

Determinants of Urban Resilience in Phase I of the Federal Capital City, Abuja, Nigeria: Evidence from Relative Importance Index and Principal Component Analysis

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ABSTRACT

Rapid urbanization and climate-related pressures are increasing the vulnerability of cities to flooding, heat stress, environmental degradation, and infrastructure challenges. Green infrastructure (GI) offers a nature-based approach to strengthening urban resilience, yet empirical evidence from Nigerian cities, particularly Abuja, remains limited. This study assessed the role of GI in enhancing urban resilience in Phase I of the Federal Capital City (FCC), Abuja, Nigeria. Data were collected from 384 respondents using a structured questionnaire. Descriptive statistics and the Relative Importance Index (RII) were used to rank factors influencing resilience, while Principal Component Analysis (PCA) with Varimax rotation identified their underlying dimensions. The highest-ranked factors were integration of environmental considerations into land-use planning (RII = 0.684; Mean = 3.42), preservation of natural drainage patterns (RII = 0.676; Mean = 3.38), and institutional capacity to implement urban plans (RII = 0.662; Mean = 3.31). PCA extracted four components with eigenvalues greater than 1, collectively explaining 72.02% of the total variance. Physical-environmental factors accounted for 36.54%, institutional-governance factors 16.46%, socioeconomic factors 10.98%, and technological factors 8.04%. Factor loadings exceeded 0.70, with cross-loadings below 0.30. The findings indicate that urban resilience in Abuja is strongly associated with environmental planning and protection of natural drainage systems, while institutional, socioeconomic, and technological conditions provide complementary support. Strengthening GI integration into land-use planning and improving institutional implementation may enhance resilience and support sustainable urban development in Abuja.

Keywords: green infrastructure; urban resilience; Abuja; land-use planning; environmental planning; principal component analysis; Relative Importance Index.

INTRODUCTION

Urban resilience has emerged as a critical concept in contemporary urban planning and development discourse due to the increasing exposure of cities to environmental, social, economic, and technological challenges. Rapid urbanization, climate change, population growth, infrastructure deficits, environmental degradation, and governance complexities have intensified the vulnerability of urban areas worldwide, particularly in developing countries (Meerow, Newell, & Stults, 2016; United Nations Human Settlements Programme [UN-Habitat], 2022). Urban resilience refers to the capacity of urban systems, institutions, communities, and individuals to withstand, adapt to, and recover from shocks and stresses while maintaining essential functions and promoting sustainable development (Resilience Alliance, 2010; United Nations Office for Disaster Risk Reduction [UNDRR], 2023). Consequently, urban resilience has become a central objective in planning and managing cities capable of responding effectively to both sudden disturbances and long-term environmental and socioeconomic changes.

The growing concern for urban resilience is particularly relevant in rapidly expanding cities within the Global South, where uncontrolled urban growth often outpaces infrastructural development, environmental protection, and institutional capacity (Ahern, 2011; Romero-Lankao & Gnatz, 2016). Many African cities

face increasing challenges associated with flooding, informal settlement expansion, environmental degradation, inadequate infrastructure, weak governance structures, and limited technological integration in urban management. These challenges reduce the ability of cities to respond effectively to climate-related hazards and other urban stresses, thereby threatening sustainable urban development (Cobbinah & Erdiaw-Kwasie, 2016; Parnell & Pieterse, 2014). As a result, identifying and understanding the determinants of urban resilience has become an important research and policy priority across developing economies.

Nigeria's Federal Capital City (FCC), Abuja, presents a unique context for examining urban resilience. Unlike many Nigerian cities that evolved organically, Abuja was developed as a planned capital city guided by a comprehensive Master Plan designed to promote orderly growth, environmental sustainability, and efficient urban management (Adeponle, 2013). The city was envisioned as a model urban centre where physical planning, environmental conservation, infrastructure provision, and administrative efficiency would support sustainable development. The Master Plan incorporated strategies such as the preservation of natural drainage channels, environmental buffer zones, green spaces, and regulated land-use systems to enhance long-term urban functionality and resilience (Enoguanbhor et al., 2021).

Despite these planning provisions, Abuja has experienced rapid population growth and urban expansion over the past three decades, leading to increasing pressure on infrastructure, housing, environmental resources, and public services. Unauthorised developments, encroachment on designated green areas, alterations of natural drainage systems, and challenges in development control have contributed to growing urban vulnerabilities, particularly flooding and environmental degradation (Akande et al., 2023; Gumel et al., 2020). Studies have further highlighted institutional challenges, including weak implementation of planning regulations, fragmented governance arrangements, and inadequate coordination among relevant agencies responsible for urban management within the Federal Capital Territory (Ibrahim, Lay, & Ekpo, 2025; Olumiji, Haruna, & Usman, 2025). These challenges raise concerns regarding the long-term resilience of Abuja despite its planned-city status.

