A GIS Approach in Assessing the Spatial Distribution of Petrol Stations in Umuahia North Local Government Area, Abia State

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ABSTRACT

The rapid expansion of urban areas and increasing vehicular population in Nigeria have necessitated the proliferation of petrol stations. However, inappropriate siting poses serious challenges to safety, environmental sustainability, and urban planning. This study leverages Geographic Information System (GIS) techniques to examine the spatial distribution and regulatory compliance of petrol stations in Umuahia North Local Government Area, Abia State. Data were sourced through field surveys using handheld GPS, satellite imagery, and existing geospatial datasets from OpenStreetMap and the Office of the Surveyor General of the Federation (OSGOF). ArcGIS software was used to perform spatial and proximity analyses using official standards set by the Nigerian Upstream Petroleum Regulatory Commission (NUPRC). The study found that 94% of the petrol stations failed to meet the required 15-meter setback from roads, only 6% adhered to the 400-meter spacing between stations, and just 2% maintained a 100-meter distance from schools. All stations complied with the market and hospital setback requirements. The findings reveal critical lapses in urban fuel infrastructure planning and call for urgent regulatory interventions. Recommendations include enforcing compliance through spatially integrated Environmental Impact Assessments (EIAs), updating urban spatial databases, and adopting GIS-based approval systems for new stations to enhance environmental safety and sustainable development.

Keywords: Geographic Information Systems (GIS), Urban Planning, Petrol Stations, Spatial Distribution, Regulatory Compliance, Umuahia North, Environmental Impact Assessment**.**

INTRODUCTION

Petrol stations are indispensable to modern society, supporting transportation, commerce, and industrial activity. In urban settings, they must be strategically located to balance accessibility with health and safety considerations. However, the unregulated expansion of such facilities often compromises urban safety and environmental sustainability. The petroleum downstream sector in Nigeria is regulated by the NUPRC, which sets physical planning standards, including:

- A minimum 15-meter distance from the edge of the road to the fuel pump.
- A minimum of 400 meters between any two petrol stations.
- A minimum distance of 100 meters from sensitive public infrastructure such as hospitals, schools, and markets [9].

Despite these regulations, many operators violate these standards due to weak enforcement, corruption, or ignorance, resulting in high-risk urban development.

Globally, the application of Geographic Information System (GIS) in urban planning has proven effective in monitoring, assessing, and controlling infrastructural development. Camille [8] used GIS in Abidjan to evaluate the influence of petrol station clustering on traffic and pollution. Alesheikh and Golestani [3] utilized GIS in Tehran to identify optimal siting for gas stations by analyzing risk factors, road access, and population

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density. In Nigeria, Ayodele [5] conducted a GIS-based assessment of Kaduna metropolis, revealing that 70% of petrol stations violated planning laws.

Despite the proven utility of GIS for infrastructure management, southeastern Nigeria has seen limited application in this area. Umuahia North, in particular, has witnessed rapid urban growth without a corresponding enhancement in spatial regulation. This study aims to bridge that gap by applying GIS tools to:

- Map the existing petrol stations in Umuahia North.
- Analyze their spatial distribution relative to physical planning standards.
- Evaluate the level of compliance.
- Make recommendations for improved urban fuel infrastructure planning.

Study Area

Umuahia North is a Local Government Area in Abia State, Southeastern Nigeria, and includes the state capital. It lies between latitudes 5° 31’ 54”N and 5° 33’ 30”N, and longitudes 7° 29’ 47”E and 7° 27’ 46”E, covering a total land area of 245 square kilometers. Based on the 2006 census, it has a population of 220,660, although the current figure is estimated to be higher due to urban growth.

The area comprises several densely populated communities such as Afara-Ukwu, Ossah, Amuzukwu, and Nkata Ibeku. The LGA is the administrative and economic hub of the state, featuring a concentration of public offices, markets, schools, hospitals, and residential zones.

Climatically, Umuahia experiences a tropical monsoon climate characterized by significant rainfall throughout most of the year and a brief dry season. Average annual rainfall is approximately 2153 mm, with March as the hottest month (27.5°C) and August the coolest (24.5°C). This weather pattern facilitates agricultural and commercial activities but also raises concerns about petroleum product runoff and pollution during heavy rains [13].

Major economic activities include retail trade, government employment, and small-scale manufacturing. Petrol stations have proliferated in response to increased vehicle ownership, urban sprawl, and the expansion of commercial hubs like Ubani Main Market and Azueke Industrial Market.

