SEISMIC RISK, INFRASTRUCTURE VULNERABILITY, AND HOUSEHOLD PREPAREDNESS IN ABUJA, NIGERIA: AN INTEGRATED URBAN PLANNING ASSESSMENT

Jibrin Ahmed Ahmed
Department of Geography, Faculty of Environmental Science,
Nasarawa State University, Keffi, Nigeria.

Bala Liman Nasir
Department of Geography, Faculty of Environmental Science,
Nasarawa State University, Keffi, Nigeria.
liman.bala@nsuk.edu.ng,

Abdullahi Suleiman
Department of Urban and Regional Planning, Faculty of Environmental Science,
Nasarawa State University, Keffi, Nigeria.
abdullahisuleiman@nsuk.edu.ng

Abstract

Accelerated urbanization, in nations that experience low-moderate seismic activity, can however be characterized by significant risk through exposure, fragility, and lack of preparedness. This research estimated the spatial distribution of reported activity, perceived structure vulnerability, community risk, and household preparedness in Abuja, Federal Capital Territory of Nigeria. An interdisciplinary mixed method research design explored literature, constructed response and structured survey questionnaires (conducted on 180 residents), conducted some field observations and mapping using a GIS, and incorporated qualitative evidence through interviews and open-ended questions. A combination of descriptive statistics and weighted indices summarized community and household vulnerability and preparedness status, while exploratory Spearman rank correlation and the Kendall's coefficient of concordance appraised associations among perceived awareness, guidance, and individual responsiveness. Places with reported activity (Gpagi Village, Bwari Village, Maitama Extension) were identified as high priority for seismic microzonation. Community ranking of infrastructure as most vulnerable (81.5%), community density and context as second most vulnerable domain (77.4%), and community resilience as third most vulnerable domain (74.8%) illustrated however community perception of a low level of risk (at 61.1%) and knowledge of the right actions to take during tremors (at 52.8%), but not their individual responsiveness (at 27.8%) or institutional support (at 47.2%), as well as lack of multiple preparedness action (with only 47.2% having already taken any action and thus only 27.8% concurrently identified sufficient institutional guidance). House-hold actions like low-cost participatory measures (such securing furniture, identifying safe exits) generally were more popular than expensive structural actions. Though Abuja experiences no high level of hazard, the interaction of localized vulnerability, rapid urban development, vulnerable infrastructure, and weak messaging increases risk. A comprehensive risk management and reduction strategy needs seismic hazard analyses and mapping, planned development regulations, structural audits of structural critical infrastructures, and community-based disaster preparedness programmes.

Keywords

Seismic Risk,

Infrastructure Vulnerability,

Household Preparedness,

Urban Planning,

GIS,

Abuja,

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1. Introduction

Earthquake losses are not only a function of the strength and recurrence of ground shaking but also of the other detailed information about the location and quality of the exposed buildings, infrastructure and population, of institutions and emergency capacity. It is global experience that seismic microzonation, improved design codes, land use regulation and public preparedness can all save lives and livelihoods by translating geotechnical information into planning and investment decisions. Japanï¼›s post-earthquake planning, the response to extreme site amplification in Mexico City and risk mitigation programmes in Turkey all demonstrate how hazard information can be integrated with the administration of buildings and urban systems (Seed et al., 1988; Ansal et al., 2009; World Bank, 2013, 2016).

The risk profile for African cities is also distinct, but no less critical. While most of West Africa is removed from plate boundaries, damaging effects are still, if less likely, possible when negligent construction, uncontrolled growth, insufficient oversight and ineffective enforcement come together. A handful of studies on African seismicity and design trends, for example, identify ongoing inadequacies in hazard understanding and regulatory adoption (Worku, 2014; Alaneme & Okotete, 2018). When urban growth accelerates, however, less common seismic events have the potential to be catastrophic if institutional resiliency lags behind trend lines of social vulnerability and economic exposure.

