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ASSESSMENT OF BUILDING ENCROACHMENT LEVEL OF RAFIN ZURFI AREA OF BAUCHI METROPOLIS ALONG THE CORRIDOR OF EXISTING 330KV POWER TRANSMISSION LINE.

Salisu Muhammad Baba[1] Buhari Mohammed Ardo[2] Abdullahi Nura Sani[3] Ahmed Wasiyya[4]
Correspondence email address: babasalisu77@gmail.com
Department of Urban and Regional Planning Federal Polytechnic Damaturu Yobe State1 Department of Building Technology Federal Polytechnic Damaturu Yobe State2 Department of Architectural Technology Federal Polytechnic Damaturu Yobe State3&4

Abstract
This study assesses the level of building encroachment along the 330kV power transmission line corridor in Rafin Zurfi, Bauchi Metropolis, Nigeria, in relation to regulatory standards established by the Nigerian Electricity Regulatory Commission (NERC) and the Transmission Company of Nigeria (TCN). Rapid urbanization and weak enforcement of land-use regulations have led to widespread encroachment into transmission line right-of-ways (ROWs), posing significant safety risks and threatening infrastructure integrity. The research employed a mixed-methods survey design, integrating spatial analysis using QGIS software with questionnaire administration to 145 household heads whose buildings fall within the 50-meter setback zone, as well as interviews with officials from the Bauchi State Urban Planning Board and TCN.The spatial analysis revealed that out of 8,315 total buildings in Rafin Zurfi, 606 buildings (7.3%) encroach within the mandated 50-meter setback of the 330kV transmission line. Of these, 87 buildings (14.4%) are situated in the critical 0-10 meter zone, 214 buildings (35.3%) in the 11-25 meter high-risk zone, 198 buildings (32.7%) in the 26-40 meter moderate-risk zone, and 107 buildings (17.6%) in the 41-50 meter low-risk zone. Residential buildings constitute the majority of encroachments (80.9%), followed by commercial (12.5%), mixed-use (5.3%), and religious/community buildings (1.3%). Findings indicate that economic pressures including land scarcity, high property costs, and proximity to livelihoods combined with regulatory failures such as lack of enforcement and public ignorance are the primary drivers of encroachment. Awareness of regulations is critically low: 66.9% of respondents were unaware of any construction restrictions when building, only 15.9% correctly identified the 50-meter setback requirement, and 55.2% were classified as having "low" overall awareness. Safety incidents are prevalent, with 46.2% reporting sparking from lines during rain, 29.7% experiencing minor electric shocks, and 8.3% reporting fires traced to electrical faults. Self-reported health issues include frequent headaches (61.4%), sleep disturbances (49.7%), and dizziness (40.0%). Power supply disruptions are frequent, with 83.5% experiencing outages at least weekly. The study concludes that significant and dangerous building encroachment exists along the 330kV transmission line corridor in Rafin Zurfi, resulting from the convergence of economic necessity among a low-income, poorly educated population and systemic failures in regulatory enforcement, public awareness, and urban planning. Urgent multi-sectoral intervention is required, including demolition of buildings in the critical zone, relocation of affected residents, strengthened enforcement mechanisms, comprehensive public awareness campaigns, and long-term urban planning reforms to prevent further encroachment and ensure public safety.

Keywords: Building encroachment, transmission line, Right-of-Way, setback regulations,

Introduction
Encroachment, as defined by Harvey and Jowsey (2019), refers to the unauthorized or gradual introduction of a building, item, or activity onto another person's property, land, or public area. This phenomenon often involves violations of zoning regulations, property boundaries, and other

land use issues. Such encroachments can lead to disputes between property owners and may require legal intervention to resolve conflicts and restore rightful boundaries and land-use policies. Building extensions, fences, driveways, and businesses that extend beyond legal boundaries are examples of encroachments, which can occur either purposefully or inadvertently (Merriam, 2020). In addition to disrupting the electrical supply, these encroachments pose significant safety risks, including the potential for electrocution and fire hazards (Okafor, 2020).