Although urban resilience has attracted increasing scholarly attention globally, existing studies on Abuja have primarily focused on specific issues such as land-use change, flood vulnerability, environmental degradation, urban growth management, housing development, and planning implementation challenges (Adeponle, 2013; Enoguanbhor et al., 2021; Akande et al., 2023). While these studies have provided valuable insights into individual aspects of resilience, limited empirical research has examined the multidimensional factors influencing urban resilience from a comprehensive planning perspective within Abuja. More importantly, there remains a paucity of studies that simultaneously investigate physical-environmental, institutional-governance, socioeconomic, and technological factors and determine their relative importance in shaping urban resilience in the city. Existing literature has also paid relatively little attention to understanding how residents perceive these factors and how such perceptions can be synthesized into underlying resilience dimensions using advanced multivariate techniques such as Principal Component Analysis (PCA).

This knowledge gap is significant because urban resilience is increasingly recognized as a multidimensional construct that extends beyond physical infrastructure to include governance capacity, social adaptability, environmental stewardship, and technological innovation (Meerow et al., 2016; Irani & Rahnamayiezekavat, 2021). Without a comprehensive understanding of these interconnected dimensions, policy interventions may fail to address the fundamental determinants of resilience in planned urban environments such as Abuja.

Accordingly, this study examines the factors affecting urban resilience in Phase I of the Federal Capital City, Abuja. Specifically, the study seeks to:

1. Assess the relative importance of factors influencing urban resilience in Phase I of the FCC, Abuja using the Relative Importance Index (RII).
2. Rank the identified factors based on residents' perceptions of their significance in enhancing urban resilience.

3. Determine the underlying dimensions of urban resilience through Principal Component Analysis (PCA).
4. Examine the extent to which physical-environmental, institutional-governance, socioeconomic, and technological factors contribute to urban resilience in the study area.

The study contributes to existing knowledge by providing an integrated assessment of the factors shaping urban resilience within Nigeria's planned capital city. By combining Relative Importance Index and Principal Component Analysis, the study identifies both the most influential resilience factors and the underlying dimensions that structure residents' perceptions of urban resilience. The findings provide evidence-based insights that can support planning authorities, policymakers, and urban managers in strengthening resilience strategies and ensuring the sustainable development of Abuja in the face of growing environmental and urbanization challenges.

METHODOLOGY

Study Area

This study was conducted in Phase I of the Federal Capital City (FCC), Abuja, Nigeria. Abuja is Nigeria's administrative capital, located within the Federal Capital Territory (FCT) between latitudes 8°25'N and 9°20'N and longitudes 6°45'E and 7°39'E. The city was developed based on the Abuja Master Plan to serve as a model capital city with organized land-use patterns, adequate infrastructure, environmental protection measures, and sustainable urban growth management.

Phase I constitutes the core development area of the Federal Capital City and comprises the earliest planned districts, including Garki, Wuse, Maitama, Asokoro, Guzape, and the Central Business District. These districts contain major residential, commercial, administrative, and institutional functions within Abuja. Over the years, rapid population growth, land-use conversion, environmental degradation, drainage encroachment, infrastructure pressure, and climate-related hazards have increasingly challenged the resilience of the city. Consequently, Phase I provides an appropriate setting for investigating the factors influencing urban resilience within a planned urban environment.

Research Design

The study adopted a quantitative cross-sectional survey design. This design was considered appropriate because it allows the collection of information from a large population at a single point in time and facilitates the examination of citizens' perceptions regarding factors affecting urban resilience. The design also supports the application of multivariate statistical techniques for identifying underlying dimensions of resilience determinants.

The study employed a structured questionnaire to collect primary data from residents of Phase I of the FCC, Abuja. Quantitative methods were preferred because urban resilience is multidimensional and requires systematic measurement of environmental, institutional, socioeconomic, and technological factors.

Population of the Study

The target population comprised all adult residents living within the selected districts of Phase I of the Federal Capital City, Abuja. The study focused on residents because they are direct beneficiaries of urban planning interventions and are most affected by environmental hazards, infrastructure conditions, governance effectiveness, and technological systems associated with urban resilience.