Intra-plate seismic activity has been widely recorded in Nigeria, with tremor occurrences around the country since the twentieth century (Tsalha et al., 2015; Olugboji et al., 2021). There has also been seismic-related anxiety within the Nigeria Capital Territory (FCT) in the wake of tremor activity across and outside the city borders. However, various disaster risk activities in the city focus primarily on persistent risks, namely, flood, erosion and fire. Isolated microzonation efforts, few structural surveys and conspicuous household-based programmes in the city are very sparse.

The role of Abuja as nationally administered administrative capital underscores the consequences of this gap. The jurisdiction includes fast-growing planned suburbs, peri-urban settlements, important state facilities, hospitals and schools, transport corridors, and high-density settlements. Development lies within a diverse framework of basement geology, weathered profiles, landforms, slopes, and isolated sedimentary and alluvial deposits. These physical parameters are coupled to build form quality, community remoteness, land use decision making processes, and socio-economic making capacity. A planning-focussed assessment must therefore discriminate between earthquake hazard and exposure/vulnerability, and not use the simple existence of tremors as a surrogate for high and uniformly distributed earthquake risk.

The paper contributes to understanding seismic risk and vulnerability in the FCT through a set of four related objectives: (1) spatially identify and map areas linked to seismicity; (2) assess physical infrastructure and community vulnerability; (3) assess community perception of risk and the influence of urban and environmental conditions; and (4) residents' perception of risk and household preparedness. Its unique contribution is a comprehensive account at the city scale, overlaying spatial evidence with community and infrastructure indicators in a Nigerian context, where seismic risk has yet to be sufficiently planned for.

2. Conceptual and Empirical Context

Risk as an Interaction of Hazard, Exposure, and Vulnerability

According to the Council of American Building Officials (CABO), a seismic hazard refers to the probability and severity of ground shaking at a specific location (i.e., the event), while exposure involves those humans and assets located in the path of the shaking (i.e., the phenomenon). Vulnerability denotes the degree to which those exposed elements are susceptible to damage, and resilience pertains to the extent to which those elements are capable of withstanding, responding to, and recovering from the event. Consequently, the concept of risk is derived from those two variables working in conjunction. A low/medium regional hazard classification, identified in Table 4, does not mean that the risk in urban Abuja is insignificant or insubstantial when the building stock, other form of critical infrastructure and natural, social and economic institutions are vulnerable.

Probabilistic seismic hazard analysis gives a statistically sound approach for determining the probabilities of exceeding given ground-motion levels. At the scale of an urban, microzonation integrates the regional hazard estimates with local lithology, soils, topography, fault or lineament maps, and site-response data. Structural vulnerability models link levels of intensity to likely damages for various typologies of buildings. In the absence of a detailed engineering inventory, field inspection and deftly conceptualized perception surveys can supplement a first rectification layer, but cannot substitute for instrumented monitoring or engineering assessment.

Lessons for rapidly Urbanizing African Cities

International experts show that hazard mapping best complements planning decisions (development control, foundation design), retrofit priorities, lifeline reinforcement, evacuation planning, and public education. HAZUS-type loss estimation, Global Earthquake Model promotes recognition of the interconnectedness of hazard, exposure, and vulnerability (FEMA, 2018; Martins & Silva, 2023). In Africa, however, lack of enforcement of seismic design codes combined with widespread un-engineered or informal construction-are even more pertinent. The West African example of Accra illustrates the point: high levels of hazard alone are not enough to force appropriate actions, given manageable hazard levels and under-framed vulnerability (Oteng-Ababio, 2012).

