GIS-based land suitability analysis using AHP for urban facilities provision in Minna

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ABSTRACT

Uncontrolled development, inter-urban migration and rural-urban migration in contemporary cities are major cause of urban sprawl and city decay, infrastructural deterioration, loss of open spaces, and lose of environmental quality. These scenarios put pressure on available facilities which results in overstretch of these facilities and consequent collapse. Minna city is identified with these urban problems. Adequate facilities provision in urban areas is vital in the comfort of life of urban dwellers, and as a matter of fact promotes urban grown and identity of a city. The study aims at evaluating the urban land suitability for the provision of facilities. In attempt to achieve the stated aim, the existing land use pattern of Minna were examined with the use of GIS and remote sensing, the spatial information of the study area were obtained as regards to the slope and topographical elevation of Minna area from satellite images and digital elevation maps, the land suitability was evaluated through the AHP method using set of criteria involving geophysical which are: Land use/land cover, elevation, slope and rock. Results of this study revealed that Minna is expanding uncontrollably to the fringe. It was also discovered that the city core areas are more served with adequate facilities than the peripheral areas and geographical factors also affect facility delivery It shows that Minna can be divided into four suitable categories of suitability zones. The findings further reveal that the highly suitable and medium suitable areas for urban growth covers about 82% of the whole area, while low and poorly suitable areas cover about 16% of the whole area. Based on findings from the study, development in Minna city is expanding to the fringes, hence the need for provision of more facilities in these areas. Government and planning agencies should keep track of urban growth of the city. Proper development control policies should be put in place to guide development and to check urban sprawl.

Key Words: *Suitability, Facilities, Land, Assessment, Urban*

INTRODUCTION

Siting of facilities and infrastructures around urban territories in the previous decades has been a troublesome undertaking on urban planners and urban leaders as far as the best area or best spot to site an infrastructure to more readily serve urban inhabitants. Urban facilities assume a significant job in improving the expectation for everyday comforts of the urban inhabitants and prosperity. An inadequately chosen area or sitting of such amenities and infrastructure will result to the incapability of such facility, make life hard for occupants and furthermore become a misuse of assets (Parry, Ganaie& Sultan, 2018).

Metropolitan regions across the world in past decades has been at war with the issue of urban development which is because of the endless socio-economic advancement (Durantan and Puga,2014). Owing to the fact that these continuously growing population in the urban territories brings about significant level of negative ecological effect on the urban condition and creates problems, for example, unordered urban extension and urban spread, infringement of open spaces and open country sides, deficient lodging facilities, traffic clog, inadequate waste structure, sewerage issues and lack of different comforts (Liu, 1998).

Suitability Analysis "is the procedure and methods used to set up the appropriateness of a framework - that is, the capacity of a framework to address the issues of a partner or other client" (Parry et al, 2018). Extensively, land-use suitability evaluation is a procedure which targets distinguishing the most proper spatial example for future land use as indicated by explicit necessities, inclinations, or indicators of some motives and requirements of the clients (Hopkins, 1977).

Land use suitability evaluation is completed with the utilization of Remote Sensing (RS), Geographic Information System (GIS), and the Multi-Criteria Decision Methods (MCDA), are significant apparatuses for recognizable proof, correlation and making examination of urban development destinations for legitimate planning and administration (Shukla, Kumar & Jain2017).

Suitability evaluation is considered as the most significant and best estimates utilized for distinguishing the best site for finding urban amenities and services by utilizing various kinds of

criteria and weights (Javadian,Shamskooshki&Momeni, 2011). This can be accomplished through a procedure of multi-criteria choice examination of spatial information of the given zone and changing these information(input) into a resultant decision(output) (Malczewski, 2004). The study tries to offer a new method for planners to help them have an appropriate planning decision for land distribution to finally reach the most suitable location for new facilities.

LITERATURE REVIEW

To match up with the needs of the fast-growing population, which is pressing for the capacity of spatial needs, the assessment of urban-land suitability is gaining ground in its need to use the most viable space to its fullest potential, closely with the current environmental resources.

Land-usesuitability evaluation requires the utilization of-Geographic-Information-Systems (GIS) to study spatial suitability. This procedure can be seen through the techno-positivist and the socio-political, open commitment points of view. In the assessment of suitability, there are likewise required variables in regards to financial open-door expenses and social ramifications inside specific territories of land. There has been an investigation in the job that both of these parts of cautious spatial arranging entail (Malczewski, 2004).

Land suitability assessment is a technique for making a choice about the imminent utilization of space for specific purposes. The utilization of land for a specific use is viewed as basic regions in scientific writing (Zabihi, et al., 2019).

Prior, before the invention of the GIS (an electronic technique that decides suitability assessment) was generally utilized in the middle to later twentieth century, town and country planners conveyed their spatial fitness assessment thoughts by arranging photos in expanding obscurity over maps of the contemporary conditions. (Malczewski, 2004). Land suitability assessment for urban extension is important to beat the issue of imperatives in land accessibility against the fast development of urban areas (Umrika, 2013).

All in all, land suitability assessment is the precise strategy for estimating the presence of a specific land when utilized for a given reason. An assessment of the atmosphere, soil, and geographical segments, alongside a comprehension of the biophysical requirements, are utilized to decide land suitability. ((Liu *et al*, 2014). The essential goal of the suitability evaluation of land is the estimate of the land's possibilities and limitations for the optimum use of the land and to guarantee the most optimum profitability (Liu *et al*, 2014).

Finding perfect suitable spaces for sitting public amenities like; open parks are colossal issues in an urban setting and urban society and as such land suitability assessment are utilized to decide and proffer suitable space for such given amenity (Yeo, & Yee 2014).

