Areas (Wokekoro & Owei, 2006, Mmom, Florence, & Fred-Nwagwu, 2013; Ogoro et al, 2022) and as the time of the study (2023), Port Harcourt's population is 3,480,101 now estimated at with an increase of 175,586 in the last year, which represents a 3.33% annual change (World Population Review , 2023). In addition to rising urban population, there are worsening environmental problems such as poor urban planning, poor solid waste management, flooding, traffic congestion, poor state of the urban physical environment and rising crime rates have been documented (Ugwuorah, 2002; Mchi, 1997). More recently, Leadership, 2018, Vanguard, 2021; Dailypost, 2022 have noted LPG station explosions while Obinna, Owei, & Mark, (2010) noted inadequate space in the city. This state of affairs triggered the desire to examine the spatial distribution of Liquefied Petroleum Gas station hazard in Port Harcourt metropolis.

3.0 Materials and Method

The study area was limited to Port Harcourt metropolis and the design consisted of a cross-sectional observational study comprising of 79 licensed Liquefied Petroleum Gas Stations located within the metropolis. Locational and distribution information of the storage stations or facilities and possibilities of LPG leaks were obtained from the plant administrators as well as the regulatory agency. Other secondary data regarding the distribution of population were gotten from the National Bureau of Statistics (NBS) and Nigeria Population Commission (NPC) estimates. The study utilized high-resolution Google earth images to enable the delineation of the urban and its periphery extent of the study area. The Global Position System (GPS) of the Kobocollect application enabled the retrieval of the global position of all licensed Liquefied Petroleum Gas Stations to examine their locational attributes and randomness across the study area. The coordinates generated from the Kobocollect application were used to identify the location of facilities. The dataset was subjected to centrographic analysis within the ArcGIS environment to examine the spatial distribution of Gas stations. The latitude, longitude and names of Liquefied Petroleum Gas stations recorded in Microsoft Excel Worksheet 2010 version was imported to generate the spatial distribution using the centrographic and Statistical analytic features of ArcGIS 9.3. Weighted standard distance was computed to measure the compactness or degree of concentration around the geometric mean centre. Weighted and Standard Deviational Ellipses (SDE) were also computed to represents the directional distribution of Liquefied Petroleum Gasstations which served as a measure of the directional trend. The computation of these was implemented as utilized by Lawal and Obafemi, (2019).

4.0 Results and Discussion

The study represents the spatial distribution of Liquefied Petroleum Gas stations of Port Harcourt Metropolis using figures 2, 3 and 4; locational distribution, directional distribution and standard distance of Liquefied Petroleum Gas stations in Port Harcourt metropolis as

utilized by Lawal & Obafemi, (2019) and Ramadan, Khairy, Alogayell, Alkadi, & Ismail, (2022).