Sample Size Determination

The sample size was determined using Cochran's (1977) formula for large populations:

$$n = \frac{Z^2 pq}{e^2}$$

Where:

- n = sample size
- Z = standard normal deviation at 95% confidence level (1.96)
- p = estimated proportion possessing the attribute (0.5)
- q = $1-p$ (0.5)
- e = margin of error (0.05)

Substituting the values:

$$n = \frac{(1.96)^2 (0.5)(0.5)}{(0.05)^2}$$

$$n = 384.16$$

Thus, a sample size of 384 respondents was adopted for the study. This sample size satisfies the requirements for robust multivariate analyses such as Principal Component Analysis (PCA) and exceeds the minimum respondent-to-variable ratio recommended in factor analytic studies.

Sampling Procedure

A multistage sampling approach was employed.

Stage 1: Selection of Districts

The major districts constituting Phase I of the FCC were purposively selected because of their strategic planning significance and concentration of urban functions.

Stage 2: Selection of Residential Areas

Residential neighbourhoods within each district were identified using district maps and planning layouts.

Stage 3: Household Selection

Systematic random sampling was used to select households within the identified neighbourhoods. Every k th household was selected after a random starting point had been established.

Stage 4: Respondent Selection

Within each selected household, one adult resident (18 years and above) who had resided in the area for at least two years was selected using simple random techniques.

This procedure ensured adequate spatial coverage and minimized sampling bias.

Data Collection Instrument

Primary data were collected through a structured questionnaire designed from an extensive review of literature on urban resilience, sustainable urban development, disaster risk reduction, climate adaptation, and urban governance.

The questionnaire contained two sections:

Section A: Socioeconomic Characteristics

This section collected information on:

- Age
- Gender
- Educational attainment
- Occupation
- Length of residence
- Household characteristics

Section B: Factors Affecting Urban Resilience

Respondents assessed sixteen resilience-related variables using a five-point Likert scale ranging from:

- 5 = Very High Importance
- 4 = High Importance
- 3 = Moderate Importance
- 2 = Low Importance
- 1 = Very Low Importance

The variables were derived from theoretical and empirical urban resilience literature and captured four broad dimensions:

- Physical-environmental factors
- Institutional-governance factors
- Socioeconomic factors
- Technological factors

Validity and Reliability of the Instrument

Content and Face Validity

The questionnaire was reviewed by experts in urban and regional planning, environmental management, and quantitative research methods to ensure content validity, construct relevance, and clarity of measurement items. Feedback obtained from the experts informed revisions to improve comprehensiveness and consistency with established urban resilience frameworks.

Pilot Study

A pilot survey involving approximately 10% of the final sample was conducted in a district outside the main study area to evaluate questionnaire clarity, item suitability, and response consistency.

Reliability Analysis

Internal consistency reliability was assessed using Cronbach's Alpha coefficient.

According to Nunnally and Bernstein (1994), a Cronbach's alpha value of 0.70 or greater indicates acceptable reliability for social science research. The reliability test yielded an overall Cronbach's Alpha value exceeding the recommended threshold, indicating satisfactory internal consistency among the measurement items.

Data Analysis Techniques

Data were coded, screened, and analysed using the Statistical Package for Social Sciences (SPSS Version 29).

The analysis was conducted in three stages.

Descriptive Statistics

Descriptive statistics including frequencies, percentages, means, and standard deviations were used to summarize respondents' characteristics and assess the distribution of responses regarding urban resilience factors. Mean scores were used to determine the central tendency of each factor, while standard deviations measured response variability.

Relative Importance Index (RII)

The Relative Importance Index (RII) was employed to determine the relative significance of each factor affecting urban resilience.

The RII was computed using:

$$RII = \frac{\sum W}{A \times N}$$

Where:

- **W**= weight assigned by respondents
- **A**= highest attainable weight (5)
- **N**= total number of respondents (384)

The RII values range between 0 and 1, with higher values indicating greater importance.

The interpretation adopted was:

Table 1: Interpretation Criteria for the Relative Importance Index (RII) Used in Assessing Factors Affecting Urban Resilience

RII Value	Interpretation
≥ 0.60	High Importance
0.50–0.59	Moderate Importance
< 0.50	Low Importance

The factors were subsequently ranked according to their RII values.

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was performed to identify the underlying dimensions influencing urban resilience and reduce the observed variables into a smaller set of latent components.

Prior to PCA, the suitability of the dataset for factor analysis was assessed using:

Kaiser-Meyer-Olkin (KMO) Measure

The KMO statistic was used to evaluate sampling adequacy. Values greater than 0.60 were considered acceptable, while values greater than 0.80 indicated meritorious sampling adequacy.