High voltages, usually between 132 kV and 330 kV, are used by electrical transmission lines worldwide; hence, proper clearance distances are necessary to avoid electromagnetic interference and safety risks (NERC, 2021). Minimum setback lengths have been established by the Transmission Company of Nigeria (TCN) and the Nigerian Electricity Regulatory Commission (NERC) to reduce these dangers. For example, the minimum distance needed to build close to electricity lines is 15 by 20 meters for 11/33 kV, 30 meters for 132 kV, and 50 meters for 330 kV. There are instances where buildings, marketplaces, and other structures encroach on the setbacks of transmission line corridors, potentially due to a lack of enforcement of these regulations (Ajayi & Akinyemi, 2019).

Uncontrolled urbanization is a major cause of transmission line corridor encroachments in Nigeria, where informal settlements commonly ignore statutory building lines and setback measures, according to research by Okonkwo, Eze, and Musa (2020). Transmission line intrusions endanger the security of maintenance workers and the general public. The risk of electrical fires, flashovers, and unintentional contact during building operations is increased by being close to high-voltage lines, according to Shilpakar, Shakya, and Pradhan (2018). Because they can interfere with the stability and operation of the electrical infrastructure, building encroachments on corridors used for electricity transmission lines have raised concerns (Gonçalves, Santos, & Ferreira, 2020). Risks associated with the construction of residential, commercial, and industrial buildings close to transmission corridors include potential safety hazards, disruptions to electrical operations, and higher maintenance and repair costs (Adebayo, 2022).

As a result, this encroachment typically results in unplanned and uncontrolled development, and the encroaching towns suffer from both chaotic development and a lack of essential infrastructure. Fahria (2009) attributes this trend to the lack of effective institutional arrangements for management.

Statement of the Research Problem

Electricity is one of the greatest inventions in human history, playing a crucial role in modern living and serving as the foundation for the socioeconomic growth of any economy. According to Patidar, Kumar, and Dubey (2015), it is transmitted at high voltages to minimize energy loss during long-distance transmission.

Electrical power generated is distributed and transported at different voltages and through a variety of ways. The three components of Nigeria's power transmission and distribution system are as follows: "high voltage transmission lines (HVTL)," which run from generating stations to transmission substations at 330KV and 132KV; "distribution lines/high tension lines (HTL)," which run from transmission substations to injection substations at 33KV and 11KV (these lines pass through the majority of our neighbourhoods and work areas); and Low Tension Lines (LTL) and service drops are 0.415KV cables that connect utility customers to poles (Soneye & Daramola, 2012). Large-scale construction of these HVTLs has made them a vital component of both urban and rural environments, a system of built infrastructure that is merely necessary for productive human endeavors (Xu, Wang, & Zhang, 2016).

However, there are other risks connected with being close to the HVTL equipment, including the possibility of electrocution, fire, and, most importantly, electromagnetic radiation exposure (Wagner, Rosch, & Kern, 2006). The public and scientific community are now concerned about these electrical infrastructures and the electromagnetic radiation they emit because of the possible negative impact they may have on the environment and human health (World Health

Organization, 2007; Alkoot & Zaeri, 2011; Nkeki, 2013; Otitoloju et al., 2013; Olamiju & Oyinlioye, 2015; Priya & Anbalagan, 2016).

The HVTLs that cross villages, isolated communities, and lagoons in Nigeria are currently noticeably exposed as a result of the settlements' quick development and integration into the city (Akinjare, Oluwunmi, & Iroham, 2012; Akinjare, Oni, & Iroham, 2014). Particularly in highly populated locations, these HVTLs are now located near residential homes, schools, offices, hospitals, churches, and mosques (Otitoloju et al., 2013; Olamiju & Oyinlioye, 2015).

Rafin Zurfi Neighborhood area of Bauchi metropolis accommodates number of HVTLs corridors presently. Thus, making the area one of the most exposed to unrestricted encroachment of Right-of-Ways in Nigeria.

The increasing rate of urbanization in Bauchi has led to encroachment into the restricted RoWs for HTVLs against the laid down regulations of the government, buildings of different kinds and shapes are being erected continuously while some other human activities are in full-fledge (Bauchi Survey, 2023).

