

Compliance Assessment of Liquefied Petroleum Gas Filling Stations with Department of Petroleum Resources and Planning Standards in Kaduna Metropolis, Nigeria

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Abstract- *The proliferation of Liquefied Petroleum Gas (LPG) filling stations in Nigerian urban centres has raised significant concerns regarding compliance with regulatory and planning standards, yet empirical evidence on the extent of compliance in Kaduna Metropolis remains limited. This study assesses the extent to which LPG filling stations in Kaduna Metropolis comply with Department of Petroleum Resources (DPR) standards and physical planning standards. Employing a mixed-methods design integrating Geographic Information System (GIS) analysis, field surveys, and stakeholder interviews, data were collected from 28 LPG stations across four Local Government Areas. Buffer analysis, tabulate intersection tools, and descriptive statistics were employed for compliance assessment. The findings reveal significant non-compliance: 43% of stations failed to meet the minimum land size requirement of two plots (100ft x 100ft); 24% did not maintain the mandatory 15-metre road setback; and 19% were located less than 100 metres from another LPG facility. However, adherence was high for setbacks from railways (100%), PHCN power lines (100%), and public buildings (100%). The study concludes that widespread non-compliance indicates a systemic failure in regulatory enforcement, creating a landscape of normalized urban risk. The study recommends a joint DPR-KASUPDA safety audit, a Kaduna-specific LPG siting master plan, and a "Safety-In-Depth" licensing model to address the compliance deficit.*

Keywords: *LPG Filling Stations, DPR Standards, Planning Standards, Compliance Assessment, Kaduna Metropolis, GIS Analysis*

I. INTRODUCTION

The rapid urbanization experienced in Kaduna Metropolis has resulted in increased use of Liquefied Petroleum Gas (LPG) for cooking energy, exacerbating demand and leading to the proliferation of LPG filling stations within the metropolis (Sule,

2022). While LPG is promoted as a cleaner and safer alternative to traditional fuels like firewood and kerosene, the location of LPG filling stations deserves adequate physical planning guidance and adherence to locational guidelines because of its significance to the health and safety of the people (Nautiya, 2021).

In Nigeria, the Directorate of Petroleum Resources (DPR) is the agency saddled with the responsibility of stipulating the minimum requirements, procedures and conditions to be fulfilled before the grant of approval and license for the construction, modification, relocation and operation of LPG stations or facilities (Lam, 2024). According to the DPR manual (2018), before granting approval to construct an LPG station, certain physical planning standards and procedures for site inspection must be satisfied. Principally, the site must not fall within any pipeline Right of Way (ROW), should be accessible from the road side, and all setbacks by relevant agencies should be observed as it affects overhead electric cables, railway lines and pipelines. The distance of the proposed LPG storage tank location shall not be less than 15 metres from another property which may be built upon and 50 metres from public buildings such as hospitals, schools, parks, train stations, mosques, and churches, among others.

Despite these regulatory provisions, challenges remain in the equitable distribution of LPG infrastructure. The locational pattern of LPG service stations in most parts of the country displays an outcome of lack of coordination, accounting for the indiscriminate and haphazard location of LPG stations in urban space (Ayodele, 2023). The locational arrangement of LPG stations is such that they are found very close to residential buildings and along road networks in

Kaduna metropolis. In most parts of the world, cities and towns are exposed to hazards such as traffic congestion, pollution, accidents, fire explosion and environmental problems. These problems are most common in developing nations like Nigeria where there is a lack of coordinated planning for development.

The growing demand for clean, efficient, and affordable energy sources in urban centres has placed increased attention on LPG as a viable alternative to traditional fuels. Kaduna, as one of the prominent cities in Nigeria, is experiencing rapid urbanization, which is driving the demand for LPG and other modern energy sources. The rapid population growth experienced in Kaduna metropolis has resulted in increased use of LPG for cooking energy, thus exacerbating the demand for LPG and leading to the proliferation of LPG filling stations within Kaduna metropolis. Consequently, there is less consideration of minimum physical planning standards and site suitability. Since LPG stations are located in space and have spatial attributes, it is expected that they are sited in a manner that adheres to physical planning standards. However, it is noticeable that despite the availability of physical planning standards regulating the location of LPG stations in Kaduna metropolis, most LPG stations are still located in a manner that is chaotic and has the potential for planning implications which needs to be unraveled.

This study therefore assesses the extent to which LPG filling stations in Kaduna Metropolis comply with DPR standards and planning standards, with a view to identifying compliance gaps and recommending appropriate planning interventions.

II. LITERATURE REVIEW

2.1 Concept of Liquefied Petroleum Gas (LPG) Filling Station

A Liquefied Petroleum Gas (LPG) filling station is a specialized facility designed to store, distribute, and dispense LPG to consumers for various uses, including domestic cooking, heating, and as a fuel for vehicles (Lam, 2024). LPG is a byproduct of both natural gas processing and crude oil refining. It consists primarily of propane and butane and is used widely across the

globe due to its clean-burning nature, efficiency, and versatility (International Energy Agency [IEA], 2020).

2.2 Regulatory Framework for LPG Station Location in Nigeria

The Department of Petroleum Resources (DPR) classified LPG stations into either Category A or B. Category "A" are industrial LPG stations located within the premises of institutions, establishments, companies and industries for their local consumption. They have few facilities and small capacities. Category "B or ATC" are commercial LPG stations located on sites along major highways and streets within towns, cities, outskirts of towns/cities and in villages en route major highways to dispense LPG to the public at payment of regulatory price (DPR, 2018). According to the DPR (2018) procedure guide for grant of approvals to construct and operate an LPG plant, the following are required: a letter/approval from the appropriate Town Planning Authority authorizing the siting of the LPG filling plant at the proposed site; two copies of the approved drawings showing existing or proposed buildings on the site and the relevant distances to the roadways and adjoining properties; two copies of the Survey plan duly endorsed by a Registered Surveyor; two copies of Piping and Instrumentation Diagram (P&ID); two copies of manufacturers' data sheet of the storage tank(s); two copies of Codes, Standards and Specification adopted in the design, construction and installation of ancillary equipment; a provisional approval letter and fire report by Chief Federal/State Fire officer; an approval letter from the Divisional Police Officer where the LPG plant will be sited; Certificate of Incorporation of the company; two copies of Memorandum and Articles of Association; a copy of Safety, Health and Environment (SHE) proposal; and evidence of payment of application fee. Prior to the grant of Approval to construct a proposed LPG plant, it is mandatory that a site suitability approval is granted, and the applicant satisfies certain criteria. The site shall be granted approval only when it meets the following criteria:

- i. It does not fall within any pipeline Right of Way (ROW)
- ii. The site should be accessible from the road side

- iii. All setbacks by relevant agencies should be observed as it affects overhead electric cables, railway lines and pipelines
- iv. The distance of the proposed LPG storage tank location shall not be less than 15 metres from another property which may be built upon and 50 metres from public buildings (hospital, school, park, train/metro stations, mosques, churches, etc.)
- v. The proposed site shall be adequate to accommodate the spacing and safety distance requirements
- vi. The drainages to be constructed or existing ones shall not be channeled to a stream or waterway. Contaminated water should be contained and treated onsite

Amenities to be provided include: functional Automated/Manual leak tester; functional Fire alarm system and mounted gas detectors at designated areas; reference scale; safety warning notices and Personnel Protective Wears for Plant operators; emergency shutdown system in at least two locations; visible display of Emergency Telephone numbers of Fire Service, Police and DPR; adequate fire water storage, deluge and sprinkler system; muster point designated areas; car parking areas outside the gas plant; public toilet facilities; demarcation of LPG Storage areas to unauthorized persons; and a fence of at least 2 metres high to enclose the LPG plant.