Metropolitan territories are developing in an irregular and unplanned way. This situation has come about to planning issues, for example, increasing events of flash floods, loss of agricultural land, metamorphosis of hills, unauthorized / slum development on river banks and on hill slopes, unavailability of waste disposal sites, air-and water pollution, traffic congestion, inflation in land values, changing rainfall – runoff statistics, and related socio-economic problems. Land suitability assessment for urban development is important to beat the issue of limitations in land accessibility against quick population grown and urban expansion (Umrika,2013). Sustainability in urban development is regarded as the key concrete stone that directly affects the quality of life of its users. The use of GIS as a multi-criteria support instrument in Land Suitability Assessment (LSA) determines the best choices for the suitability of landscapes for sustainable land development (Sepideh*et al.*, 2017).

Analytical Hierarchy Process is a fundamental basic structure for making decisions; like other multi-criteria decision methods, whereby both emotional and target estimations are pondered to clarify complex, multi-party criteria issues through the evaluation of choices against other varying objectives (Saaty, 1980).

A study by Zemba, et al, (2016), explored land suitability assessment in the agricultural sector assessed the physical land suitability for cassava development in the southern part of Adamawa State utilizing Multi-criteria assessment and GIS strategy. The ecological factors analysed were; Mean Annual precipitation, Mean Temperature, Length of precipitation, Relief and Soil. The essential information was sourced by field survey method to acquire the coordinates of the present cassava developing territories for mapping. The five-factor maps were reclassified dependent on the ecological necessity of cassava crop in the IDRISI Taiga environment and various weights were assigned to each factor to depict their relative significance using the pair-wise comparison grid. The outcome, which is

unequivocally presented on a single map, shows that the zones that are appropriate for cassava cultivation constitute 65.92% while those that are not suitable add up to 34.08%. Additionally, the present cassava growing regions were mapped and the regions distinguished are Dissol, Mbulo, Maitani, Farang, Timdore, and Wadore which fell inside the appropriate classification. The outcome derived from the study shows that GIS strategy could give a better guide map for decision makers which could be utilized to consider crop substitution to accomplish better agricultural production.

Rikalovic, et al, (2014), opined that the development of new industrial framework is a significant long-haul investment, and in this sense choosing the area is basic in the journey toward progress or failure of an industrial framework. One of the primary objectives in industrial site selection is finding the most suitable site with wanted conditions characterized by the determination criteria. A large portion of the information utilized by supervisors and leaders in industrial site selection are topographical which implies that modern site selection process is a spatial choice issue. Such studies are turning out to be increasingly normal, because of the accessibility of the Geographic Information Systems (GIS) with easy to use interfaces.

Study Area

Minna is theadministrative capital of Niger state and the headquarter of the Chanchaga LGA. Minna covers a landmass of 72km^2.Minna lies on Latitude: 9° 36' 54.86" N Longitude: 6° 32' 51.94" E on a geological-base of-undifferentiated basement complex of numerous gneiss and magnetite arranged at the base of unmistakable-slopes in an undulating plain.Minna occupied the central portion of the Nigerian basement complex. The geology of the soils in the study area comprises of meta-sedimentary and meta-igneous rocks which have undergone poly-phase deformation and metamorphism. The raining period commences in the month of April and continues tillOctober. Ithas an average yearly downpour of 1334mm (52 inches) with September recording-the most significant downpour of 300mm. (11.7 inches), of normal month to month precipitation. The average month-to-month temperature is most noticeable in the month of. March at 30-50°C (83°F) and least inAugust at 33.3°C (27.9°F). The prevailing geology in Minna is in the valley of high grounds and for the most part in waterway Niger valley with scopes of secluded slopes the primary stream is channel with source waterway Kaduna, stream Gardun (rafingardun) and two different streams presently framing a piece of the manufactured waste framework around the local area.Figures 1 to 4 shows the Map of Nigeria showing Niger state, Map of Niger State Showing Minna Local Government, Map showing Minna within the boundary of Bosso Local Government and the Minna street guide.