Therefore, this study aims to assess building encroachment level of Rafin Zurfi Area of Bauchi Metropolis along the corridor of existing 330kV power transmission line in line with the regulatory standards.

Literature Review

Population expansion and urbanization have put more strain on land use, which has caused utility corridors such as those carrying electricity to encroach. Significant concerns associated with power line encroachment include electrical hazards, service interruptions, and regulatory infractions (Olerum, 2022). Research on the effects of high voltage overhead transmission lines (HVOTLs) on property prices has been encouraged by recent changes in infrastructure and energy policy (Anderson, Williamson, & Wohl, 2017).

According to a report published by the Nigeria Electricity Regulation Company (NERC) in the second quarter of 2019, at least three (3) people nationwide were electrocuted every week between April and June 2019, supporting the systemic decay in the power industry. In order to guarantee public safety, system dependability, and ease of maintenance, electricity transmission lines which are essential parts of the country's energy infrastructure need clearly defined setbacks, or clearances. However, in many nations, especially in areas that are fast becoming more urbanized, encroachments, illegal occupations, or developments within these designated corridors continue to be a chronic concern (Lawal, 2021).

The Nigeria Power Regulation Company (NERC) maintains a mandatory "no-obstruction" policy for its power transmission lines' rights-of-way because of these factors. For the safety of the inhabitants and NERC employees, the corridors underneath them must remain free. In accordance with the Nigerian Electricity Supply and Installation Standards Regulations (NESISR) (2015), the minimum clearance lengths between power lines and any type of ground-based development activities are 11 m, 11 m, 30 m, and 50 m for 11 kV, 33 kV, 132 kV, and 330 kV, respectively. Additionally, considering the rate of urban expansion due to rural-urban migration, the federal government has strict overhead power line reliability standards (Olerum, 2022).

Causes of Encroachments on the Setbacks of Electricity Transmission Lines

Rapid urbanization, inadequate urban planning, and lax enforcement of land-use restrictions frequently result in encroachment on transmission lines (Ogunleye & Adebayo, 2019). According to Lawal (2021), informal settlements are fueled by the growing need for housing in emerging nations and frequently spread into areas intended for vital infrastructure.

Economic factors like land scarcity and high property costs are major causes of encroachment, according to a study by Okafor and Chukwuma (2022). Inadequate public awareness and poor governance also contribute to the ongoing issue of illegal construction near power lines (Nuhu, Mohammed, & Ibrahim, 2021). Electricity transmission lines are essential parts of the country's

energy infrastructure and require clearly defined setbacks (clearances) to ensure public safety, system reliability, and ease of maintenance.

Unauthorized occupations and developments within these designated corridors, however, continue to be a persistent problem in many countries, especially in areas that are rapidly urbanizing. These issues include a lack of up-to-date mapping and infrastructure records, socioeconomic pressures and informal settlements, poor public awareness and community engagement, political interference and corruption, land scarcity and high property costs, and weak land use regulations and enforcement (Lawal, 2021).

Impacts of Encroachments on Electricity Transmission Lines

Encroachment on transmission lines presents a number of risks, such as damage to infrastructure, problems with service reliability, and hazards to public safety. Structures constructed within power lines' right-of-way raise the possibility of electrical failures, fires, and electrocution. According to Adekunle, Bamidele, and Ogunleye (2020), encroachments on electrical transmission line corridors have major effects on safety, operations, and the economy in addition to creating planning and regulatory difficulties.

Numerous academics have looked into how unpermitted construction beneath or close to high-voltage lines jeopardizes public safety, urban development, and infrastructure integrity (Oladipo, 2018). According to a case study conducted in Nigeria by Yusuf and Bello (2021), encroachment on electrical transmission corridors causes frequent power outages and lowers energy suppliers' profits. Public health and safety risks, operational and maintenance challenges, transmission line failures and system disruptions, economic losses and cost implications, environmental degradation, and compromise of urban planning and development are some of the effects of these encroachments, according to Adewuyi and Oduwaye (2020).