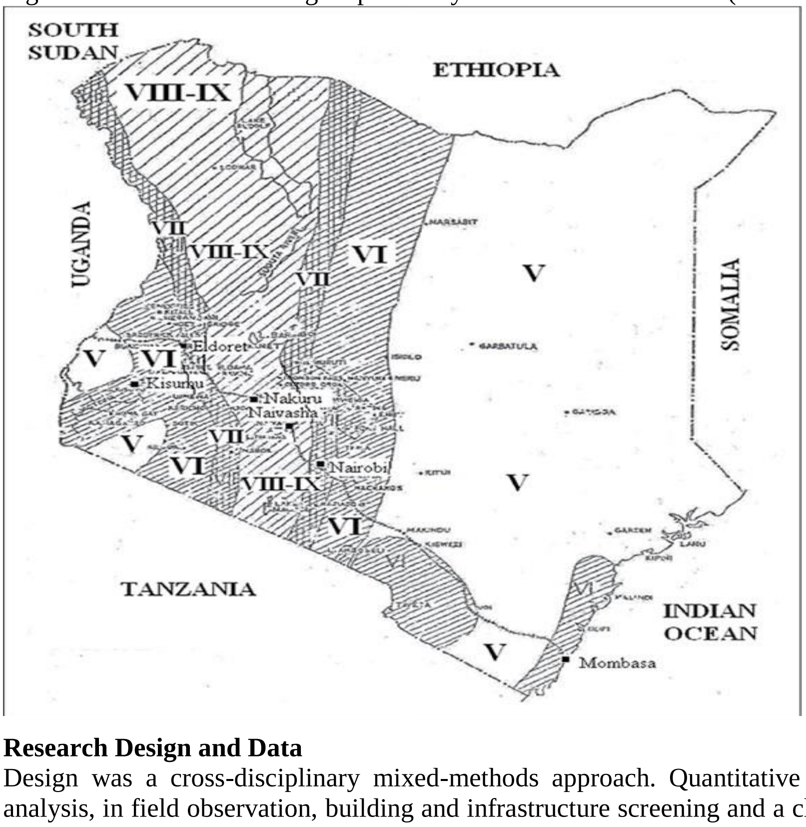
For Nigeria, however, existing historical seismic catalogues and recent geophysical studies cast doubt on the assumption of constant stability (Tsalha et al., 2015; Olugboji et al., 2021). So the core planning problem is therefore precautionary: decision-makers need spatial and structural evidence strong enough to avoid adding new risk exposures, but not so strong as to underprepare for the settlements and key facilities that exist.

3. Materials and Methods

Study Area

The FCT covers about 7,700 Km 2 in the middle of Nigeria and includes the federal capital city (Abuja) as well as the three surrounding area councils. The FCT has topography of undulating plains, hills, valleys, prominent inselbergs and morphological remnants. The territory is characterized by Precambrian Basement Complex rocks (granite, gneiss, schist and quartzite), weathered and fractured zones and some locally contained sedimentary/ alluvial deposits. The variation of elevation, slope, depth of the soils, drainage system and soil moisture conditions can affect the site response. The fast rates of urban migration and construction activities have altered the settlement system to a mixed legacy of planned urban centers as well as lower density peri urban, informal communities see Figure 1.

Figure 1: The Seismic zoning map of Kenya in terms of MMI scale (MWK1973)



Research Design and Data

Design was a cross-disciplinary mixed-methods approach. Quantitative data were gathered through spatial analysis, in field observation, building and infrastructure screening and a closed ended household questionnaire. Qualitative data were gathered from key-informant interviews, field notes and open ended questionnaire responses. Triangulation was used to compare spatial patterns, observable conditions and residents' experience.

Primary data comprised of Grid reference, visible building features and infrastructure state, Demographic and perception factors, Knowledge of tremors, Preparedness, and opinion of local- authority guidance. Secondary data comprised of geological and soil data, satellite spot measurements, Digital elevation model, Land use and settlement data, Population data, and seismic data available from relevant Nigerian authorities and open sources.

Sampling and Field Procedures

A multistage approach began by stratifying the study area according to land use, settlement form, population density, and geology/soil. Households and building-selected within strata, institutional knowledge respondents-selected purposively for qualitative information. The questionnaire data set was collected from 180 respondents. Field teams collected observable construction material, building form, apparent distress, infrastructure performance, coordinates using checklists and hand-held GPS devices.