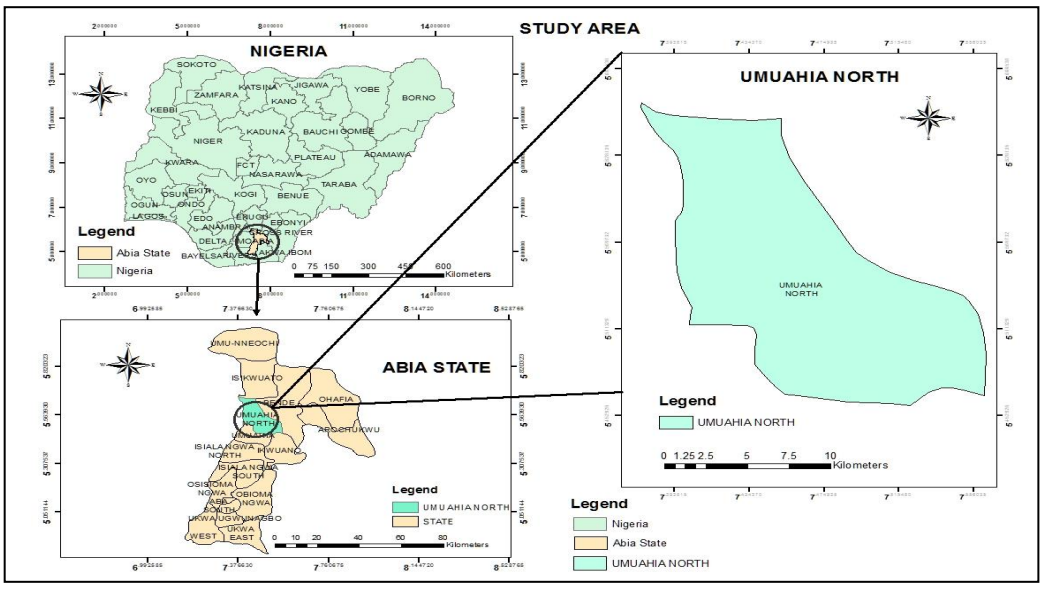

Figure 2.1 Study Area Map

Source: OSGOF Admin Shape File

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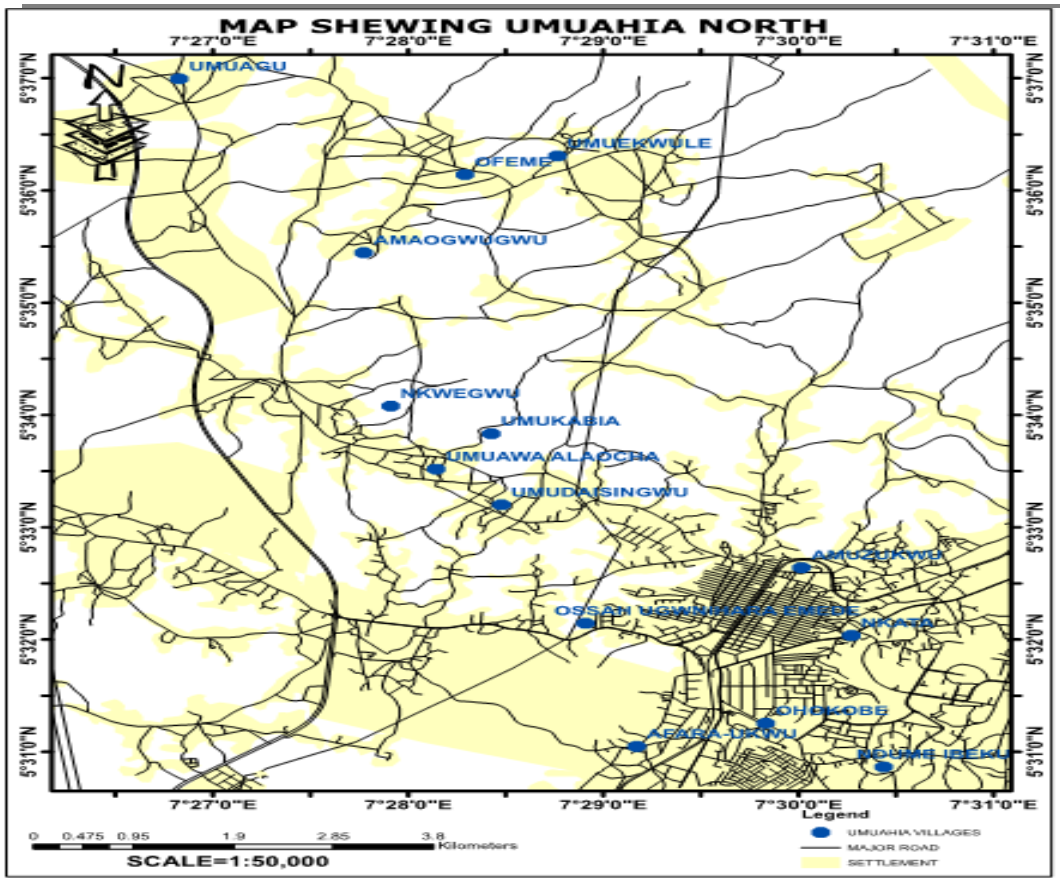

Figure 2.1b Map Showing Villages And Road Network

Source: Author's GIS analysis (2025)