Clearance Requirements for Electricity Transmission Lines in Nigeria

Vertical and horizontal clearance distance requirements.

According to NEMSA (2016) and NERC Guidelines (2020), the following minimum clearance distances are required:

Table 1: Vertical Clearance (From Ground to Conductor)

Voltage Level	Minimum Clearance (to Ground)
11kV	5.5 meters
33kV	6.0 meters
132kV	7.5 meters
330kV	8.5 – 9.0 meters

Source: NERC Guidelines, 2020; Author's Compilation, 2026

Table 2: Horizontal Clearance (From Buildings or Structures)

Voltage Level	Minimum Horizontal Clearance
11kV	3.0 meters
33Kv	4.0 meters
2kV13	10.0 meters
330kV	15.0 meters

Note: For safety, no building or permanent structure is allowed within the Right-of-Way (ROW) corridor.

Source: NERC Guidelines, 2020; Author's Compilation, 2026

Table 3: Right-of-Way (ROW) Width Requirements

Voltage Level	Required ROW Width (Total)
11kV	15 meters (7.5 m each side)
33kV	20 meters

132kV	30 meters
330Kv	50 meters

Source: NERC Guidelines, 2020; Author's Compilation, 2026

Regulatory authorities and document.

Nigerian Electricity Management Services Agency (NEMSA): Ensures technical standards and safety under the Electric Power Sector Reform Act (2005).

Nigerian Electricity Regulatory Commission (NERC): Issues codes and safety guidelines (NERC Health and Safety Code, 2020).

Transmission Company of Nigeria (TCN) enforces right-of-way and operational guidelines, while the National Building Code (2006) Specifies clearance from electrical infrastructure for construction safety. Encroachments into transmission ROWs are considered illegal under the Electric Power Sector Reform Act and can lead to demolition, prosecution, or compensation denial in the event of loss.

Methodology

The study is a non-experimental research design. Specifically, it utilized the survey research design using the mixed approach. Creswell and Clark (2018) highlighted the value of mixed-methods research in providing a more nuanced understanding of complex phenomena by integrating the strengths of both quantitative and qualitative approaches. It focused on the extent of building encroachment within the setbacks of 330kV electricity transmission line, factors contributing to building encroachment within the corridor of electricity transmission line, the impacts of building encroachment on the setbacks of electricity transmission line, household awareness on the associated dangers of building under high voltage electricity transmission lines (HVETL), and highlight the existing strategies for mitigating building encroachment within the setbacks of electricity transmission line.

Data for this research was obtained from two main sources which include primary and secondary sources. The Primary data was obtained from the household heads of the selected residents, official of the BSUPDB and TCN through field survey and questionnaire administration. While secondary data was obtained from journal articles, text books, and relevant literatures. ArcGIS software (GIS Version 3.32.0) was used to map out the prescribed setback of the electricity transmission lines. Consequently, the building that fall within the 50m setback was counted in the GIS environment to determine the number of buildings that have encroach the setback of the transmission lines for each settlement.

The target population for this study comprises household heads whose buildings are encroached within the 50m setbacks of the electricity transmission lines, officials of the Bauchi State Urban Planning and Physical Development Board and Transmission Company of Nigeria.

The Study Area

Bauchi Metropolis, the capital city of Bauchi State, is situated in the northeastern geopolitical zone of Nigeria. Geographically, it lies between latitudes 10°18′N to 10°22′N and longitudes 9°47′E to 9°52′E, resting on the northern edge of the Jos Plateau. The metropolis is part of the larger Bauchi Local Government Area, one of the 20 LGAs that make up the state (Ogbonna, 2016).

