Development of Road Network GIS for Urban Safety and Security in Awka, Anambra State

Adeboboye, A. J.[1], Oji Dobe Okpa[2], Atoki L.O.[3]

Department of Surveying and Geoinformatics Nnamdi Azikiwe University Awka, Anambra State, Nigeria

DOI: https://doi.org/10.51584/IJRIAS.2026.11030042

Received: 12 March 2026; Accepted: 18 March 2026; Published: 04 April 2026

ABSTRACT

Urban safety and effective emergency management depend greatly on the efficiency of road network systems. This study focuses on developing a Geographic Information System (GIS)-based road network database for enhancing urban safety and emergency response in Awka, Anambra State, Nigeria. The research integrates spatial data derived from satellite imagery, Global Positioning System (GPS) surveys, and administrative datasets into a digital geodatabase using ArcGIS 10.7. Network analysis tools such as Service Area and Closest Facility were employed to evaluate the distribution of police stations, determine emergency response coverage, and optimize travel routes.Results revealed significant disparities in police coverage across Awka's urban core, particularly in rapidly developing neighborhoods like Ifite, Okpuno, and Ngozika Estate. These areas fall outside optimal emergency response radii, increasing vulnerability to delayed security intervention. The study recommends establishing additional police outposts and adopting GIS-based monitoring systems to ensure more balanced spatial coverage. The developed GIS model serves as a decision-support tool for urban planners, transport authorities, and law enforcement agencies, demonstrating how spatial analysis can reduce response time, enhance resource allocation, and strengthen community safety.

Keywords: GIS, Road Network, Urban Safety, Emergency Response, Spatial Analysis.

INTRODUCTION

Urban safety and security are vital components of sustainable development. In Nigeria, the challenge of maintaining order in rapidly growing cities has intensified due to uncoordinated urban expansion, inadequate infrastructure, and limited access to real-time spatial data for planning. Awka, the capital of Anambra State, has experienced a surge in population density and vehicular movement following its designation as a state capital. However, the absence of an integrated spatial database for road management and emergency operations has hindered timely security responses.

Geographic Information Systems (GIS) provide a powerful platform for spatial data integration, visualization, and analysis. GIS tools can assess the spatial distribution of law enforcement facilities, model road network efficiency, and guide decision-making for emergency response optimization (Chainey & Ratcliffe, 2005; Miller & Shaw, 2015). Previous studies have shown that GIS-based network models enhance the ability of security and emergency agencies to allocate resources effectively and identify underserved areas (Longley et al., 2015).

This study aims to apply GIS techniques in developing a road network database for urban safety enhancement in Awka. Specifically, it seeks to (1) map the existing road network and police station distribution, (2) analyze service coverage and accessibility using network analysis, and (3) recommend strategies for improving emergency response and spatial safety management.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue III March 2026

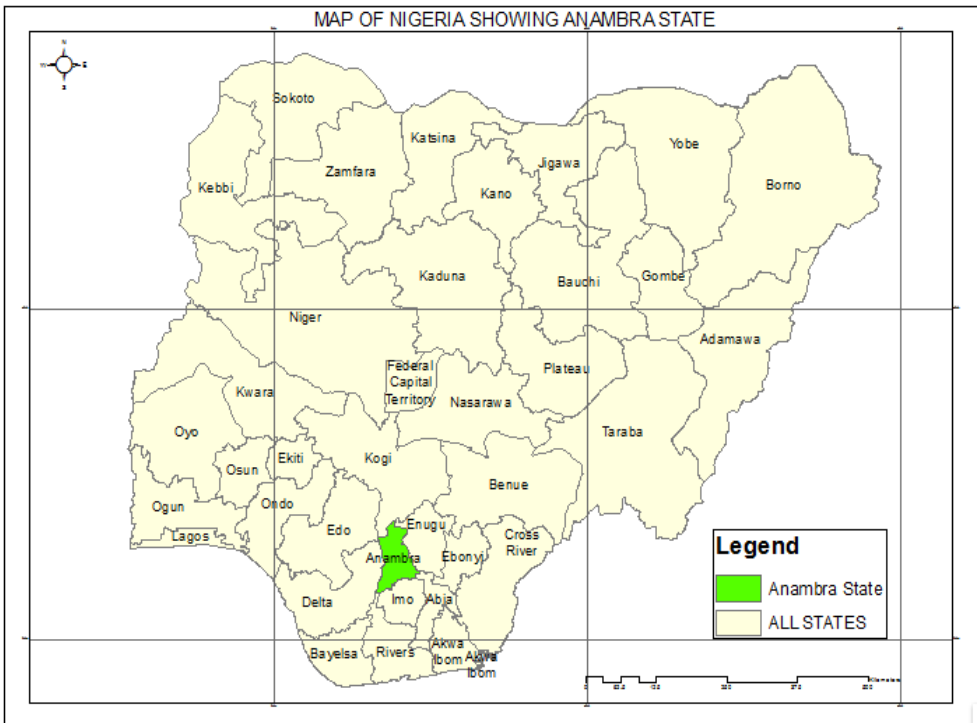
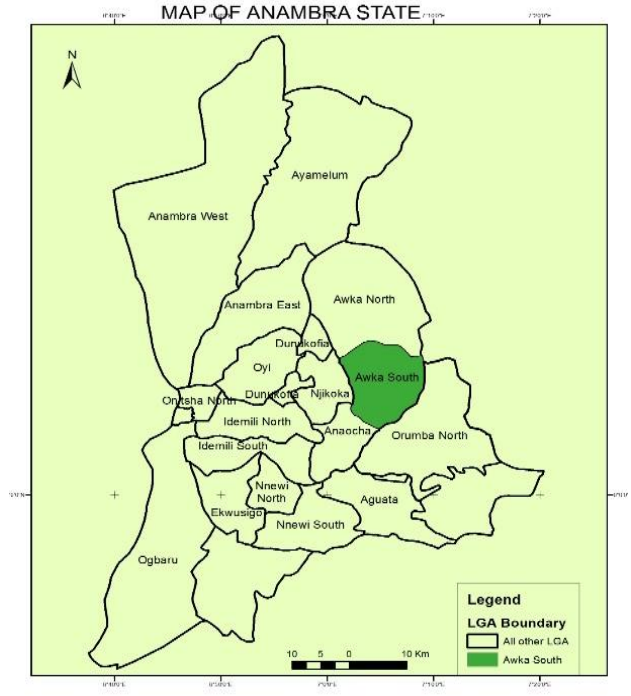