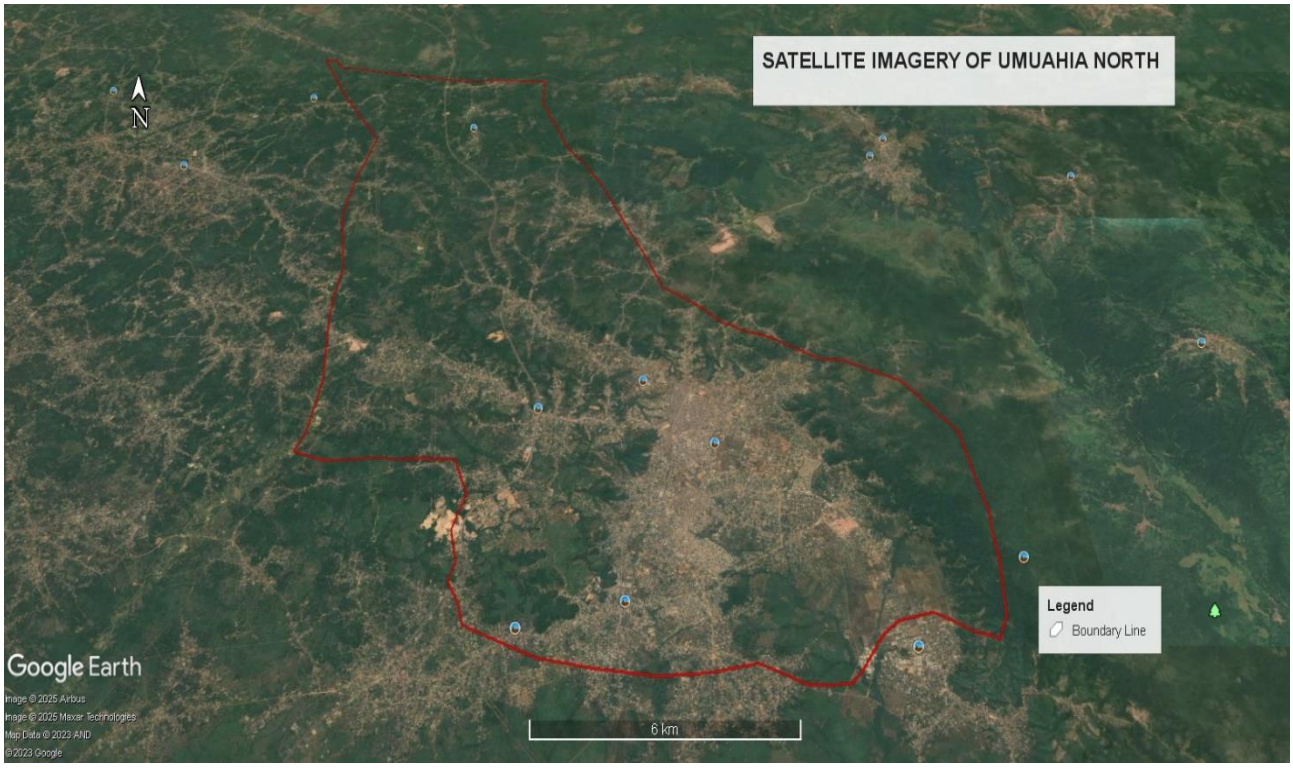

Figure 1c Satellite Imagery of the Study Area

Source: Downloaded from Google Earth Pro (2025)