Bartlett's Test of Sphericity

Bartlett's Test was conducted to verify whether the correlation matrix differed significantly from an identity matrix.

A significance level of: indicated the appropriateness of PCA.

$$p < 0.05$$

Component Extraction

Components were extracted using the Kaiser Criterion, whereby only components with eigenvalues greater than 1.0 were retained.

The procedure identified four principal components explaining 72.02% of the total variance.

Rotation Procedure

To improve interpretability, Varimax orthogonal rotation with Kaiser Normalization was employed.

Varimax rotation maximizes variance among loadings and produces a simpler factor structure by enhancing high loadings and suppressing weak loadings.

Factor Retention Criteria

Variables were retained based on the following criteria:

- Factor loading ≥ 0.70
- Eigenvalue > 1.0
- Communality ≥ 0.50
- Cross-loadings < 0.30

These thresholds ensured strong construct validity and clear component interpretation.

Component Naming

Extracted components were named according to the conceptual characteristics of variables exhibiting the strongest loadings:

1. Physical-Environmental Factors
2. Institutional-Governance Factors

3. Socioeconomic Factors

4. Technological Factors

Ethical Considerations

Ethical principles guiding social science research were strictly observed throughout the study. Participation in the survey was voluntary, and informed consent was obtained from all respondents prior to questionnaire administration.

Respondents were assured of anonymity, confidentiality, and the exclusive use of collected information for academic purposes. No identifying personal information was included in the analytical dataset. Participants were also informed of their right to withdraw from the study at any stage without consequences.

Analytical Framework

The analytical framework of the study assumed that urban resilience in Phase I of the FCC Abuja is influenced by four interrelated dimensions:

- Physical-environmental factors
- Institutional-governance factors
- Socioeconomic factors
- Technological factors

The Relative Importance Index was used to evaluate the perceived significance of individual factors, while Principal Component Analysis identified the latent structure underlying respondents' perceptions. Together, these techniques provided both ranking and dimensional reduction capabilities, enabling a comprehensive understanding of the determinants of urban resilience in the study area.

RESULTS AND DISCUSSION

Factors affecting Urban Resilience in Phase I of the FCC, Abuja

This section used both descriptive statistics (mean scores and Relative Importance Index) and inferential statistics (Principal Component Analysis) to examine the factors affecting urban resilience in Phase I of the Federal Capital City, Abuja.

Relative Importance Index of Factors

The Relative Importance Index (RII) was calculated to rank the factors affecting urban resilience based on respondents' perceptions. The RII was computed using the formula: $RII = \Sigma W / (A \times N)$, where W is the weighting given to each factor by respondents (ranging from 1 to 5), A is the highest weight (5 on the Likert scale), and N is the total number of respondents (384). The RII values range from 0 to 1, with higher values indicating greater perceived importance of the factor in affecting urban resilience.

The results presented in Table 4.7 reveal the relative importance of various factors affecting urban resilience in Phase I of FCC Abuja. Particularly, the top-ranked factors are mainly related to physical planning and environmental considerations, which aligns with the unique planning perspective of Abuja as Nigeria's purpose-built capital city developed under a comprehensive Master Plan. The factor with the highest RII was 'Integration of environmental factors in land-use planning' (RII = 0.684, Mean = 3.42), indicating that respondents recognize the fundamental importance of environmentally sensitive planning for urban resilience. This finding is particularly significant in the Abuja context, where the original Master Plan

developed by International Planning Associates (IPA) incorporated extensive environmental provisions, including the preservation of natural vegetation, protection of drainage channels, and designation of green buffer zones between districts (Olukoya & Olukoya, 2023; Adeponle, 2013). The high-ranking shows that residents value these planning principles and their contribution to the city's resilience. The second-ranked factor, 'Preservation of natural drainage patterns' (RII = 0.676, Mean = 3.38), reflects growing awareness of flood risks in Abuja. A study by Akande, et. al (2023) documented increasing flood incidents in Abuja due to the blockage and modification of natural drainage channels by unauthorized developments. Reports from the FCT Emergency Management Agency (FEMA) and the Federal Ministry of Environment (2024) identified Wuse and Garki districts as recurring flash-flood zones, attributed largely to blocked drainage infrastructure and high surface runoff in commercial areas.