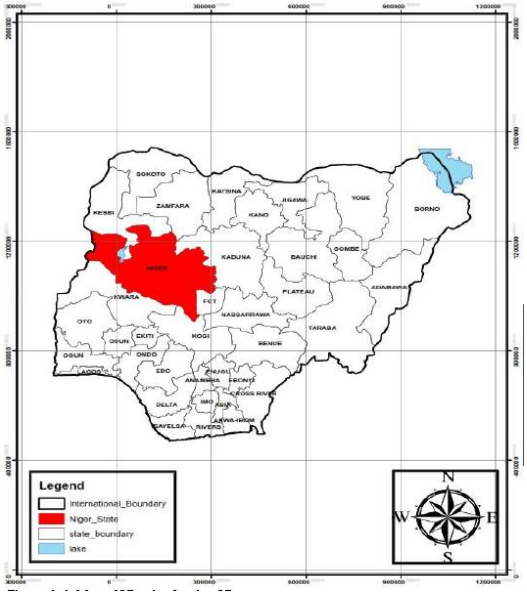


Figure1. Map of Nigeria Showing Niger State

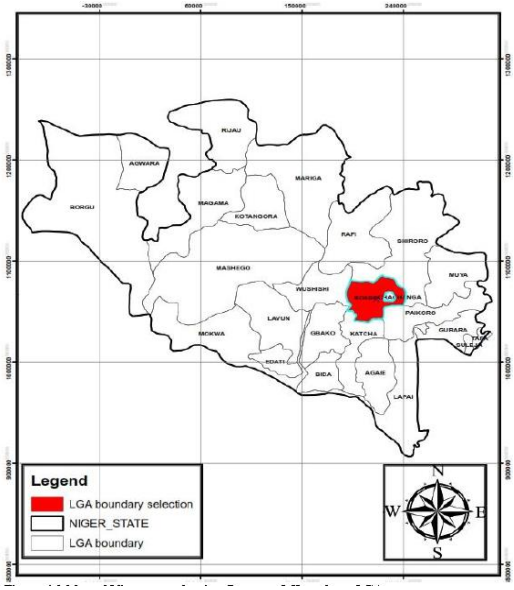


Figure 2. Map of Niger State Showing Minna

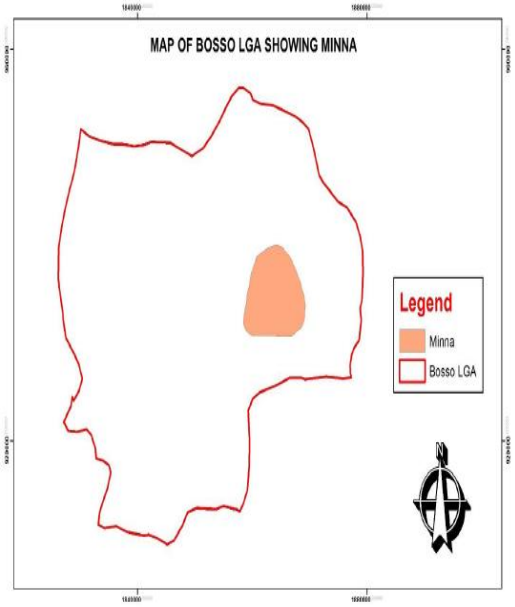


Figure 3. Map of Bosso LGA Showing Minna

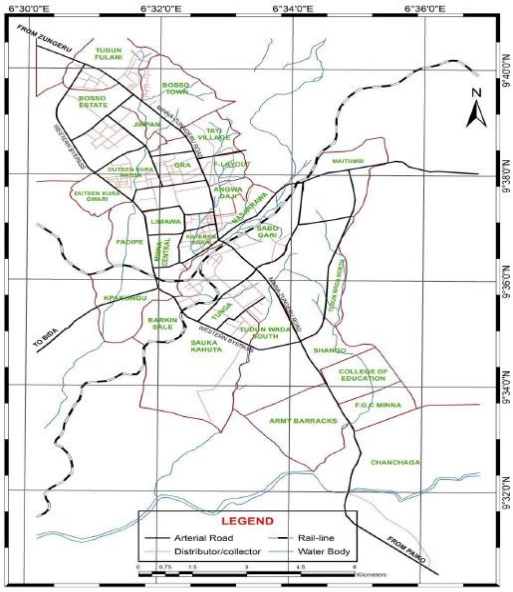


Figure 4. Street Guide Map of Minna

Figures 1 to 4 Sourced from Niger Geographic Information System (2019)

MATERIALS AND METHODS

The data employed for this study were acquired from primary and secondary sources. The primary data was obtained using a mobile phone Global Positioning System (GPS) application: UTM Geo Map, to capture the coordinates of existing amenities in the study area. The secondary data used include quick bird image which is a high-resolution image (65cm), and administrative map data. The georeferenced image and thematic features such as road network, political wards boundary, and other existing infrastructures were extracted using onscreen digitizing. GPS coordinate of schools, boreholes, electricity transformers, Telecommunication masts, and the Public health facilities, digitized with the use of ArcGIS to produce a facility map.The data analysis was carried out using the nearest neighbour analysis- to determine the pattern of distribution of each amenity in the study area; and the Analytical Hierarchy Process Model- to determine spatial suitability of the study area.

The Nearest Neighbour Analysis analyses the distance between each point and the nearest point and measures the degree to which a particular pattern is clustered (nucleated), random and normal (uniform) and the of Manhattan distance method that measures the distance between two points along axes at right angles was used to evaluate the spatial pattern of distribution of amenities in the case study (Mustapha *et al*, 2016). The Euclidean method was used to measure the distance between two points.

The Nearest Neighbour formula is given as:

$$R_n = 2đ\sqrt{n}/a$$ (Clark & Evans, 1954)

Where

Rn = the nearest neighbour index

a = the size of the study area

đ = the mean distance between each category of amenity

n = the total number of categories of amenity.

Therefore, When Rn = 0. The pattern is clustered. This means that all the points are close to the same location.

When Rn = 1. The pattern is random. Meaning the observation does not follow any pattern and

When Rn = 2.15. The pattern is regular. This means that there is an accurate regular pattern where each point is equidistant fromits neighbours.

The Analytic Hierarchy Process (AHP) is a pair-by-pair relationship estimation hypothesis. The connections are settled on using size of straightforward choices that logically address the sum; with respect to a given segment, one part will have quality over the other. The construed need scales

are coordinated by expanding them by the need of their parent center points and including for each and every such center (Saaty, 2007). In this investigation, to achieve an authentic suitability assessment, tendency would be given to physical and economic related factors by using association examination module. The linkage between the joined urban amenity deficiency status and the decision factors gives the exhibition of variables taken for the examination. (Parry *et al*, 2018).

The process is summarized into 4 individual procedures: 1. Separating or disintegrating, 2. Weighting, 3. Surveying, and 4. Picking an option. Despite which point of view you purchase in to, the blueprint of the technique isolates as such: characterize the issue and the favored arrangement, give a chain of command of the issue from a top-down perspective, build up a pairwise examination of every one of the hubs in the various levelled tree guaranteeing they liken to 100% or 1 (contingent upon your approach), register weights by normalizing any section in your investigation framework (through a need vector), at long last, needs are gotten from every elective hub permitting thought for an assortment of activities. Applying the AHP strategy incorporates three central advances: (1) disintegration, or the reorder of development; (2) near decisions, or characterizing and executing information assortment to get pairwise correlation information on components of the various levelled structure; and (3) blend of needs, or building a general need rating (Harker and Vargas, 1987). The Saaty scale is shown in Table 1.

Table 1. Saaty Scale

Ranking weights	**Preferences shown in linguistic variables**
1	Equivalent significance
3	Relative significance
5	Strong significance
7	Very strong significance
9	Extreme significance
2,4,6,8	Transitional values amid adjacent scale values

Source: The Saaty Scale, 1980.

RESULTS AND DISCUSSION

Based on the field survey, a total of 21 public boreholes, 13 public health facilities comprising of general hospital, clinics and maternity homes, 52 public schools comprising of both primary and secondary schools, 63 telecom masts, and 166 power transformers were identified in the study area. The results are shown in Figure 5 and Table 2.