Figure 1: Map of Nigeria, showing Anambra State. *Source: Author*)

MATERIALS AND METHODS

Study Area

Awka, the capital of Anambra State, lies approximately between latitudes 6°10′N and 6°15′N and longitudes 7°03′E and 7°06′E. It occupies a strategic position along the Onitsha–Enugu expressway and serves as an administrative and educational hub in southeastern Nigeria. The city's rapid expansion has resulted in increased vehicular traffic, land-use conversion, and a corresponding rise in urban safety concerns. Awka's terrain is undulating with elevations between 80 and 120 meters above mean sea level, influencing drainage and road design.



(Figure 2: Location Map of Awka within Anambra State. *Source: Author*)

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue III March 2026

Data Acquisition

The study utilized both primary and secondary data sources.

- Primary data included GPS coordinates of major road intersections and police stations collected through field surveys using handheld GPS receivers.
- Secondary data comprised topographic maps, satellite imagery from SAS Planet, administrative shapefiles, and road network data obtained from the Anambra State Ministry of Works and the OpenStreetMap platform.

All datasets were projected to the Universal Transverse Mercator (UTM) Zone 32N, WGS 84 coordinate system to ensure consistency and positional accuracy. The handheld GPS receiver (Garmin Etrex 10) used to collect police station coordinates has a stated horizontal accuracy of ±3–5 meters under open-sky conditions. To improve reliability, each point was recorded for 3–5 minutes. Satellite imagery downloaded from SAS Planet (Google high-resolution layers) has a spatial resolution of approximately 0.5–1.0 meters, sufficient for digitizing roads and buildings.

For georeferencing, nine ground control points (GCPs) were established using a differential GNSS (DGNSS) receiver, achieving centimeter-level precision. A second-order polynomial transformation applied in ArcGIS yielded a root mean square error (RMSE) of 0.87 meters, confirming the internal consistency of the image rectification.

(Figure 3: Map of Awka Urban. *Source: Author*)

Data Processing

The datasets were pre-processed in ArcGIS 10.7, involving georeferencing, digitization, topology correction, and attribute editing. Road segments were classified based on their functional hierarchy (primary, secondary, tertiary, and access roads). Each feature was assigned attributes such as name, length, and surface type.

Police stations were mapped as point features and linked to the road network to enable network analysis. The final geodatabase comprised both spatial and non-spatial attributes relevant for network modeling.

Network Analysis

Network analysis tools in ArcGIS were used to evaluate spatial accessibility and coverage efficiency. Two key operations were performed:

1. Service Area Analysis – to determine the geographical extent each police station could cover within defined travel time thresholds (e.g., 5, 10, and 15 minutes).

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue III March 2026

2. Closest Facility Analysis – to compute optimal routes between incident locations and the nearest police facility, minimizing travel time along the existing road network.

Travel time impedance was derived from road segment lengths and assigned speeds based on road hierarchy: primary roads at 40–50 km/h, secondary roads at 30–40 km/h, and tertiary/access roads at 20–25 km/h.

For emergency response modelling, an average operational speed of 30 km/h was adopted, reflecting typical conditions in Awka based on field observations and reconnaissance surveys. While constant speeds simplify real-world conditions, this classification provides a basis for future refinement to incorporate variable speeds influenced by traffic congestion, road conditions, and time-of-day variations.

