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Urban Form as a Seismic-Risk Multiplier in a Low-To-Moderate Hazard City: Planning, Density, and Environmental Management in Abuja, Nigeria

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Abstract
Urban earthquake risk is commonly elevated solely in terms of ground motion, but the effects of shaking are influenced by the urban arrangement, infrastructure and institutions of the exposed population. The paper investigates how residents perceive urban planning and environmental factors contributing to seismic susceptibility in Abuja FCT Nigeria, providing the only representative urban risk study within the larger mixed-methods thesis. It is distinguished from companion papers in a household preparedness study and an integrated seismic risk framework. From 180 residents selected by proportional sampling, information has been collected through pre-coded household survey, supplemented by site-visit, interview and GIS identification of communities associated with present and past tremor perception, to arrive at frequencies, percentages, perception indices. An overwhelmed majority believe that poor planning and management aggravate seismic risk (66.7%), and believe communities are vulnerable (61.1%). Population density and settlement environment associations produce a 77.4% perceived vulnerability index, with 57.8% believing crowding intensifies safe response. Infrastructure receives the highest perceived vulnerability index (81.5%), followed by population density/settlement environment (77.4%) and structural integrity (74.8%). Implication for a framework of planning-mediated risk builds on quantification of a risk pathway by associated factors: uncontrolled rapid urban growth, resulting in high dense settlements and geopolitical fragmentation, together with fragility of erected infrastructure, constrained access and uncertain site conditions, triggers moderate dynamic shaking into major impacts. Results are perceptions and screening criteria, not engineering damage probabilities. Risk-sensitive development controls, well distributed open spaces and access, linked emergency routes, geotechnical screening, settlement microzonation and multi-hazard planning audit are recommended. Future research should tie settlement profiles to building structures and site responses.

Keywords: Urban Form, Seismic Vulnerability, Development Control, Population Density, Environmental Planning.

Introduction

The combined elements of hazard, exposure, vulnerability and capacity produce the seismic risk. It is possible for a city to be subjected to minimal or infrequent shaking but still be at risk if the

city undergoes rapid urbanization, increasing the population and assets exposed; buildings are poorly designed for lateral forces, access networks are limited and critical services are not duplicated. This difference is significant in many West African cities where low frequency of historical events may cause institutions to neglect preparations even as the city is increasingly subjected to risk.

Abuja is the base map of Nigeria‘s Federal Capital Territory (FCT) and among its most rapidly evolving urban landscapes. State-designed neighborhoods are juxtaposed with neighboring satellite towns, peri-urban villages and informal settlements, large-scale transport infrastructure, nationally significant institutions and an extensive variety of geological and soil types. Documented tremors and Nigerian intraplate seismic investigations call into suspicion the conception of the FCT as being entirely unaffected by seismic risk (Tsalha et al., 2015; Olugboji et al., 2021). Nevertheless, signs of tremors on maps should not be taken as evidence of uniformly high or high hazard for the entire territory. The urban planning query is a more precise one: which elements of urbanization could exacerbate impacts in the event of shaking?

This article is based on a thesis that defined 3 communities, resident building survey, assessment of public infrastructure, population density, local authority preparedness, and environmental management in context of the three reportable seismic communities. Two papers has already investigated the issue of awareness action gap and the combined profile of seismic risk, infrastructure vulnerability and household preparedness. This article leaves that scope to examine the issue of urban form and environmental management as possible risk multiplier.

Goals are (1) to describe local perceptions of planning and environment that faculty residents’ perceived seismic vulnerability; (2) to compare resident-selected perceptions of building, public-infrastructure, and density-vulnerability; and (3) to generate these results as risk-sensitive urban planning priorities. The main premise is not that perception causes building collapse. It is instead that resident-documented evidence may be an advance warning layer to guide survey teams, microzonation, planning-based development-control reforms, and neighborhood resilience planning.

Literature Review

Risk Creation through Urbanisation

According to the Sendai Framework, reduction of disaster risk involves preventing new risk and decreasing current risk (UNDRR, 2015). This encourages a focus on future decisions of development that result in movement and aggregation of exposure and vulnerability. Decisions made about the conversion of land, infrastructure investment, building approval, density controls and provision of service, all influence the future geography of risk. A hazard that is low probability can have great urban effects where assets are concentrated and lack of coping capacity.

The global analysis (He et al., 2021) indicates expanding population and urban land also in earthquake regions. It underscores the need to move the hazard information to the planning process. In some African cities, Oteng-Ababio (2012) has shown that lower institutional attention is often coupled with growing exposure and fragile construction. Worku (2014) has reported deficiencies in fundamental ground-motion provisions in several sub-Saharan African design standards. These researches can be summarized into one lesson that: do not relate a few past events with no planning responsibility.