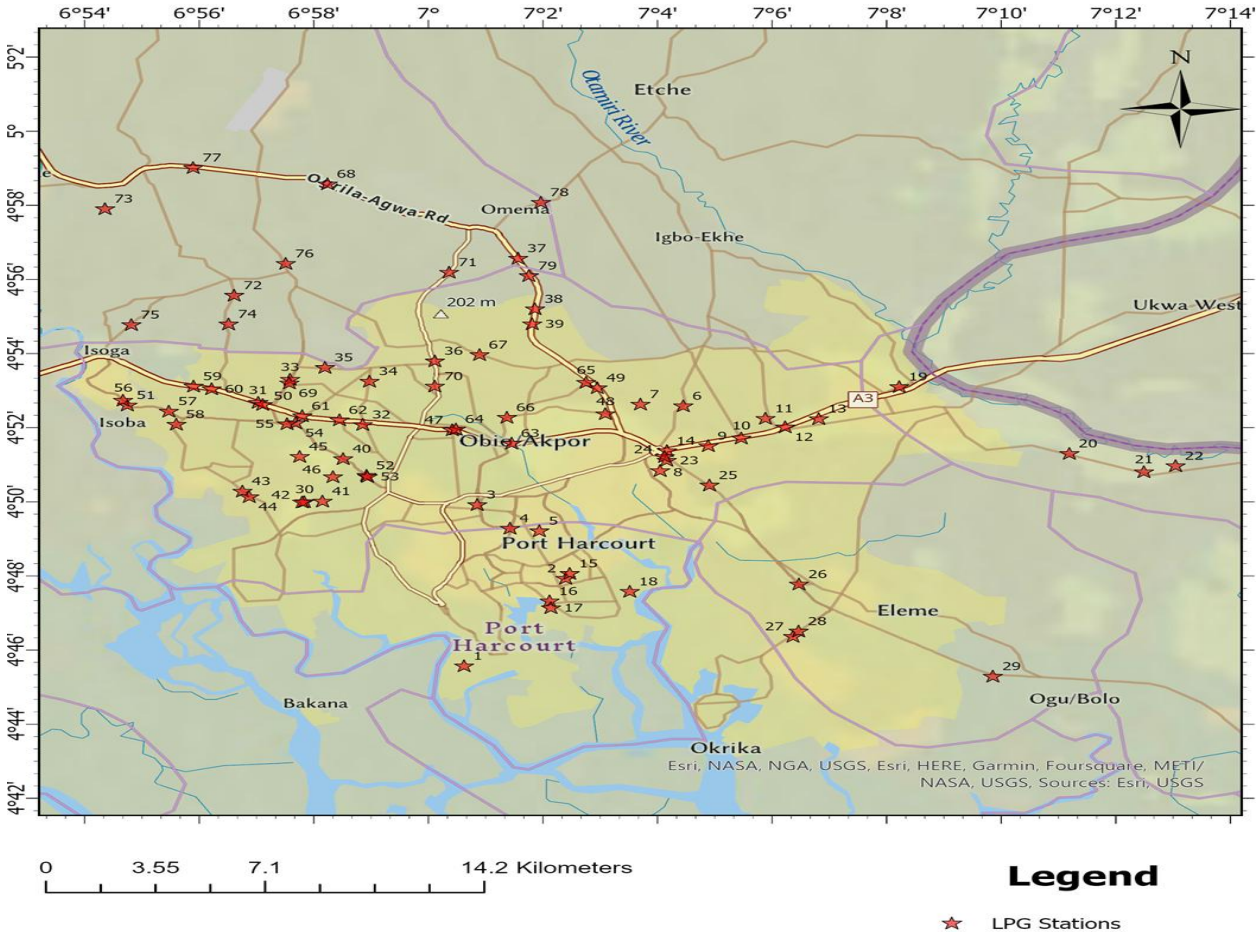


Figure 2: Spatial distribution of LPG stations in Port Harcourt Metropolis