2.3 Factors Influencing LPG Station Distribution

LPG station distribution is significantly influenced by geographic factors. Areas with high population density, such as urban centres, naturally attract more LPG stations due to increased demand for cooking gas. Conversely, remote rural areas often face challenges in accessing LPG because of poor road infrastructure, high transportation costs, and limited demand (Akinola et al., 2018). The regulatory environment in which LPG stations operate plays a key role in determining their location and density. Regulatory bodies such as the Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA) enforce safety standards and zoning laws that govern the establishment of LPG stations (DPR, 2019). These regulations include safety distances between LPG tanks and residential or commercial

buildings, as well as clearance zones for risk mitigation.

The economic feasibility of establishing LPG stations is a major driver of distribution patterns. Market demand plays a central role in determining where new stations are established. Affluent urban centres with higher incomes are more likely to have a larger number of LPG stations because these areas have higher demand for cleaner energy and greater financial capacity to pay for the installation and maintenance of LPG infrastructure (Akinola et al., 2018). The availability and condition of transportation infrastructure also significantly impact LPG distribution. Road quality, storage facilities, and pipeline access are essential for the smooth delivery of LPG to filling stations (Eze & Arinze, 2019). Safety is a significant concern in the distribution and operation of LPG stations. LPG is a highly flammable fuel, and stations must comply with strict safety guidelines to mitigate the risk of leaks or explosions (Sule, 2022).

2.4 Empirical Review

2.4.1 Petrol Gas Stations' Location and Minimum Environmental Safety Requirements in Akpor, Port Harcourt, Nigeria

The study examines the proliferation of petrol gas filling stations in relation to the minimum environmental safety requirements by the Department of Petroleum Resources (DPR) that 'distance from the edge of the road to the nearest pump and from the next petrol gas filling station should not be less than 15 and 400 meters respectively.' The Global Positioning System (GPS) was used to acquire the coordinates of each filling station in the study area and then imported to the ArcGIS 9.3 software environment. Distances between filling stations from the road and from each other were determined using the ArcGIS 9.3 measurement tool alongside buffering analysis in respect to their coordinates. The Z ratio analytical technique was used to examine the conformity of petrol filling stations to the required distance of 400m and 15m from each other and from the road respectively as stipulated by DPR amendment decree 37 of 1997. Findings from the z ratio analysis at 152 degrees of freedom and 95% confidence level revealed that the petrol filling stations in the study area neither conform to the required distance of 400m apart nor

conform to the required distance of 15m from the road. Thus, the study recommends, among others, the need for the regulatory agency, DPR, to improve their capacity in enforcing the compliance of petrol gas filling stations with laid down regulations.

2.4.2 Assessing the Location and Spatial Distribution of Petrol Gas Stations in Ilaro, Ogun State, Nigeria

The study aims at assessing the location and spatial distribution of petrol gas stations in Ilaro, Ogun state. The objectives are to identify and map all the petrol gas filling stations in the study area; assess their conformity with planning standards; and determine the distributional pattern of the petrol filling stations. The research adopted field surveys and remote sensing, especially the instrumentality of Geographic Information System (GIS), in identifying the existing petrol gas filling stations as well as conducting queries to assess the level of compliance of the petrol filling stations with extant planning standards. Nearest Neighbour Analysis was equally employed in determining the distribution pattern of the facilities. With an Rn value of 0.36, the study among others, pointedly revealed that the locational pattern of petrol gas filling stations in the study area tends towards clustering. The study recommends a moratorium on approval of petrol filling stations within the fully developed road corridors of the town.

2.4.3 Assessment and Determination of Spatial Distribution Pattern of Gas Filling Stations in Akure Metropolis, Ondo State Nigeria

This study aimed at assessing and determining the spatial distribution pattern of filling stations in Akure Metropolis, Ondo State Nigeria. Department of Petroleum Resources (DPR) stipulated that 'distance from the edge of the road to any nearest pump should not be less than 15m and less than 400 meters to the next petrol filling station and not be located less than 100 meters from school, hospital, theatres, clinics and other public and semi-public buildings.' The Global Positioning System (GPS) instrument was used to acquire spatial and attribute data where queries employing proximity and buffering analysis was performed using ArcGIS 10.3 software respectively. The Z ratio analytical technique was used to examine the conformity of petrol filling stations to the required distance of 400m and 15m from each other and from

the road respectively as stipulated by DPR amendment decree 37 of 1997. Findings from the Z ratio analysis at 66 degrees of freedom and 95% confidence level revealed that 32 (57%) conform to the required distance of 400m apart, 25 (40%) conformed to the required distance of 15m from the existing road, 95.5% conformed to the required distance of 100m from existing school and 100% conformed to the required distance of 100m from the existing healthcare facility. There is a general indication that the distribution of filling stations in Akure metropolis is tending towards a clustered pattern which automatically translates into high level vulnerability to potential hazards associated with each utility. Thus, recommendation is hereby made for adoption of this work by the regulatory agency DPR, as an A-priori data to improve their capacity in enforcing the compliance of petrol filling stations with laid down regulations.

2.4.4 Liquefied Petroleum Gas in Kolkata, India

An important energy poverty reduction initiative in India is aimed at replacing the use of solid cooking fuels with cleaner burning Liquefied Petroleum Gas (LPG). Projections suggest however that India will become increasingly dependent on LPG imports, the cost of which is strongly linked to the prevailing oil price and associated volatility. Dimethyl ether (DME) is a synthetic fuel which may be manufactured from domestically available carbonaceous feedstocks and is compatible with blending with LPG. Very large quantities of Municipal Solid Waste (MSW) are generated in India's metropolitan cities, 90% of which is disposed of onto unsanitary landfills, creating major environmental and health concerns. This article investigates the techno-economic merits of reducing these impacts by using a portion of the MSW generated in Kolkata (in the form of a Refuse Derived Fuel (RDF)) to produce DME. Results suggest that the production of DME from a 50:50 blend of locally available coal and RDF (comprising 10% of the MSW placed at Kolkata's main landfill) will enable the supply of a clean cooking fuel to approximately 15% of Kolkata's population, and become cost competitive with imported LPG at an Indian basket oil price of \$130 per barrel. Results also suggest that, at this blend ratio, the fossil fuel derived greenhouse gas emissions

at the DME production plant will be more than offset by landfill methane emissions avoided using the RDF.

