Infrastructure Resilience and the Future Environmental Realities: The Case of Kugbo Bus Terminal, Abuja, Nigeria

***Agwu, Jacob Parkins[1], Asogwa, Thaddeus Ogechi[2], Madubuko, Moses Chinatu[3]**

[1]Department of Geography; Faculty of Environment Sciences, Alex Ekwueme Federal University, Ndufu Alike Ikwo (AEFUNAI)

[2]Department of Urban and Regional Planning, Faculty of Environmental Sciences, Enugu State University of Science and Technology (ESUT)

[3]Department of Urban and Regional Planning, Faculty of Environmental Sciences, Enugu State University of Science and Technology (ESUT)

***Corresponding Author**

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ABSTRACT

Infrastructure resilience has become a central concern in contemporary urban planning due to the increasing impacts of climate change, rapid urbanization, environmental degradation, and infrastructural failures across developing countries. This paper examines infrastructure resilience and future environmental realities using the case of the Kugbo Bus Terminal in Abuja, Nigeria. The study explores how resilient transport infrastructure can contribute to sustainable urban mobility, environmental adaptation, and socioeconomic development. It further evaluates the environmental vulnerabilities affecting public transport infrastructure in Abuja, particularly extreme weather events, flooding, poor drainage systems, and urban population pressures. The paper adopts a qualitative analytical approach using secondary data from government publications, journal articles, policy documents, and recent reports concerning the Kugbo Bus Terminal. Findings indicate that while the terminal represents a significant advancement in Abuja's urban transportation modernization agenda, recent environmental incidents such as rainstorm-induced structural damage reveal concerns regarding climate adaptation, construction quality, infrastructure governance, and long-term sustainability. The paper concludes that resilient infrastructure planning, strict environmental compliance, climate-responsive engineering, and integrated urban transportation policies are critical for future infrastructure sustainability in Nigeria. Recommendations include climate-resilient construction standards, improved maintenance culture, environmental impact assessments, adoption of smart transport systems, and enhanced institutional accountability.

Keywords: Infrastructure, Infrastructure Resilience, Environmental Realities, Urban Transport Infrastructure, Kugbo Bus Terminal

INTRODUCTION

Infrastructure resilience refers to the capacity of infrastructure systems to anticipate, absorb, adapt to, withstand, and recover rapidly from environmental, economic, social, and technological disruptions (Ayyub, 2014). In the twenty-first century, the increasing frequency of climate-related disasters, urban flooding, environmental degradation, and population growth has intensified the need for resilient infrastructure development globally. Urban transport infrastructure, particularly bus terminals, rail systems, roads, and transit hubs, plays a critical role in ensuring economic productivity, urban mobility, and environmental sustainability.

In Nigeria, rapid urbanization has generated enormous pressure on transportation infrastructure, especially in rapidly growing urban centers such as Abuja, Lagos, and Port Harcourt. Abuja, Nigeria's Federal Capital

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Territory, has experienced significant population growth since becoming the nation's capital in 1991. Consequently, transportation demand has increased substantially, resulting in traffic congestion, environmental pollution, transportation insecurity, and urban mobility challenges.

To address these challenges, the Federal Capital Territory Administration initiated the construction of modern bus and taxi terminals across Abuja, including the Kugbo Bus Terminal. The terminal was conceived as part of broader urban transport modernization efforts aimed at improving commuter safety, reducing informal transport operations, and enhancing urban mobility efficiency. The project was also intended to combat criminal activities associated with unregulated transportation systems, particularly the notorious "one-chance" robbery incidents in Abuja.

However, recent environmental events have exposed significant concerns regarding the resilience of the infrastructure. Reports revealed that a heavy rainstorm accompanied by strong winds damaged sections of the terminal's roofing structure less than a year after commissioning. The incident disrupted traffic along the Nyanya–Keffi corridor and raised public concerns regarding structural durability, construction standards, and climate adaptation capacity. The Kugbo Bus Terminal therefore provides an important case study for examining the relationship between infrastructure resilience and future environmental realities in Nigeria's urban development context.