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MATERIALS AND METHODS

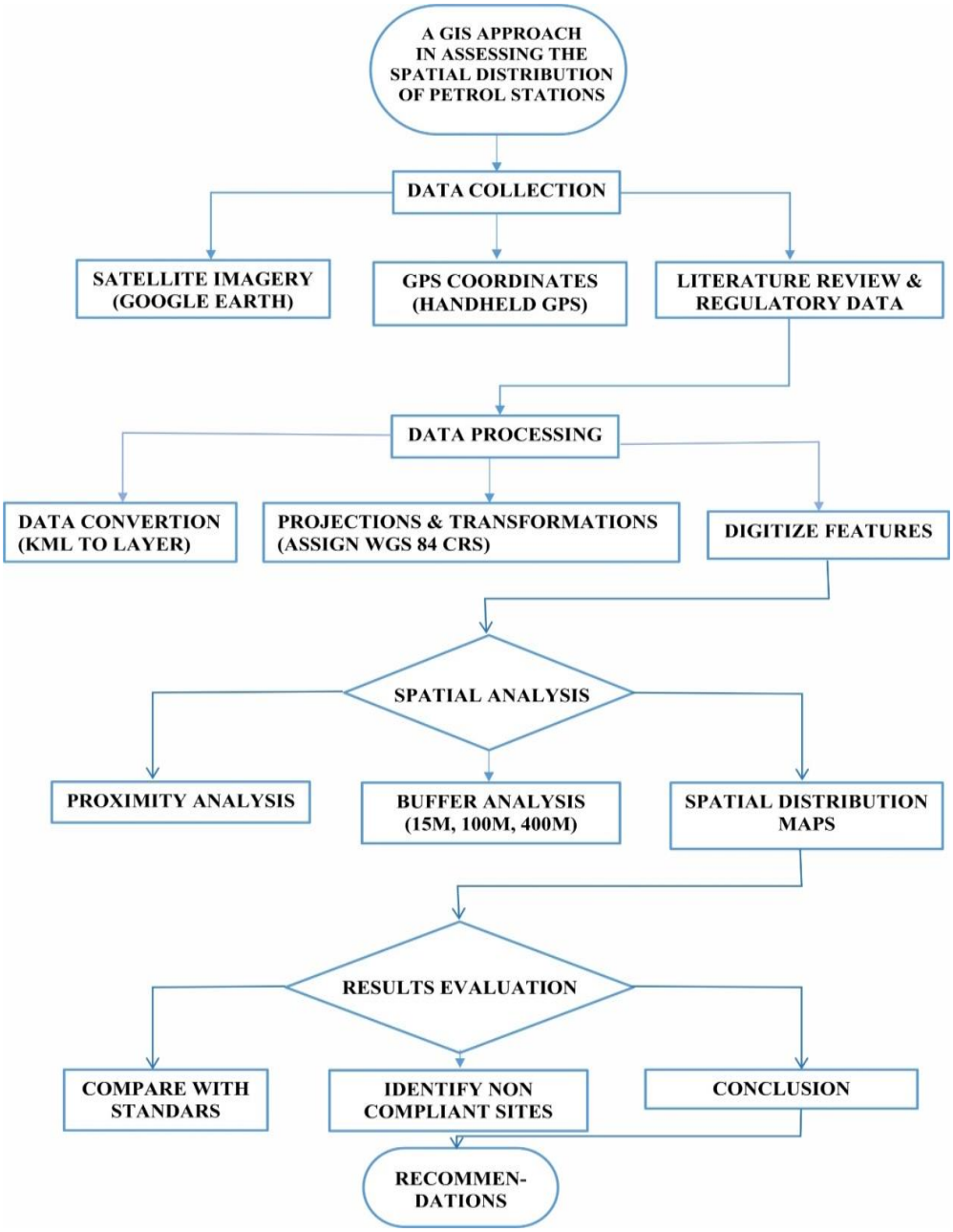

Figure 3.1 Methodology Flowchart

Source: Author (2025)

Flowchart

Research Design

This study adopts a descriptive and spatial analytical approach, integrating field data with geospatial analysis to assess petrol station siting against regulatory benchmarks. The methodological framework consists of data acquisition, processing, spatial database creation, and spatial analysis.

Data Acquisition

Primary Data:

- Geographic coordinates of petrol stations were collected using Garmin handheld GPS.

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- Field observations were conducted to validate the operational status and precise locations of the stations.

Secondary Data:

- Administrative boundaries: Downloaded from OSGOF.
- Road network: Extracted from OpenStreetMap.
- Google Earth imagery: Used for visual referencing.
- Literature: Academic publications, planning regulations, and government reports.

GIS Data Processing and Spatial Database Development

- KML data from Google Earth were converted into shapefiles using ArcGIS 10.1.
- Each feature class (roads, schools, hospitals, markets, and stations) was georeferenced using WGS 1984 datum [7].
- Attributes such as name, coordinates, proximity details, and compliance status were stored in relational tables and linked to spatial features.

Spatial Analysis

1. Proximity Analysis using the ArcGIS "Buffer" tool to create zones:
   - 15m around roads.
   - 100m around public infrastructure (schools, hospitals, markets).
   - 400m around other petrol stations.
2. Spatial Query using the "Select by Location" function to identify features within the buffer zones.
3. Overlay Analysis to combine results and identify overlaps of non-compliance.

RESULTS AND ANALYSIS

Distribution and Density of Petrol Stations

The spatial inventory identified 65 petrol stations across the LGA. Most are clustered along major routes:

- Afara Ibeku: 23 stations (36%)
- Ndume Ibeku: 20 stations (31%)
- Ossah Ibeku: 12 stations (19%)
- Nkata Ibeku: 6 stations (9%)
- Umueze: 2 stations (3%)
- Nunya: 1 station (2%)

High-density clusters along Aba Road and Ikot-Ekpene Road exceed safe capacity thresholds, creating congestion and infrastructural strain.

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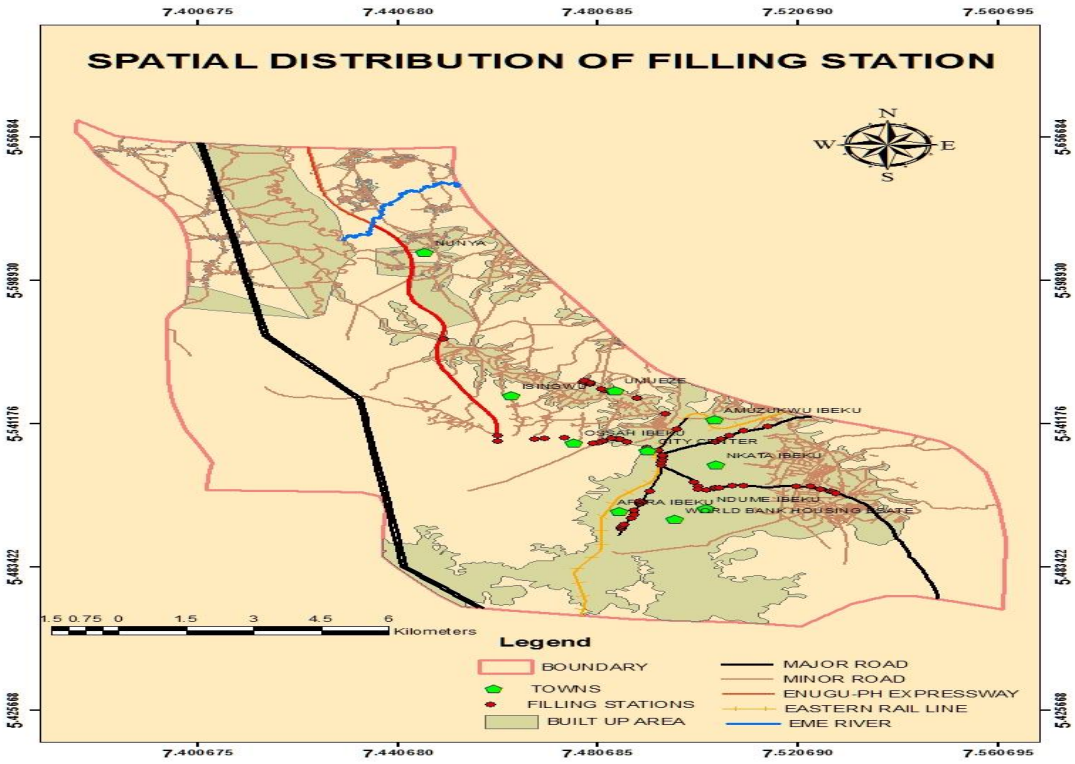