2.4.5 Urban Bearing Capacity of Gas Supply Stations, Wuhan, China

Given the continuous optimization of the energy structure, the proportion of natural gas consumption in China increases annually, the urban gas pipeline network continues to extend outward, and the supply range continues to expand. Although an increasing number of users can use natural gas, the coverage of the natural gas pipeline network remains low in some areas in China. A "point supply" pattern, which provides gas through liquefied natural gas (LNG), compressed natural gas (CNG) and liquefied petroleum gas (LPG) supply stations, has been developed to solve the problem of gas unavailability in areas not covered by the pipeline network. This pattern flexibly supplies gas, whose cost is low and market determined. Thus, the substantial development of these gas supply stations has been promoted. This pattern will continue to play an important role in the future. However, no unified standards for the construction of these gas supply stations have been provided, resulting in various problems, such as unreasonable location, inadequate management, potential risk and imbalance between supply and demand. On the basis of these concerns, this research attempts to study the urban bearing capacity of gas supply stations, provide some new ideas for the construction and planning of urban gas supply stations, and help promote sustainable urban development. The pressure state response model is adjusted to the pressure state capability model, which is used as a basis for proposing an evaluation index system and calculation models for the comprehensive evaluation of the urban bearing capacity of gas supply stations on city and country scales. The proposed methodology is used in a case study of urban agglomerations in the Yangtze River Delta.

2.4.6 Liquefied Petroleum Gas Storage Design in Malaysia

Liquefied Petroleum Gas (LPG) is a common fuel used for domestic, industrial and commercial appliances in Malaysia. Homes in Malaysia get LPG cylinders in various sizes offered by suppliers, but most of them use 14kg cylinders. Generally, LPG is

composed of volatile low boiling point gases - ethane, propane, propene, iso-butane, butane, but-1-ene, isobutene, trans-2-butene, cis-2-butene, and also isopentane and pentane due to the availability of higher boiling point components. When LPG is used, the low boiling point components will evaporate and the high boiling point components will remain. The research aimed to design an exploratory instrumentation for liquid LPG sampling under pressure, to explore the composition of liquid LPG in the LPG cylinder used in Malaysia and conclude whether some of the product might stay in the cylinder as liquid component after the volatiles are used. When the availability of high boiling point components which in turn will stay in the cylinder after it is empty from low boiling point components was proved, the research aimed to recommend a new idea for LPG cylinder design that is more energy-efficient. The first stage of the research was to design the easy and safe exploratory instrumentation for liquid LPG sampling under pressure and collect a sample. Then, the second stage is to determine the LPG composition using the available gas chromatography (GC) column available in FKKS laboratory. The composition analysed and the retention time then compared to the reference for each of the expected substances to exist in the LPG mixtures. The third stage is to propose a new design of LPG cylinder based on the existence of liquid component LPG in the LPG cylinder. The design is proposed based on the existence of the liquid LPG in used up LPG cylinder in Malaysia.

2.5 Theoretical Framework

2.5.1 Risk Society Theory (Beck, 1992)

The proliferation of non-compliant LPG stations in Kaduna metropolis can be analyzed through Ulrich Beck's concept of "organized irresponsibility." The system is structured such that risks are produced (by station owners/developers), but accountability is diffused across multiple agencies (DPR, KASUPDA, and Fire Service), with no single entity holding ultimate responsibility for prevention. The modern risk of a gas explosion is manufactured through urban development decisions, yet the consequences are borne by the public.

2.5.2 Implementation Gap Theory (Pressman & Wildavsky, 1973)

Policy implementation theory helps analyze the compliance failure as a classic "implementation deficit." The vertical governance structure sees policy formulated at the federal level (DPR), but implementation relies on state (KASUDA, Fire Service) and local actors with different priorities and capacities. The "clearance chain" for a compliant station is as weak as its weakest link. If KASUPDA is underfunded or prone to informal influence, the entire regulatory edifice collapses, regardless of DPR's technical competence.

2.5.3 Defensible Space Theory (Newman, 1972)

Applied to Kaduna's metropolis LPG stations, a non-compliant station embedded in a residential area has no "defensible" safety zone. Its boundaries are blurred; activities like smoking or cell phone use by the public go unsupervised. In contrast, a station in a properly zoned industrial area has a clearly defined territory where safety protocols are more naturally enforced. The very siting violates principles of defensible space, making daily safety management inherently harder.

III. MATERIALS AND METHODS

3.1 Study Area

Kaduna metropolis serves as the administrative headquarters of Kaduna State. The study area comprises Kaduna North, Kaduna South, part of Igabi, and Chikun Local Government Areas. The metropolis shares boundaries in the north with Katsina State, in the south Plateau State, in the west Niger State and Abuja, and the east Kano State. Kaduna metropolis covers roughly 50 km² from the city centre (Figure 3.1).

Based on Ayoade (1988) classification, Kaduna metropolis has a tropical continental climate type characterized by wet and dry seasons. The tropical continental is more pronounced in the dry season particularly in December and January. The dry season is dominated by the north-east trade wind called Harmattan which prevails between November and February. The dry season is also rainless from October to April. The wet season is dominated by the tropical maritime trade wind which starts around May to

October. The area has a mean daily temperature showing a major peak in April. Temperatures are hot all year round except for the dry cool and dusty months of harmattan in November to February. The maximum temperature seldom falls from about 36°C in April to about 27°C in the heart of the rainy season (August-October). The annual rainfall is about 1000mm (Ayoade, 1988).

Kaduna Metropolis records the highest temperature in April and the lowest in January. The range varies between 90°F - 15°F and 45°F - 55°F respectively. The extreme of these figures places a lot of strains on the humidity. This is further aggravated by considerable changes in humidity which may be below 10% in the afternoon and 30% at dawn.

3.2 Research Design

Research design is an overall strategy or blueprint that outlines how a research study is to be conducted. It provides the framework for collecting, measuring, and analyzing data in a way that ensures the research question is answered accurately and reliably. According to Creswell (2014), research design is "the plan or proposal to conduct research, involving the intersection of philosophy, strategies of inquiry, and specific method." This study employed a mixed method of research design. This combination provides a more complete, accurate, and reliable understanding of the research problem.