Software and Tools

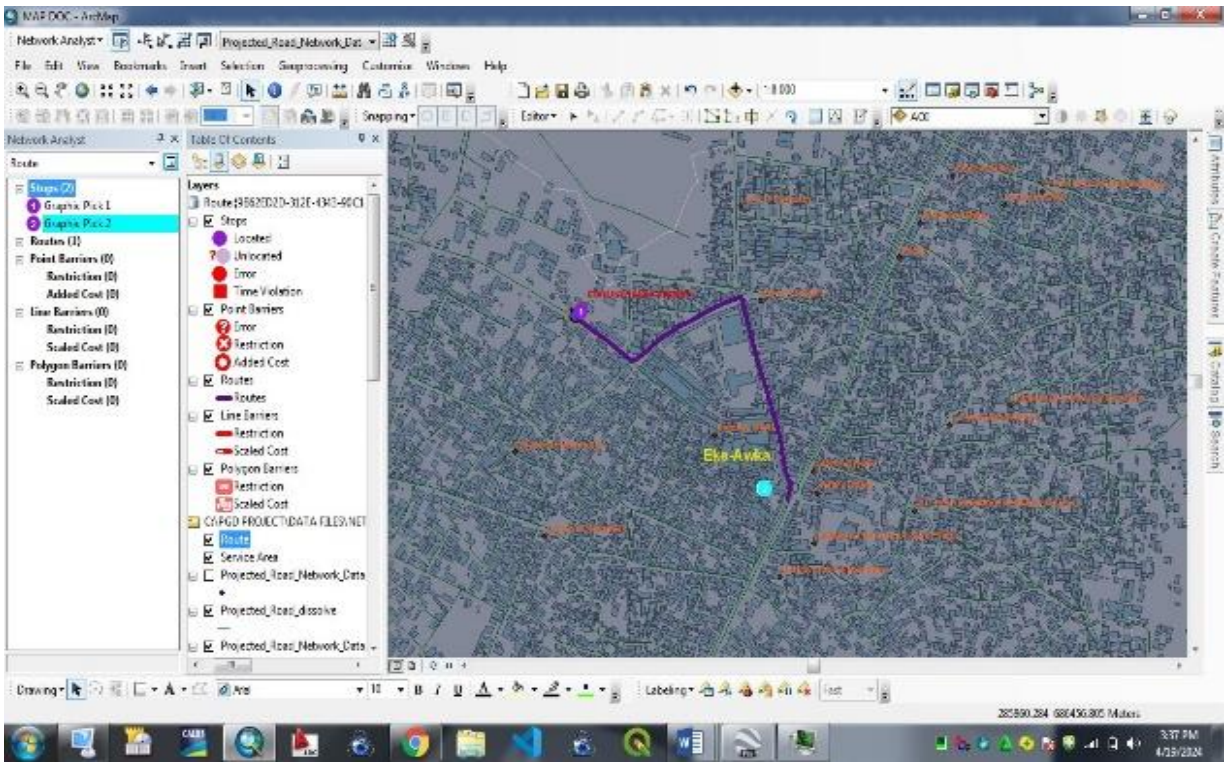
Data processing and map production were performed using:

- ArcGIS 10.7 – for spatial analysis and cartographic visualization.
- Google Earth Engine – To download building footprint data.
- Microsoft Excel 2016 – for attribute data management and documentations.

RESULTS AND DISCUSSION

Spatial Distribution of Road Network and Police Stations

- The developed GIS road network database provided a comprehensive visualization of Awka's transportation layout and the spatial pattern of police stations. Major roads such as the Enugu–Onitsha Expressway, Zik Avenue, Arthur Eze Avenue, and Ifite Road form the city's primary circulation framework, linking administrative, residential, and institutional areas.
- The spatial analysis revealed that the majority of existing police facilities are concentrated along the central corridor of the city, particularly near the expressway and older settlements. Peripheral zones such as Ifite, Okpuno, Amansea, and Ngozika Estate were identified as having limited accessibility to police services. This uneven distribution contributes to longer response times during emergencies and reduced operational efficiency.