Urban Morphology, Density, and Accessibility

Density, however, is neither safe in all circumstances nor equally protective of hazards. Higher density intensifies service needs, and maximizes the efficiency of emergency coverage. A population that is dense and simultaneously vulnerable is characterized by weak structural conditions, narrow or broken-up streets, limited open space, congestion, and constrained emergency access. Population density fluctuates. Users arriving at locations for commerce, education, health, and transport often reshape population patterns in the course of a day (Ara, 2014).

Urban morphology influences response in terms of block size, connectivity, spacing of buildings, redundant access, and proportions of safe open space. A robust pattern should enable emergency services to be able to gain access via alternative routes in the event of blockade, and a single corridor losing access should not fragment the surrounding town or neighbourhood. This is of

especial importance in peri-urban areas, where incremental development often exceeds road reservation and infrastructure investment.

Environmental Management and Site Conditions

Seismic response is controlled by local site response. Local variables such as ground type, weathering, groundwater, slope, fill and sediment depth can intensify shaking or generate secondary ground effects. The ground motion in Mexico City proved the great influence of ground conditions over shaking (Seed et al., 1988). Urban microzonation converts regional hazard into local planning data based on geology, soil, topography and site-response data (Ansal et al., 2009).

Drainage failure and waste management are not direct causes of earthquake events, but they interact with unstable terrain, erosion, waterlogged conditions, inaccessible areas and deteriorated infrastructure. Multi-hazard planning is therefore recommended on an integrated basis rather than as a technical programme of seismic resilience in isolation. In the case of Abuja, environemtnal screening should identify validated geotechnical mechanisms apart from wider service and access issues; perceived linkages need to be confirmed through field investigations.

Built Environment and Critical Services

Buildings and infrastructure convert ground shaking into social and economic loss. The physical vulnerability depends on the type of construction material, the structural system, the age of the building, the level of maintenance, the quality of the design, and adherence to standards. Moreover, critical facilities will have an important functional role: schools, hospitals, transport networks, water supplies, communications and emergency facilities, need be available or quickly recover after an earthquake. For this reason the Sendai Framework specifically addressed to reduce damage to critical facilities and interruptions of basic services. (UNDRR, 2015)

In Nigeria, studies of past and recent seismicity advocate for precautionary monitoring and planning while notinflatinghazard (Alaneme & Okotete, 2018; Olugboji et al., 2021; Tsalha et al., 2015). However, one urban-planning lacuna is noticeable. Most works – reporting seismicity, engineering responses, or general awareness; with limited focus on how urban structure, development strategy, and ecological services could escalate risk in Abuja.

Analytical Proposition

This table is on a planning-mediated risk pathway: local hazard data drive probable shaking; city growth situates populations and industrial capital; city shapes determines density, access and open space; building and services condition determine vulnerability; governance in turn determines whether risk is acknowledged and mitigated. In this framework, residents' perceptions are indicators within the pathway rather than replacements for engineering and geotechnical analysis.

Materials and Methods

Study Design and Setting

A mixed methodology and cross-sectional design in the Federal Capital Territory, Abuja was employed for the study. The full thesis was comprised of GIS mapping, secondary geological and environmental data, field survey, structured questionnaires, open ended questionnaire responses, and institutional interviews. This paper aims to specifically analyze the survey questions that most directly related to urban planning, density, building, public infrastructure, and perceived community risks.

Sampling and Data Collection

A multistage design stratified the study area (by settlement and land-use type, and then within land-use types by dominant population density and environmental factor) using a pre-designed, pre-tested questionnaire: the household and adult respondent samples were randomly selected within the strata and institutional informants by purposive sampling. The analysed questionnaire sample comprises 180 respondents. The stored thesis does not provide a respondent-specific data set or a full sex-by-sex table of responses at the land-use stratum level, so the present paper provides overall numbers (and implies causal factors across the population, where appropriate).

Variables and Analysis

Five indicators were preserved (1) community tremor-risk perception; (2) perceived impact of

environmental and urban-planning factors; (3) perceived building strength; (4) perceived vulnerability of public infrastructure; (5) perceived impact of population density/community conditions. Frequencies and percentages were used to analyze categorical questions while weighted perception indices on the 1 to 3 interval scale were produced by thesis. These perceived-vulnerability indices are named so because they represent judgments rather than real probabilities of damage.

