International Journal of Engineering Research and Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 21, Issue 6 (June 2025), PP 90-92

A Geospatial Decision-Support Framework for Infrastructure Vulnerability Assessment in Auchi, Edo State, Nigeria

Aigberua, O.D., Igbokwe, E.C. Ezeh, F.C. and Oliha A.O.

Abstract-*As critical infrastructure in rapidly urbanizing areas such as Auchi, Edo State continues to face mounting threats from floods and inadequate planning, a robust decision-support system is urgently needed. This paper proposes a comprehensive geospatial decision-support framework built on remote sensing and Geographic Information Systems (GIS) techniques. The framework is structured around hazard assessment, infrastructure exposure, spatial multi-criteria evaluation, and geovisualization. It aims to integrate spatially referenced data and infrastructure metrics to produce actionable vulnerability insights that will enhance decision-making processes in urban infrastructure planning and disaster risk mitigation. Drawing from the recent vulnerability assessment of educational and healthcare facilities in Auchi, the framework is contextualized to address the town's unique topographic, hydrological, and infrastructural realities.*
Keywords: *GIS, Remote Sensing, Infrastructure Vulnerability, Spatial Decision-Support Framework, Auchi, Edo State, Flood Hazard Mapping, AHP, Urban Resilience*

Date of Submission: 06-06-2025 Date of acceptance: 16-06-2025

I. Introduction

Urban infrastructure systems are the lifelines of growing towns, providing essential services such as education, healthcare, and transportation. However, in regions like Auchi, the rapid rate of urban expansion, combined with poor drainage systems, recurrent flooding, and informal settlement development, has significantly increased the vulnerability of critical infrastructure (Eze & Agbo, 2021; Akinyemi et al., 2022). This has compromised service delivery and exposed residents to heightened risks during emergencies. Traditional infrastructure assessments often lack spatial specificity, which limits proactive planning.

Remote sensing and GIS have emerged as transformative tools for spatial planning and hazard analysis (Goodchild, 2007; Malczewski, 2006). When combined with decision-support methodologies, these tools enable a more comprehensive understanding of infrastructure vulnerabilities. This paper develops a conceptual geospatial decision-support framework tailored to Auchi, integrating multi-source geospatial data, spatial analysis models, and decision-support outputs to guide infrastructure vulnerability assessment and planning.

II. Rationale for a Geospatial Decision-Support Framework

The rationale behind developing a geospatial decision-support framework for infrastructure vulnerability in Auchi is threefold. First, conventional planning methods often fail to consider spatial heterogeneity and the cumulative impact of environmental hazards on infrastructure. Second, the town has experienced significant infrastructure failure due to poor flood management and lack of risk-informed spatial data (Oluwasanya & Ayeni, 2020). Third, existing assessment methods rarely support interactive, data-driven decision-making.

A geospatial decision-support framework combines spatial analysis with decision theory to support informed urban planning. It integrates hydrological modeling, remote sensing imagery, GIS-based infrastructure mapping, and vulnerability assessment tools. In this context, decision-makers can simulate flood impact scenarios, evaluate infrastructure exposure, and identify areas where investment or intervention is most needed (Youssef et al., 2016). Such an integrated tool is particularly relevant for Auchi, where over 50% of infrastructure is located in high or very high flood-risk zones.

III. Proposed Conceptual Framework

The conceptual framework consists of six interconnected components that together support a systematic and quantitative assessment of infrastructure vulnerability in Auchi.

1. **Data Acquisition and Harmonization**: This component focuses on sourcing and preparing diverse geospatial datasets necessary for modeling. Key data inputs include high-resolution satellite imagery (e.g., Landsat 8, Digital Globe), Digital Elevation Models (DEMs) from sources such as SRTM or ALOS, and field-collected GPS coordinates of critical infrastructure. Radiometric correction, geometric

alignment, projection transformation, and mosaicking are performed to harmonize datasets for spatial analysis in a GIS environment.