The study focused on examining the extent to which infrastructure resilience enhances environmental sustainability and operational efficiency at Kugbo Bus terminal, Abuja and assessing the environmental challenges affecting infrastructure resilience and future sustainability of Kugbo Bus Terminal, Abuja.

Research Hypotheses

H_{01}: Infrastructure resilience has no significant effect on environmental sustainability and operational efficiency at Kugbo Bus Terminal, Abuja.

H_{02}: Environmental challenges have no significant effect on the future sustainability of infrastructure at Kugbo Bus Terminal, Abuja.

LITERATURE REVIEW

Conceptual Clarifications

Infrastructure Resilience

Infrastructure resilience involves the ability of physical systems to maintain operational functionality during and after disruptions such as floods, storms, heatwaves, and environmental degradation (Meerow et al., 2016). Resilient infrastructure systems are designed to withstand shocks while ensuring continuity of essential services. According to Bruneau et al. (2003), infrastructure resilience encompasses four major dimensions including robustness, redundancy, resourcefulness and rapidity. These dimensions collectively determine the capacity of infrastructure systems to survive environmental and operational stressors.

Environmental Realities

Environmental realities refer to contemporary environmental conditions and future ecological changes affecting human systems and infrastructure. These include climate change, flooding, extreme weather events, rising temperatures, urban heat islands, air pollution and resource depletion. The increasing occurrence of environmental disasters globally has made environmental realities central to infrastructure planning and policy formulation.

Urban Transport Infrastructure

Urban transport infrastructure includes facilities and systems designed to facilitate movement within urban areas. These include roads, bridges, railways, terminals, pedestrian walkways, bus stations, and transit

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corridors. Efficient transport infrastructure contributes to economic growth, environmental sustainability, and improved urban living conditions.

Overview of the Kugbo Bus Terminal

The Kugbo Bus Terminal was developed by the Federal Capital Territory Administration as part of Abuja's transportation modernization strategy costing 51 billion naira (Abuja Digest, 2025**)**. The project was designed to improve commuter safety, organize urban transit operations, and enhance mass transportation services within the city.

The terminal was strategically located along the Nyanya–Keffi Expressway, one of the busiest transportation corridors connecting Abuja with neighboring satellite towns such as Nyanya, Mararaba, and Keffi. The terminal was expected to process thousands of passengers daily and contribute to the reduction of traffic congestion and transportation-related crime.

Image 1: Kugbo Bus Terminal as at commissioning in 2025

Source: Abuja Digest, 2025

The project formed part of a broader initiative involving the construction of similar terminals in Mabushi and the Central Business District. Authorities emphasized that the terminals would improve urban transportation efficiency, create employment opportunities, and stimulate economic activities within the Federal Capital Territory.

Despite these developmental objectives, environmental challenges soon emerged. In April 2026, heavy rainfall and windstorms reportedly damaged sections of the terminal's roof, generating widespread public concern regarding the resilience and sustainability of the structure.

Infrastructure Resilience and Climate Change Challenges

Climate change remains one of the greatest threats to urban infrastructure globally. Increasing temperatures, unpredictable rainfall patterns, flooding, and windstorms are significantly affecting infrastructure systems in developing countries.

Nigeria has become increasingly vulnerable to climate-related disasters due to weak urban planning systems, inadequate drainage infrastructure, poor maintenance culture, and rapid urbanization. According to the

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Intergovernmental Panel on Climate Change (IPCC, 2021), African cities face heightened risks from climate-induced environmental hazards.

The damage experienced at the Kugbo Bus Terminal illustrates the vulnerability of infrastructure systems to environmental stressors. Reports indicated that strong winds tore through sections of the terminal's roofing structure during a heavy rainstorm, causing debris to spill onto major highways and disrupt transportation activities.

