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# GIS-Based Multi Criteria Modelling and Analysis for Urban Development Potential in Awka Capital Territory, Anambra State

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**Abstract**
Urban development in Awka Capital Territory, Nigeria, faces challenges arising from uncoordinated expansion, inadequate infrastructure, and limited planning strategies. This study applies Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) to assess urban development potential across Awka Capital Territory. The research integrates environmental and socio-economic factors including slope, elevation, proximity to infrastructure, and population density. Using AHP, each criterion was weighted based on expert judgment and combined via GIS Weighted Overlay Analysis. The results revealed urban development potential in Awka Capital Territory, categorized land into High, Moderate, and Low potential. Out of the total 399.84 km², 66.16% (264.53 km²) was classified as high potential, 22.63% (90.47 km²) as moderate, and 11.21% (44.84 km²) as low potential, indicating strong prospects for urban expansion due to favorable topography, accessibility, and infrastructure. Among the LGAs, Awka South (78.15%, 128.66 km²) and Anaocha (80.51%, 19.09 km²) exhibited the highest potential, followed by Njikoka (66.71%) and Awka North (61.67%). Dunukofia (43.28% high, 38.59% low) and Orumba North (33.87% high, 39.93% moderate) displayed mixed suitability, requiring infrastructure improvements. The study successfully integrated an approach to investigate development potential within the Awka Capital Territory. This evaluation approach, is hereby recommended to be used as tool for planning and decision making in urban development in the study area.

**Keywords:** GIS, AHP, Multi-Criteria Analysis, Urban Development, Spatial Planning, Awka Capital Territory

## 1. Introduction

Urban development plays a vital role in shaping the spatial, economic, and environmental framework of cities across the globe. As cities grow and populations increase, the demand for housing, infrastructure, and public services also escalates. In developing countries, especially across sub-Saharan Africa, rapid urbanization is often accompanied by significant spatial and planning challenges, including uncoordinated land use, inadequate infrastructure, environmental degradation, and social inequalities (Agboola *et al*., 2023; Ede *et al*., 2019) [1, 4]. These issues are particularly evident in Awka Capital Territory, Anambra State, Nigeria, where urban expansion has not been adequately supported by strategic planning or modern geospatial technologies (Ugwuanyi *et al*., 2022) [16].

Nigeria, the most populous country in Africa, has witnessed unprecedented urban population growth over the past four decades. According to United Nations estimates, more than 50% of Nigerians currently live in urban areas, and this figure is expected to rise to 70% by 2050 (UN-Habitat, 2020). However, urban planning mechanisms in many Nigerian cities remain underdeveloped and disconnected from modern spatial decision support systems, leading to haphazard development, encroachment into floodplains, and loss of agricultural land (Oluwaseun & Ayeni, 2020; Akinyemi *et al*., 2022) [12, 2].

Awka, designated the capital of Anambra State in 1991, is a prime example of a city experiencing rapid urbanization without comprehensive spatial planning frameworks. The city has expanded in response to growing demand for public institutions, housing, and business infrastructure. However, this expansion has occurred with limited consideration of terrain, flood vulnerability, or infrastructure capacity, resulting in land-use conflicts, poor accessibility, traffic congestion, and deteriorating environmental conditions (Okeke *et al*., 2018; Mmom *et al*., 2021) [11, 8]. These problems underscore the need for a data-driven urban planning model that integrates environmental and socio-economic considerations.

Geographic Information System (GIS) technology has emerged as a powerful tool in spatial planning and land suitability analysis. It allows for the integration and analysis of multi-dimensional spatial datasets to support evidence-based decision-making (Goodchild, 2007) [6]. When combined with Multi-Criteria Decision Analysis (MCDA) methods such as the Analytical Hierarchy Process (AHP), GIS provides a framework to assess land suitability by assigning weights to different factors based on their relative importance (Saaty, 1980; Malczewski, 2006) [14, 7]. This approach facilitates a comprehensive evaluation of environmental constraints, accessibility, and infrastructural availability.

Several studies globally have demonstrated the effectiveness of GIS-AHP models in urban development planning. For example, Chen, Zhang, and Wang (2021) [3] applied GIS-AHP to identify urban growth zones in Wuhan, China, considering factors like land use, road networks, and elevation. Similarly, Thangavel and Vasanthakumar (2021) [15] successfully used the model to prioritize development areas in Tamil Nadu, India. In Africa, Akinyemi *et al*. (2022) [2] utilized GIS-based suitability analysis to guide urban expansion in Akure, Nigeria, while Nduka *et al*. (2021) [9] demonstrated its application in assessing development potential in Owerri.