Figure 4.1: Map Showing the Spatial Distribution of Petrol Stations in Umuahia North

Source: Author's fieldwork and GIS analysis (2025)

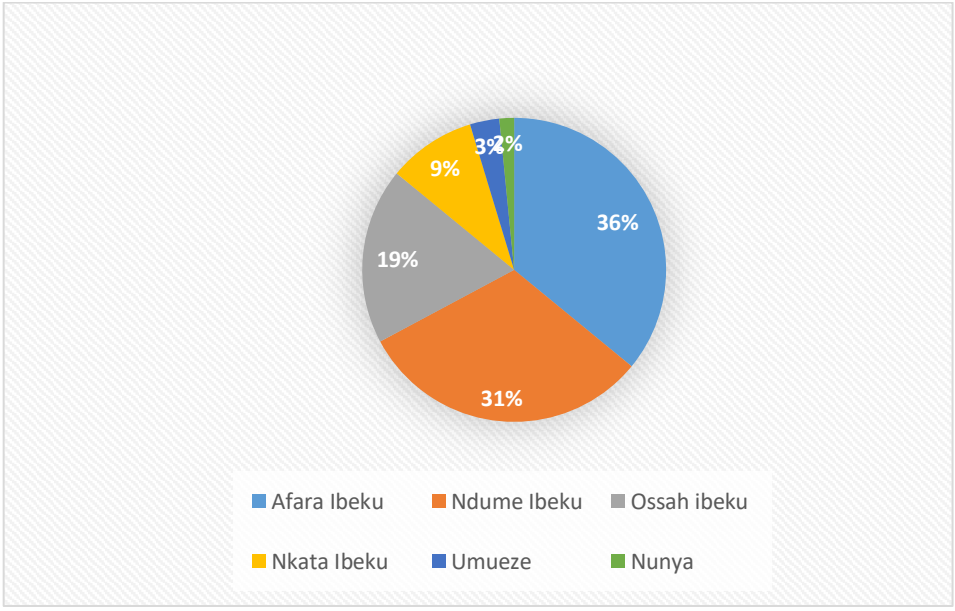

Figure 4.2: Pie Chart of Petrol Station Distribution by Community

Source: Computed by author using ArcGIS (2025)

Compliance Evaluation

1. **15m from Road Requirement:**
   - Compliant: 4 stations (6%)
   - Non-compliant: 61 stations (94%)

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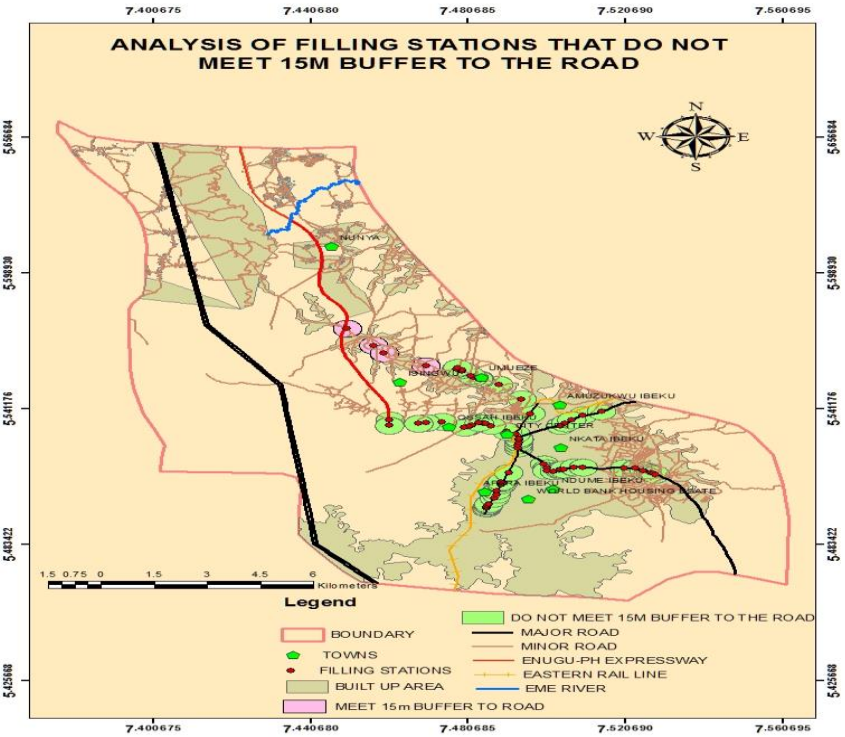

Figure 4.3: Buffer Analysis Map Showing 15m Proximity of Stations to Roads

Source: ArcGIS Proximity Tool, Field Survey (2025)