3.3 Source of Data

3.3.1 Primary Sources of Data Collection

These are original, first-hand sources collected directly by the researcher for a specific research purpose. Examples include: survey and questionnaire, observations, experiments, focus group discussion and interviews (structured, semi-structured, or unstructured).

3.3.2 Secondary Sources of Data Collection

These are existing data collected by someone else, used for analysis or reference in the current research. Examples include: books and journals, government publications and reports, online databases, archives and historical records, and media content (newspapers, radio, television).

3.4 Sampling Procedure

Creswell (2014) explains that sampling procedures are "the strategies used to select individuals, sites, or documents for study." Examples include: Probability Sampling and Non-Probability Sampling.

3.4.1 Sampling Element

Babbie (2010) defines a sample element as "that unit of analysis or observation in a population that is selected in a sampling process." For this research, the sampling elements include: 338,803 estimated number of households in the four LGAs that make up Kaduna metropolis, 28 number of LPG stations and all key stakeholders in charge of the siting of LPGs and enforcing of compliance standards, this includes: DPR, KASUPDA, and KADGIS among others.

3.4.2 Sample Frame

According to Kothari (2004), a sample frame is "a list of all items in the population from which a sample is drawn." For this research study, the sample frame includes all the 338,803 estimated households within the Kaduna metropolis, the 28 LPG stations and all the stakeholders responsible for enforcing and compliance of standards, this includes: DPR, KASUPDA, and KADGIS.

3.4.3 Sampling Size

Creswell (2014) explains that: "sample size is the number of individuals chosen from a population for a study." In order to obtain the sample size, Yamane (1967) formula was used to calculate the sample size at 95% confidence level and 5% sampling error assumption thus:

$$n = N / (1 + Ne^2)$$

Where,

$$\begin{array}{lclcl} n & = & \text{Sample} & \text{size} & \\ N & = & \text{Total} & \text{household} & \text{size} \\ e & = & \text{Margin of error} & (0.05) & \end{array}$$

Based on the formula, 400 respondents were sampled for this study. The proportionate distribution of the sample size by the neighbourhoods in the study area: Sample size per neighborhood = Neighborhood household size × Sample size / Total household size.

3.4.4 Sampling Technique

Sampling technique is the strategy adopted in composing a representative sample of the population in a sample study. Convenience sampling technique was used to administer questionnaires to the adult members of the neighbourhood where LPG stations are located at household level in the study area while Purposive sampling was used to conduct structured interviews with the managers of the LPG stations within Kaduna metropolis.

3.5 Method of Data Collection

This research study relied on both primary and secondary methods of data collection for the purpose of achieving the research objectives.

3.6 Data Analysis Procedures

The study considered the compliance of liquefied petroleum gas stations in the study area to the DPR standards namely: land size, 15 metres setback to the road, 15 metres to railway right of way, 60 metres to 330kv PHCN power line cable, 50 metres setback to public buildings, and 100 metres distance between two LPG stations.

GIS analysis was performed using ArcGIS version 10.2 environment. The tabulate intersection tool was used to obtain the LPG filling stations in buffer of 15 metres radius on both sides of the road. Buffer analysis was employed to determine compliance with setback requirements. Descriptive statistics (frequencies and percentages) were used to summarize compliance levels.

IV. RESULTS AND DISCUSSION

4.1 Compliance Level of Liquefied Petroleum Gas Stations to DPR and Planning Standards in Kaduna Metropolis

This study considered the compliance of liquefied petroleum gas stations in the study area to the DPR standards namely: land size, 15 metres setback to the road, 15 metres to railway right of way, 60 metres to 330kv PHCN power line cable, 50 metres setback to public buildings, and 100 metres distance between two LPG stations.

4.1.1 Analysis 1: Applying the "Risk Society" Theory (Beck, 1992)

The proliferation of non-compliant LPG stations in Kaduna metropolis can be analyzed through Ulrich Beck's concept of "organized irresponsibility." The system is structured such that risks are produced (by station owners/developers), but accountability is diffused across multiple agencies (DPR, KASUPDA, and Fire Service), with no single entity holding ultimate responsibility for prevention. The modern risk of a gas explosion is manufactured through urban development decisions, yet the consequences are borne by the public.

4.1.2 Analysis 2: The "Perverse Subsidy" of Non-Compliance

Drawing from environmental economics literature, non-compliance can be analyzed as an implicit subsidy. A station that avoids the costs of proper land (in an industrial zone), advanced safety engineering, and full permitting gains an unfair competitive advantage over a fully compliant station. This creates a market distortion that penalizes safety. In Kaduna's competitive LPG market, this economic pressure likely forces even well-intentioned operators to cut corners to survive, creating a race to the bottom in safety standards.

4.1.3 Analysis 3: The "Implementation Gap" in Multi-Level Governance

Policy implementation theory (Pressman & Wildavsky, 1973) helps analyze the compliance failure as a classic "implementation deficit." The vertical governance structure sees policy formulated at the federal level (DPR), but implementation relies on state (KASUPDA, Fire Service) and local actors with different priorities and capacities. The "clearance chain" for a compliant station is as weak as its weakest link. If KASUPDA is underfunded or prone to informal influence, the entire regulatory edifice collapses, regardless of DPR's technical competence.

4.1.4 Analysis 4: Spatial Analysis Using "Defensible Space" Theory (Newman, 1972)

Applied to Kaduna's metropolis LPG stations, a non-compliant station embedded in a residential area has no "defensible" safety zone. Its boundaries are blurred; activities like smoking or cell phone use by the public go unsupervised. In contrast, a station in a properly zoned industrial area has a clearly defined territory where safety protocols are more naturally enforced. The very siting violates principles of defensible space, making daily safety management inherently harder.

4.2 Land Size of Liquefied Petroleum Gas Stations

Table 4.1 shows the level of compliance of liquefied petroleum gas stations to the minimum of 2 plots of 100 by 100 feet land size in the study area.

Table 4.1: Compliance of Liquefied Petroleum Gas Stations to Land Size in Kaduna Metropolis

Land Size	No. of LPG Stations	Percentage
Less than 2 plots of 100 by 100 feet	9	42.9
Equal to and greater than 2 plots of 100 by 100 feet	12	57.1
Total	21	100

Table 4.1 revealed that 57% of the LPG filling stations in Kaduna metropolis satisfy the minimum 2 plots of 100 by 100 feet land size planning standard while only 43% did not meet the standard. This implies that the

minimum land size standard for siting LPG filling stations has been complied with by most LPGs in Kaduna metropolis.



Figure 4.1: Compliance to Land Size in Kaduna Metropolis

Figure 4.1 gives a graphical representation of the distribution of liquefied petroleum gas stations compliance to minimum land size in Kaduna metropolis.