This analysis contrasts indicators, and interprets them in terms of the planning-mediated risk pathway. Qualitative evidence was utilized solely to provide further explanation of themes already addressed by the aggregate evidence. Verbatim quotations were not included to ensure respondent privacy; author contact information was not included as consent documentation is to be verified prior to journal submission.

Results

Perceived Planning and Environmental Amplification

Out of 180 respondents, 120 (66.7%), 35 (19.4%) opposed the assertion that deficiencies in environmental & urban-planning contexts influence seismic risk (dugg), 25 (13.9%) expressed they didn‘t know. The high share of ‘yes’ responses suggest that dwellers associate the possible effects of tremor with development regulation, human settlement expansion, works & site management see Figure 1.

Table 1. Perceived Influence of Environmental and Urban-planning Factors

Response	Frequency	Percentage
Yes	120	66.7
No	35	19.4
Not sure	25	13.9
Total	180	100.0

Source: Authors’ Analysis, 2025

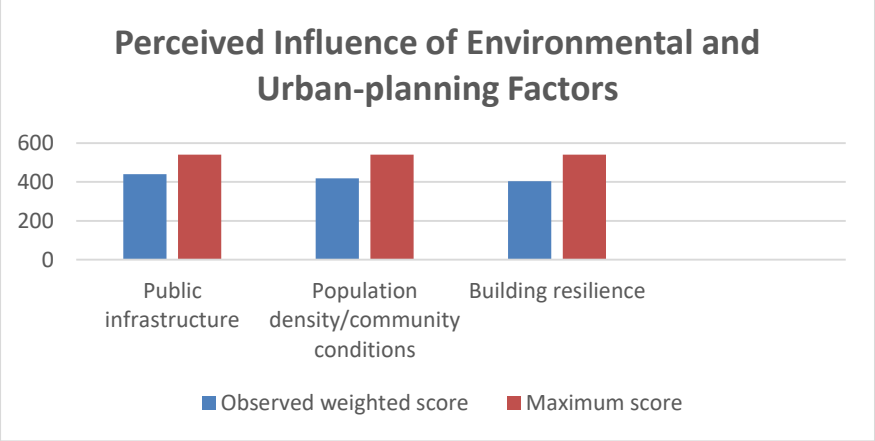

Figure 1: Perceived Influence of Environmental and Urban-planning Factors

Density and Community Conditions

One hundred and four respondents (57.8%) indicated that density and community conditions increased vulnerability, 46 (25.6%) indicated no increase, and 30 (16.7%) were unsure. The domain yielded a perceived vulnerability index of 77.4% according to the thesis weighting procedure. The result should best be taken as indicating concern about the combination of crowding with close together development, limited movement, and emergency access, rather than density per se being a cause of seismic damage.

Comparative Perception-based Indices

The index value of public infrastructure was the highest (81.5%), followed by the index value of population density/community conditions (77.4%) and building resilience (74.8%), all were within the high perceived-vulnerability category of this thesis.

Table 2. Comparative Perceived-vulnerability Indices

Domain	Observed weighted score	Maximum score	Index (%)	Interpretation
Public infrastructure	440	540	81.5	Highest screening priority
Population density/community conditions	418	540	77.4	High planning concern
Building resilience	404	540	74.8	High structural concern

Source: Authors' Analysis, 2025

The rankings represent a community worried about public networks as well as cohabited spaces. They further indicate an interconnected system: compromised buildings lead to increased community exposure, constrained urban form hinders movement and hampers emergency response, and unprotected public infrastructure endangers public service continuity (see Figure 2).