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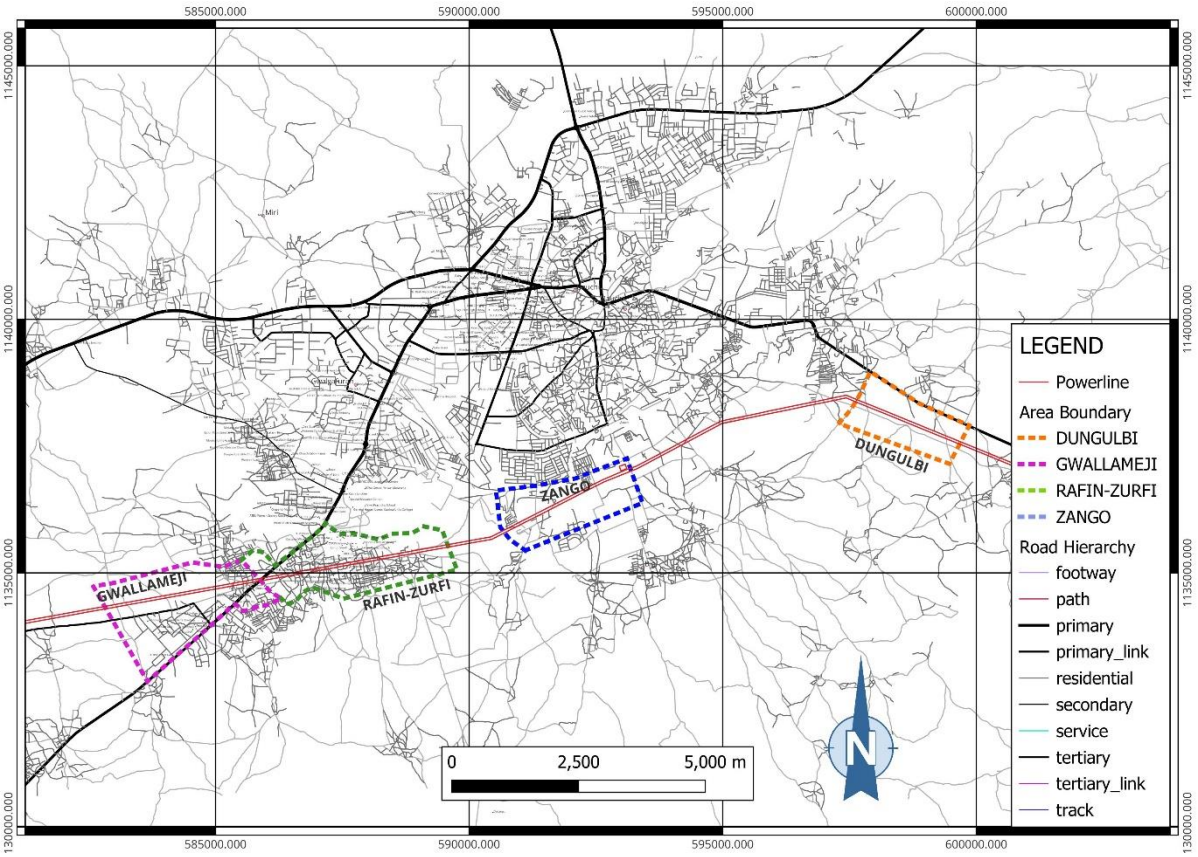

Figure 1: Map of Neighborhoods in Bauchi metropolis with 330kv power line
Source: Author's Compilation (2026)