'Institutional capacity to implement urban plans' ranked third (RII = 0.662, Mean = 3.31), highlighting the critical role of governance in urban resilience. This is particularly relevant for Abuja, where the Federal Capital Development Authority (FCDA) has faced challenges in enforcing development control regulations and implementing the Master Plan provisions (Enoguanbhor, Gollnow, Walker, Nielsen, & Lakes, 2021). Research by (Gumel, Aplin, Marston, & Morley, 2020) documented how institutional weaknesses have contributed to unplanned developments that compromise the city's environmental integrity and resilience. On the other hand, 'Sustainable management of population growth' ranked lowest (RII = 0.510, Mean = 2.55), though still within the moderate importance range. This finding reflects the challenges of managing rapid urbanization in Abuja, which is because of population growth. The relatively lower ranking reveals a perception that population management is beyond the immediate control of urban planning authorities, or that other factors are more directly actionable for enhancing resilience. Studies by Madu et.al (2025) have linked Abuja's rapid population growth to increased pressure on infrastructure, housing, and environmental resources.

Table 2: Relative Importance of Factors Influencing Urban Resilience in Phase I of the FCC, Abuja

Rank	Factor	Mean	SD	RII	Remark
1	Integration of environmental factors in land-use planning	3.42	0.96	0.684	High
2	Preservation of natural drainage patterns	3.38	0.98	0.676	High
3	Institutional capacity to implement urban plans	3.31	1.01	0.662	High
4	Consideration of climate conditions in urban planning	3.26	0.99	0.652	High
5	Quality of infrastructure designed for local conditions	3.19	1.03	0.638	High
6	Adequacy of regulations supporting resilience building	3.12	1.05	0.624	High
7	Effectiveness of disaster early warning systems	3.08	1.06	0.616	High
8	Level of public awareness and environmental understanding	3.02	1.07	0.604	High
9	Use of data-driven approaches in urban management	2.97	1.09	0.594	Moderate
10	Innovation and technology adoption in urban management	2.91	1.08	0.582	Moderate
11	Quality of housing meeting resilience standards	2.86	1.11	0.572	Moderate
12	Use of technology for resilience monitoring	2.79	1.10	0.558	Moderate
13	Coherence of urban planning policies	2.74	1.12	0.548	Moderate
14	Efficiency of resource allocation for urban development	2.68	1.14	0.536	Moderate
15	Equitable distribution of resilience benefits across groups	2.61	1.16	0.522	Moderate
16	Sustainable management of population growth	2.55	1.18	0.510	Moderate

Source: Author's Field Survey, 2026.

Decision Criteria: $RII \geq 0.60$ = High Importance; $0.50 - 0.59$ = Moderate Importance; < 0.50 = Low Importance

Principal Component Analysis (PCA) of Factors Affecting Urban Resilience

Table 4.8 presents the results of the principal component extraction using the eigenvalue-greater-than-one criterion (Kaiser, 1960). Four components were extracted, collectively explaining 72.02% of the total variance in the factors affecting urban resilience. This exceeds the 60% threshold recommended by Hair et al. (2019) for satisfactory solutions in social science research. Component 1 (Physical-Environmental) accounted for the largest proportion of variance at about 36.54%, followed by Component 2 (Institutional-Governance) at 16.46%, Component 3 (Socio-Economic) at 10.98%, and Component 4 (Technological) at 8.04%. The dominance of the Physical-Environmental component reflects the tangible nature of environmental challenges facing Phase I Abuja and the historical emphasis on physical planning in the city's development.

Figure 1 presents the scree plot from the Principal Component Analysis. The plot reveals a clear elbow after the fourth component, indicating that the other components contribute minimally to explaining variance. Based on the Kaiser criterion (eigenvalue > 1) and the scree test (Cattell, 1966), four components were retained, accounting for 72.02% of the total variance, exceeding the 60% threshold recommended for social science research (Hair et al., 2019). This four-component structure aligns with theoretical frameworks of urban resilience that emphasize the interconnected nature of physical, institutional, social, and technical systems (Irani & Rahnamayiezekavat, 2021).

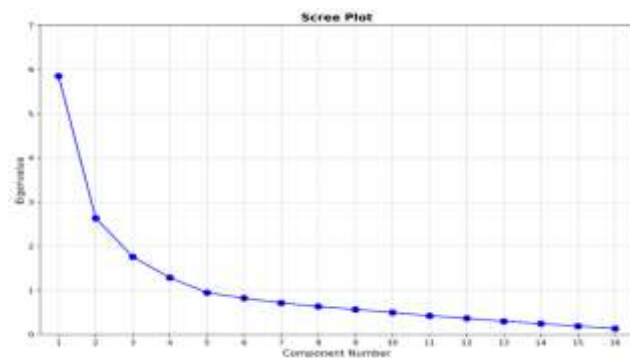


Figure 1: Scree Plot of the PCA

Source: Author's Field Survey, 2026.