Despite these advancements, urban planning in Awka Capital Territory continues to rely on outdated regulatory instruments such as zoning ordinances and development control regulations, which lack spatial intelligence and are often poorly enforced (Ugwuanyi *et al*., 2022; Eze *et al*., 2022) [16, 5]. Moreover, urban development decisions are rarely informed by comprehensive land suitability assessments, leading to poor allocation of infrastructure and services. For instance, roads and drainage channels are often constructed in unsuitable areas prone to flooding or erosion (Mmom *et al*., 2021) [8].

This research proposes the development of a GIS-based Multi-Criteria Evaluation (MCE) model using the AHP technique to assess urban development potential in Awka Capital Territory. The model incorporates physical factors such as slope, elevation, and proximity to infrastructure, alongside socio-economic variables like population density and land use. The integration of these datasets enables the identification of high, moderate, and low potential areas for urban development.

In addition to improving land-use planning, the GIS-AHP model supports climate-resilient development by identifying environmentally sensitive zones that should be excluded from intensive development. For instance, flood-prone areas and steep slopes are assigned lower suitability scores to reduce exposure to natural hazards (Rahman *et al*., 2020; Oladele *et al*., 2019) [13, 10]. The application of this spatial decision-support system will enable policymakers and planners to make informed, equitable, and sustainable urban development decisions.

Ultimately, this study aims to fill the critical gap in spatial decision-making in Awka Capital Territory by providing a replicable and scientifically robust framework for land suitability analysis. The outcome is expected to support the efforts of urban development agencies like the Awka Capital Territory Development Authority (ACTDA), ensuring efficient land allocation, infrastructure optimization, and improved quality of life for residents.

## 2. Materials and Methods

This section outlines the data sources, spatial and analytical tools, and multi-criteria modeling procedures employed in the study to assess urban development potential in Awka Capital Territory. The methodology was designed to integrate environmental and socio-economic factors using a Geographic Information System (GIS)-based Analytical Hierarchy Process (AHP), allowing for the creation of a spatially explicit development suitability model.

### 2.1 Study Area Description

The study was conducted within Awka Capital Territory, located in Anambra State, southeastern Nigeria. Geographically, the territory lies between latitudes 6°05′N and 6°15′N and longitudes 7°00′E and 7°05′E. It spans approximately 399.84 square kilometers and comprises six local government areas (LGAs): Awka South, Awka North, Anaocha, Dunukofia, Njikoka, and Orumba North, either wholly or partially. The region experiences a tropical rainforest climate with two distinct seasons—wet and dry—and annual rainfall averaging over 1,450 mm. The dominant topographic features include lowlands and escarpments, with elevations generally below 333 meters above sea level. Soils in the region are primarily derived from the Imo Shale and Ameki formations, which affect drainage characteristics and suitability for construction.

### 2.2 Data Requirements and Sources

To effectively model urban development potential, both spatial and non-spatial datasets were acquired and processed. Primary data were collected through field surveys using handheld GPS devices to capture the coordinates of key infrastructure such as roads, built-up areas, and landmarks. These datasets were supplemented by high-resolution remote sensing imagery and secondary data obtained from authoritative sources.

The following datasets were utilized:

1. ALOS PALSAR Digital Elevation Model (DEM) with a 12.5-meter spatial resolution for generating slope and elevation layers.
2. KOMPSAT-3 multispectral imagery and Landsat 8 OLI imagery for land cover classification and detection of built-up areas.
3. Population density data obtained from the National Population Commission and global gridded population databases.

4. Administrative boundaries and road network shapefiles, acquired from the Awka Capital Territory Development Authority (ACTDA).
5. Building footprint data, extracted from high-resolution imagery and supplemented with manual digitization in areas lacking data.

### 2.3 Data Processing and Pre-Analysis Operations

All spatial datasets were projected to the Universal Transverse Mercator (UTM) Zone 32N with WGS84 datum to ensure consistency. Pre-processing steps for the imagery included radiometric and atmospheric corrections, sub-setting of the area of interest, and image enhancement to improve classification accuracy. DEM processing involved void filling, hillshading, and slope derivation using ArcGIS 10.8 and QGIS.