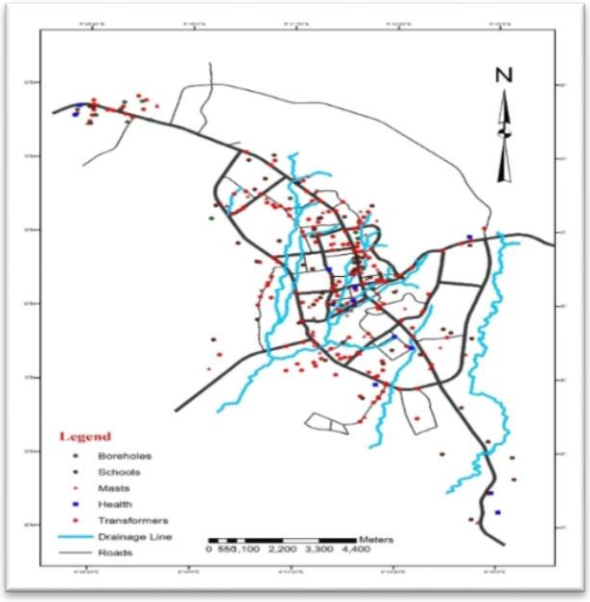


Figure 5: Existing Facility map of Minna.

Source: Niger Geographic Information System (2019)

Table 2. Statistics of Identified facilities in the studyarea

Statistics of amenities in the study area		
S/N	**Public Amenity**	**Amount Captured**
1	Borehole	21
2	Health facility	13
3	School	52
4	Mast	63
5	Transformer	166

The figures below showthe Nearest Neighbour Analysis for the spatial distribution of amenities in Minna which revealed that the Nearest NeighbourRatio (NNR) in most areas of Minna for health care facility, education facility, masts and electricity facilities are higher than the Z-Score. The implication of the Nearest NeighbourRatio (NNR) value of these facilities being higher than the Z score is that the pattern is more clustered than dispersed.

There is an uneven spatial distribution of borehole amenity in the study area with NNR of 0.92 and Z-Score of 0.67. This indicates that a good number of the amenities in Minna are located at the city core and having a scanty location of amenities at the periphery of the city. Also, the people living off the city core may find it difficult or rather have to travel a far distance to access these facilities. The pattern of distribution of the facilities is shown below;

Figure 6a: Borehole Locations in the Study area

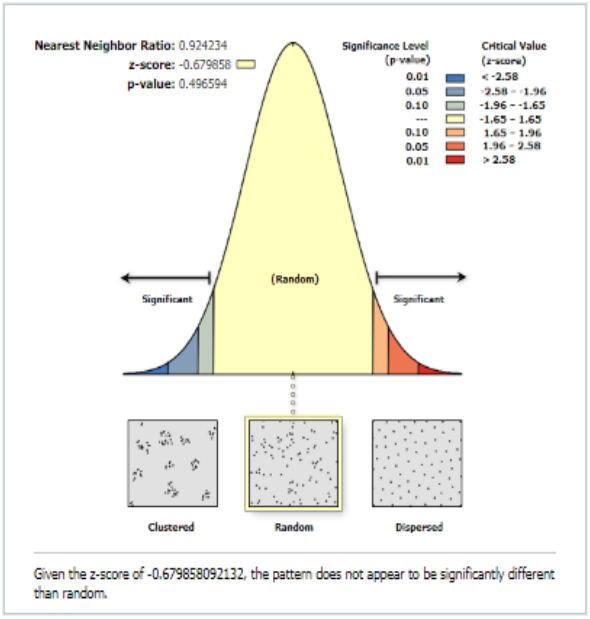
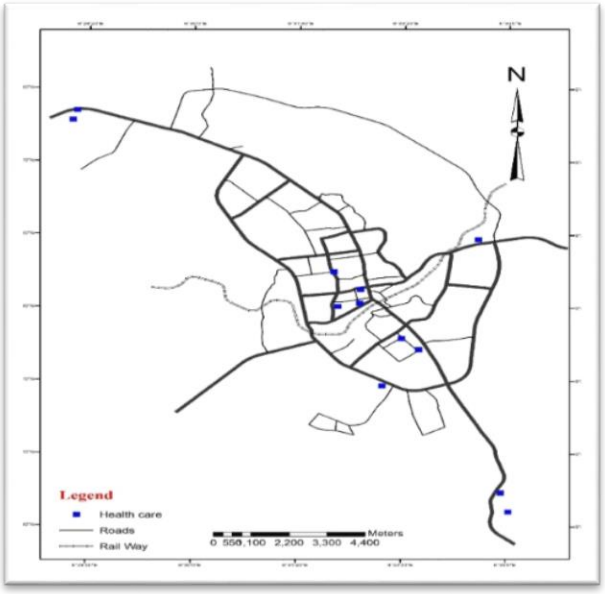