4.3 Road Setback to Liquefied Petroleum Gas Stations
Figure 4.2 shows the liquefied petroleum gas stations compliance to a road setback of 15 metres in the study area.

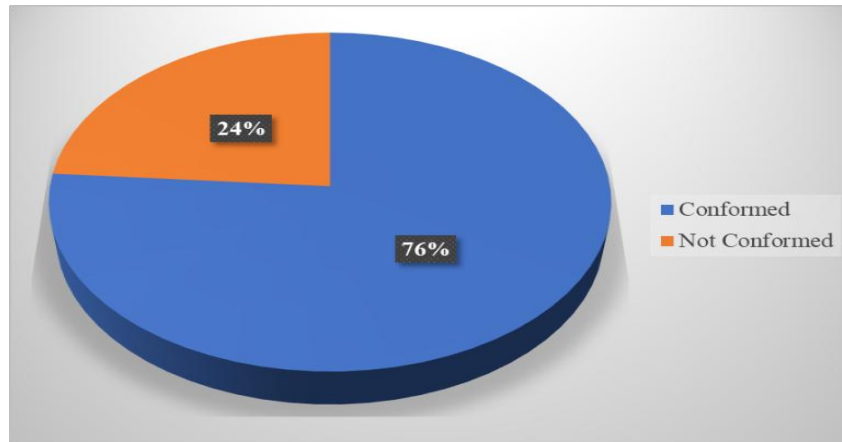


Figure 4.2: LPG Stations Compliance to Road Setback

The tabulate intersection tool in ArcGIS was used to obtain the LPG filling station in buffer of 15 metres radius on both sides of the road. The result revealed that 76% of the LPGs met the standard of 15 metres road setback while 24% of the LPGs didn't meet up

with the 15 metres' setback. The graphical representation of the buffer radius is as shown in Figure 4.3.

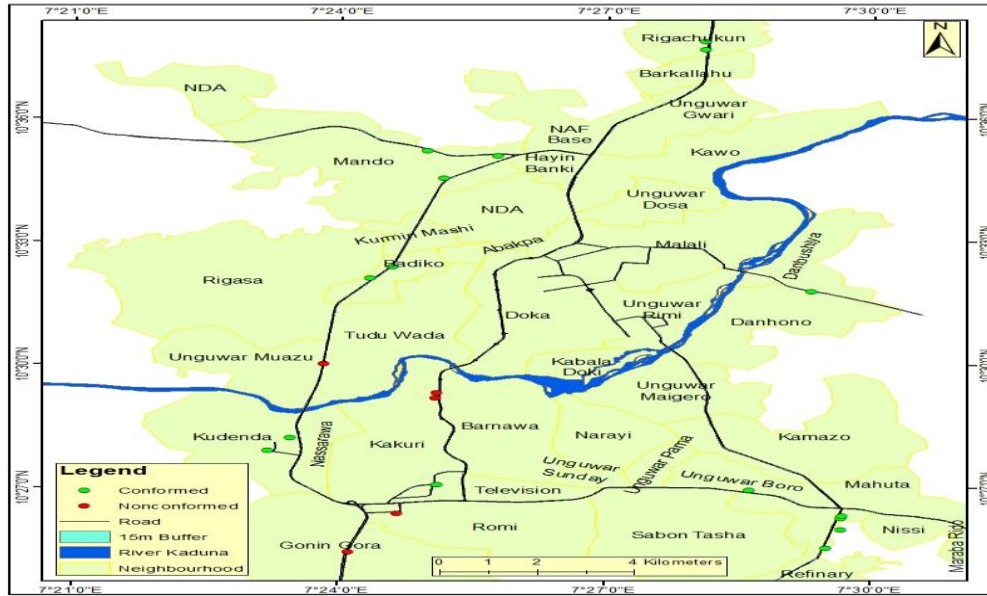


Figure 4.3: LPGs Compliance to Road Set Back in Kaduna Metropolis

4.4 Railway Right of Way to Liquefied Petroleum Gas Stations

Figure 4.4 shows the liquefied petroleum gas stations compliance to 15 metres setback to railway right of way in the study area.

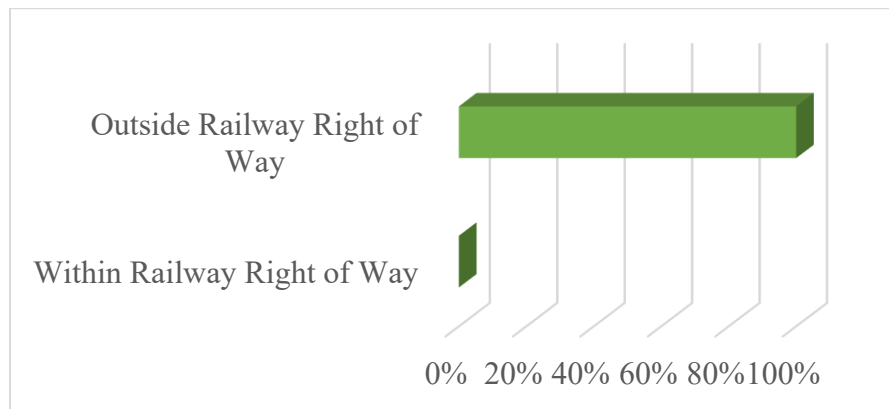


Figure 4.4: LPG Stations Compliance to Railway Right of Way

Figure 4.4 revealed that 100% of the LPG stations in Kaduna metropolis were located outside the 15 metres buffer radius to rail line right of way. Figure 4.5 further illustrates the graphical distribution of the LPG

stations compliance to 15 metres located away from the railway right of way.