Land use and land cover classification was performed using supervised classification techniques, applying the Maximum Likelihood and Support Vector Machine (SVM) algorithms in ENVI software. Training samples were selected for five classes: built-up area, vegetation, bare surface, cropland, and waterbody. Classification accuracy was validated using ground truth data and a confusion matrix, yielding a kappa coefficient of 0.82, indicating high agreement.

### 2.4 Criteria Selection and Reclassification

Based on literature review and consultations with urban planning experts, six key criteria were selected for evaluating urban development potential: slope, elevation, land use/land cover, proximity to roads, proximity to built-up areas, and population density. Each criterion was standardized and reclassified into suitability classes ranging from 1 (least suitable) to 5 (most suitable). For instance, slopes less than 5% were reclassified as highly suitable for development, while slopes above 15% were considered unsuitable. Proximity analyses were conducted using the Euclidean Distance tool to measure distances to roads and built-up areas, which were then categorized into buffer zones and reclassified accordingly.

### 2.5 Analytical Hierarchy Process (AHP) Implementation

To objectively assign weights to each criterion, the Analytical Hierarchy Process (AHP) was employed. A pairwise comparison matrix was constructed based on expert judgment, and weights were derived using the principal eigenvector method. The matrix was then subjected to a consistency test using the Consistency Ratio (CR), which was found to be 0.03, indicating acceptable consistency (CR < 0.1) as recommended by Saaty (1980) [14]. The final weights assigned were as follows: land use/land cover (0.25), proximity to roads (0.20), slope (0.18), elevation (0.15), proximity to built-up areas (0.12), and population density (0.10). These weights reflect the relative influence of each criterion on urban development suitability within the study area.

### 2.6 Weighted Overlay Analysis and Suitability Mapping

The standardized criteria layers and their corresponding weights were integrated using the Weighted Overlay Analysis tool in ArcGIS. This process involves assigning influence values to each reclassified criterion and summing the weighted layers to generate a composite suitability map. The output map was classified into three suitability zones: high, moderate, and low development potential. Threshold values were defined using natural breaks (Jenks optimization) to ensure meaningful differentiation of spatial patterns.

### 2.7 Model Validation

To assess the reliability of the suitability map, a sensitivity analysis was conducted by altering the weights of the top three influencing factors (land use, road proximity, slope) and observing changes in the suitability output. Results showed minimal variation in the classification of high-potential areas, confirming model stability. In addition, field validation was carried out by visiting selected high and low suitability zones to verify their correspondence with on-ground conditions. This triangulation confirmed the accuracy of the suitability model in reflecting real-world development patterns.

## 3. Results

The development potential results from figure 1 and 2, provides an assessment of urban development potential in Awka Capital Territory, categorizing the land into three classes: High Potential, Moderate Potential, and Low Potential. The total study area covers 399.84 square kilometers, with 66.16% (264.53 km²) classified as high potential (green segment), 22.63% (90.47 km²) as moderate potential (orange segment), and 11.21% (44.84 km²) as low potential (red segment). This classification indicates that a significant portion of the territory is well-suited for urban expansion, due to favorable factors such as topography, accessibility, and existing infrastructure.

The high-potential areas, making up the majority of the land, indicate strong prospects for urban growth with minimal development constraints. In contrast, the moderate-potential areas, covering 90.47 km², may have some limitations that require additional planning and investment in infrastructure to enhance their suitability for development. The low-potential areas, representing the smallest proportion of land (44.84 km²), are likely constrained by factors such as steep terrain, poor soil conditions, or environmental restrictions, making development more challenging and costly. Figure 3 shows the distribution of high potential, moderate potential and low potential areas for the LGAs within Awka Capital Territory.