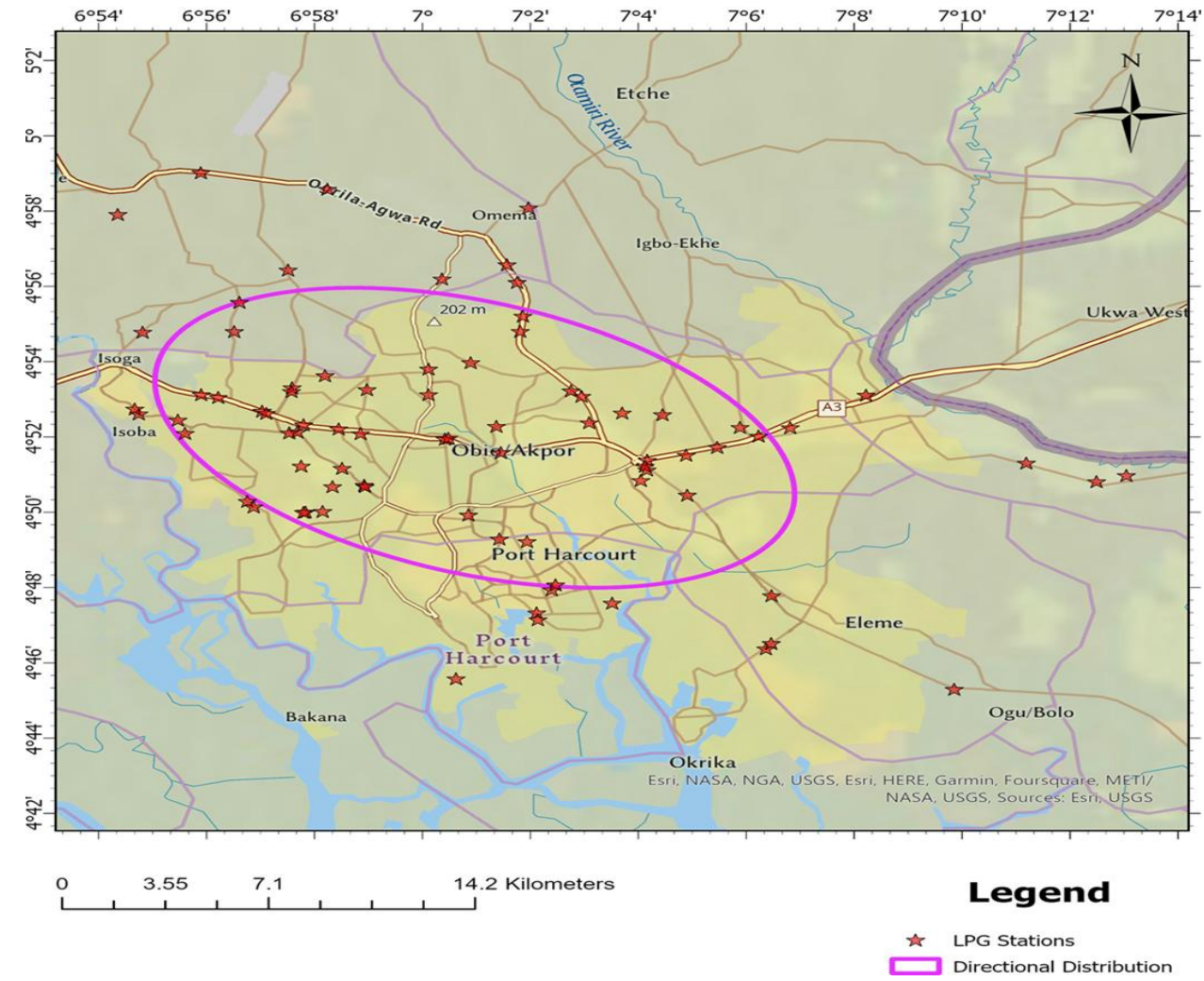


Figure 3: Directional distribution of LPG stations in Port Harcourt metropolis.