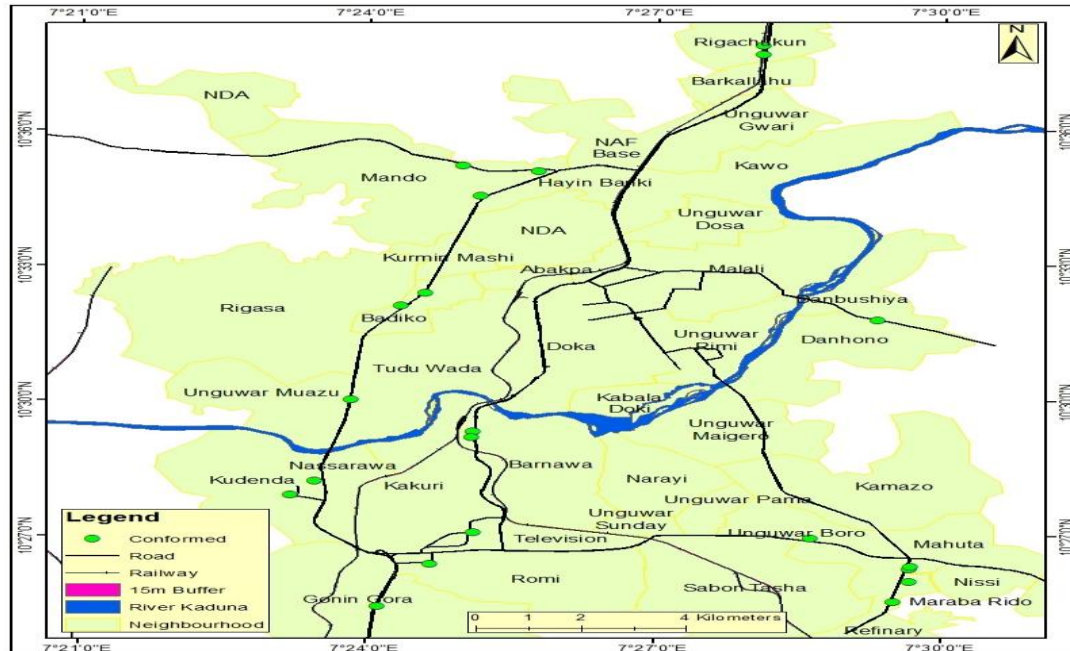


Figure 4.5: LPG Compliance to Railway Right of Way in Kaduna Metropolis

4.5 PHCN Power Line Right of Way to Liquefied Petroleum Gas Stations

Figure 4.6 shows the liquefied petroleum gas stations compliance to 15 metres setback to PHCN power line right of way in the study area.

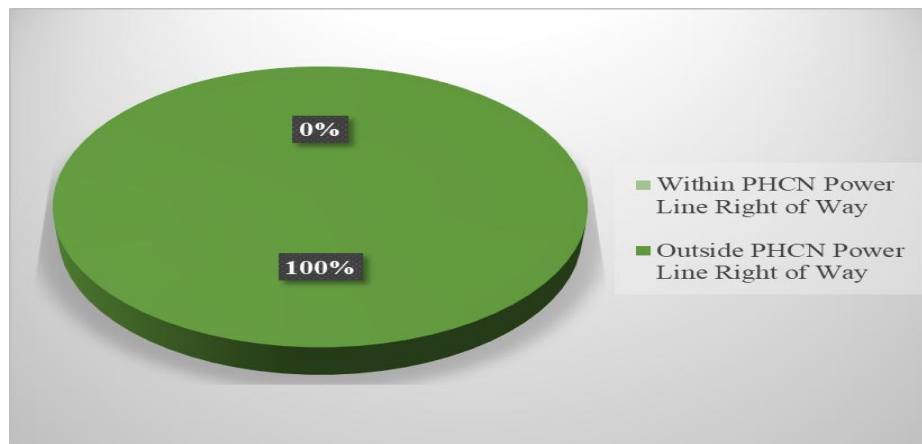


Figure 4.6: LPG Stations Compliance to PHCN Power Line Right of Way

Figure 4.6 shows that all the LPG stations were not located within the 15 metres buffer radius to PHCN power line right of way. This is an indication that there is total compliance of LPG stations to PHCN power line setback. The graphical distribution of the LPG

stations compliance to 15 metres not to be sited within PHCN transmission power lines right of way is as indicated in Figure 4.7.

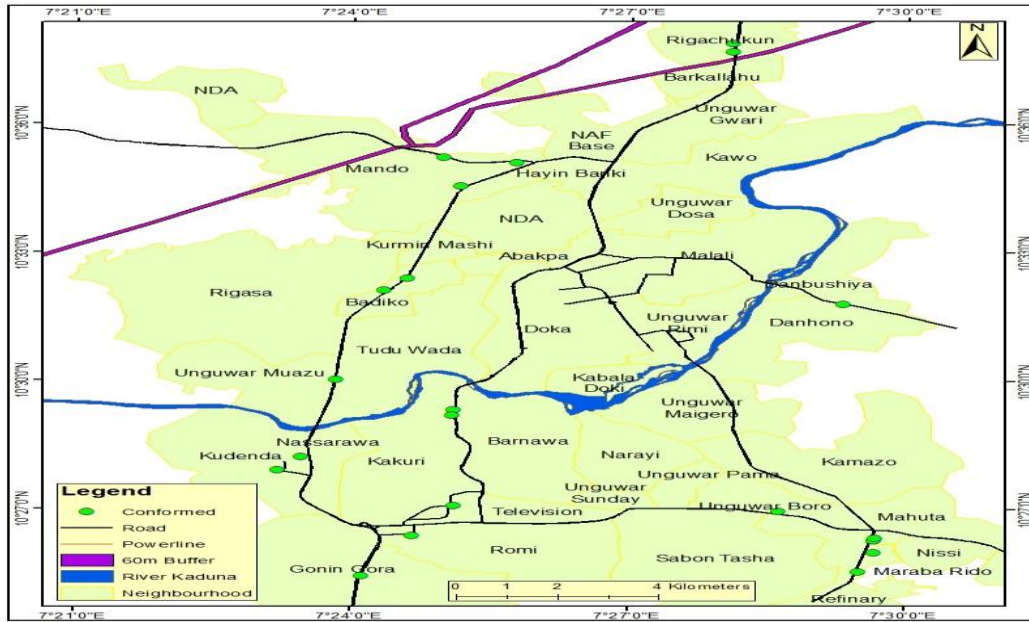


Figure 4.7: LPGs Compliance to PHCN Power Line Right of Way in Kaduna Metropolis

4.6 Public Buildings Setback to Liquefied Petroleum Gas Stations

Figure 4.8 shows the liquefied petroleum gas stations compliance to 50 metres setback to public buildings in the study area.



Figure 4.8: LPG Stations Compliance to Public Buildings Setback

Figure 4.8 indicated that 100% of the LPG stations were located 50 metres away from public buildings such as schools, healthcare facilities, parks among others in Kaduna metropolis. The graphical

distribution of the LPG stations compliance to 50 metres buffer radius to public buildings is as shown in Figure 4.9.