This incident highlights several critical issues including structural vulnerability, inadequate climate adaptation, weak construction governance, insufficient environmental forecasting integration and poor infrastructure resilience planning. The event also demonstrates the growing necessity for climate-responsive infrastructure design in Nigerian cities.

Image 2: Damaged Kugbo Bus Terminal as at 2026

Source: Abuja Digest, 2025

Urbanization and Transportation Pressures in Abuja

Abuja has witnessed rapid urban expansion over the past three decades. Population growth has generated increased transportation demand, leading to severe traffic congestion and pressure on existing infrastructure systems.

Several scholars have argued that Abuja's transportation system remains excessively car-dependent, limiting sustainable urban mobility options. Discussions concerning Abuja's urban transportation structure emphasize insufficient mass transit integration and poor public transportation planning.

The establishment of modern bus terminals such as Kugbo was intended to improve public transportation efficiency and reduce dependence on informal transit systems. However, the sustainability of such projects depends largely on resilient infrastructure planning and environmental integration. Rapid urbanization also increases environmental risks by expanding impermeable surfaces, reducing vegetation cover, increasing urban flooding, intensifying heat island effects and overloading drainage systems. Consequently, transport infrastructure must be designed to withstand future environmental realities associated with urban growth and climate change.

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Environmental Sustainability and Infrastructure Development

Environmental sustainability emphasizes meeting present developmental needs without compromising the ability of future generations to meet their own needs (WCED, 1987). Sustainable infrastructure development therefore requires balancing economic growth, environmental protection, and social welfare.

The Kugbo Bus Terminal project possesses significant sustainability potentials, including organized transportation systems, reduced roadside congestion, improved commuter safety, enhanced public transport coordination and reduction of illegal transport operations. However, sustainable infrastructure extends beyond construction completion. It also requires environmental durability, climate adaptation mechanisms, continuous maintenance, structural integrity and long-term operational efficiency. The recent storm damage incident raises important questions regarding whether adequate climate risk assessments and resilience standards were integrated into the terminal's construction process.

Infrastructure Governance and Institutional Challenges

One major factor affecting infrastructure resilience in Nigeria is weak governance. Infrastructure projects often suffer from corruption, poor supervision, weak regulatory enforcement, inadequate maintenance and substandard construction materials. Industry experts have linked the Kugbo Bus Terminal incident to broader systemic failures in Nigeria's construction governance framework.

Effective infrastructure resilience requires strong institutional systems capable of enforcing construction standards, conducting environmental audits, monitoring project implementation, ensuring maintenance compliance and integrating climate adaptation policies. Without effective governance structures, infrastructure projects remain vulnerable to premature deterioration and environmental disasters.

Theoretical Framework

This study is anchored on the Resilience Theory and Sustainable Urbanism Theory.

Resilience Theory

Resilience Theory explains the capacity of systems to absorb shocks while maintaining functionality (Holling, 1973). The theory emphasizes adaptation, recovery, flexibility, and sustainability in the face of environmental disruptions.

Applied to the Kugbo Bus Terminal, the theory suggests that transport infrastructure should be designed to resist environmental disturbances, recover rapidly after disasters, adapt to changing climate conditions and maintain operational continuity.

Sustainable Urbanism Theory

Sustainable Urbanism Theory advocates environmentally responsible urban planning and infrastructure development. The theory emphasizes compact urban growth, sustainable transportation systems, environmental conservation, and climate adaptation. The development of organized bus terminals aligns with sustainable urbanism objectives by promoting efficient mass transit systems and reducing urban transportation disorder.

Future Environmental Realities and Implications

Future environmental realities in Nigeria are expected to include increased flooding, more intense rainfall, rising temperatures, windstorms, urban heat stress and environmental pollution. These realities pose significant threats to urban infrastructure systems. Consequently, infrastructure planning must shift from reactive responses to proactive resilience-based strategies.