Table 1. Alignment of objectives, evidence, and analytical methods

Objective	Principal evidence	Analysis
Map areas associated with seismic activity	Seismic records, geology, lineaments, soils, elevation and GPS locations	GIS compilation and spatial overlay
Assess infrastructure and community vulnerability	Building condition, public facilities, settlement density and respondent assessments	Weighted vulnerability indices, descriptive statistics and spatial interpretation
Assess current risk and planning factors	Community risk perception, institutional preparedness, land-use and environmental conditions	Frequencies, percentages and comparative synthesis
Assess awareness and preparedness	Knowledge, household measures, specific actions and authority guidance	Weighted means, rank analysis, exploratory Spearman correlations and Kendall's W

Source: Adapted from the thesis methodology and fieldwork design.

Data Analysis

GIS was employed to collate reported earthquake locations and interpret their distribution with respect to settlements and main roads. The survey variables were summarized by frequencies and percentages. Three vulnerability indices were derived as follows: assigning ordinal weights of 1–3 in the direction of increasing vulnerability and dividing the observed weighted score by maximum weighted score (180×3=540) observed thus derived. The percentage ratios so derived were used as screening indices and not as engineering probabilities of damage.

Awareness, household preparedness, and perception of authority guidance were totaled into three-point scales. Were ranked in order of occurrence for specific preparedness activities. The thesis presents Kendall's value of W and Spearman rank-order correlations (ρ) between preparedness activities, awareness, and authority guidance. These inferential findings are regarded as exploratory in nature because the article was written from the combined thesis tables, unlike the respondent-level dataset. Qualitative data were thematically coded in order to interpret structural challenges, preparedness impediments, and institutional communication.

Ethical Considerations

Participation was voluntary and with the informed consent of the participants, their responses were anonymized and they were not personally identified in the results, and seismic hazard was described in a manner that was meant to be informative and not frightening. Field work adhered to the relevant institutional and community entry protocols.

4. Results

Spatial Pattern of Reported Seismic Activity

The spatial evaluation pinpointed three communities (Gpagi, Bwari, and Maitama Extension) that are proximate to known seismic activity. Their approximate n–s orientation may indicate structural controls or zones of weakness further instrumented seismic and geophysical work is necessary to substantiate such a correlation. Consideration of this information during urban planning is prudent because severe disruption in those communities would compromise access and egress. This map demonstrates that seismic concern is not evenly distributed and encourages further research; it does not delineate a fault trace or predict the spatial occurrence of the next earthquake.

Perceived Vulnerability of Buildings, Public Infrastructure, and Communities

All three domains tested were in the high-vulnerability screening category of the study. The public infrastructure domain had the highest index at 81.5%. It was followed by population density and community conditions at 77.4% and building resilience at 74.8%. The public-infrastructure score indicated perceived risk that schools, hospitals, roads and other infrastructure might be damaged in an earthquake event. The building index reflected pervasive concern about the capacity of residential and commercial buildings to withstand vibrations. A high community-vulnerability score could be explained by high density and limited open space, with small access routes.

Table 2. Weighted vulnerability indices for physical infrastructure and communities

Domain	Observed score	Maximum score	Index (%)	Interpretation
Building resilience to tremors	404	540	74.8	High vulnerability
Public infrastructure	440	540	81.5	High vulnerability
Population density and community conditions	418	540	77.4	High vulnerability

Source: Fieldwork (2025). Indices are perception-based screening measures, not engineering damage probabilities.

Common indicators of vulnerability (to which respondents typically referred) were cracks on buildings, deterioration of public infrastructure, poorly maintained roads, high density of development and fears over whether standards were being maintained. These indicators give some guidance as to what requires professional assessment, but visible condition and public opinion alone cannot diagnose an individual facility or structure as seismically unsafe.

Community Risk, Institutional Preparedness, and Planning Factors

Most people (61.1%) felt their community would be vulnerable to tremors, 22.2% did not and 16.7% were unsure. Fewer people (27.8%) felt the authorities had adequately assessed or prepared for tremors; 38.9% felt they had not and 33.3% were unsure. The high number of unsure responses suggests the authorities may not have done much to prepare and/or have not well communicated their actions.

