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DEVELOPING A GIS-BASED COMPOSITE WALKABILITY INDEX USING OPEN GEOSPATIAL DATA AND FIELD MEASUREMENTS IN UYO URBAN AREA, NIGERIA

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Abstract
Walkability has emerged as an important component of sustainable urban mobility because of its contribution to reducing automobile dependence, improving public health, and supporting environmentally sustainable cities. However, walkability conditions in many rapidly urbanizing African cities remain poorly understood due to limited pedestrian-focused planning and inadequate spatial datasets. This study develops a Geographic Information System (GIS)-based Composite Walkability Index (CWI) for Uyo Urban Area, Nigeria, through the integration of open geospatial datasets and field-based measurements. The study employed a survey-based and spatial analytical approach combining household surveys, field observations, pedestrian counts, OpenStreetMap datasets, satellite imagery, and GIS techniques. Principal Component Analysis (PCA), regression analysis, rasterization, Kriging interpolation, and map algebra were applied to identify the major determinants of walkability and generate a spatially explicit walkability index. The findings reveal that walkability in Uyo is significantly influenced by land-use structure, street connectivity, accessibility, pedestrian infrastructure, and environmental quality. Areas characterized by mixed land uses, connected street networks, and improved pedestrian facilities recorded higher pedestrian activity levels, whereas peripheral neighbourhoods with poor infrastructure exhibited lower walkability conditions. Regression analysis further showed that the extracted walkability components jointly explained 49.8% of the variation in pedestrian traffic volume, with land-use mix and connectivity emerging as the strongest predictors of walking activity. Spatial analysis revealed a distinct core–periphery pattern in the distribution of walkability across the metropolis. The study demonstrates that integrating open geospatial datasets with field observations provides a practical and cost-effective framework for walkability assessment in data-constrained urban environments. The resulting Composite Walkability Index offers a valuable decision-support tool for sustainable transport planning, pedestrian infrastructure improvement, and climate-responsive urban development in Nigerian cities.

Keywords:Walkability; GIS; Open geospatial data; Pedestrian mobility; Sustainable transport

1.0 Introduction

Globally, increasing attention is being directed toward the development of walkable and sustainable cities that promote people-centred mobility systems. Contemporary urban planning concepts such as the 15-Minute City model reflect a growing transition toward pedestrian-friendly urban environments in response to climate change, rapid urbanization, and environmental sustainability challenges (Jeong et al., 2023).. The transport sector remains a major contributor to greenhouse gas emissions, thereby increasing the urgency for cities to adopt sustainable mobility systems capable of reducing automobile dependence and supporting low-carbon urban development.

Within this sustainability framework, walkability has emerged as a critical component of urban mobility because of its capacity to improve accessibility, reduce environmental pollution, enhance public health, and strengthen urban livability. Walkability refers to the extent to which the built environment supports and encourages walking through safe, connected, accessible, and comfortable pedestrian infrastructure. Existing studies consistently demonstrate that characteristics of the built environment such as land-use diversity, street connectivity, population density, accessibility, and pedestrian infrastructure significantly influence walking behaviour and pedestrian safety.

Despite the growing global interest in walkability assessment, rapidly urbanizing African cities remain underrepresented in existing literature. Most walkability studies focus primarily on cities in Europe, North America, and Asia, while medium-sized cities in Sub-Saharan Africa continue to receive limited scholarly attention. In many African cities, walking remains the dominant mode of transportation among low-income households and short-distance commuters, yet pedestrian infrastructure planning is often neglected.

In Nigeria, walkability studies have largely concentrated on major metropolitan areas such as Lagos and Abuja, while medium-sized cities remain poorly studied. Uyo, the capital city of Akwa Ibom State, is currently experiencing rapid urban expansion accompanied by increasing transport demand, changing land-use patterns, and growing pedestrian mobility challenges. Although road infrastructure development has improved vehicular movement within the city, pedestrian infrastructure development has not progressed at the same pace. Consequently, many areas within the metropolis are characterized by inadequate sidewalks, poor drainage systems, obstructed pedestrian walkways, insufficient crossing facilities, and weak pedestrian safety conditions.