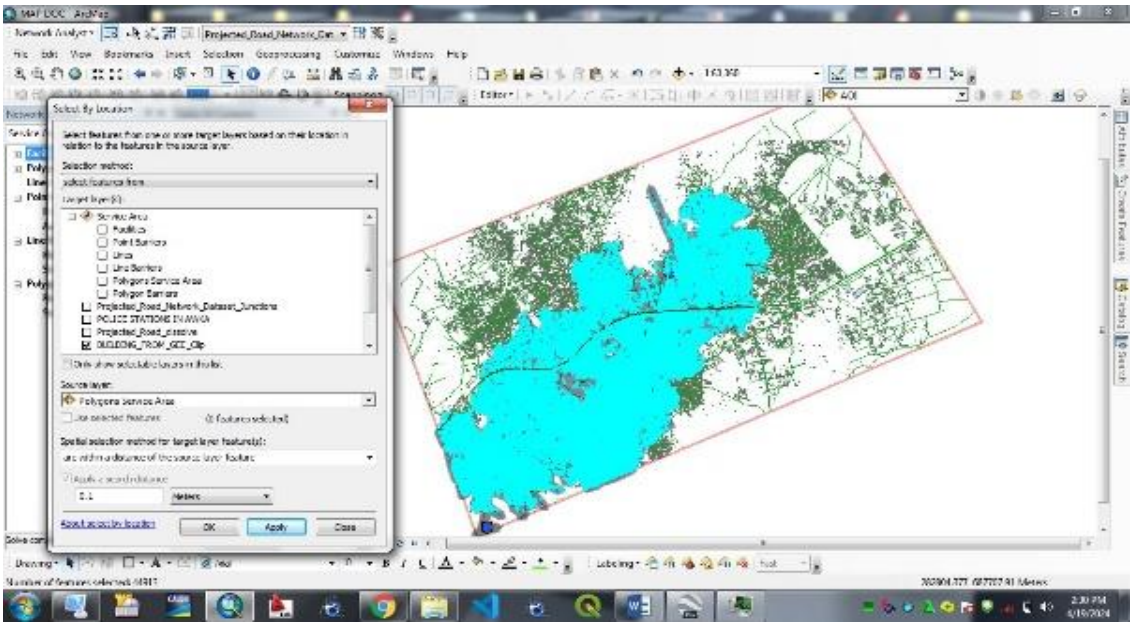


(Figure 4: Screenshot Showing Query for Shortest Distance from Police Station to Incidence Location)

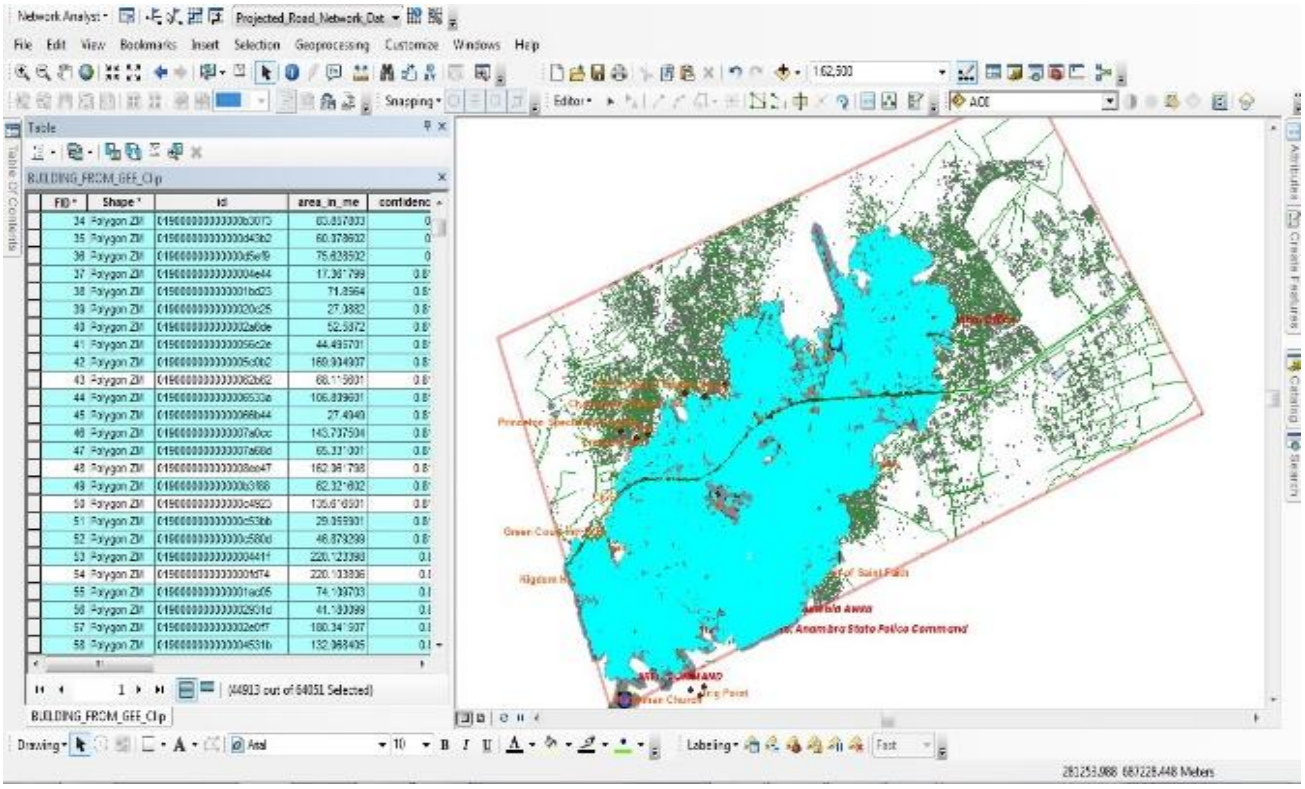
ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue III March 2026

Service Area and Accessibility Analysis

- The Service Area Analysis indicated that only about 70% of Awka's built-up area falls within a 10-minute response radius of existing police stations. The remaining 30%, located in newly developed neighborhoods, remains inadequately covered. This spatial disparity aligns with the city's expansion pattern, where new housing developments outpace the establishment of safety infrastructure.
- Accessibility surfaces generated from the model show that central districts like Amawbia, Agu-Awka, and Arroma benefit from high accessibility, while outer zones such as Okpuno and Ifite fall within moderate to low accessibility ranges. These results emphasize the need for a decentralized policing framework supported by spatial data infrastructure.