Environmental and urban-planning factors were the most commonly cited hazards, with 66.7% of participants citing weak planning or poor environmental management as a factor contributing to vulnerability. The participants reported unauthorized construction, unplanned urban sprawl, poor drainage, high population density and settlement on weak or saturated soils. The findings highlight the importance of development control and hazard aware communication in seismic resilience.

Table 3. Community perceptions of risk and preparedness

Indicator	Yes (%)	No (%)	Unsure (%)	Main inference
Community perceived to be at risk	61.1	22.2	16.7	Risk is recognized by a majority
Local authority assessed/prepared	27.8	38.9	33.3	Low visibility and confidence
Planning/environmental factors increase risk	66.7	19.4	13.9	Strong concern about development conditions

Source: Fieldwork (2025), n = 180.

Awareness and Household Preparedness

A little more than half of respondents (52.8%) knew (mean=2.25) what to do during a tremor, while a third indicated household preparedness (mean=1.86), and a third indicated understanding of authority guidance (mean=1.83). Perception of knowledge of authority guidance was generally positive than in a higher proportion of people felt adequately guided (27.8%). A large proportion of people felt that authority guidance was not Adequate (44.4%).

Prepared households more readily took low cost and quick observed measures. Fixing furniture constituted 35% of the first action, while locating safe corners or exits counted for 25%. Stockpiling emergency supplies represented 15%, whereas retrofitting structures only accounted for 5% and 20% had no preparation. The thesis found fair agreement in the ranking of measures (Kendall‘s W = 0.62, p < .05).

Table 4. Awareness, preparedness, and reported household actions

Measure	Response distribution	Summary statistic
Knowledge of actions during tremors	Yes 52.8%; unsure 19.4%; no 27.8%	Mean = 2.25/3
Household preparedness	Prepared 33.3%; partly 19.4%; not prepared 47.2%	Mean = 1.86/3
Adequacy of authority guidance	Yes 27.8%; unsure 27.8%; no 44.4%	Mean = 1.83/3
Most common specific actions	Secure furniture 35%; identify exits 25%; supplies 15%; retrofit 5%; none 20%	Kendall’s W = 0.62*

Source: Fieldwork (2025), n = 180. *p < .05 as reported in the thesis.

Exploratory correlations were positive between awareness and preparing actions individuals engaged in (ρ = .31–.52), and between perceived authority guidance and actions (ρ = .28–.47). 'No preparation' was negatively associated with awareness ($\rho = -.42$) and perceived authority guidance ($\rho = -.38$). However, these cross-sectional associations are consistent with the potential for knowledge and visible institutional support to directly facilitate action.

5. Discussion

Overall, the results can be summarized in that they suggest that Abuja's seismic risk is caused primarily by an interplay of site-specific concern, episodic exposure, institutional fragility and limited capacity to adapt. This phenomenon seems to be generic in Africa, where lower or less common levels of seismicity occur alongside high levels of vulnerability (Oteng-Ababio, 2012; Alaneme & Okotete, 2018). The policy implication, therefore, ought to be a cautious one, as the evidence, while not indicative of a high hazard at all of the city, nonetheless suggests that moderate levels of shaking could have far-reaching impacts on the fragility of buildings and institutions.

All three mapped communities offer the beginning of a loading plan. They also have distribution and proximity to transportation routes, which allows for concentrated detection; geophysical and geotechnical investigations, including site-specific response, with particular investments in site response and ground motion studies; and fully instrumented building data collection. However, one should not conflate the mapped pattern with an active fault displacement. A robust microzonation programme would include a contemporary seismicity record, lineament and fault site-specific follow-up, coring and shear-wave studies, groundwater and liquefaction signs, topography and a probabilistic ground motion analysis.

The vulnerability index of 81.5% for the public infrastructure is significant, as hospitals, schools, roads and government buildings have both exposure and continuity functions. Failure of a crucial facility could exponentially increase the impact of a disaster by denying the community access to treatment, shelter, transportation, communication and coordination. International practice in risk-reduction would consequently see official reliance on a renovated, evaluated inventory of priority facilities (FEMA, 2018; World Bank, 2013). For Abuja, a tiered screening programme should include facilities within the mapped priority zones, high occupancy buildings, antiquated facilities and sites whose distress or pernicious geology is evident.