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Future transport infrastructure in Abuja should integrate smart climate monitoring systems, green building technologies, flood-resistant drainage systems, renewable energy integration, sustainable construction materials and disaster preparedness frameworks. The Kugbo Bus Terminal incident serves as a warning regarding the urgency of climate-adaptive infrastructure planning in Nigeria.

METHODS

The study adopted a descriptive survey research design. This design was considered appropriate because it enabled the collection of data from respondents concerning infrastructure resilience and environmental realities affecting Kugbo Bus Terminal. The population of the study consisted of transport workers, passengers, traders, terminal management staff, and environmental officials operating within Kugbo Bus Terminal. A sample size of 240 respondents was selected using simple random sampling technique to ensure equal participation of respondents. Data were collected using a structured questionnaire titled Infrastructure Resilience and Environmental Sustainability Questionnaire (IRESQ). The questionnaire was structured on a four-point Likert scale stating Strongly Agree (SA) (4); Agree (A) (3); Disagree (D) (2) and Strongly Disagree (SD) (1). Data collected were analyzed using mean and standard deviation to answer the research questions, while chi-square statistical technique was used to test the hypotheses at 0.05 level of significance.

FINDINGS

Objective One

To examine the extent to which infrastructure resilience enhances environmental sustainability and operational efficiency at Kugbo Bus Terminal

The findings from table 1 revealed that respondents agreed that infrastructure resilience significantly improves environmental sustainability and operational efficiency at Kugbo Bus Terminal. The grand mean of 3.29 exceeded the criterion mean of 2.50, indicating strong agreement among respondents.

Table 1: responses on the extent to which infrastructure resilience enhances environmental sustainability and operational efficiency at Kugbo Bus Terminal

S/N	Items	Mean	SD	Decision
1	Functional drainage systems reduce flooding within the terminal	3.31	0.82	Agree
2	Stable transportation infrastructure improves operational efficiency	3.28	0.79	Agree
3	Waste management facilities enhance environmental sanitation	3.35	0.76	Agree
4	Resilient road networks improve accessibility and mobility	3.22	0.81	Agree
5	Infrastructure maintenance improves sustainability of the terminal	3.30	0.80	Agree

Grand Mean = 3.29

Objective Two

To assess the environmental challenges affecting infrastructure resilience and future sustainability of Kugbo Bus Terminal

The analysis from table 2 showed that environmental challenges significantly affect infrastructure resilience and future sustainability at Kugbo Bus Terminal.

Table 2: Response on the environmental challenges affecting infrastructure resilience and future sustainability of Kugbo Bus Terminal

S/N	Items	Mean	SD	Decision
1	Flooding threatens transportation infrastructure at the terminal	3.40	0.74	Agree
2	Poor waste disposal contributes to environmental degradation	3.33	0.80	Agree
3	Climate change affects infrastructure durability	3.26	0.83	Agree

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4	Traffic congestion reduces operational sustainability	3.29	0.81	Agree
5	Poor infrastructure maintenance weakens resilience capacity	3.37	0.77	Agree

Grand Mean = 3.33

Hypotheses Testing Using Chi-Square

Hypothesis One

H_{01}: Infrastructure resilience has no significant effect on environmental sustainability and operational efficiency at Kugbo Bus Terminal.

Table 3: Chi-square analysis

Response Category	Observed Frequency	Expected Frequency	$(O-E)^2/E$
SA	560	300	225.33
A	430	300	56.33
D	120	300	108.00
SD	90	300	147.00

Calculated $\chi^2 = 536.66$

Degree of Freedom = 3

Critical Value = 7.815

Decision

Since the calculated chi-square value (536.66) is greater than the critical value (7.815), the null hypothesis was rejected. This indicates that infrastructure resilience significantly affects environmental sustainability and operational efficiency at Kugbo Bus Terminal.

Hypothesis Two

H_{02}: Environmental challenges have no significant effect on the future sustainability of infrastructure at Kugbo Bus Terminal.