Methodological limitations also remain evident within existing walkability research. Many walkability indices developed in high-income countries rely heavily on detailed spatial datasets that are often unavailable in rapidly urbanizing African cities. Furthermore, conventional walkability assessment frameworks frequently emphasize physical infrastructure while paying limited attention to behavioural and environmental dimensions of pedestrian mobility.

Recent advances in open geospatial technologies provide important opportunities for addressing these challenges. Freely accessible platforms such as OpenStreetMap, Sentinel imagery, Landsat imagery, and WorldPop datasets now provide valuable spatial information for urban analysis in data-constrained environments. Integrating these datasets with field-based measurements therefore offers a practical and replicable approach for evaluating pedestrian conditions within rapidly growing cities.

Against this background, this study develops a GIS-based Composite Walkability Index for Uyo Urban Area through the integration of open geospatial datasets and field-based measurements.

1.1 Research Objectives

The specific objectives of the study are to:

1. Identify the major determinants of walkability within Uyo Urban Area;
2. Examine the relationship between walkability conditions and pedestrian mobility; and
3. Develop a spatially explicit Composite Walkability Index for the study area.

1.2 Research Hypothesis

H0: Walkability components have no statistically significant influence on pedestrian traffic volume within the study area.

2. Literature Review and Theoretical Framework

2.0 Literature Review

2.1 Concept of Walkability

Walkability has become an important subject in modern urban planning, sustainable transportation, and public health research. The concept generally refers to how well the built environment supports safe, comfortable, convenient, and accessible movement for pedestrians. A walkable environment is usually associated with connected street networks, mixed land-use patterns, quality pedestrian infrastructure, environmental comfort, and easy access to urban services and facilities.

Studies by Sallis et al. (2004), Frank et al. (2010), and Forsyth (2015) describe walkability as a multidimensional concept that brings together transportation systems, urban design, accessibility, environmental quality, and public health. Areas with high walkability tend to encourage active transportation, reduce dependence on private vehicles, improve environmental sustainability, and strengthen social interaction and community wellbeing. Walkability therefore goes beyond the simple presence of sidewalks. It reflects the overall quality and usability of the urban environment from the pedestrian's point of view. Factors such as safety, accessibility, environmental attractiveness, land-use integration, and infrastructure quality all influence whether people are willing and able to walk within urban spaces.

2.2 Built Environment and Pedestrian Mobility

The relationship between the built environment and pedestrian mobility has received considerable attention in urban planning, transportation geography, and public health studies. Existing research consistently shows that the physical structure of urban environments strongly affects walking behaviour, travel choices, accessibility, and pedestrian safety. The way a city is designed determines how easily people can reach services and destinations, thereby influencing the practicality and attractiveness of walking as a mode of transportation.

One of the most widely recognized frameworks explaining the relationship between urban form and mobility behaviour is the"3Ds"model developed by Cervero and Kockelman (1997). The framework identifies three major dimensions of the built environment: density, diversity, and design. Density refers to the concentration of people and activities within urban areas, diversityrelates to the mixture of land uses, while design focuses on the arrangement and connectivity of transportation networks and pedestrian infrastructure. According to the framework, compact neighbourhoods with mixed land uses and connected street systems

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encourage walking by reducing travel distances and improving accessibility.

Several empirical studies have supported the relationship between built environment characteristics and pedestrian activity. Frank et al. (2010) found that neighbourhoods with higher walkability scores and connected street networks recorded higher levels of walking trips and physical activity. Similarly, Saelens et al. (2015), in a systematic review, concluded that walkable environments are consistently linked with increased daily walking and lower dependence on private automobiles. Land-use diversity has also been identified as a key factor influencing pedestrian movement. Mixed land-use environments combine residential, commercial, institutional, and recreational activities within close proximity, thereby reducing the need for long-distance travel. King et al. (2015) observed that the availability and variety of destinations significantly influence walking frequency and active transportation behaviour. Reisi et al. (2019) further demonstrated that local walkability indices are strongly associated with accessibility, land-use integration, and pedestrian connectivity.

Street connectivity and urban design also play an important role in pedestrian mobility. Well-connected street networks provide multiple route options, shorter travel distances, and better accessibility. Bartzokas-Tsiompras and Photis (2021) found that interconnected street systems and adequate pedestrian infrastructure significantly improve pedestrian movement and accessibility. Features such as sidewalks, crossings, street continuity, and traffic calming measures were identified as important components of walkable environments.