(Figure 5: Screenshot Showing Query for Service Area Covered by all Police Stations within Awka)

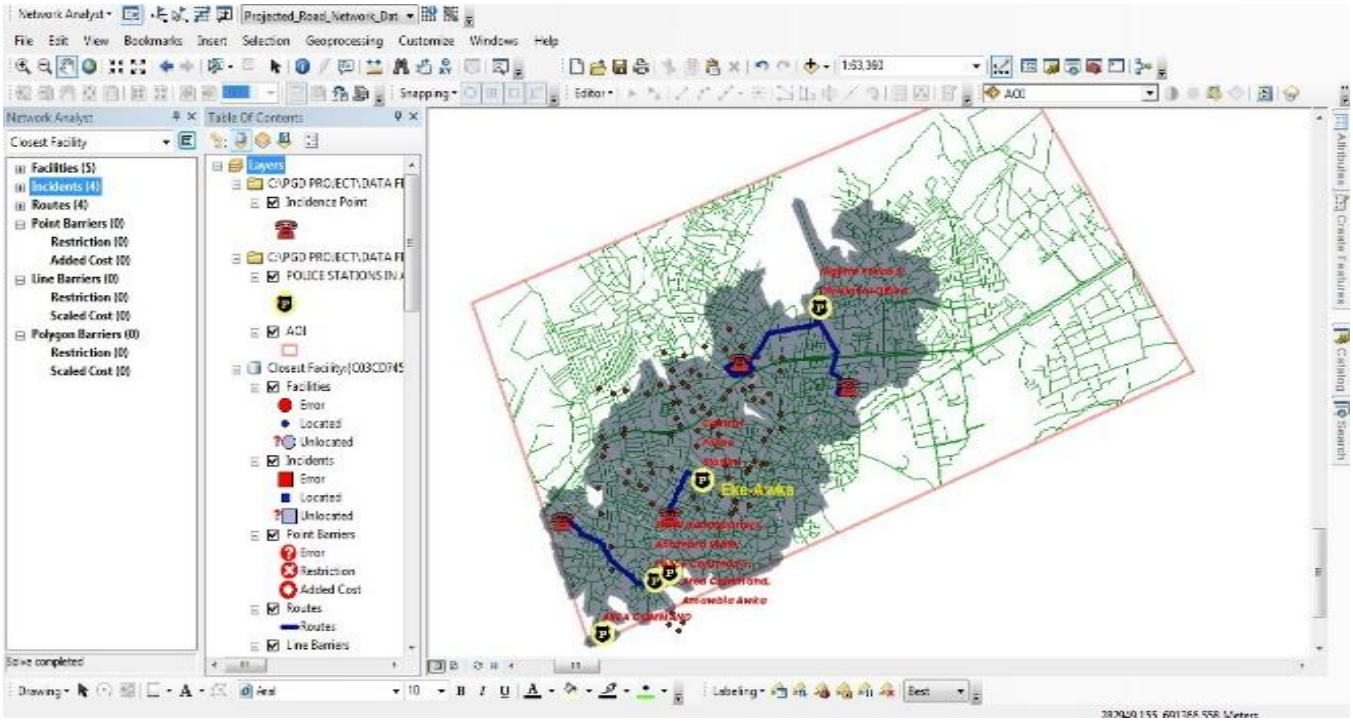


(Figure 6: Screenshot showing query for building count within the service area covered by all police stations within Awka)

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue III March 2026

Closest Facility Analysis

- The Closest Facility Analysis modeled optimal routes between hypothetical emergency points and the nearest police stations. Findings revealed that response times along major arterial roads ranged between 3 and 8 minutes, whereas response to peripheral areas could exceed 15 minutes during peak traffic periods.
- For example, incidents originating from the Ifite–Permanent Site axis were found to experience delayed intervention, primarily due to network congestion and distance from available police facilities. This insight demonstrates the significance of integrating traffic-weighted impedance factors into future models for more realistic simulation of urban dynamics.



(Figure 7: Shows query for shortest possible distance between incidence point and police station within the service area covered by all police station within Awka)

Validation

The network model was validated using ground truthing, sensitivity analysis, and expert review to ensure the reliability of the results.

Ground Truthing: Fifteen randomly selected locations were used to compare modeled response times with actual travel times. A vehicle equipped with a GPS device followed the optimal routes generated by the GIS model. The results showed close agreement, with minor variations due to real-time traffic conditions.

Sensitivity Analysis: The model was tested using different speed assumptions (20 km/h and 40 km/h) and response time thresholds. The spatial pattern of coverage gaps remained consistent, confirming the robustness of the model.