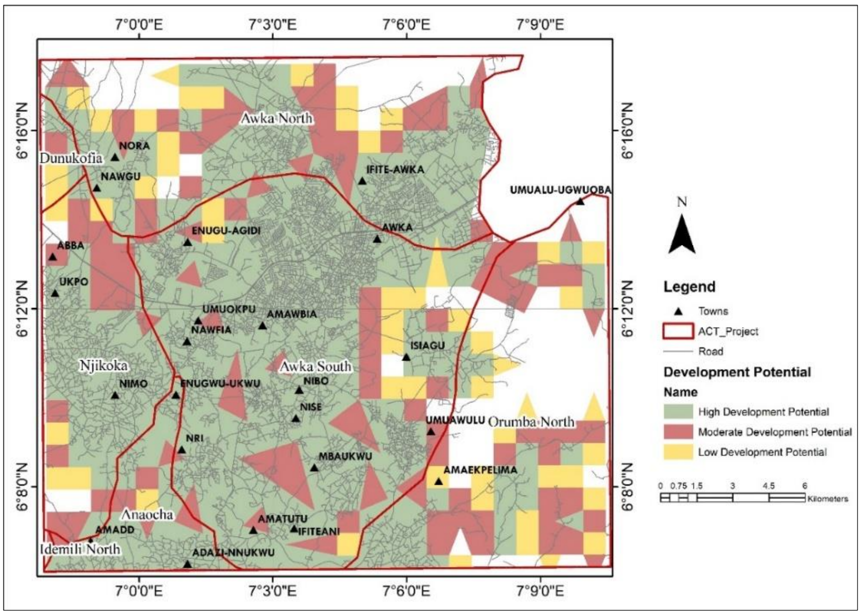


**Fig 1:** Urban Development Potential map

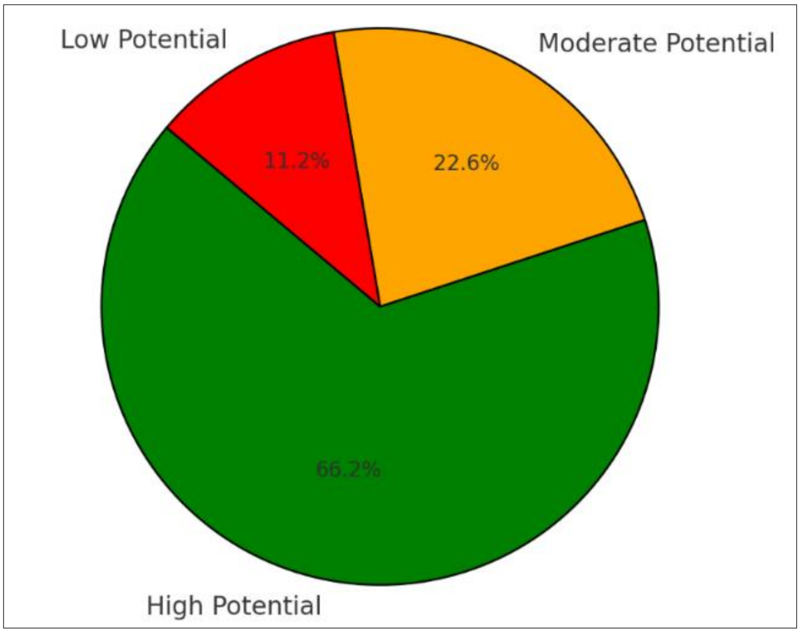


**Fig 2:** Urban Development Potential in Awka Capital Territory

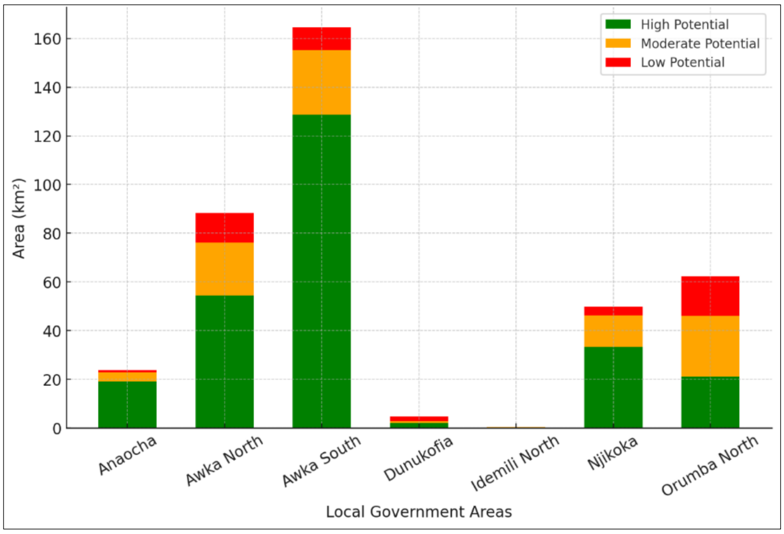


**Fig 3:** Urban Development Potential Across LGAs in Awka Capital Territory

Figure 3 visually represents the urban development potential across various Local Government Areas (LGAs) in Awka Capital Territory. Each LGA is broken down into High Potential (green), Moderate Potential (orange), and Low Potential (red) categories, with their respective land areas in square kilometers.