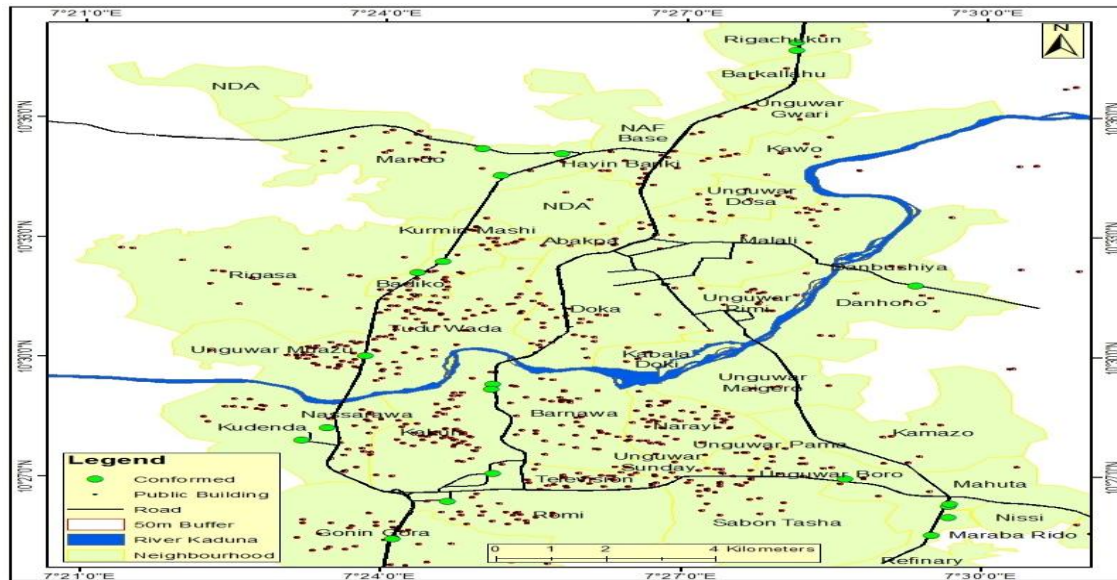


Figure 4.9: LPGs Compliance to Setback to Public Buildings in Kaduna Metropolis

4.7 Minimum Distance between Two Liquefied Petroleum Gas Stations

Figure 4.10 shows the liquefied petroleum gas stations compliance to 100 metres minimum distance between two LPG stations in the study area.

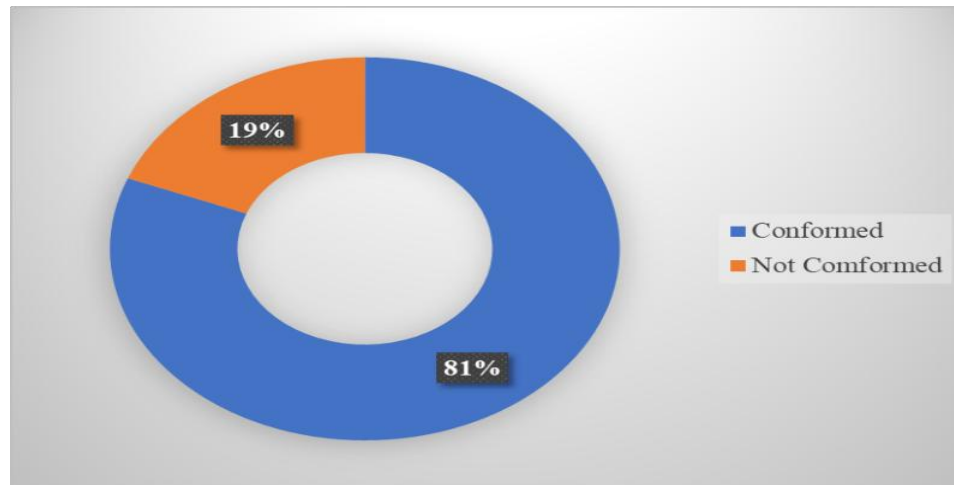


Figure 4.10: LPG Stations Compliance to Minimum Distance Between Two LPG Stations

Figure 4.10 revealed that about 81% of the LPG stations in Kaduna metropolis conformed with the 100 metres distance while only 19% did not meet the standard. This implies that distance as a standard for siting LPG stations has relatively been complied with

by the LPG station operators in Kaduna metropolis. Figure 4.11 indicates the graphical representation distribution of LPG stations compliance to 100 metres distance apart standard.

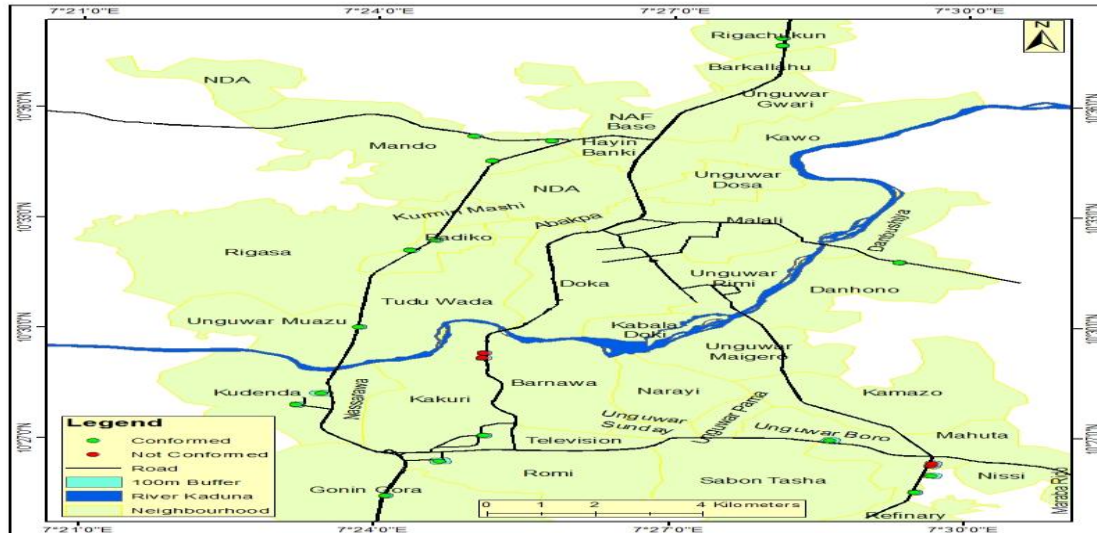


Figure 4.11: Compliance to Distance between two LPGs in Kaduna Metropolis

4.8 Discussion of Findings

The compliance assessment reveals a mixed landscape that reflects both regulatory successes and systemic failures in the siting and operation of LPG filling stations in Kaduna Metropolis. The finding that 100% of stations complied with setbacks from railways, PHCN power lines, and public buildings is encouraging and suggests that where regulatory oversight is straightforward and measurable particularly regarding fixed infrastructure like transmission lines and public institutions operators have largely adhered to DPR standards. However, the significant non-compliance with land size requirements (43% failure rate), road setbacks (24% failure rate), and inter-station spacing (19% failure rate) exposes a more troubling pattern: compliance is weakest precisely where it matters most for daily safety and emergency response. These findings align with empirical evidence from Akpor, Port Harcourt, where petrol stations neither conformed to the required 15-metre road setback nor the 400-metre inter-station distance (Samuel et al., 2015), and from Ilaro, Ogun State, where the clustered pattern of stations reflected a similar disregard for planning standards (Abdullahi, 2020). The consistency of these findings across multiple Nigerian cities suggests that non-compliance is not an isolated Kaduna phenomenon but rather a nationwide regulatory enforcement challenge, validating Ogunkoya and Adewoyin's (2020) observation that zoning laws and safety regulations are routinely undermined in high-density urban areas

where market demand and space constraints create tension with regulatory adherence.