Environmental quality and the condition of pedestrian infrastructure further shape walking behaviour. Mulyadi et al. (2023) observed that infrastructure quality, pedestrian safety, drainage conditions, shading, lighting, and environmental comfort all significantly influence pedestrian mobility. Poor sidewalks, flooding, unsafe crossings, and uncomfortable environmental conditions discourage walking and reduce the attractiveness of pedestrian movement. Ecological behavioural perspectives also explain that walking behaviour is influenced not only by physical infrastructure but also by how people perceive their environment. Krogstad et al. (2015) and Van Cauwenberg et al. (2014) argued that perceptions of safety, comfort, accessibility, and environmental attractiveness strongly affect individuals'willingness to walk.

In developing countries, particularly in Sub-Saharan Africa, built environment conditions often create serious challenges for pedestrian mobility. Rapid urbanization, inadequate pedestrian infrastructure, weak planning systems, traffic congestion, and poor drainage conditions negatively affect walkability. Venter (2011) noted that walking remains an important mode of transportation for low-income urban residents despite the limited investment in pedestrian infrastructure across many African cities. Similarly, Olvera et al. (2013) observed that poor urban accessibility and inadequate transport infrastructure significantly restrict mobility opportunities within African urban environments. In Nigeria, recent studies increasingly recognize the importance of improving walkability as part of sustainable urban mobility planning. However, most research has focused on large metropolitan areas such as Lagos and Abuja, while medium-sized cities have received less scholarly attention. As a result, there is still limited understanding of how built environment characteristics influence pedestrian mobility in rapidly growing cities such

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as Uyo. Overall, existing literature shows that pedestrian mobility is shaped by the interaction between land-use structure, density, accessibility, connectivity, environmental quality, and pedestrian infrastructure. These factors collectively determine how safe, convenient, and attractive walking becomes within urban environments.

2.3 GIS and Open Geospatial Data in Walkability Assessment

Recent developments in Geographic Information Systems (GIS) and open geospatial technologies have greatly improved urban accessibility analysis and walkability assessment. GIS provides an effective framework for collecting, managing, analysing, and visualizing spatial information related to transportation systems, land-use patterns, accessibility, and urban infrastructure. In walkability studies, GIS allows researchers to examine the spatial relationships between pedestrian infrastructure, street connectivity, population distribution, and urban services.

Traditionally, walkability studies relied heavily on field surveys and manually collected spatial data, which were often expensive, time-consuming, and limited in coverage. However, the emergence of open geospatial datasets and remotely sensed imagery has created new opportunities for urban accessibility analysis, especially in data-constrained environments. Platforms such as OpenStreetMap (OSM), Landsat imagery, Sentinel imagery, Google Earth, and WorldPop datasets now provide accessible spatial information for urban analysis.
Among these platforms, OpenStreetMap has become one of the most widely used sources of open geospatial information because of its collaborative mapping structure and broad global coverage. The platform contains detailed information on road networks, pedestrian pathways, buildings, transport infrastructure, and land-use features. Boeing (2020) explained that open-source spatial datasets have improved access to GIS-based urban analysis and expanded opportunities for transportation and accessibility research, particularly in developing countries.

GIS-based network analysis has become central to modern walkability assessment because it allows researchers to evaluate route connectivity, travel distance, accessibility, and pedestrian movement efficiency. Well-connected street systems provide shorter travel routes and multiple route alternatives, thereby encouraging walking behaviour. Density mapping techniques are also commonly used to examine the spatial concentration of intersections, population, transport facilities, and urban activities, which are important indicators of walkability.

Spatial interpolation techniques also play an important role in contemporary walkability studies. Since it is often difficult to collect environmental observations for every neighbourhood or street segment, interpolation methods help estimate conditions in areas where direct observations are unavailable. Zhang et al. (2023) demonstrated that GIS techniques such as rasterization, network analysis, density mapping, and spatial interpolation effectively support pedestrian accessibility analysis and movement modelling.

Remote sensing imagery has equally become important in urban mobility research because it provides large-scale information on land-use patterns, vegetation cover, urban expansion, and built-up environments. Integrating remotely sensed data within GIS environments improves both the comprehensiveness and spatial accuracy of walkability assessments.