2. **GIS-Based Infrastructure Mapping**: Here, all critical infrastructure—particularly educational and healthcare facilities—is digitized, classified, and geocoded. Each feature is attributed with structural, functional, and locational information, allowing integration into geospatial databases. Attribute tables are constructed to store relevant variables such as age of building, elevation, material type, number of users, and proximity to service routes. The use of relational joins between spatial features and tabular data ensures comprehensive querying and analysis.
3. **Flood Hazard Modeling**: This stage models flood-prone areas based on topography, hydrology, and land cover conditions. The DEM is first processed using sink filling and flow direction algorithms to ensure hydrologic correctness. Surface runoff is computed using the Soil Conservation Service (SCS) Curve Number (CN) method. The Curve Number is derived from land use, soil type, and hydrologic condition layers. Using ArcGIS Hydrology tools, flow direction, flow accumulation, stream order, and watershed delineation are derived. These layers help define flood basins and potential inundation zones, providing a spatial foundation for vulnerability overlay analysis.
4. **Exposure and Vulnerability Analysis**: The exposure of infrastructure is evaluated by overlaying geocoded facilities on flood hazard maps. A vulnerability index is calculated based on spatial and physical attributes, such as distance to river channels, elevation, building age, and usage intensity. Vulnerability is assessed using a normalized scoring system.
5. **Spatial Multi-Criteria Evaluation (SMCE)**: AHP is employed to derive weights for each vulnerability criterion based on expert judgment. Pairwise comparison matrices are developed, and eigenvalues are computed to determine priority weights. A CR ≤ 0.1 is considered acceptable.
6. **Decision-Support Outputs**: The framework outputs include spatial vulnerability maps highlighting zones of varying infrastructure risk levels. These maps are visualized using color-coded raster layers, with dashboards developed in web-GIS platforms such as Leaflet or ArcGIS Online for interactive exploration. Outputs also include tabular reports of infrastructure risk categories (e.g., high, moderate, low) and recommendations for zoning adjustments or infrastructure upgrades.

Collectively, these six modules provide a replicable structure for assessing infrastructure vulnerability with high spatial precision and decision-making utility.

IV. Framework Implementation Strategy

Implementing this framework in Auchi requires a phased and inclusive approach. Initially, institutional capacity for geospatial data handling must be built through training in remote sensing, GIS, and MCDA techniques. Local data should be integrated with national open data sources, and participatory mapping can enrich datasets with community perspectives.

Next, municipal authorities and urban planners should adopt open-source GIS platforms (QGIS, SAGA GIS) to conduct spatial analyses. Decision-support dashboards can be built using Web GIS applications to disseminate results and allow interactive scenario testing. Partnerships with academic institutions like Nnamdi Azikiwe University can ensure methodological rigor and continuous improvement.

V. Anticipated Benefits and Outcomes

The geospatial decision-support framework is expected to deliver the following outcomes:

1. Comprehensive vulnerability maps showing the distribution of flood-prone infrastructure
2. Identification of underserved and high-risk zones for targeted intervention
3. Support for proactive urban development planning and zoning enforcement
4. Evidence-based prioritization of infrastructure investments
5. Strengthened capacity for disaster risk reduction and climate resilience

In Auchi, where over 63% of educational and 68% of healthcare facilities are located in high flood-risk zones, this framework provides an urgently needed tool for aligning infrastructure development with risk-informed spatial planning.

VI. Conclusion

This conceptual paper presents a geospatial decision-support framework tailored to address the infrastructure vulnerability challenges of Auchi, Edo State. By integrating hazard modeling, infrastructure exposure analysis, and multi-criteria evaluation within a GIS environment, the framework provides a comprehensive and adaptable solution for planners and policy-makers. Future research should focus on refining the model through dynamic hazard simulations, incorporating socioeconomic vulnerability metrics, and deploying participatory GIS tools for real-time community engagement.

References

[1]. Akinyemi, F. O., Adeyeye, T. B., & Ogunbiyi, J. S. (2022). Mapping urban development potential in Akure using GIS and multi-criteria evaluation. *GeoSpatial World*, 29(1), 56–69.

[2]. Eze, P. N., & Agbo, F. O. (2021). GIS-based flood risk mapping and analysis of vulnerable infrastructure in urban centers. *Nigerian Journal of Environmental Sciences and Technology*, 5(2), 102–114.

[3]. Goodchild, M. F. (2007). Citizens as sensors: The world of volunteered geography. *GeoJournal*, 69(4), 211–221.

[4]. Malczewski, J. (2006). GIS-based multicriteria decision analysis: a survey of the literature. *International Journal of Geographical Information Science*, 20(7), 703–726.

[5]. Oluwasanya, G. O., & Ayeni, A. O. (2020). Infrastructure vulnerability mapping in flood-prone urban environments using spatial modeling techniques. *Urban and Regional Planning Review*, 12(3), 45–58.

[6]. Youssef, A. M., Maerz, N. H., & El-Magd, I. A. (2016). GIS-based multi-criteria evaluation for flood risk mapping in urban areas. *Hydrological Sciences Journal*, 61(6), 1001–1012.