Figure 6b: Average Nearest Neighbor Summary for Boreholes



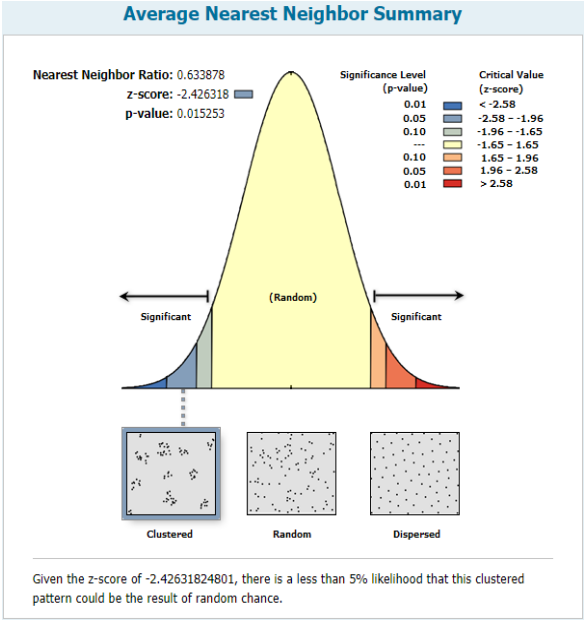
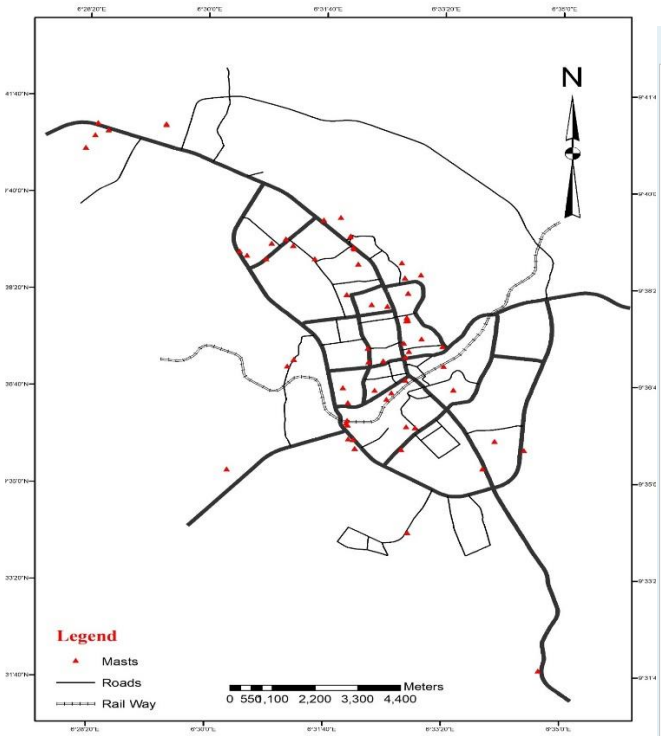


Figure 7a: Health care facilities in the study area.

Figure 7b: Average Nearest Neighbor Summary for Health facilities



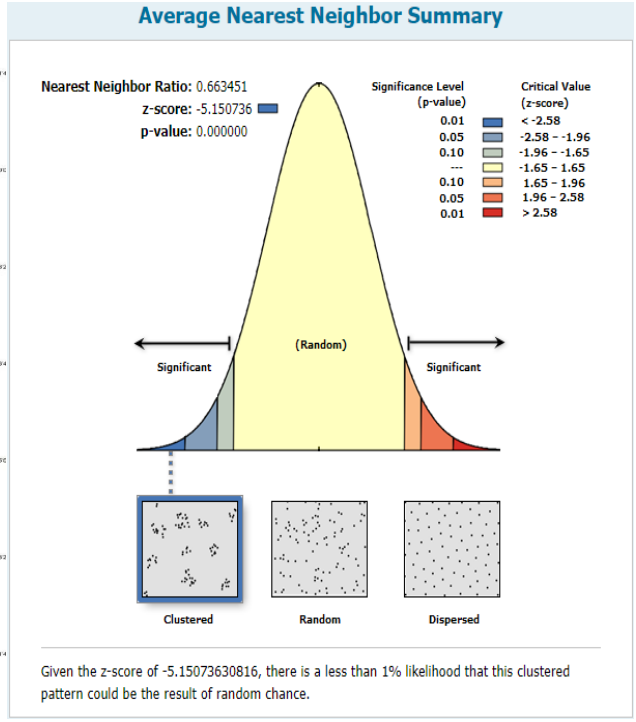


Figure 8a: Telecom masts in the study area.

Figure 8b: Average Nearest Neighbor Summary for Masts.

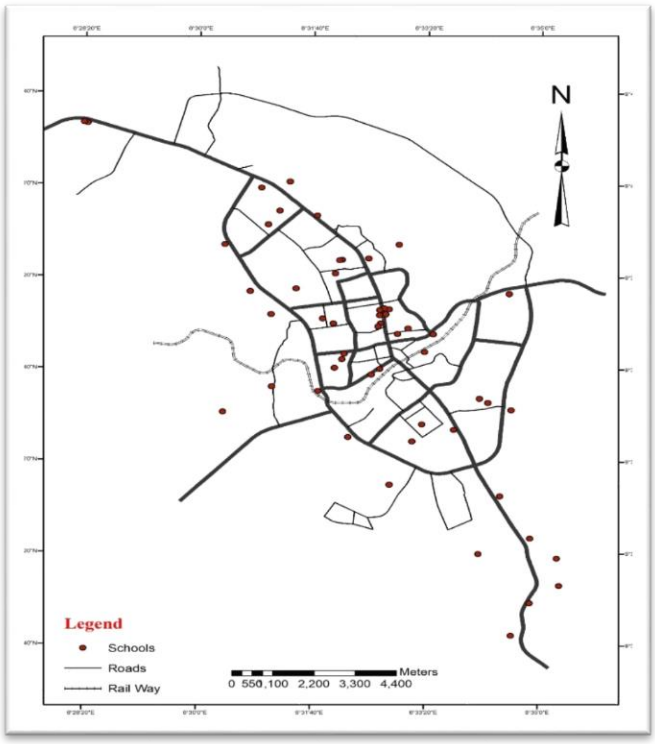


Figure 9a: Location of public schools in the study area.