Table 3: Total Variance Explained by Extracted Components

Component	Eigenvalue	% Variance of	Cumulative %	Rotation SS	Component Name
1	5.847	36.54	36.54	4.126	Physical-Environmental
2	2.634	16.46	53.00	3.287	Institutional-Governance
3	1.756	10.98	63.98	2.541	Socio-Economic
4	1.287	8.04	72.02	1.898	Technological

Extraction Method: Principal Component Analysis. Only components with Eigenvalue > 1.0 retained.

Source: Author's Field Survey, 2026.

Varimax rotation with Kaiser normalization was applied to achieve a simpler and more interpretable factor structure by maximizing the variance of loadings within each component. Table 2 presents the rotated component matrix showing the factor loadings of each variable on the four extracted components. The

rotated component matrix in Table 4.9 reveals a clear four-component structure with all items loading strongly (> 0.70) on their respective components and minimal cross-loadings (all < 0.30), indicating excellent construct validity and discriminant validity. This structure provides a meaningful framework for understanding the factors affecting urban resilience in Phase I of FCC Abuja.

Component 1: Physical-Environmental Factors accounted for 36.54% of the variance and it comprises of factors related to environmental planning and infrastructure design. The high loadings of 'Integration of environmental factors in land-use planning' (0.847) and 'Preservation of natural drainage patterns' (0.823) on this component underscore the importance of physical planning considerations in determining urban resilience. Relating this to the study area, this component reflects the foundational principles of the 1979 Master Plan, which designated significant portions of the city for green spaces, natural drainage preservation, and environmental buffer zones (Gumel, et. al. 2020). Nasiru & Yusuf (2024) demonstrated how deviations from these environmental provisions through unauthorized developments have compromised the city's resilience to flooding and other environmental hazards.

Component 2: Institutional-Governance Factors accounted for 16.46% of the variance and this includes factors related to policy implementation, regulatory frameworks, and resource management. The strong loading of 'Institutional capacity to implement urban plans' (0.834) highlights the critical role of governance in translating planning intentions into reality. Research by (Ibrahim, Lay, & Ekpo, 2025) highlighted how institutional disintegration between the FCDA, AMAC, and other agencies has hindered effective implementation of the Master Plan. Similarly, (Olumiji, Haruna, & Usman, 2025) documented challenges in development control enforcement that have allowed non-compliant structures to proliferate, compromising urban resilience.

Component 3: Socio-Economic Factors (10.98% variance) encompasses human capital, housing quality, equity, and demographic factors. The loading of 'Level of public awareness and environmental understanding' (0.856) on this component indicates the importance of social learning and adaptive capacity for resilience. In Abuja, (Gabdo & Sule, 2025) found that residents with higher environmental awareness and quality education were more likely to adopt sustainable practices and support green infrastructure initiatives. The inclusion of 'Sustainable management of population growth' (0.745) reflects the challenge of accommodating Abuja's rapid population increase, which is one of the highest urban growth rates in Africa (Fahad, 2025).

Component 4: Technological Factors account for 8.04% variance, and it contains factors related to innovation, technology adoption, and information systems. The strong loading of 'Innovation and technology adoption in urban management' (0.867) reflects growing recognition of the role of smart city technologies in enhancing urban resilience. While Abuja has made some progress in adopting Geographic Information Systems (GIS) for land administration and urban planning (Abubakar, et.al, 2025), the relatively lower variance explained by this component suggests that technological factors are still emerging compared to the more established physical and institutional determinants of resilience.

The PCA results identified four interrelated dimensions underlying respondents' perceptions of factors influencing urban resilience in Phase I of the FCC, Abuja: physical-environmental, institutional-governance, socioeconomic, and technological dimensions. Notably, Physical/Environmental factors stand out as the most significant, accounting for more than a third of the total variance in the model. This aligns with research by Muktar, et.al (2025) who argued that environmental deterioration is the biggest threat to Abuja's future.