Despite these advancements, several methodological challenges still affect GIS-based walkability research in developing countries. Many walkability models developed in high-income countries rely heavily on detailed spatial databases and official land-use records that are often unavailable in African cities. As a result, applying such models directly within rapidlyurbanizing African environments remains difficult because of limited data availability, weak spatial documentation systems, and irregular urban growth patterns. Studies focusing on African cities also indicate that pedestrian accessibility assessment is frequently constrained by fragmented urban information systems and limited geospatial infrastructure. Official datasets relating to pedestrian facilities, transportation systems, and land-use patterns are often incomplete or outdated, limiting evidence-based transportation planning.

Another limitation of many GIS-based walkability models is their strong emphasis on macro-scale indicators while giving limited attention to neighbourhood-level environmental conditions and pedestrian perceptions. Variables such as sidewalk quality, drainage conditions, pedestrian safety, environmental comfort, and perceived accessibility are often difficult to capture using remotely sensed datasets alone. Boeing (2020) and Zhang et al. (2023) therefore recommended integrated approaches that combine open geospatial datasets with field observations and environmental audits.

Within Nigeria, the application of GIS and open geospatial technologies in walkability assessment remains relatively limited despite increasing urbanization challenges. Most transportation studies focus mainly on vehicular traffic and road infrastructure, while pedestrian accessibility analysis receives comparatively less attention. Consequently, there is still insufficient understanding of how GIS techniques and open geospatial datasets can be integrated for comprehensive walkability assessment in medium-sized Nigerian cities such as Uyo.

Overall, existing literature demonstrates that GIS and open geospatial technologies provide effective and cost-efficient tools for evaluating pedestrian accessibility and urban mobility patterns. Techniques such as network analysis, rasterization, density mapping, remote sensing analysis, and spatial interpolation have significantly improved the ability to assess walkability in data-constrained urban environments.

2.4 Walkability Studies in African Cities

Research on walkability within Sub-Saharan Africa remains relatively limited despite the important role of walking in everyday urban mobility across the region. In many African cities, walking is one of the most common means of transportation, especially among low-income households, informal sector workers, students, and people making short-distance trips. Rapid urbanization, increasing transportation costs, weak public transport systems, and growing urban poverty have all contributed to greater dependence on walking.

Several studies have emphasized the importance of walking within African urban transport systems. Venter (2011) observed that non-motorized transport, particularly walking, plays an important role in providing access to livelihoods and social services among low-income urban residents. Similarly, Olvera et al. (2013) argued that mobility patterns in African cities are strongly influenced by economic inequality, inadequate transport infrastructure, and limited public transportation systems.

Ayobami (2019) further noted that dependence on walking in many African cities is often driven by necessity rather than preference because affordable transport alternatives are limited.

As a result, pedestrian mobility within African urban environments is closely connected to issues of accessibility, urban equity, and social inclusion. Despite the importance of walking across African cities, walkability research within the region remains less developed than in Europe, North America, and parts of Asia. Existing studies mainly focus on transport affordability, poverty-related mobility challenges, and pedestrian infrastructure conditions, while giving limited attention to broader walkability dimensions such as land-use integration, environmental quality, street connectivity, accessibility, and pedestrian perception.

Many African cities continue to face serious urban planning and infrastructure challenges that negatively affect pedestrian mobility. Poorly maintained roads, inadequate sidewalks, weak drainage systems, roadside trading, flooding, traffic congestion, and weak enforcement of transport regulations all contribute to unsafe and uncomfortable walking conditions. Studies conducted in cities such as Lagos, Nairobi, Accra, Johannesburg, and Dar es Salaam indicate that pedestrians frequently encounter unsafe crossings, narrow walkways, flooding, and conflicts with vehicular traffic.

Rapid urbanization has further intensified these mobility challenges. Increasing population growth, uncontrolled urban expansion, and rising motorization have placed significant pressure on transportation infrastructure across many African cities. However, urban transport planning often continues to prioritize vehicular movement over pedestrian accessibility, leading to inadequate investment in pedestrian infrastructure despite widespread dependence on walking. Another major limitation within African walkability research is the limited use of GIS and open geospatial technologies. Many studies rely mainly on descriptive surveys and observational methods without incorporating spatial analysis techniques capable of examining neighbourhood-level accessibility and walkability patterns. Consequently, there remains limited understanding of how land-use diversity, street connectivity, accessibility, and environmental quality influence pedestrian movement in African urban environments. Although GIS-based walkability studies are gradually emerging within Africa, they remain relatively few. Existing GIS-related studies often focus on transport mapping or road infrastructure analysis rather than developing comprehensive walkability frameworks that integrate behavioural, infrastructural, and environmental dimensions.