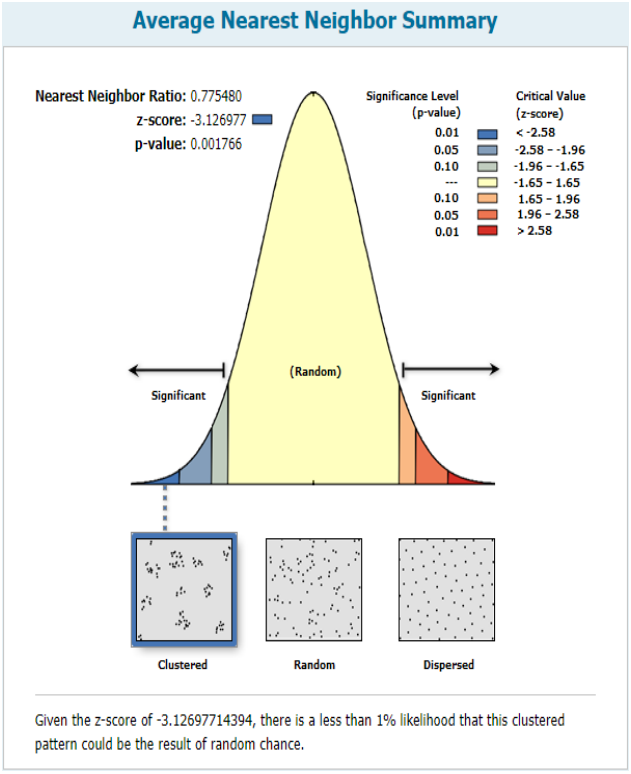
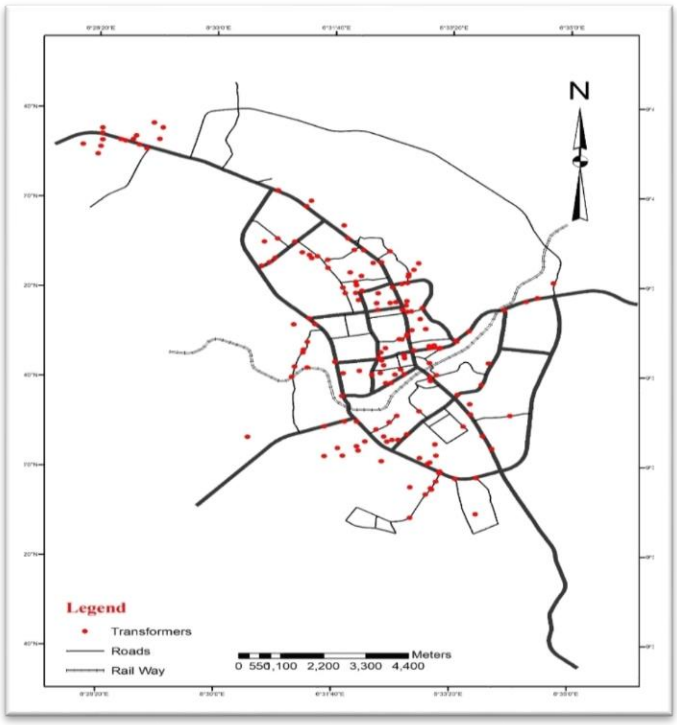


Figure 9b: Average Nearest Neighbor Summary for Schools.



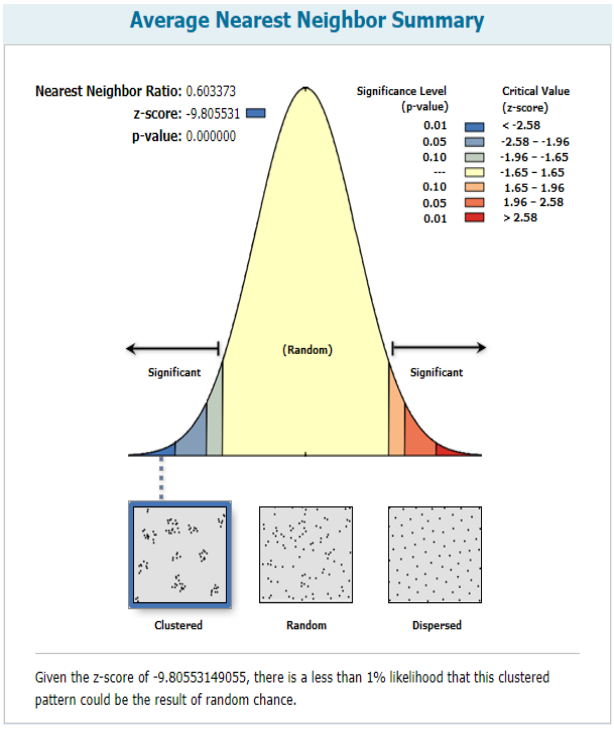


Figure 10a: Location of power transformers in the study area.Figure 10b: Average Nearest Neighbor Summary for power transformers.

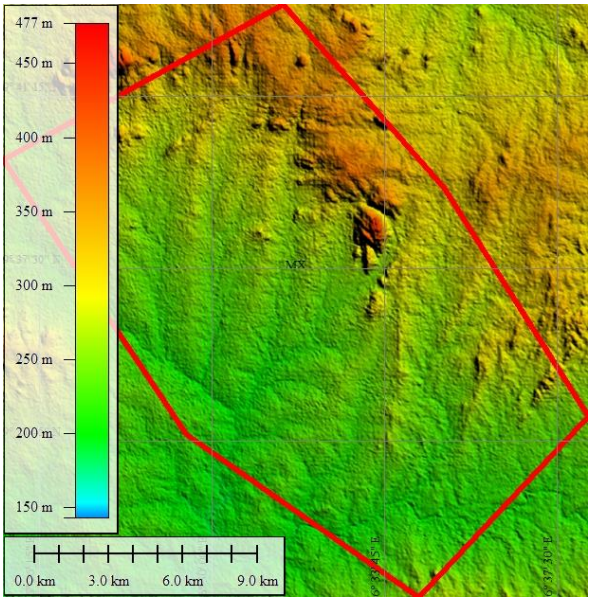


Figure 11: Showing elevation map of the study area.