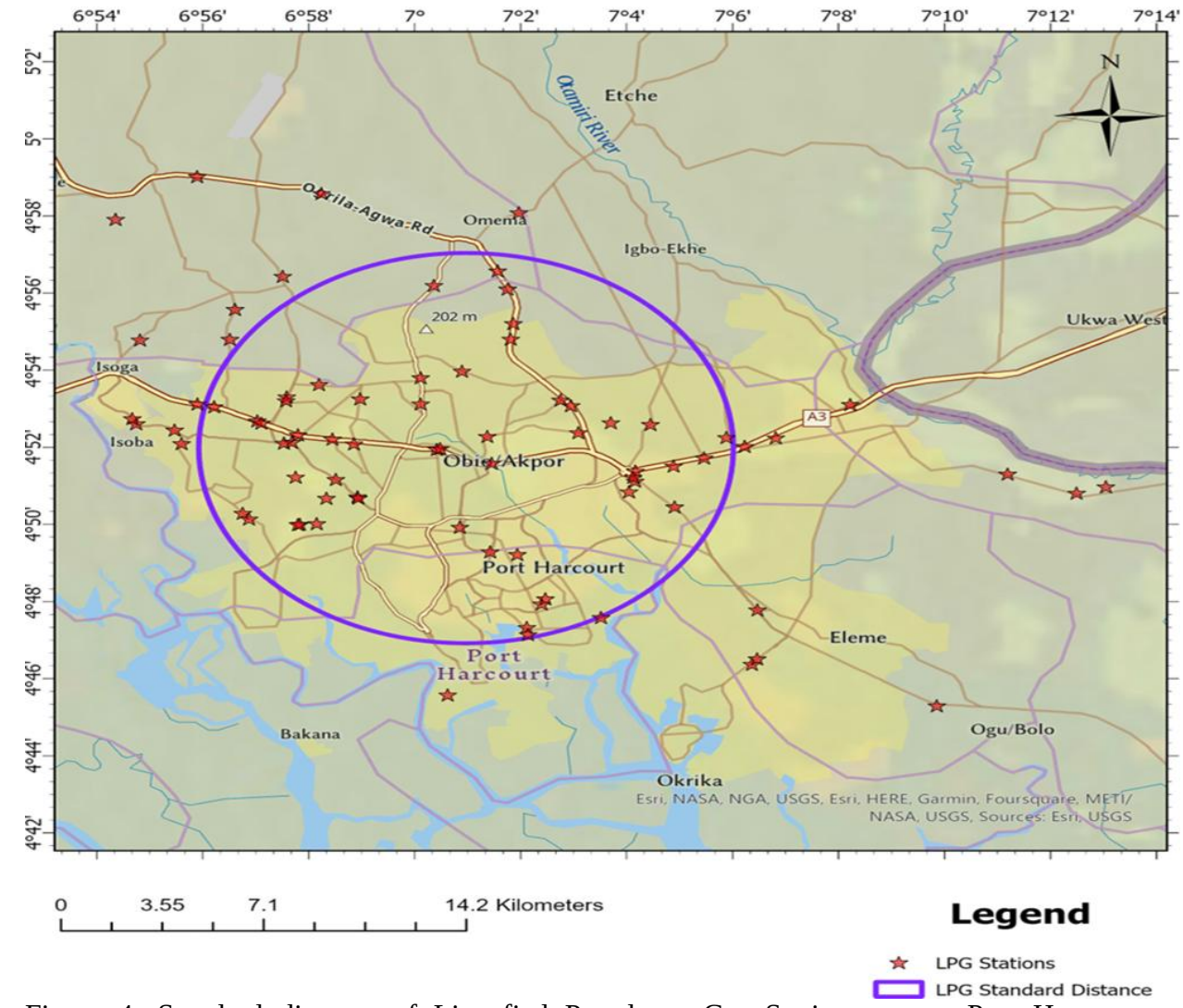


Figure 4: Standard distance of Liquefied Petroleum Gas Stations across Port Harcourt metropolis

Figure 3 reveals the directional distribution of Liquefied Petroleum Gas stations in Port Harcourt city. The figure reveals that directional distribution of points are clustered deeply towards the North-Western end almost at a North-East directional distribution. The directional distribution is towed towards the Obio/Akpor and Ikwerre end of the metropolis.

Figure 4 shows the standard distance or the compactness around the geometric mean centre of Liquefied Petroleum Gas stations in Port Harcourt city. The figure indicates that there is compactness or clustering around the geographic mean centre. It shows that the circle contains 51 Liquefied Petroleum Gas stations while 28 gas stations are outside. As the number of points (Liquefied Petroleum Gas) stations inside the circle are more than the ones outside the circle, we say that the pattern is concentrated or clustered in relation to other areas outside the circle this in line. The standard distance reveals that the clustering is concentrated in the Obio/Akpor and Ikwerre end of the metropolis.

The study reveals a concentration or clustering of Liquefied Petroleum Gas stations in the metropolis mostly around road networks (figure 2) with directional distribution of gas stations clustered deeply towards the North-Western and North-East end Figure (figure 3) (Obio/Akpor and Ikwerre) with those around Oyibo and Eleme randomly located (figure 4).

This is in line with findings of Ramadan, Khairy, Alogayell, Alkadi, & Ismail, (2022) that if the number of points (Liquefied Petroleum Gas) stations inside the circle close to the geometric mean centre are more than the ones outside the circle, we say that the distribution pattern is concentrated or clustered in relation to other areas outside the geometric mean centre while the polygon is used in reading the distributional direction in relation to whether it is tilted towards the North-West and North-Eastern developing area of the metropolis. This may be as a result of the availability and low cost of land in the Obio/Akpor-Ikwerre axis. In view of urban distribution patterns of energy installations several works corroborates the findings of this study; in the spatial analysis of the locational pattern of filling stations in Oyo West Local Government Area findings of Adedeji, (2018) revealed that the locational pattern of filling stations exhibits a cluster pattern with factors such as influence, cheap land value, proximity to market, and profitable location influencing the location of filling stations in Oyo West local government, Ogunyemi et al, (2017); analyzed the spatial pattern of petrol service stations in Sango Ota metropolis revealing three spatial pattern; from Iju to Iyana and Iyana to Ojuore showed dispersed pattern, Abeokuta highway showed random pattern, while Sango Ota showed clustered pattern while a similar work by Ogundahunsi, (2014) in fuel stations in Ilesa, Osun state, revealed that the distribution of pattern of the fuel stations was tending towards clustering which is not an ideal situation for such a facility in view of the safety implications. Furthermore, in a study carried out by Oloko-oba, et al., (2016) in Ilorin, Kwara state, Olapeju, (2017) in Ilaro Ogun state, a clustered spatial pattern of distribution of filling stations was revealed. The studies observed that due to land shortage people build station wherever the land is available.