2. **400m Spacing Between Stations:**

- Compliant: 4 stations (6%)
- Non-compliant: 61 stations (94%)

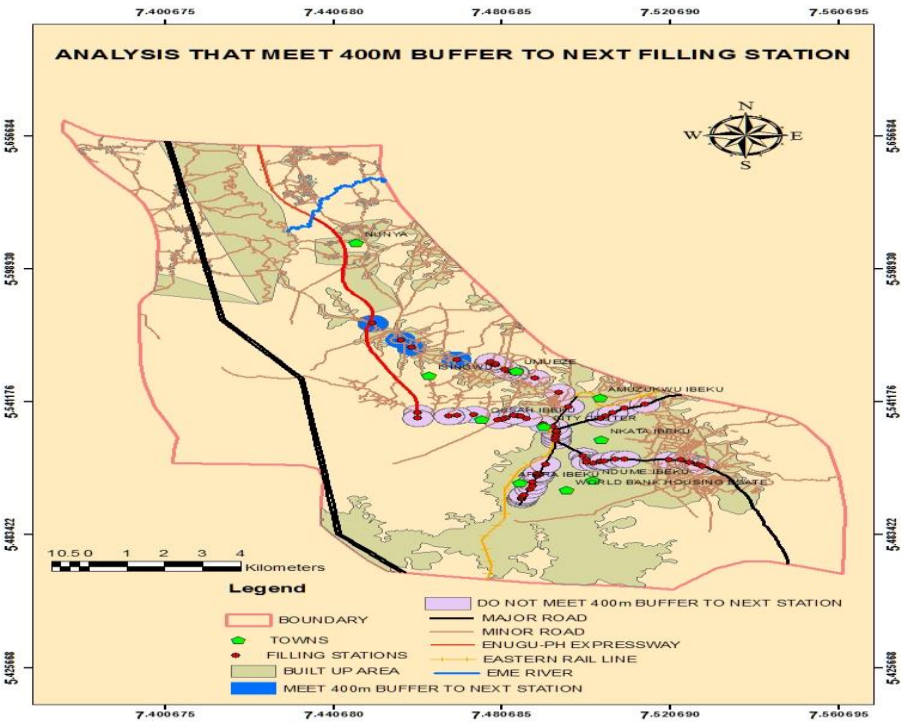

Figure 4.4: Buffer Map Indicating 400m Radius Between Petrol Stations

Source: ArcGIS Spatial Analysis (2025)

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3. **100m from Schools:**

- Compliant: 1 station (2%)
- Non-compliant: 64 stations (98%)

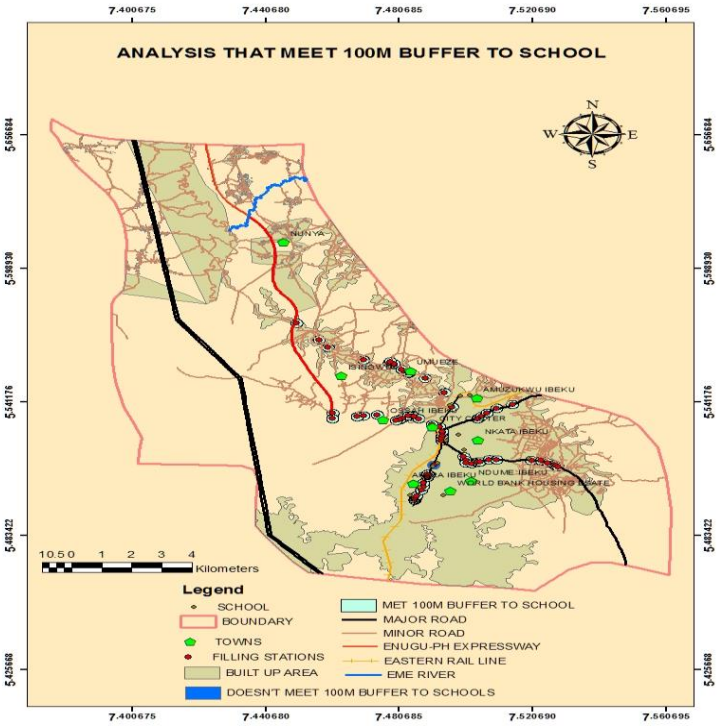

Figure 4.5: Buffer Map Showing Petrol Stations and Nearby Schools Within 100m

Source: Derived from School Dataset and GPS Mapping (2025)

4. **100m from Hospitals and Markets:**

Compliant: All 65 stations (100%)

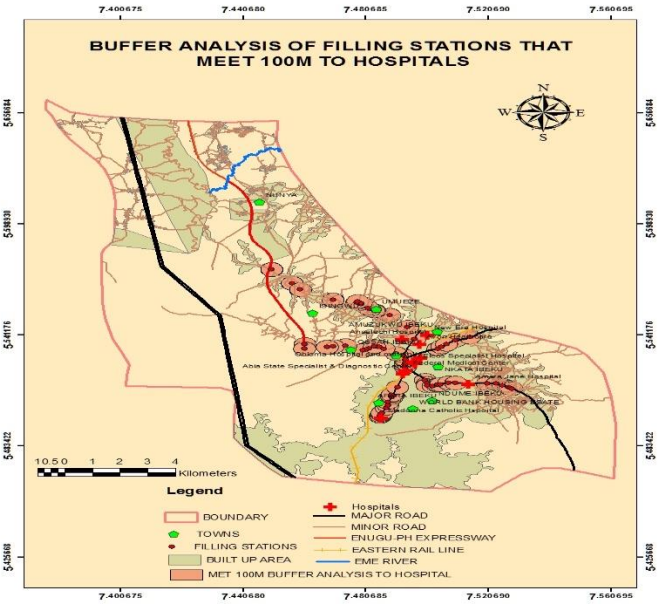

Figure 4.6a: Buffer Maps for Hospitals in Relation to Petrol Stations

Source: OSM/OSGOF and Author's Compilation (2025)