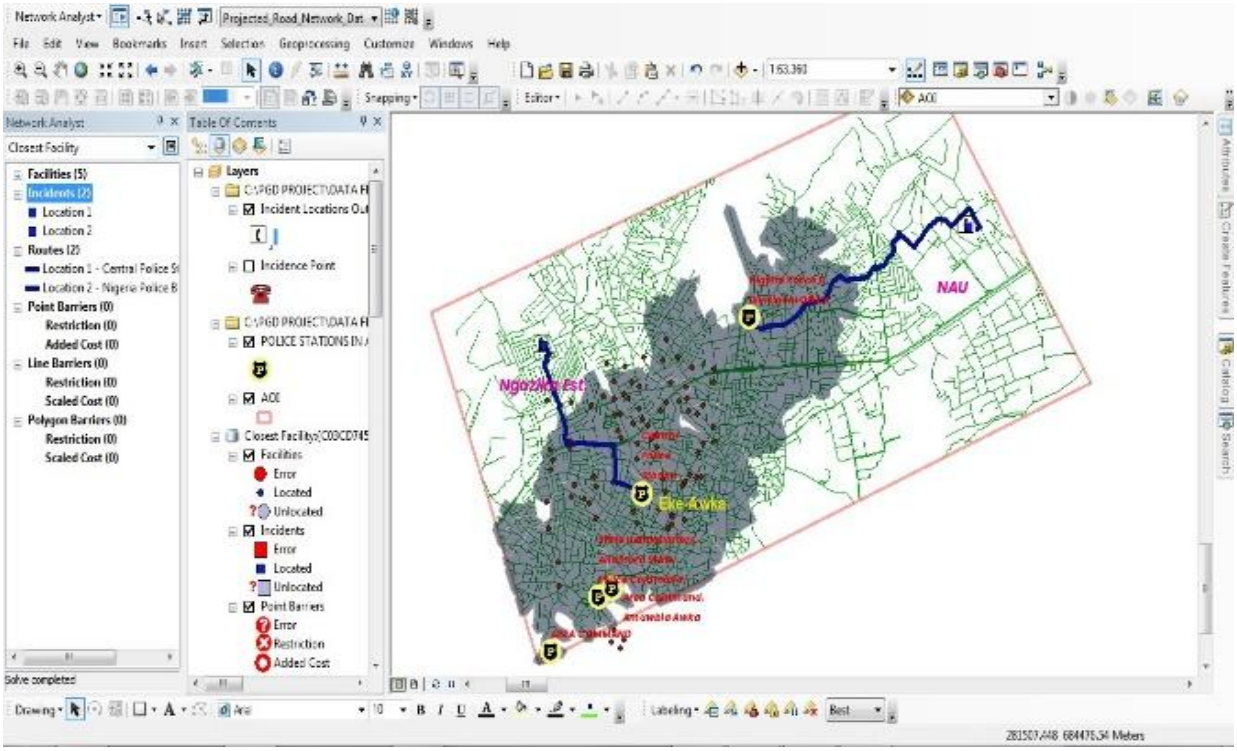
Expert Review: The results were compared with practical knowledge of the study area. Observations confirmed that areas identified as having poor coverage are known to experience delayed response times, supporting the validity of the model outputs.

Implications for Urban Safety and Planning

- The study highlights the vital role of spatial data in bridging the gap between law enforcement and urban management. A well-structured road network GIS enables security agencies to visualize coverage gaps, plan patrol routes, and optimize resource deployment.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue III March 2026

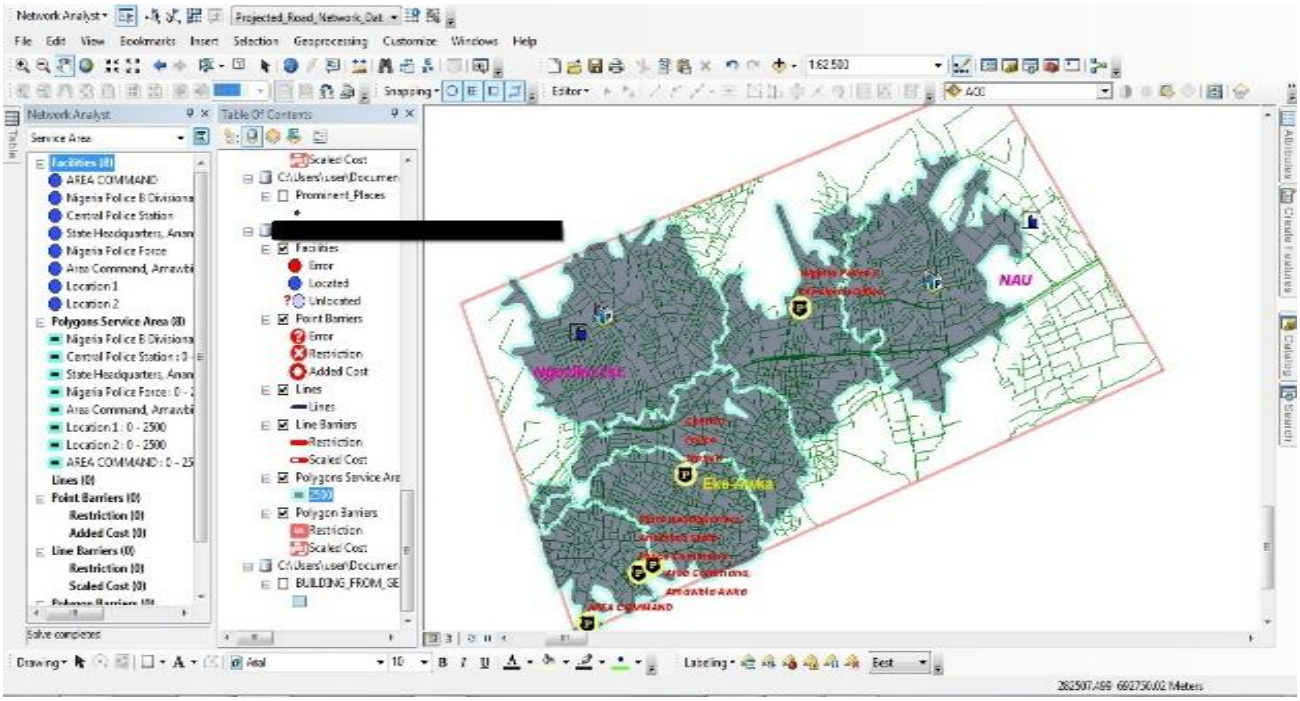
- Moreover, the integration of GIS with real-time data (e.g., mobile tracking or emergency dispatch systems) could further improve responsiveness and situational awareness. These findings correspond with prior research that emphasizes GIS as a cost-effective decision support tool for urban safety enhancement (Johnson et al., 2021; Batty et al., 2012).