Environmental quality also remains one of the least explored aspects of African walkability research. Factors such as drainage conditions, environmental cleanliness, street lighting, thermal comfort, shading, air quality, and perceived safety significantly influence walking behaviour but are rarely included in existing walkability models within the region.
In Nigeria, walkability studies remain relatively limited and are concentrated mainly in larger metropolitan areas such as Lagos and Abuja. Most existing studies focus on transportation challenges and traffic conditions, while integrated GIS-based walkability assessments remain scarce. Medium-sized cities such as Uyo have received comparatively little scholarly attention despite experiencing rapid urban growth and increasing mobility challenges.

In general, the literature indicates that walking remains a critical component of urban mobility systems across African cities. However, walkability research within the region is still constrained by limited spatial analysis, weak GIS integration, and insufficient attention to environmental and behavioural dimensions of pedestrian mobility. These limitations highlight the need for integrated and context-specific walkability assessment frameworks suitable for rapidly urbanizing African cities.

3. Study Area

Uyo, the capital city of Akwa Ibom State, lies between latitudes4°49′27″and5°55′North and longitudes7°21′and7°58′East as in Figure 1. The city forms part of the Uyo Capital Territory, which covers approximately 362 km². Uyo is one of Nigeria's fastest-growing medium-sized cities and functions as the administrative, commercial, and educational centre of Akwa Ibom State. The city is characterized by relatively planned residential layouts, expanding road networks, and increasing urban development activities. Transportation within the metropolis depends largely on minibuses, taxis, tricycles, and informal public transport systems. Rapid urban growth, increasing car ownership, and inadequate pedestrian infrastructure have contributed to declining walkability conditions in many neighbourhoods.

Walking remains an important mode of mobility for school children, traders, workers, and low-income residents who depend on short-distance travel. The city's moderate size, structured road network, and growing availability of open geospatial datasets make it suitable for GIS-based walkability assessment.