The theoretical frameworks employed in this study provide a compelling explanation for why such widespread non-compliance persists despite the existence of clear regulatory standards. Beck's (1992) concept of "organized irresponsibility" aptly describes the Kaduna situation, where risks are produced by station owners and developers, yet accountability is diffused across multiple agencies DPR, KASUPDA, and the Fire Service with no single entity holding ultimate responsibility for prevention. The "implementation gap" identified by Pressman and Wildavsky (1973) further explains how federal policies formulated by DPR fail to translate into effective enforcement at the state and local levels, where underfunded agencies and informal influences weaken the entire regulatory chain. The economic dimension of non-compliance, analyzed as a "perverse subsidy," reveals a troubling market dynamic: stations that avoid the costs of proper land acquisition in industrial zones, advanced safety engineering, and full permitting gain an unfair competitive advantage over compliant operators, creating a race to the bottom in safety standards. This economic pressure, combined with the jurisdictional ambiguity between DPR and KASUPDA, creates an environment where non-compliance becomes rational for individual operators even as it produces collectively dangerous outcomes. The result is a landscape of normalized urban risk

where 43% of LPG stations operate on substandard land sizes and nearly one in four violate basic road setback requirements conditions that violate Newman's (1972) principles of defensible space and render daily safety management inherently difficult. Without decisive intervention to close the implementation gap, strengthen inter-agency

coordination, and realign economic incentives toward compliance, Kaduna Metropolis remains vulnerable to the cascading consequences of a major LPG incident, a risk that grows more acute with each additional non-compliant station approved.

4.9 Summary of Compliance Findings

Table 4.2: Summary of LPG Station Compliance with DPR and Planning Standards in Kaduna Metropolis

Standard	Compliance Rate (%)	Non-Compliance Rate (%)	Status
Land Size (min. 2 plots of 100ft x 100ft)	57.1	42.9	Partial Compliance
Road Setback (15 metres)	76.0	24.0	Partial Compliance
Railway Right of Way (15 metres)	100.0	0.0	Full Compliance
PHCN Power Line Right of Way (15 metres)	100.0	0.0	Full Compliance
Public Buildings Setback (50 metres)	100.0	0.0	Full Compliance
Inter-Station Distance (100 metres)	81.0	19.0	Partial Compliance

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study assessed the extent to which LPG filling stations in Kaduna Metropolis comply with DPR standards and planning standards. The findings reveal a mixed compliance landscape. While adherence was high for setbacks from railways (100%), PHCN power lines (100%), and public buildings (100%), critical violations were prevalent:

Land Size: 43% of stations failed to meet the minimum requirement of two plots (100ft x 100ft), **Inter-station Spacing:** 19% of stations were located less than 100 metres from another LPG facility, **Road Setback:** 24% of stations did not maintain the mandatory 15-metre setback from the road.

This widespread non-compliance indicates a systemic failure in regulatory enforcement and creates a landscape of normalized urban risk. The study concludes that the spatial distribution and compliance failures of LPG stations in Kaduna Metropolis are products of unregulated market forces overriding formal planning and safety regulations. The pervasive

non-compliance with DPR standards is not merely a technical oversight but a symptom of deeper institutional failures in multi-level governance, regulatory enforcement, and development control. Consequently, the city has inadvertently zoned itself into areas of high-risk concentration and areas of energy deprivation. Without decisive intervention, the continued proliferation of LPG stations under the current paradigm poses a significant threat to urban safety, equity, and orderly development.

5.2 Recommendations

Based on the findings and conclusions, the following recommendations are made to guide policymakers, regulatory agencies, and urban planners towards a safer, more equitable, and better-planned LPG distribution system in Kaduna Metropolis and similar contexts:

5.2.1 To the Government and Regulatory Agencies (DPR & KASUPDA):

1. **Enforce a Moratorium and Conduct a Safety Audit:** Immediately impose a moratorium on the approval of new LPG stations in identified high-density risk clusters. A comprehensive, joint DPR-KASUPDA safety audit of all existing stations must be

conducted. Stations found in severe violation, especially those within residential areas or posing imminent danger, should be relocated or decommissioned.

2. **Strengthen Inter-Agency Collaboration and Create a One-Stop Portal:** Establish a mandatory, integrated approval process. A digital "One-Stop Portal" should be created where developers must secure sequential, verified clearances from KASUPDA (planning/zoning), the Fire Service (safety and emergency access), and DPR (technical standards) before any license is issued. The approval chain must be transparent and each agency should have veto power based on its mandate.
3. **Develop and Enforce a Kaduna-Specific LPG Siting Master Plan:** Move beyond generic federal guidelines. KASUPDA, in collaboration with DPR, should use GIS to develop a detailed LPG Infrastructure Master Plan. This plan must:
 - i. Designate specific, safe zones (preferably within industrial or commercial layouts) for LPG stations.
 - ii. Define "exclusion zones" (near schools, hospitals, high-density residential areas, markets).
 - iii. Mandate a minimum spacing between stations to prevent clustering.
 - iv. Be integrated into the broader Kaduna Urban Master Plan.
4. **Adopt a "Safety-In-Depth" Licensing Model:** Shift from a one-time permit to a periodic, performance-based licensing system. Licenses should be renewable annually contingent upon:
 - i. Proof of valid insurance.
 - ii. Certification of safety equipment maintenance.
 - iii. Successful participation in mandatory emergency drills with the Fire Service.
 - iv. A clean record of regulatory compliance.

5.2.2 To Urban Planners and Policy Makers:

1. **Promote Decentralized Distribution Models:** To address access gaps without creating large, hazardous stations, encourage safer, smaller-scale models. This includes:
 - i. Cylinder Exchange Points: Advocate for licensed, secure retail shops in underserved neighbourhoods that only handle pre-filled, sealed cylinders, eliminating on-site bulk storage and refilling.

2. **Launch Public Awareness and Consumer Safety Campaigns:** The government should fund campaigns to educate residents on:
 - i. The dangers of non-compliant stations and how to identify them.
 - ii. Safe LPG usage practices in the home.
 - iii. Their right to report illegally sited or unsafe facilities to a dedicated hotline.
3. **Invest in Critical Emergency Response Infrastructure:** The Kaduna State Government must prioritize investment in the State Fire Service, including:
 - i. Acquiring specialized firefighting equipment for hydrocarbon fires.
 - ii. Establishing new fire stations strategically located to serve high-risk LPG clusters.
 - iii. Conducting regular, joint simulation exercises with LPG station operators.

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