(Figure 8: Shows query for shortest possible distance outside the service area)

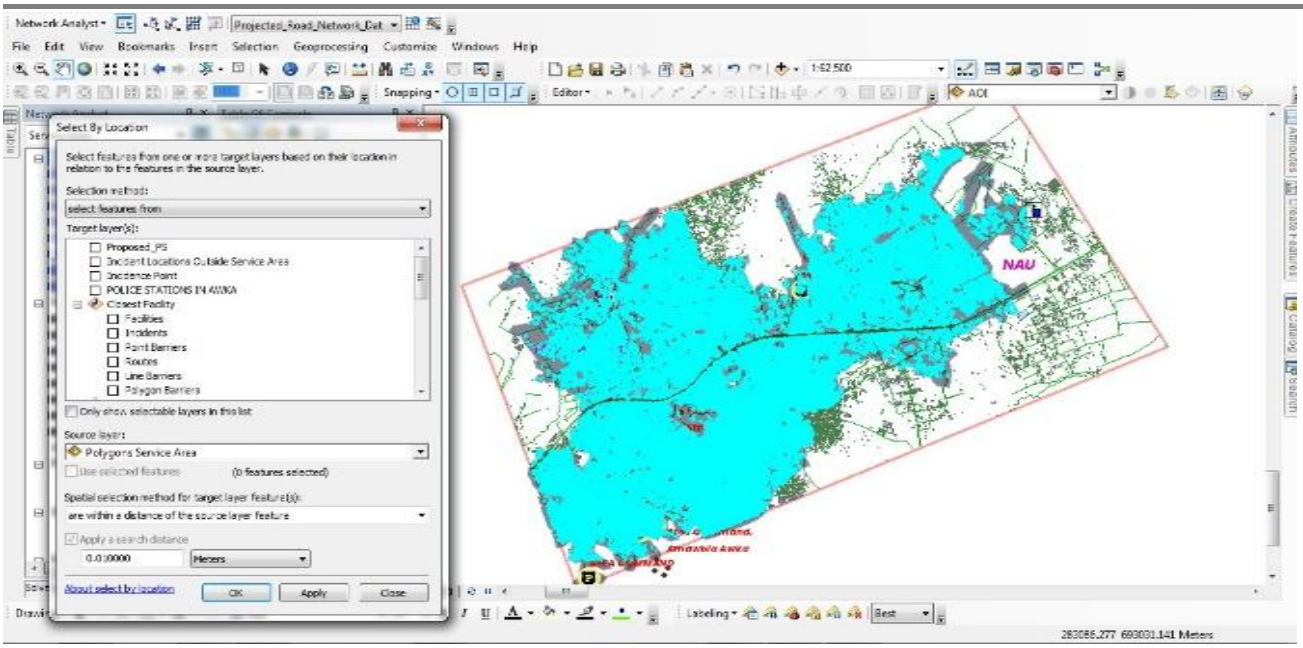
DISCUSSION

The results affirm that spatial inequality in police station distribution negatively affects emergency service delivery in Awka. The integration of GIS in urban safety planning therefore offers a systematic means of identifying underserved regions and prioritizing infrastructure development.