Table 4: Rotated Component Matrix (Factor Loadings)

Factor/Variable	PC1	PC2	PC3	PC4
Component 1: Physical-Environmental Factors				
Integration of environmental factors in land-use planning	0.847	0.156	0.134	0.098
Preservation of natural drainage patterns	0.823	0.178	0.112	0.089

Consideration of climate conditions in urban planning	0.798	0.167	0.145	0.123
Quality of infrastructure designed for local conditions	0.776	0.189	0.134	0.156
Component 2: Institutional-Governance Factors				
Institutional capacity to implement urban plans	0.178	0.834	0.145	0.112
Adequacy of regulations supporting resilience building	0.167	0.812	0.156	0.134
Coherence of urban planning policies	0.145	0.789	0.178	0.098
Efficiency of resource allocation for urban development	0.156	0.756	0.189	0.123
Component 3: Socio-Economic Factors				
Level of public awareness and environmental understanding	0.134	0.145	0.856	0.098
Quality of housing meeting resilience standards	0.167	0.178	0.812	0.112
Equitable distribution of resilience benefits across groups	0.145	0.156	0.778	0.134
Sustainable management of population growth	0.156	0.167	0.745	0.123
Component 4: Technological Factors				
Innovation and technology adoption in urban management	0.123	0.134	0.112	0.867
Use of technology for resilience monitoring	0.134	0.145	0.098	0.834
Effectiveness of disaster early warning systems	0.156	0.167	0.123	0.798
Use of data-driven approaches in urban management	0.145	0.156	0.134	0.767

Extraction: Principal Component Analysis. Rotation: Varimax with Kaiser Normalization.

Loadings > 0.70 shown in bold. Cross-loadings < 0.30 indicate good discriminant validity.

Source: SPSS Output, 2026

CONCLUSION

This study assessed the role of green infrastructure (GI) in enhancing urban resilience in Phase I of the Federal Capital City, Abuja. The findings indicate that urban resilience is multidimensional, involving physical-environmental, institutional-governance, socioeconomic, and technological factors. Physical-environmental factors were the most prominent, with environmental integration in land-use planning and preservation of natural drainage patterns receiving the highest importance.

The findings further suggest that the resilience benefits of GI depend not only on the availability of green spaces but also on effective planning, institutional capacity, infrastructure quality, public awareness, and appropriate use of technology. Weak implementation of planning policies and inadequate management may limit the ability of existing GI to provide sustained resilience benefits.

Overall, GI represents an important component of urban resilience in Abuja, particularly for addressing environmental pressures such as flooding and the impacts of rapid urban development. Strengthening the integration of GI into land-use planning, protecting natural drainage systems, and improving institutional coordination may enhance the city's capacity to respond to environmental challenges and support more sustainable urban development.

REFERENCES

1. Abubakar, A., Muritala, O., Mbamara, B., & Popoola, O. (2025). The Use of GIS in Development Control Enforcement in Nigeria: Opportunities and Challenges. *INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)*, 9(4), 7061-7072. doi:<https://dx.doi.org/10.47772/IJRISS.2025.90400519>
2. Adeponle, B. (2013). The Integrated City as a Tool for Sustainable Development Abuja Master Plan. *Journal of Educational and Social Research*, 3(5).
3. Adeponle, B. J. (2013). The integrated city development strategy (ICDS) and the sustainable development of the Federal Capital City Abuja, Nigeria. *Journal of Sustainable Development*, 6(7), 1-14.