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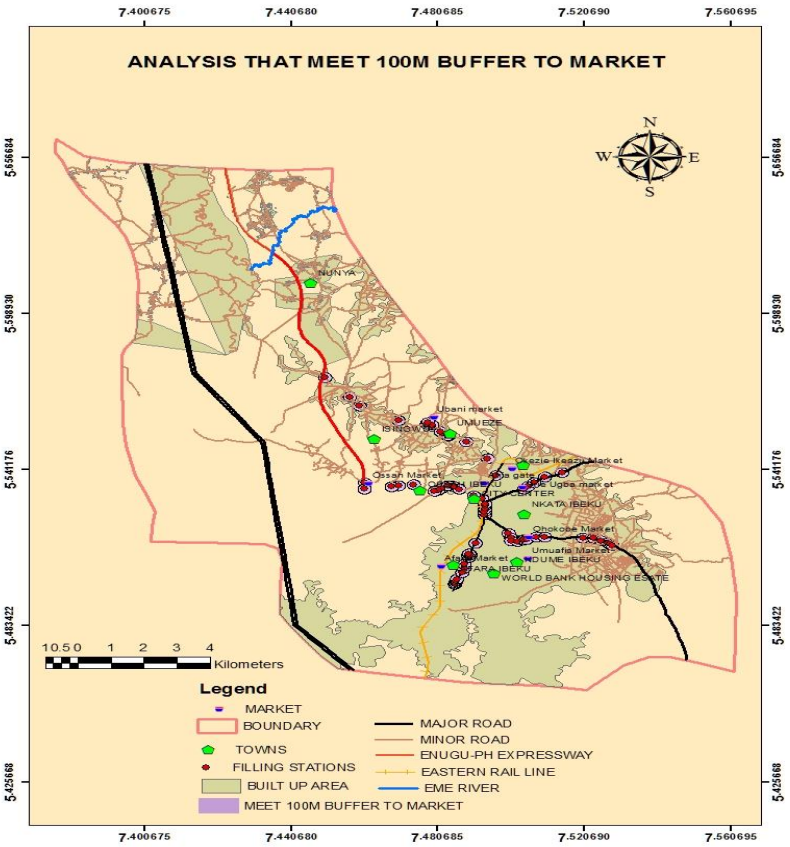

Figure 4.6b: Buffer Maps for Markets in Relation to Petrol Stations

Source: OSM/OSGOF and Author's Compilation (2025)

Visualization and Mapping

The output maps show a high level of spatial conflict, especially within densely populated communities and near commercial areas. Buffer overlays visually demonstrate encroachments, particularly around educational institutions.

Table 4.1: Compliance Summary of Petrol Stations with NUPRC Standards in Umuahia North

Compliance Criterion	Required Standard	No. of Compliant Stations	% Compliant	No. of Non-Compliant Stations	% Non-Compliant
Distance from Road	≥ 15 meters	4	6%	61	94%
Distance Between Stations	≥ 400 meters	4	6%	61	94%
Distance from Schools	≥ 100 meters	1	2%	64	98%
Distance from Hospitals	≥ 100 meters	65	100%	0	0%
Distance from Markets	≥ 100 meters	65	100%	0	0%

Source: Computed from GIS Query Outputs (2025)

DISCUSSION

The results of this study underscore critical spatial planning deficiencies in the siting of petrol stations within Umuahia North Local Government Area. The findings reveal that a significant proportion of petrol stations violate the spatial regulations stipulated by the Nigerian Upstream Petroleum Regulatory Commission

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(NUPRC), especially with regard to setback distances from roads and public infrastructure. These violations highlight a gap between urban planning policy and implementation, with potentially grave implications for environmental sustainability, public health, traffic management, and disaster risk reduction.

One of the most striking findings is that 94% of the petrol stations in the study area are situated less than the required 15 meters from the road. This creates severe risks of traffic congestion, vehicular accidents, and pedestrian safety hazards, especially in a rapidly urbanizing area like Umuahia North, where motor traffic is on the rise due to population and economic growth. The siting of stations so close to the road also increases the vulnerability of both the station and the surrounding area to fire incidents and fuel spills, particularly during fuel delivery and storage activities.

Furthermore, 94% of stations were also found to violate the 400-meter minimum spacing between stations. This leads to high clustering of stations in particular areas, especially along major roads such as Aba Road and Ikot-Ekpene Road. Such clustering may be economically driven by operators targeting high-traffic corridors, but it results in infrastructural overload, land use inefficiency, and potential inter-operator conflicts. From an environmental management perspective, this increases the cumulative impact of noise, emissions, and the risk of hazardous incidents.