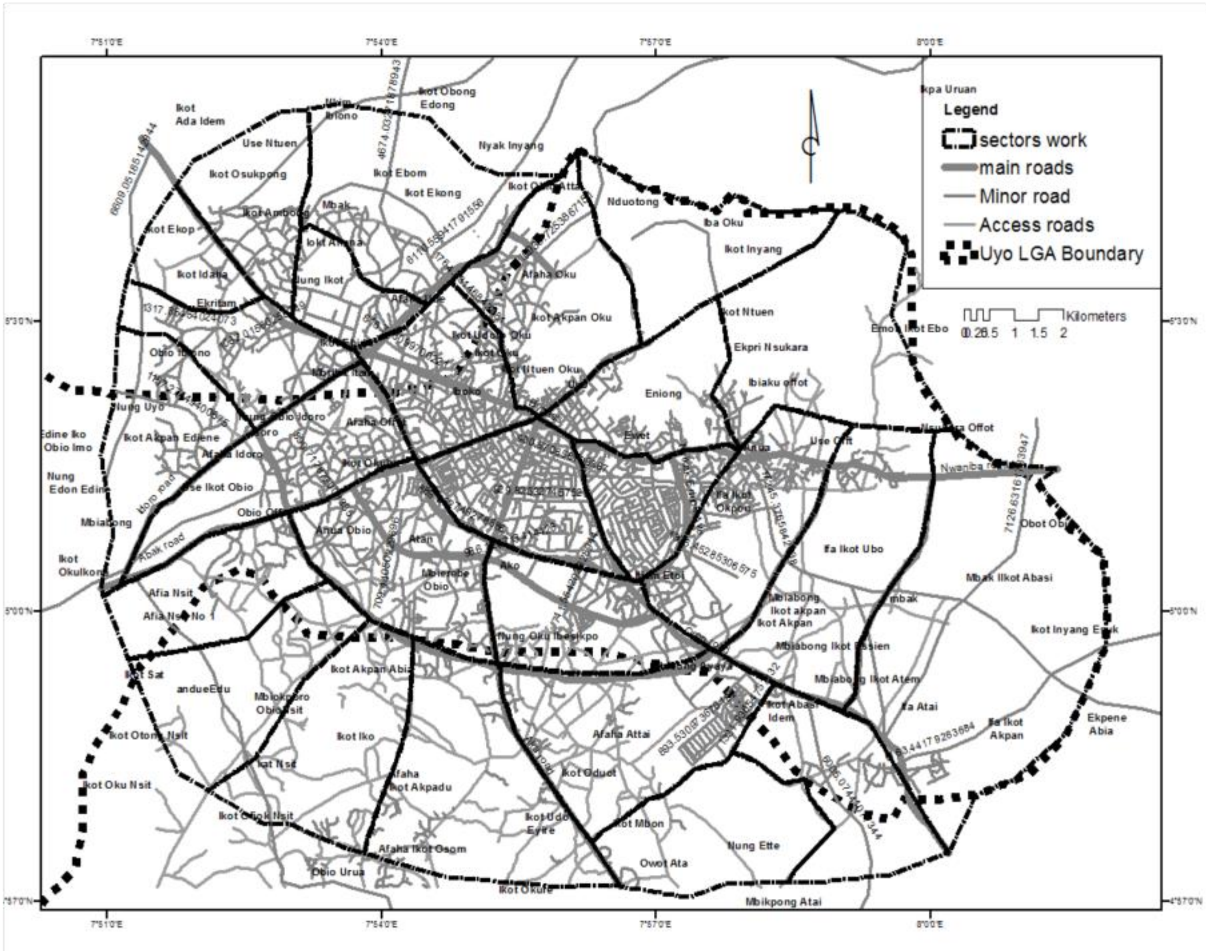

Figure 1: Study location showing Uyo Metropolis

4. Materials and Methods

4.1 Research Design

The study adopted a cross-sectional survey research design integrating Geographic Information System (GIS) techniques, open geospatial datasets, field observations, and household survey methods to assess walkability conditions within Uyo Urban Area. The approach combined spatial analysis with statistical modelling to evaluate the relationship between the built environment and pedestrian mobility patterns.

4.2 Data Sources and Variables

Both primary and secondary data sources were utilised for the study. Primary data were obtained through field observations, environmental audits, pedestrian traffic counts, and questionnaire surveys administered to residents across the study area. Secondary data were sourced from OpenStreetMap Foundation road network datasets, Google Earth satellite imagery, population and census publications, and other publicly available GIS datasets. The variables considered in the analysis included population density, road width, street density, intersection density, transit stop density, pedestrian infrastructure quality, accessibility to services, environmental quality, household income, and walking frequency. These variables were selected because of their established relationship with pedestrian movement and urban walkability.

4.3 Sampling Procedure

The study area was stratified into three spatial zones comprising the urban core, middle core, and outer core areas to capture variations in urban form and pedestrian conditions. A total of 33 Traffic Analysis Zones (TAZs) were delineated based on neighbourhood structure, land-use characteristics, and transport network patterns.

A multi-stage sampling procedure involving purposive and simple random sampling techniques was adopted. Purposive sampling was first used in delineating the TAZs and identifying representative neighbourhoods, while random sampling was subsequently applied in selecting households within each zone. A total of 400 households were selected for questionnaire administration using the Taro Yamane sample size determination formula.

4.4 GIS and Spatial Analysis

Open geospatial datasets comprising road networks, land-use features, street intersections, pedestrian facilities, and transit stop locations were processed within a GIS environment. Spatial analysis techniques including network analysis, kernel density estimation, rasterization, buffering, and spatial interpolation were employed to derive walkability indicators and examine the spatial distribution of pedestrian-supportive infrastructure across the study area.

4.5 Principal Component Analysis

Principal Component Analysis (PCA) was employed to reduce multicollinearity among the walkability indicators and to identify the major underlying dimensions influencing pedestrian mobility. Prior to component extraction, the suitability of the dataset for PCA was evaluated using the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. Components with eigenvalues greater than 1.0 were retained in accordance with Kaiser's criterion, while Varimax orthogonal rotation was applied to improve the interpretability of the factor structure and enhance component loading clarity.