4. Ahern, J. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. *Landscape and Urban Planning*, 100(4), 341-343.
5. Akande, A., et al. (2023). Flood risk and urban development challenges in Abuja, Nigeria. *Environmental Monitoring and Assessment*, 195(2), 1-18.
6. Akande, O., Obi-George, L., Ahmed, S., Nwokorie, A., & Makun, C. (2023). Flood Vulnerability and Adaptation Practices of Residential Areas in Abuja, Nigeria. *Khylna University Studies*, 20(1), 111-129. doi:<https://doi.org/10.53808/KUS.2023.20.01.2225-se>
7. Akande, O., Obi-George, L., Ahmed, S., Nwokorie, A., & Makun, C. (2023). Flood Vulnerability and Adaptation Practices of Residential Areas in Abuja, Nigeria. *Khylna University Studies*, 20(1), 111-129. doi:<https://doi.org/10.53808/KUS.2023.20.01.2225-se>
8. Cattell, R. B. (1966). The scree test for the number of factors. *Multivariate Behavioral Research*, 1(2), 245–276. https://doi.org/10.1207/s15327906mbr0102_10
9. Cobbinah, P. B., & Erdiaw-Kwasie, M. O. (2016). Urbanization in Africa: Insights and implications for sustainable development. *Cities*, 47, 62-72.
10. Cochran, W. G. (1977). *Sampling techniques* (3rd ed.). John Wiley & Sons.
11. Enoguanbhor, E. C., Gollnow, F., Walker, B. B., Nielsen, J. O., & Lakes, T. (2021). Simulating urban growth in the Federal Capital Territory, Abuja, Nigeria. *Remote Sensing Applications: Society and Environment*, 21, 100448.
12. Fahad, M. (2025). Assessing the Sustainability of Urban Growth: A Study on Abuja City, Nigeria. *Asian Review of Social Sciences*, 14(2), 63-69. doi:<https://doi.org/10.70112/arss-2025.14.2.4340>
13. Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). Sage Publications.
14. Gabdo, A. L., & Sule, M. (2025). Examining the Relationship between Urban Sustainable Development and Quality Education in FCT Abuja, Nigeria. *frican Journal of Environment and Sustainable Development*, 3(2), 11-22.
15. Gumel, D. Y., Aplin, P., Marston, C. G., & Morley, J. G. (2020). Urban growth and environmental sustainability in Abuja. *Sustainability*, 12(6), 2345.
16. Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage Learning.
17. Hair, J., Babin, B., Anderson, R., & Black, W. (2019). *Multivariate Data Analysis* (8th ed.). Cengage Learning. Retrieved from <https://www.cengage.uk/c/multivariate-data-analysis-8e-hair-babin-anderson-black/9781473756540/?searchIsbn=9781473756540>
18. Ibrahim, M., Lay, J., & Ekpo, C. (2025). Institutional coordination and urban governance challenges in Abuja. *Urban Studies Review*, 18(2), 112-129.
19. Ibrahim, M., Lay, U., & Ekpo, A. (2025). IMPACT OF FEDERAL CAPITAL DEVELOPMENT AUTHORITY LAND ALLOCATION AND ZONING PROCESSES ON URBAN PLANNING OF FEDERALCAPITAL CITY, ABUJA NIGERIA. *Journal of Biodiversity and Environmental Research*, 7(4), 218-234. doi:<https://doi.org/10.70382/sjber.v7i4.019>
20. Irani, F., & Rahnamayiezekavat, P. (2021). A framework for urban resilience assessment. *International Journal of Disaster Risk Reduction*, 58, 102195.
21. Irani, M., & Rahnamayiezekavat, P. (2021). An overview of urban resilience: dimensions, components, and approaches. *Acta Sci. Pol. Administratio Locorum*, 20(4), 305-322. doi:10.31648/aspal.7054
22. Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, 20(1), 141–151. <https://doi.org/10.1177/001316446002000116>
23. Madu, M., Gaddafi, I., & Weinoh, O. (2025). MPACT OF URBAN PLANNING AND MANAGEMENT ON THE FCT DWELLERS: 2007-2020. *International Journal of Earth Design and Innovation Research*, 7(4). doi:<https://doi.org/10.70382/mejedir.v7i4.022>
24. Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, 147, 38-49.
25. Muktar, H., Aremu, J., & Daful, M. (2025). Assessment of Urban Heat Island in the Federal Capital City, Abuja, Nigeria. *UMYU Scientifica*, 4(1), 92-100. doi:<https://doi.org/10.56919/usci.2541.010>
26. Nasiru, U., & Yusuf, A. (2024). Impact of Urbanization on Landuse in FCT, Abuja, Nigeria. *Journal of Biodiversity and Evnironmental Research*, 6(4).
27. Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill.



28. Olukoya, O., & Olukoya, O. (2023). Green Spaces in the Context of Spatial Urban Development: Interrogating the Case of Federal Capital City of Nigeria.
29. Olumiji, J. A., Haruna, M. A., & Usman, A. M. (2025). Development control and planning compliance in Abuja. *Journal of Urban Management*, 14(1), 45-61.
30. Olumiji, P., Haruna, K., & Usman, Y. (2025). Urbanization, Development Control, and Insecurity in the Federal Capital Territory, Abuja, Nigeria. *International Journal of African Sustainable Development Research*, 9(2), 199-210. doi:<https://doi.org/10.70382/tijasdr.v09i2.048>
31. Parnell, S., & Pieterse, E. (2014). *Africa's urban revolution*. London: Zed Books.
32. Resilience Alliance. (2010). *Assessing resilience in social-ecological systems: Workbook for practitioners (Version 2.0)*.
33. UNDRR. (2023). *Global Assessment Report on Disaster Risk Reduction 2023*.
34. UN-Habitat. (2022). *World Cities Report 2022: Envisaging the Future of Cities*.