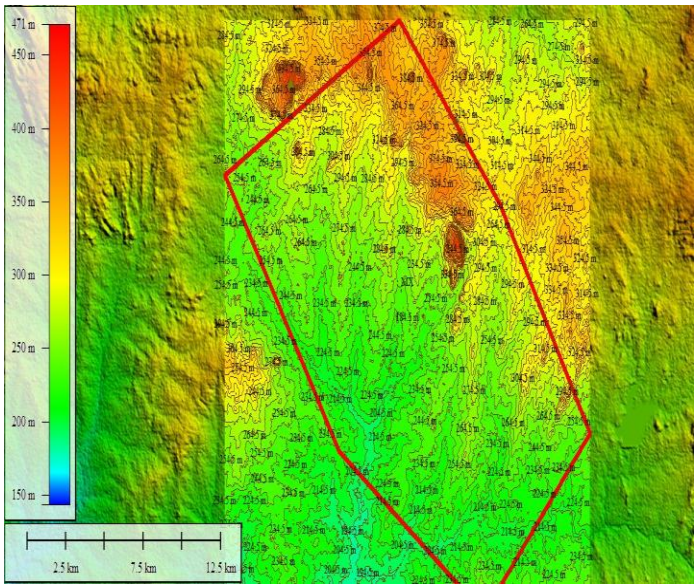


Figure 12: Slope of the study area.

Source: Global mapper 20, SRTM Worldwide Elevation Data (1-arc-second Resolution, SRTM Plus V3)

Figure11 above, shows the study area lies within an elevation of between 150 – 300 meters elevation. These areas are used for residential, socio-economic and sociocultural activities. The highly elevated areas of 350 – 500meters of elevation lies at the north-east periphery of the city. Theses area used for agricultural activities.The topographic map of the study area was created with an interval of 20 meters. Also as shown in *fig. 12*, the north, north-east and eastern part of the study area has steep slope, which includes Maitumbi, Tudun Wada, Tudun Fulani, Bosso and Tayi while the north-west, western, south-western, southern and south-eastern parts of the study area which includesKpagungu, Barkin Sale, SaukaKahuta, Dutsen Kura are of gentle slope and some parts of depressed areas at the south western areas.

AHP Multi-Criteria Evaluation.

Step 1: Define the unstructured problem

The below figure shows the hierarchical structure with the goal placed at the first level, followed by the criteria at the second level.

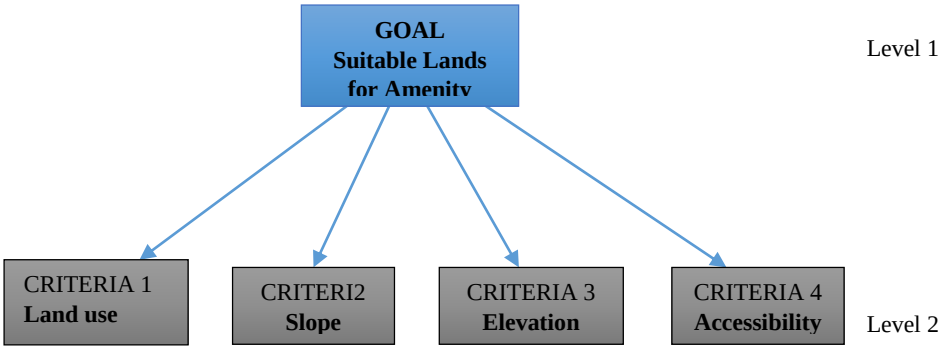


Figure 13: Hierarchical Structure.

Step 2: Developing the AHP hierarchy

The above criteria will be paired and compared against each other in a matrix table. This comparison in done in the table below using a scale of numbers from the Saaty scale.

Table 3Saaty Scale

Criteria	Land use	Slope	Elevation	Accessibility
Scale	9	5	3	7

Step 3: Pair wise Comparison

Table 4

PAIRWISE COMPARISON MATRIX				
CRITERIA	LAND USE	SLOPE	ELEVATION	ACCESSIBILITY
LAND USE	1.00	5.00	7.00	9.00
SLOPE	0.20	1.00	0.33	3.00
ELEVATION	0.14	3.00	1.00	7.00
ACCESSIBILITY	0.11	0.33	0.15	1.00
SUM TOTAL	**1.45**	**9.33**	**8.48**	**20.00**

Step 4: Estimate the relative weights.

Table 5

NORMALISED PAIRWISE COMPARISON MATRIX					
CRITERIA	LAND USE	SLOPE	ELEVATION	ACCESSIBILITY	**CRITERIA WEIGHTS**
LAND USE	0.69	0.54	0.83	0.45	**0.62**
SLOPE	0.14	0.11	0.04	0.15	**0.11**
ELEVATION	0.10	0.32	0.12	0.35	**0.22**
ACCESSIBILITY	0.08	0.04	0.02	0.05	**0.04**
Total	1.10	1.10	1.10	1.0	**.99**

The primary eigenvalue and the corresponding normalized right eigenvector of the comparison matrix give the overall significance of the different criteria being compared. The components of the normalized eigenvector are labelled weights with respect to the attributes or sub-attributes and ratings with respect to the alternatives.

Step 5: Check the consistency

Table 6

CONSISTENCY MATRIX				
CRITERIA WEIGHTS	**0.62**	**0.11**	**0.22**	**0.04**
CRITERIA	LAND USE	SLOPE	ELEVATION	ACCESSIBILITY
LAND USE	0.62	0.55	1.54	0.36
SLOPE	0.12	0.11	0.07	0.12
ELEVATION	0.08	0.33	0.22	0.28
ACCESSIBILITY	0.06	0.04	0.03	0.04

At this stage the consistency of the matrix is checked by multiplying each unnormalized criteria value by the corresponding criteria weights or eigen vector.

Step 6: Obtain the overall rating

Table 7

CRITERIA	LAND USE	SLOPE	ELEVATION	ACCESSIBILITY	W. SUM VALUE	CRITERIA WEIGHTS
LAND USE	0.62	0.55	1.54	0.36	**3.07**	**0.62**
SLOPE	0.12	0.11	0.07	0.12	**0.42**	**0.11**
ELEVATION	0.08	0.33	0.22	0.28	**0.91**	**0.22**
ACCESSIBILITY	0.06	0.04	0.03	0.04	**0.17**	**0.04**

The **Weighted Sum Value** is obtained by summing up the consistent criteria values in each row.