The proximity of petrol stations to schools also raises serious concerns. Only 2% of the stations complied with the 100-meter setback from educational institutions, which raises issues regarding student safety and long-term health effects due to continuous exposure to pollutants like benzene and other volatile organic compounds (VOCs). Children are particularly susceptible to respiratory diseases, and the presence of petrol stations in close proximity to learning environments is a public health issue that should be urgently addressed.

Interestingly, the analysis showed full compliance (100%) with the 100-meter setback from hospitals and markets. This may be attributed to more active regulation and enforcement in areas considered high-priority or more visible to the public. However, this selective compliance suggests inconsistencies in enforcement practices and the need for a standardized and spatially driven regulatory framework.

Comparative studies further validate the findings. Ayodele [5], in a similar study in Kaduna Metropolis, found that over 70% of petrol stations did not meet regulatory spacing and siting criteria, confirming a nationwide trend of weak urban control mechanisms. Camille [8] also highlighted in her study of Abidjan that uncontrolled proliferation of filling stations led to high levels of pollution and a sharp increase in vehicular conflicts. These studies align with the conditions observed in Umuahia North and emphasize the importance of a systemic shift toward geospatially-informed decision-making in Nigeria's urban infrastructure development.

The discussion also extends to urban governance and institutional capacity. Regulatory bodies such as the NUPRC and local planning authorities may lack the technical resources, up-to-date spatial data, or GIS skills required for proactive urban infrastructure monitoring. In many cases, planning approvals are granted based on paper submissions without field verification or spatial analysis, thereby creating a planning gap. Moreover, existing urban master plans are either outdated or not adequately digitized, making it difficult to ensure consistency between development proposals and ground realities.

Integrating GIS into the planning and regulatory processes offers a practical and scalable solution. Through GIS, planners can visualize existing infrastructure, identify saturation points, simulate growth scenarios, and determine optimal locations for new facilities. GIS also allows for dynamic spatial querying and real-time monitoring of compliance, which can enhance transparency, accountability, and responsiveness in planning systems.

In sum, this study demonstrates that spatial non-compliance in petrol station siting is not just a technical issue but a governance and policy challenge that requires urgent institutional reforms, technological adoption, and community participation. Addressing this challenge is vital to ensuring public safety, minimizing environmental risks, and promoting sustainable urban development in Umuahia North and similar urbanizing regions across Nigeria.

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CONCLUSION AND RECOMMENDATIONS

Conclusion

This study has demonstrated the critical role that Geographic Information Systems (GIS) can play in evaluating and enhancing the spatial distribution of petrol stations in rapidly urbanizing environments such as Umuahia North Local Government Area, Abia State. Through the integration of field data, spatial datasets, and advanced geoprocessing techniques in ArcGIS, it was possible to assess compliance with the physical planning standards set by the Nigerian Upstream Petroleum Regulatory Commission (NUPRC).

The results revealed widespread non-compliance across key regulatory benchmarks. Only 6% of the petrol stations maintained the recommended 15-meter setback from roads, and just 6% adhered to the minimum 400-meter spacing between stations. Additionally, a mere 2% of petrol stations complied with the 100-meter buffer from schools. These violations not only undermine the objectives of urban planning but also expose the population to significant risks including traffic accidents, environmental degradation, respiratory illnesses, fire hazards, and reduced urban livability.

The clustering of petrol stations along major corridors such as Aba Road and Ikot-Ekpene Road illustrates the tendency of developers to prioritize commercial visibility and accessibility over regulatory compliance. This commercial pressure, when left unchecked by weak regulatory enforcement and outdated planning systems, leads to chaotic land use patterns and worsens urban vulnerabilities.

Despite this, the full compliance observed in relation to hospitals and markets suggests that with adequate enforcement and visibility, spatial planning standards can be achieved. This compliance gap reflects both institutional weaknesses and opportunities for reform. Many local planning authorities lack the technical capacity, up-to-date geospatial datasets, and decision-support tools needed to monitor and enforce siting regulations effectively.

Ultimately, the study illustrates that GIS is not merely a technical tool but a strategic asset for urban governance. It can improve transparency, accountability, and efficiency in infrastructure planning and regulation. By embedding GIS into Environmental Impact Assessments (EIAs), approval workflows, and urban master plans, regulatory agencies can ensure that petrol station development supports, rather than threatens, sustainable urban development.

In conclusion, if Nigeria is to improve public safety, environmental quality, and orderly development, the integration of geospatial technology into planning systems must be prioritized. Umuahia North serves as a microcosm of broader challenges in urban fuel infrastructure planning across the country, and this study provides a replicable framework for spatial compliance monitoring and policy formulation.

Recommendations

1. **GIS-Based EIA Requirement**: Regulatory bodies should mandate that all Environmental Impact Assessments (EIAs) include spatial analysis and GIS mapping.
2. **Spatial Database Development**: Create a centralized, regularly updated geospatial database of petrol stations and other critical infrastructure [6].
3. **Strict Enforcement**: Stations violating spatial regulations should be issued compliance deadlines, fined, or shut down.
4. **Urban Master Plan Revision**: Abia State should revise its master plans to integrate spatial standards and GIS oversight.
5. **Public Sensitization**: Educate the public on the risks associated with poorly sited petrol stations and involve community stakeholders in planning.
6. **Capacity Building**: Train planning officers and regulators in the use of GIS tools for infrastructure management.

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