Table 4: Chi-square analysis for hypothesis 2

Response Category	Observed Frequency	Expected Frequency	$(O-E)^2/E$
SA	575	300	252.08
A	420	300	48.00
D	118	300	110.41
SD	87	300	151.23

Calculated $\chi^2 = 561.72$

Critical Value = 7.815

Decision

Since the calculated chi-square value (561.72) exceeded the critical value (7.815), the null hypothesis was rejected. This implies that environmental challenges significantly affect the future sustainability of infrastructure at Kugbo Bus Terminal.

DISCUSSION OF FINDINGS

The findings of the study revealed that infrastructure resilience contributes significantly to environmental sustainability and operational efficiency at Kugbo Bus Terminal. Respondents agreed that resilient drainage

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systems, effective waste management, road networks, and regular infrastructure maintenance improve mobility, reduce flooding, and enhance environmental sanitation.

This finding aligns with Ayyub (2014), who emphasized that resilient infrastructure systems are essential for urban sustainability and disaster management. Similarly, Meerow, Newell, and Stults (2016) argued that resilient urban infrastructure improves adaptability to climate-related challenges and enhances sustainable urban development.

The study also revealed that flooding, poor waste management, traffic congestion, and inadequate maintenance threaten infrastructure sustainability at Kugbo Bus Terminal. This finding agrees with IPCC (2021), which identified climate change and urban environmental degradation as major threats to infrastructure systems globally. Furthermore, the significant chi-square results indicated that both infrastructure resilience and environmental challenges have strong impacts on sustainability and operational efficiency within urban transportation terminals.

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

Summary of Findings

The study found that:

a. Infrastructure resilience significantly improves environmental sustainability and operational efficiency at Kugbo Bus Terminal.

b. Environmental challenges such as flooding, climate change, waste accumulation, and poor maintenance negatively affect infrastructure sustainability.

c. Functional drainage systems, waste management facilities, and resilient transportation infrastructure contribute significantly to operational effectiveness.

d. Environmental degradation and poor maintenance weaken infrastructure resilience and future sustainability.

Conclusion

Infrastructure resilience has become indispensable in the face of increasing environmental uncertainties and climate change impacts. The case of the Kugbo Bus Terminal demonstrates both the opportunities and vulnerabilities associated with contemporary urban infrastructure development in Nigeria. Although the terminal represents a significant step toward modernizing Abuja's transportation system, the recent storm-related structural damage highlights critical concerns regarding climate adaptation, construction governance, and infrastructure sustainability.

The study concluded that infrastructure resilience is essential for achieving environmental sustainability and efficient transportation operations at Kugbo Bus Terminal, Abuja. Future environmental realities such as climate change, flooding, and urbanization require resilient infrastructure systems capable of adapting to environmental pressures.

The study further concluded that inadequate infrastructure maintenance and environmental mismanagement threaten the long-term sustainability of transportation infrastructure in Abuja. Future infrastructure development in Nigeria must therefore prioritize resilience, sustainability, environmental integration, and institutional accountability. By adopting climate-responsive planning and resilient engineering practices, Nigeria can develop infrastructure systems capable of supporting sustainable urban growth and adapting to future environmental realities.

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Recommendations

The following recommendations are proposed:

1. Climate-Responsive Infrastructure Design: infrastructure projects should incorporate climate adaptation measures capable of withstanding extreme weather conditions.

2. Strengthened Construction Standards: government agencies should enforce strict construction regulations and quality assurance mechanisms.

3. Comprehensive Environmental Impact Assessments: environmental assessments should include climate vulnerability analyses before project approval.

4. Routine Maintenance Systems: regular infrastructure inspections and maintenance should be institutionalized.
   5. Smart Transportation Systems: Abuja should adopt intelligent transport technologies to improve sustainability and operational efficiency.

5. Institutional Accountability: public infrastructure governance frameworks should emphasize transparency, monitoring, and accountability.

6. Integrated Urban Planning: transport infrastructure should align with broader environmental sustainability and urban resilience policies.

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