Anaocha LGA exhibits strong urban development potential, with 80.51% (19.09 km²) of its land classified as high potential. A smaller portion, 15.90% (3.77 km²), falls under moderate potential, while only 3.58% (0.85 km²) is categorized as low potential. This indicates that Anaocha has highly favorable conditions for urban expansion, with minimal constraints.

Awka North has 61.67% (54.5 km²) of its land classified as high potential, making it a suitable area for urban development. However, 24.45% (21.61 km²) falls under moderate potential, while 13.88% (12.27 km²) is categorized as low potential. While a significant portion is ideal for growth, a substantial moderate-potential area indicates that some regions may require infrastructure investments or environmental considerations.

Awka South demonstrates the highest urban development potential, with 78.15% (128.66 km²) of its land classified as high potential. A moderate proportion, 16.17% (26.62 km²), is categorized as moderate potential, while only 5.69% (9.36 km²) is low potential. The high percentage of developable land makes Awka South a prime location for expansion, requiring minimal interventions.

Dunukofia presents a more balanced distribution, with 43.28% (2.03 km²) of its land classified as high potential, while 18.12% (0.85 km²) falls under moderate potential. A relatively high percentage, 38.59% (1.81 km²), is low potential, indicating that development may be significantly constrained in parts of this LGA due to environmental or infrastructural challenges.

Njikoka has 66.71% (33.25 km²) of its land classified as high potential, indicating strong urban development prospects. Moderate-potential land accounts for 25.86% (12.89 km²), while only 7.42% (3.7 km²) falls under low potential. This distribution makes Njikoka a favorable area for growth, with some sections requiring additional infrastructure investments.

Orumba North presents a more complex development pattern, with 33.87% (21.08 km²) of its land classified as high potential. However, a significant portion, 39.93% (24.85 km²), falls under moderate potential, while 26.19% (16.3 km²) is low potential. This indicates that while some areas are well-suited for development, others face constraints that may require environmental management and infrastructure development.

Overall, Awka South and Anaocha emerge as the most favorable LGAs for urban expansion, given their high percentages of developable land. Awka North and Njikoka also show strong potential, though they have moderate constraints that need to be addressed. Dunukofia and Orumba North present more significant challenges due to the higher proportions of moderate and low-potential areas. Strategic planning, infrastructure investment, and environmental considerations was essential in optimizing land use across these LGAs.

## 4. Conclusion

From existing literature, the analysis provided a comprehensive framework for assessing urban expansion suitability across the region. The process involved systematically classifying and weighting factors such as topography, accessibility, and infrastructure to identify areas with varying potential for development.

The AHP method proved to be a reliable tool for determining the relative importance of different criteria, with a low consistency ratio (CR = 0.008), which confirms the validity of the pairwise comparisons made during the evaluation. This methodological rigor highlights the robustness of the results and ensures confidence in the accuracy of the urban development potential map produced.

The spatial analysis revealed notable differences in development potential across the territory, with Awka South, Anaocha, Awka North, and Njikoka identified as having the highest potential for urban expansion. These areas are characterized by favorable conditions such as accessible terrain, established infrastructure, and minimal constraints. Conversely, LGAs like Dunukofia, Orumba North, and Idemili North were marked by lower potential, primarily due to environmental challenges such as steep slopes and poor soil conditions.

The findings of this study provide critical insights into the factors influencing urban development in the Awka Capital Territory. They underscore the importance of infrastructure, accessibility, and terrain in shaping urban growth patterns. These insights can guide policymakers and urban planners in making data-driven decisions that support sustainable urban development strategies.

Furthermore, the framework used in this study, combining AHP with spatial analysis, offers a replicable model for evaluating urban development potential in other regions. By integrating both objective data and expert judgment, this approach ensures a comprehensive assessment that can be applied to future urban planning initiatives.

This study not only maps the current urban development potential in Awka Capital Territory but also offers strategic guidance for future planning. High-potential areas should be prioritized for immediate investment and infrastructure development, while lower-potential regions may require targeted interventions to improve their suitability for urban expansion. This balanced approach will contribute to sustainable, well-planned growth in the territory, fostering long-term development.

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