Table 8: Consistence Index

W. SUM VALUE	CRITERIA WEIGHTS	$\frac{WS}{CW}$
3.07	0.62	**4.95**
0.42	0.11	**3.81**
0.91	0.22	**4.14**
0.17	0.04	**4.25**

In calculating the consistency index, first, the weighted sum value is divided by the criteria weighted value each row.

To calculate the consistency index, the λmax must first be obtained.

Which is given as: $\lambda max = \frac{4.95+3.81+4.14+4.25}{4} = 4.28$

To obtain the consistency is given as

CI = (4.82 - 4)/ (4-1) = 0.0933

To obtain the Consistency Proportion (CR), is given as:CI/RI
Where: CI = Consistency Index, RI = Random Index; therefore; 0.0933/0.90 = $\underline{0.10} \leq 0.10$
Given that the consistency Proportion is less than or equal to 0.10 it can be assumed that the matrix is reasonably consistent.
To further prioritize criteria weights to enable further decision making, the percentage of each weighted criteria is calculated, which is given below:

Table 9: Suitability Ranking

ATTRIBUTES	CRITERIA WEIGHTS	PERCENTAGE%	**SUITABILITY**
LAND USE	0.62	62	HIGH
SLOPE	0.11	11	LOW
ELEVATION	0.22	22	MEDIUM
ACCESSIBILITY	0.04	4	POOR

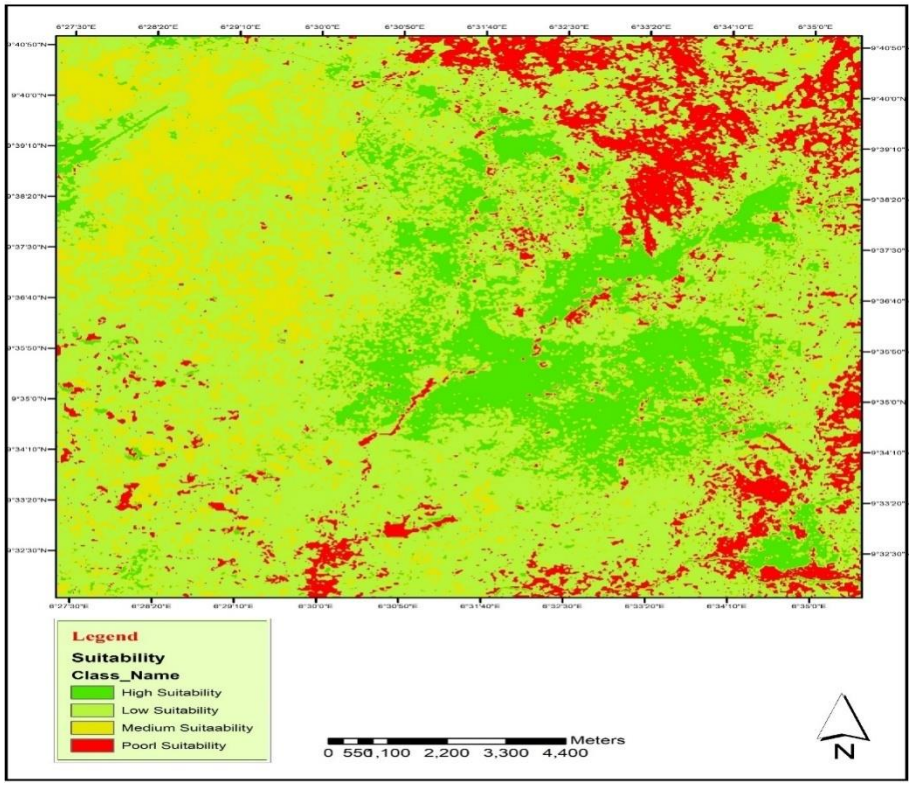


Figure 13: Suitability map of Minna.Source: Idrisi selva 17.2 desktop application software.

CONCLUSION AND RECOMENDATION

Minna city is expanding as a result of inter-urban migration causing uncontrolled urban expansion. Hence the need for adequate planning and control measure to better accommodate the beaming population and to provide adequate amenities to make life worth living for them at proper location.

Land Suitability Evaluation allows to identify constraints and opportunities in planning and planning decision making as regards to site suitability in choosing best sites and location for development amidst other factors.

Based on findings from the study, development in Minna city is expanding to the fringes, hence the need for provision of more civic amenities in these areas. Government and planning agencies should keep track of urban growth of the city. Proper development control policies should be put in place to guide development and to check urban sprawl. Development control agencies should be set up, equipped and charged with the responsibility of enforcing planning and development codes.

As revealed by the study, the city core which includes GRA, Limawa, Minna Central, Tunga and F-Layout has more facilities and are better served with adequate amenities as compared with those living in the periphery if the city. Adequate facilities should be provided to the people living off the city core to better

serve those living in the peripheral areas which include Fadipe, Shango, Maitumbi, Kpakungu and Tudeun Fulani, make life comfortable for them. Also, government, planning bodies and agencies should be up-and-doing in the provision of adequate amenities and see to it that proper routine maintenance of these amenities is carried out regularly.

Comprehensive policies should be put in place by the government, to guide the provision of civic amenities and their maintenance. Enforcement bodies or agencies should also be set up to see to it that these policies are properly implemented to the fullest and constant review of these policies is necessary to evaluate the degree of their functionality based on the current condition and future potentials.

Furthermore, physical development plan, planning laws and of Minna city and mode of implementation must be reviewed to assess the level of functionality of the plan in both space and time. The use of technology like the Geographic Information System should be adopted to help check and keep track of urban growth.

Finally, Multi Criteria decision Analysis should be adopted by planners in and other urban decision makers in making choices for site selection in provision of urban amenities and other physical planning sectors to help in making better and sustainable plans and decisions.

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