The time lag between knowledge and behaviour is just as important. Although it was stated that 52.8% knew the basics, nearly half of the respondents had made no preparation to the house. Those that had made preparations chose inexpensive measures and re-fitting was hardly ever done. This is part of a constraints model: while information will help with some immediate actions, structural factors need technical assistance, financial support, landlord pressure and regulation to motivate change. The correlations related to awareness, guide downstream action and communities submit a programme of visible action will be, at best, suggestive of the potential benefits of community schemes; only longitudinal or experimental work can determine if, and how, they lead to long term preparedness.

Planners are the forum where these conclusions are combined. Development-control measures can adjust the depth of geotechnical investigation to the risk of the site and importance of the building; land-use planning can plan for access routes and open spaces; permit systems can alleviate the problem of structural non-compliance; capital planning can give priority to strong lifelines. It is thus clear that the Sendai Framework's focus on risk identification and resilience investment is not only relevant, but essential. The seismic risk must be incorporated into the broader multi-hazard planning in Abuja, not considered an emergency management issue in isolation.

6. Planning and Policy Implications

Develop a Phased Seismic Microzonation Programme

Gpagi, Bwari, Maitama Extension, etc. where tremors are noted or shown to be rapidly developing. Carry out combined program of monitoring, geological confirmation, geotechnical testing, response analysis, settlement exposure, and critical-facility inventory.

Introduce Risk-sensitive Development Control

May mandate site investigation and structural review according to building occupancy, height, importance, and ground conditions. Seeking planning approvals should note geotechnical suitability and compliance with relevant structural standards.

Audit and Prioritize Critical Infrastructure

Conduct a rapid visual inspection in conjunction with a detailed engineering evaluation of hospitals, schools, bridges, emergency facilities and other major public buildings. The retrofit priorities should be based on both the probable danger and the importance of services.

Create Visible Community Preparedness Programmes
Offer borough level accessible information, regular simulated drills, evacuation plans and household checklists through area councils, schools, health facilities, residents associations, media. All communication should clearly know the difference between tremors, hazard and risk.

Strengthen Data and Institutional Coordination
Create a joint geospatial risk database, connecting seismic data, geology, soils, building permits, infrastructure condition, population and emergency resource data. Updating and application protocols should be shared by planning, geology, building regulation and emergency response agencies.

7. Limitations and Research Priorities

There are limitations to the data: instrumental seismic and geotechnical data were do not cover the entire study area field statistically, were limited to a handful of variables, and were selected rather than covering the entire territory; indicators for the pipeline, the airport, and infrastructure indicators cited in the article are based on residents' perceptions; the weighted vulnerability indices are screening measures based on ordinal data and should not be cautiously interpreted as the probability of structural failure; the correlation coefficients presented in this article are not able to be independently recomputed from the thesis tables because they were only available in aggregated form. Various socio-economic relationship explored in the thesis are not included in this article as the cross-tabulations and models did not accompany the discussion.

In addition, future work should include verification of the mapped priority zones through instrumented monitoring and geophysical investigations; creation of a georeferenced inventory of buildings and critical infrastructure; prediction of site response and liquefaction potential; and integration of hazard, exposure and vulnerability using transparent multi-criteria or probabilistic models. Furthermore, household survey repetitions or intervention studies are required to assess the long-term impacts of training and official guidance.

8. Conclusion

Abuja's seismic challenge is in the confluence of localized tremor apprehension, hasty urban development, frail settlement-records, crowded settlements and limited institutional visibility. The study identified Gpagi Village, Bwari Village and Maitama Extension; showed high perception-based vulnerability values for public infrastructure, community-situational state and structure, and established that 'basic awareness' surpasses 'concrete household vulnerability'. These findings valid in Nigeria may bolster a principle of reduction from reflexive concern to proportionate, evidence-based prevention. Microzonation, risk-sensitive development control, critical-facility checks, shared spatial records-and-sensory tools, and household-capacity building should become part of the FCT's.

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