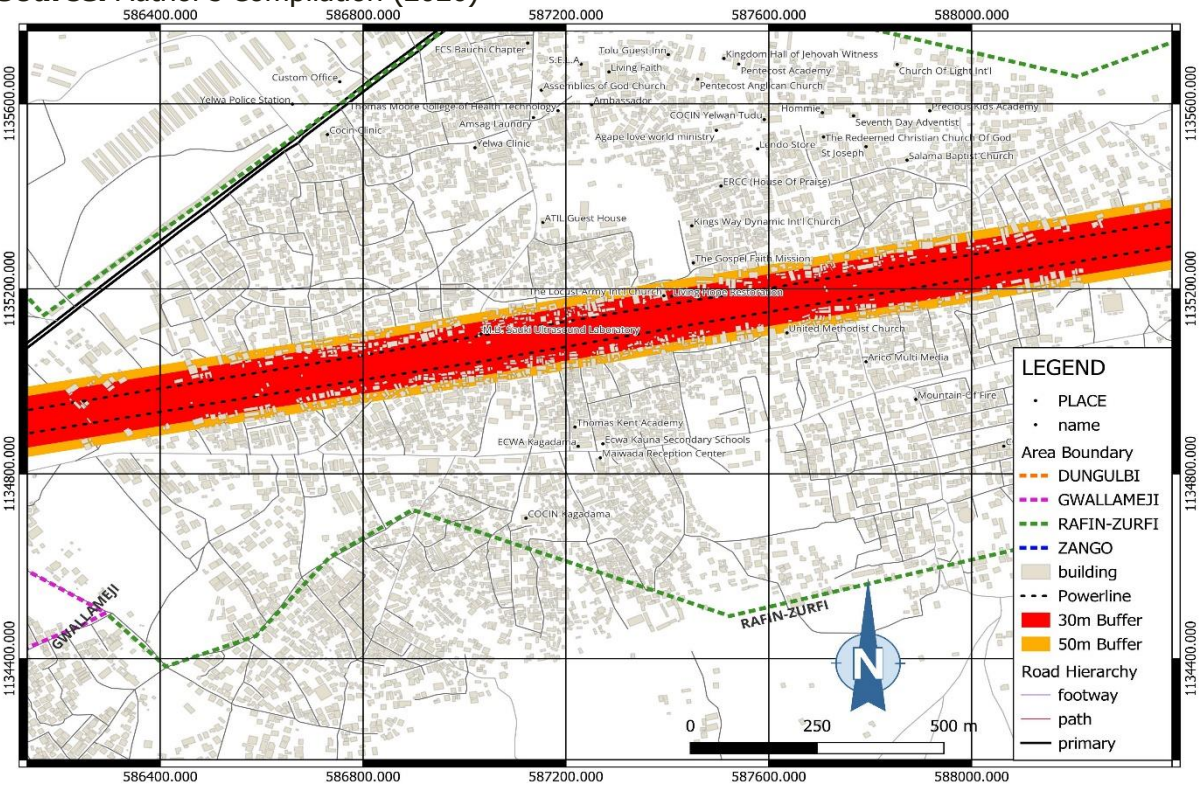

Figure 2: Rafin Zurfi neighborhood Map
Source: Author's Compilation (2026)

Analysis and Results

The spatial analysis conducted in QGIS revealed a significant level of building encroachment in Rafin Zurfi within the mandated 50-meter setback of the 330kV transmission lines. Using QGIS software (Version 3.32.0), a 50-meter buffer zone was created on both sides of the 330kV transmission line traversing the study area in accordance with NERC (2020) regulations requiring 50m Right-of-Way (ROW) for 330kV lines (Figure 2).

Critical finding of 8,315 total buildings in Rafin Zurfi, 606 buildings (7.3%) encroach within the 50m setback of the 330kV transmission line (Table 4). Eighty-seven buildings (14.4%) are in the 0-10m critical zone – immediate danger, 214 buildings (35.3%) are within 11-25m high-risk zone, 198 buildings (32.7%) within 26-40m moderate-risk zone while 107 buildings (17.6%) are within 41-50m low-risk zone. Table 5 shows that residential buildings dominate (80.9%), followed by commercial uses which account for 12.5%, mixed-use 5.3% while religious/community buildings account for 1.3% have encroached. The affected population (n=145 respondents) is characterized by male which dominated 77.2% household heads, predominantly working-age account for 69% between 31-60 years. 46.2% of the population has no formal education while 66.2% without basic formal education (Table 7).

Factors contributing to encroachment indicated that economic pressures (land cost, poverty, proximity to livelihoods) and regulatory failure (lack of enforcement, ignorance) emerge as the strongest drivers as shown in (Table 8). Awareness of Regulations as shown in (Tables 9, 13, 17) reveals that 66.9% were unaware of any construction restrictions when building, only 15.9% correctly identified the 50m setback requirement for 330kV lines and 48.2% admitted not knowing the required distance. Overall awareness level only 12.4% classified as "high" awareness; 55.2% have "low" awareness.