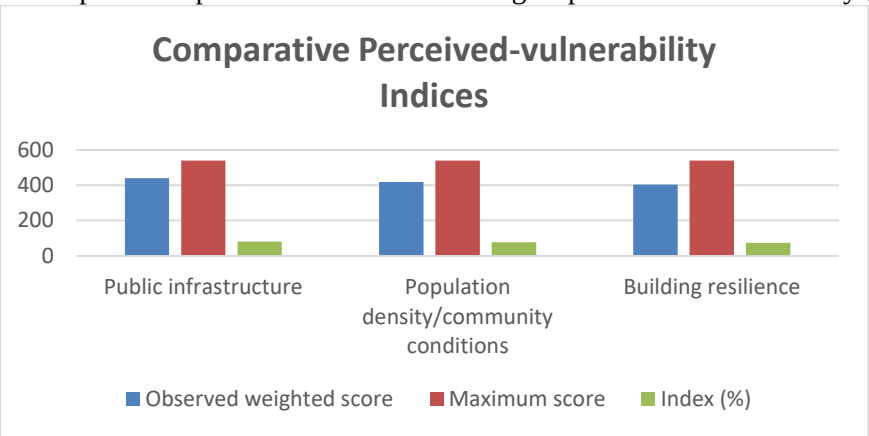

Figure 2: Comparative Perceived-vulnerability Indices

Planning-Mediated Risk Pathway

A synthesis of the aggregate evidence indicates four associated arguments. One, the global phenomenon of SE is supposedly patchy but not universal across the FCT. Two, spreading the urban and environmental resource base cannot logically and widely in itself be a mitigatory measure. Three, 3rd world density vulnerability is a function of morphology, infrastructure and access rather than absolute population size. Four, of the resources, critical public infrastructure is the most the significant perceived weakness and which need hence logically be first professionally scrutinized.

Discussion

Broughton is shifting the seismic question for Abuja from "Is it a high-hazard area" toward "is urbanisation at fault for unnecessary impact in a range of possible, but not-proven hazards"? The latter is a more reasonable question for us planners to 'address' (albeit followed by the 'what can we do?' part!).Nigeria's intra-plate seismicity offers justification for caution, but does not support characterising theWholeFCT as a 'high-seismicity' zone. Risk-sensitive planning should be calibrated according to this ambiguity.

The 66.7% planning environment response also suggests that vulnerability is locally regarded as a consequence of development practice. It is consistent with the Sendai principle of avoiding new risk through land-use and investment decisions and it is consistent with the Aboja dual morphology (formal planned districts and Building-Boom areas (peri-urban/satellite)).

Density as presented isn't simple, one example of misuse of the density index will show density can proxy for resilience, where it can be used to reflect the safety of buildings, connectivity of streets, availability of services. The threat is when the concentration is overlaid with lack of open space, lack of access, marginal construction and inadequate emergency capacity. Planning measures should instead intervene on quality of density: permeability of street network, spaces between buildings, number of people in the space, times when people seek shelter and to be evacuated,

capacity of services, and flow of people in the new condition.

The 'public-infrastructure' ranking is dynamic, as community consideration may guide targeting of professional audits. Yet on retrofit, engineering assessment, asset criticality based on engineering inspection and verified hazard potential guide decisions, as school/ hospital occupation is high with critical post-event operation, whereas road/ bridge accessibility, utilities provider dictates cascade of damage.

Planning and Policy Implications

Risk-prioritized analysis and design controls would be based on site info relative to magnitude and location of development. Infrastructure and habitable structures with large occupancy loads in priority areas would be subjected to geotechnical screening and engineering analysis. Planning databases would incorporate permit geoids with latitude/longitude, use, system, occupant loads and inspection data.

Neighbourhood plans should seek to safeguard a cohesive web of accessible open space rather than 'every last patch of land'. Indicative analysis of emergency routes should consider alternative routes (such as through estate roads), width of roads, constraints (such as junctions) and potential access closures. New high density development should be accessible and serviceable in emergency situations.

The Abuja area needs well-advanced seismic microzonation. Initial stages could assemble known record information, geology, lineaments, soils and terrain, and building exposure of critical facilities. Later stages would be supplemented by instrumented site-response data and engineering information. Microzonation products should inform (not dictating) the development potential, infrastructure investment, and audit priorities.

Finally, the integration of seismic concerns should be incorporated into multi-hazard planning. Water-runoff, where and how we manage the slope, access provision, fire safety, building control, necessary continuance of critical Service and the similar data and governance requirements. This perhaps will be easier in the long-term as a stand-alone earthquake programme is perhaps not sustainable in a population receiving very low frequency hazards.

Limitations

The evidence is cross-sectional and perception-based; indices do not quantify estimate probability of building failure or economic loss. Archival material does not contain respondent-level records, spatial cross-tabulations, instrumented records of ground motion, complete inventory of building or verified as current regulatory standards. Mapping of communities is thesis evidence and deserves true geophysical confirmation; so results should only direct screening and research direction and not parcel hazard or enforcement action.

Conclusion

Urban planning is, at least in part, part of the problem. Because residents perceived risk was significantly and positively associated with five urban planning measures urban and environmental management, open-space provisions, density-related conditions, buildings and public infrastructure the analysis justify proportionate measures preserve open space and access networks, enhance development control, screen critical facilities, and implement progressive microzonation. Its contribution is a planning translation of aggregate indicia of resident perceptions not an engineering pronouncement of structural unsafely. An urban area can mitigate future seismic impact with imperfect scientific knowledge by controlling urban design choices that avoid unnecessary physical exposure and negative social conditions.

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