Furthermore, in the analysis of the spatial distribution of filling stations in the Obio/Akpor Local Government Area of Rivers State, Samuel, Ogoro, & Amanoritsewo, (2015) revealed clustering of petrol stations along roads which was in line with the findings of Olapeju, (2017) and Ulakpa, Ulakpa, Eyankware, & Egwunyenga, (2022). They emphasized that energy installations had been found to be abundantly near roadways and residential buildings and that the locational pattern of nearby energy installations towed towards a cluster in a specific zone. The study recommended that installations should be closed or restricted from the town's-built road flight path and strictly designated residential zones. Also, in the research on the distribution of petrol stations in the Kassena-Nankana district (Ghana), Douti, Abanyie, Ampofo, & Amuah, (2019) found that the distribution pattern was haphazard with stations located close to residential buildings, public places, roads and other energy stations. A similar study carried out in Port Harcourt City Local Government Area, Orupabo& York, (2018) observed that energy storage installations within the study area were close to each other, along minor and major roads and were located amidst residential houses or sharing walls with residential buildings. In the works of Muhammad & Wali, (2020) and Odeh, (2017); in Bauchi Town and Khan-Younis city installations were found to be clustered along roads and located close to public places like schools, hospitals and wedding halls.

In the findings of Dalil, Abbas, Yaya, & Adewale, (2016), base trans-receiver stations are sited within residential, commercial, industrial and transit routes with telecommunication masts indiscriminately located within residential areas in Abuja without recourse to human safety. This resulted in the provision of infrastructure and the proliferation of base stations with 80 clustering Maitama, Garki, Wuse, Asokoro and the Central Business districts with Maitama district most clustered and Garki district least clustered while revealing a dispersed pattern of distribution of single antenna masts and multiple antenna masts of the identified Telecom operators (MTN, GLO, Aitrtel, 9mobile). The clustering of hazardous chemicals in a specific area increases the exposure levels of the population and severity of impact of an incident in line with findings of Laminu, Umar, & Oyedeji, (2023) that prolonged exposure

to hazardous substances results in risks of death, burns, injuries, asphyxiation, sleeping disorders, memory loss, cancer to exposed population while Sengupta, (2016) emphasizes that narcotics are organic compounds which depress the central nervous system on severe exposure leading loss of consciousness, paralysis of the respiratory system and possibly deaths as asphyxiants could cause injuries when inhaled if it is present in high concentration by displacing oxygen needed to maintain consciousness and life. Also, with the tendency of Liquefied Petroleum Gas evaporating, forming a vapor cloud that may result in a cascade or domino effect, the clustering of gas stations would increase the extent of area, population at risk and severity of impact according to Gautam & Saxena, (2001) while the proximity of stations to major roads may increase accessibility during emergency for evacuation but in the event of an explosion affect commuters and vehicles who ply such routes thereby increasing their vulnerability. Finally, in locating Energy installations Odeh, (2017) recommends that, it is important to take some precautionary measures like locating stations in required distance from buildings; places of public assembly such as markets, hospitals and schools and areas of high traffic congestions and residential buildings in accordance with specified guidelines.

5.0 Conclusion

The study concludes that the metropolis has a clustered spatial distribution pattern tending towards the developing North-West and North-East end in Obio-Akpor and Ikwerre axis while being randomly placed in the Port Harcourt, Eleme and Oyigbo ends. This may be due to availability to land, nearness to markets or the installations are tending towards the developing areas of the metropolis.

6.0 Recommendations

The study therefore recommends that hazardous energy installations should not be located close to individuals, households, communities but be relocated to areas with less population considering safe distances and buffer zones in the design and scoping stages of hazardous facilities installation by planners while continuous research should be carried out by government through the regulatory agency, research bodies and academia on ways of reducing the impact of hazardous energy installations on population and environment to foster sustainable development.

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