Table 14 has shown the respondent knowledge of specific risks where 77.2% are aware of electrocution risk (most recognized), 67.6% are aware of fire hazard, only 23.4% are aware of electromagnetic field (EMF) health effects while 60% are aware of lightning attraction risk. Safety Impacts (multiple responses) are shown in Tables 10-12 where 46.2% reported sparking from lines during rain, 29.7% experienced minor electric shocks, 21.4% reported near-miss accidents, 8.3% experienced fires traced to electrical faults, and 3.4% reported injuries from fallen conductors while 35.9% reported no incidents. Self-reported health issues, 61.4% frequent headaches, 49.7% sleep disturbances, 40.0% dizziness, 35.2% fatigue/weakness, 15.9% skin irritations and 28.3% reported no health issue. It also reveals power supply disruptions where 83.5% experience outages at least weekly (46.2% several times weekly; 15.9% daily). Government awareness campaigns reaching only 5.5% of affected population represent a critical gap.

Table 4: Building Encroachment Statistics for Rafin Zurfi

Parameter	Value
Total number of buildings in Rafin Zurfi	8,315
Buildings within 50m setback (encroached)	606
Buildings on left-hand side within 50m	402
Buildings on right-hand side within 50m	204
Percentage of total buildings encroached	7.3%
Linear extent of transmission line through area	3.2 km
Density of encroachment (buildings/km)	189 buildings/km

Source: Author's Compilation, 2026

Table 5: Proximity Classification of Encroached Buildings

Distance from Transmission Line	Number of Buildings	Percentage
0-10 meters (Critical zone)	87	14.4%
11-25 meters (High risk zone)	214	35.3%
26-40 meters (Moderate risk zone)	198	32.7%
41-50 meters (Low risk zone)	107	17.6%
Total	**606**	**100%**

Source: Author's Compilation, 2026

Table 6: Building Types within Setback Zone

Building Type	Number	Percentage
Residential (single-family)	372	61.4%
Residential (multi-family/rooming)	118	19.5%
Commercial shops/stores	76	12.5%
Mixed-use (residential + commercial)	32	5.3%
Religious/Community buildings	8	1.3%
Total	**606**	**100%**

Source: Author's Compilation, 2026

Table 7: Socio-demographic Profile of Respondents

Characteristic	Category	Frequency (n=145)	Percentage
Gender	Male	112	77.2%
	Female	33	22.8%
Age Group	18-30 years	31	21.4%
	31-45 years	58	40.0%
	46-60 years	42	29.0%
	Above 60 years	14	9.6%
Education Level	No formal education	67	46.2%
	Quranic only	14	10.0%
	Primary	23	15.9%
	Secondary	18	12.4%
	Tertiary	8	5.5%
Occupation	Trading/Business	54	37.2%
	Artisan	38	26.2%
	Civil servant	12	8.3%
	Farming	21	14.5%
	Unemployed	20	13.8%
Monthly Income	< ₦70,000	78	53.8%
	₦71,000 - ₦100,000	41	28.3%

₦101,000 - ₦200,000	18	12.4%
> ₦201,000	8	5.5%

Source: Author's Compilation, 2026

Table 8: Mean Score Ranking of Contributing Factors

Factor	Mean Score	Standard Deviation	Rank
Land scarcity/high cost of land elsewhere	4.62	0.51	1
Lack of enforcement of building regulations	4.58	0.63	2
Proximity to economic activities/employment	4.41	0.72	3
Ignorance of setback regulations	4.38	0.68	4
Poverty/lack of affordable housing alternatives	4.32	0.81	5
Family ties/inherited family land	4.11	0.94	6
Corruption among regulatory officials	3.89	1.12	7
Political interference/connections	3.76	1.24	8
Speculative development for future compensation	3.42	1.31	9

Source: Author's Compilation, 2026; **Note: Mean score interpretation: 1.00-1.80=Not significant; 1.81-2.60=slightly significant; 2.61-3.40=moderately significant; 3.41-4.20=Significant; 4.21-5.00=Very significant**