(Figure 9: Shows query for service area covered by existing and proposed police stations within Awka)

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue III March 2026



(Figure 9: Shows query for building count within the service area covered by existing and proposed police stations within Awka)

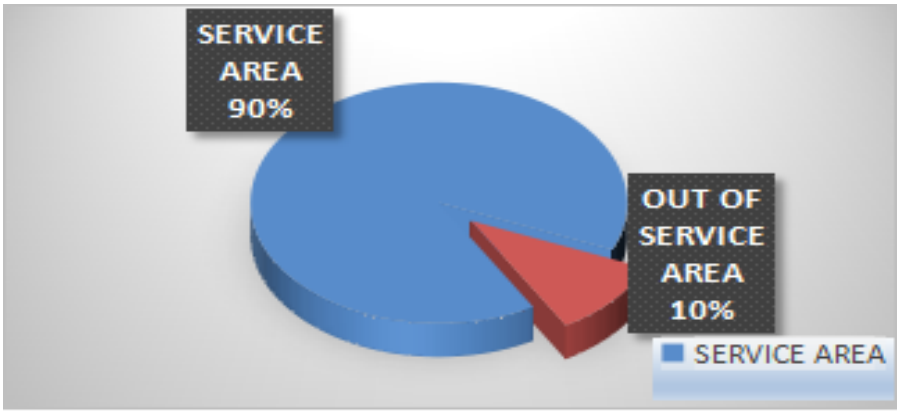
•This research supports the argument that cities in developing countries must institutionalize GIS-based approaches for sustainable urban management. Incorporating these spatial insights into state-level planning policies will not only enhance law enforcement efficiency but also foster safer and more resilient communities.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study demonstrates the application of Geographic Information System (GIS) techniques in assessing and improving the spatial distribution of police services and emergency response coverage in Awka, Anambra State. The developed GIS-based road network database serves as a decision-support framework that enables law enforcement and urban planners to visualize spatial disparities and evaluate the efficiency of existing safety infrastructure.

Findings revealed that approximately one-third of Awka's urban area remains outside optimal emergency service coverage. Peripheral areas such as Ifite, Okpuno, and Ngozika Estate exhibit longer response times due to poor connectivity and distant police facilities. By modeling accessibility through Service Area and Closest Facility analyses, the research highlights how GIS can guide the optimal siting of new facilities to minimize travel time and improve coverage equity.



(Figure 10: The pie chart illustrates the distribution of building counts within the service areas covered by existing and proposed police stations in Awka Urban)

The integration of GIS into urban management provides a sustainable and data-driven approach for improving public safety. Beyond enhancing police logistics, the system contributes to real-time decision-making, spatial monitoring, and inter-agency collaboration for urban governance.

RECOMMENDATIONS

Based on the results of the study, the following recommendations are proposed:

1. Establishment of Additional Police Stations:

Two new police stations should be sited in the eastern and northern parts of Awka (Ifite–Permanent Site and Okpuno) to bridge existing service gaps.

2. Integration of GIS in Security Operations:

The Anambra State Police Command should adopt GIS as a planning and operational tool to facilitate spatial data management, patrol scheduling, and response optimization.

3. Regular Update of Spatial Databases:

Continuous data acquisition and updating of the road network and security facility layers are necessary to reflect changes in land use and urban expansion.

4. Capacity Building:

Training programs in GIS and spatial analysis should be organized for police officers and planning authorities to improve institutional capacity in spatial decision-making.

5. Collaboration among Stakeholders:

Urban planners, transport agencies, and security institutions should collaborate through shared geospatial platforms to ensure coordinated safety management in Awka.

6. Integration with Smart City Initiatives:

The developed GIS model should be expanded to include real-time traffic feeds and mobile emergency reporting systems to support smart policing.

REFERENCES

1. Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., ... & Portugali, Y. (2012). Smart cities of the future. European Physical Journal Special Topics, 214(1), 481–518.
2. Chainey, S., & Ratcliffe, J. (2005). GIS and Crime Mapping. Chichester: John Wiley & Sons.
3. Church, R. L., & Murray, A. T. (2009). Business Site Selection, Location Analysis, and GIS. Hoboken, NJ: John Wiley & Sons.
4. Hodgson, M. E., & Briassoulis, H. (2016). Network Analysis in Geography. London: Routledge.
5. Johnson, S. D., Bowers, K. J., & Hirschfield, A. (2021). New insights into the spatial and temporal patterns of crime. Environment and Planning A: Economy and Space, 33(5), 959–976.
6. Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). Geographic Information Systems and Science. Hoboken, NJ: Wiley.
7. Miller, H. J., & Shaw, S. L. (2015). Geographic Information Systems for Transportation: Principles and Applications. New York, NY: Oxford University Press.
8. ESRI. (2020). GIS for Public Safety. Redlands, CA: Environmental Systems Research Institute.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue III March 2026

Figure Legends

Figure 1: Map of Awka Urban Road Network.

Figure 2: Location Map of Awka within Anambra State.

Figure 3: Network Dataset and Service Area Analysis Workflow.

Figure 4: Spatial Distribution of Police Stations and Major Roads in Awka.

Figure 5: 10-Minute Service Area Coverage of Police Stations.

Figure 6: Optimal Routing for Emergency Response between Facilities and Incident Points.

Figure 7: Proposed New Police Station Locations Based on Coverage Gaps.