Table 9: Awareness of Regulations during Construction

Response	Frequency	Percentage
Unaware of any restrictions	97	66.9%
Aware but proceeded due to lack of enforcement	38	26.2%
Aware and attempted to comply	10	6.9%
Total	**145**	**100%**

Source: Author's Compilation, 2026

Table 10: Safety Incidents Experienced by Residents

Incident Type	Number Reporting (n=145)	Percentage
Electric shocks (minor)	43	29.7%
Sparking from lines during rain	67	46.2%
Fires traced to electrical faults	12	8.3%
Injuries from fallen conductors	5	3.4%
Near-miss accidents	31	21.4%
No incidents experienced	52	35.9%

Source: Author's Compilation, 2026
Note: Multiple responses possible

Table 11: Self-Reported Health Issues

Health Complaint	Frequency	Percentage
Frequent headaches	89	61.4%
Sleep disturbances	72	49.7%
Dizziness	58	40.0%
Fatigue/weakness	51	35.2%
Skin irritations	23	15.9%
No health issues reported	41	28.3%

Source: Author's Compilation, 2026

Table 12: Frequency of Power Outages Attributed to Encroachment

Frequency	Number of Respondents	Percentage
Daily	23	15.9%
Several times weekly	67	46.2%
Weekly	31	21.4%
Monthly	18	12.4%
Rarely	6	4.1%
Total	**145**	**100%**

Source: Author's Compilation, 2026

Table 13: Awareness of Required Setback Distance for 330kV Lines

Response	Frequency	Percentage
Correct (50m)	23	15.9%
Incorrect (less than 50m)	52	35.9%
Don't know	70	48.2%
Total	**145**	**100%**

Source: Author's Compilation, 2026

Table 14: Knowledge of Specific Risks

Hazard Type	Aware	Percentage
Risk of electrocution	112	77.2%
Fire hazard	98	67.6%
Electromagnetic field (EMF) health effects	34	23.4%
Lightning attraction	87	60.0%
Interference with radio/TV signals	45	31.0%
Danger during maintenance	63	43.4%

Source: Author's Compilation, 2026

Table 15: How Residents Learned About Power Line Dangers

Information Source	Frequency	Percentage
Personal experience/observation	76	52.4%
Neighbors/community members	58	40.0%
Witnessed accidents	43	29.7%
Radio/TV	31	21.4%
TCN/NEPA officials	18	12.4%
School/education	12	8.3%

Government awareness campaigns	8	5.5%

Source: Author's Compilation, 2026

Table 17: Awareness Level Classification

Awareness Level	Score Range	Number of Respondents	Percentage
High	8-10	18	12.4%
Moderate	5-7	47	32.4%
Low	0-4	80	55.2%
Total		**145**	**100%**

Source: Author's Compilation, 2026

Conclusion

The findings of this study conclusively establish that significant building encroachment exists along the 330kV transmission line corridor in Rafin Zurfi, Bauchi Metropolis, with 606 buildings housing thousands of residents in violation of NERC/TCN regulations and exposed to multiple deathtraps. The encroachment results from the convergence of economic necessity among a low and middle income, poorly educated population and systemic failure in regulatory enforcement, public awareness, and urban planning. The consequences are manifest in frequent safety incidents, widespread health complaints, and compromised electricity supply reliability. Urgent multi-sectoral intervention is required to address this situation through a combination of relocation or resettlement of those in the critical zone, strengthened enforcement, comprehensive public awareness campaigns, and long-term urban planning reforms.

Recommendations

Based on the study findings, it is recommended that the Transmission Company of Nigeria (TCN) and Bauchi State Urban Planning and Physical Development Board urgently enforce regulatory standards by demolishing identified buildings within the 50 meter danger zone and conducting regular joint monitoring patrols to prevent further encroachment. Public awareness campaigns should be intensified to educate residents on the mandatory 50-meter setback clearance requirement for 330kV lines and associated risks, utilizing community leaders and visible boundary markings. Additionally, the state government should develop a comprehensive structure plan designating transmission corridors as restricted green buffers, while strengthening institutional frameworks through GIS-based monitoring systems and enhanced collaboration between planning authorities and electricity regulatory agencies.

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