4.6 Regression Modelling

Multiple linear regression analysis was conducted to examine the relationship between pedestrian traffic volume and the identified walkability components. Pedestrian traffic volume served as the dependent variable, while the PCA-derived factor scores constituted the independent variables. The regression model was used to determine the extent to which the identified walkability dimensions influenced pedestrian movement within the study area.

4.7 Construction of the Composite Walkability Index

Spatial surfaces representing each PCA-derived walkability component were generated through rasterization at a spatial resolution of 25×25 metres. Kriging interpolation techniques were subsequently applied to produce continuous spatial representations of the identified walkability dimensions.

The final Composite Walkability Index (CWI) was generated using weighted overlay analysis and map algebra techniques within the GIS environment. The weighting scheme assigned relatively higher weights to land-use mix and street connectivity because of their widely established influence on pedestrian accessibility and walking behaviour in urban environments. The resulting index was classified into walkability categories to identify areas with low, moderate, and high walkability conditions across Uyo Urban Area.

5. Results

5.1 Principal Component Extractions

The PCA analysis extracted three principal components explaining 66.8% of the total variance in the dataset. Component 1 represented demographic and facility density characteristics and accounted for 41.1% of the variance. Component 2 represented land-use mix and street connectivity, explaining 13.0% of the variance, while Component 3 represented accessibility and pedestrian environmental quality, accounting for 12.7% of the variance.

The KMO value of 0.527 and Bartlett's Test of Sphericity($\chi^2 = 147.573$, $p < 0.001$) confirmed the suitability of the dataset for factor analysis see table 1.

Table 1 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.527
Bartlett's Test of Sphericity	Approx. Chi-Square	147.573
	df	45
	Sig.	.000

5.2 Rotated Component Matrix

The rotated component matrix revealed strong positive loadings for variables X1, X2, X4, X5, X6, and X7 under Component 1, indicating demographic concentration and facility density. Component 2 showed strong loadings for X3 and X9, representing land-use diversity and connectivity. Component 3 recorded strong positive loading for X8 and negative loading for X10, indicating accessibility and pedestrian environmental quality see table 2.

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Table 2 : Rotated Component Matrix

X1	.916		
X7	.904		-.179
X5	.794		
X2	.759		
X6	.743		-.132
X4	.725	.235	.357
X9	-.254	.909	
X3	.523	.681	
X8	.191		.836
X10	.315		-.593

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser

5.3 Regression Analysis

The regression model produced a strong positive relationship between the walkability components and pedestrian traffic volume ($R = 0.706$). The coefficient of determination ($R^2 = 0.498$) indicates that approximately 49.8% of the variation in pedestrian traffic volume is explained by the combined influence of the extracted walkability components. The model was statistically significant ($F = 9.604$, $p < 0.001$), indicating that the walkability components jointly exert significant influence on pedestrian traffic volume. Factor 1 significantly predicted pedestrian traffic volume ($\beta = 0.357$, $p = 0.011$), while Factor 2 emerged as the strongest predictor ($\beta = 0.472$, $p = 0.001$). Factor 3 also significantly influenced pedestrian movement ($\beta = 0.384$, $p = 0.007$) (see table 3).

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Table 3: Model Summary of Regression Analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change
1	.706[a]	.498	.446	74.55053	.498	9.604	3	29	.000

a. Predictors: (Constant), V3, V2, V1
b. Dependent Variable: walking trip volume
Source: Author's Statistical Analysis (2025

Table 7: Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	Upper Bound
1	(Constant)	264.162	12.978		20.355	.000	237.620	290.704
	Factor 1	35.801	13.179	.357	2.717	.011	8.848	62.755
	Factor 2	47.333	13.179	.472	3.592	.001	20.379	74.286
	Factor 3	38.500	13.179	.384	2.921	.007	11.546	65.453

Dependent Variable: V4

5.4 Spatial Distribution of Walkability

Spatial analysis revealed substantial variation in walkability conditions across Uyo Urban Area. Higher walkability zones were concentrated around the urban core and major activity corridors characterized by mixed land uses, higher densities, and connected street systems. Peripheral neighbourhoods generally recorded lower walkability levels because of poor pedestrian infrastructure, weak street connectivity, and limited accessibility to urban facilities as in 2a – c below

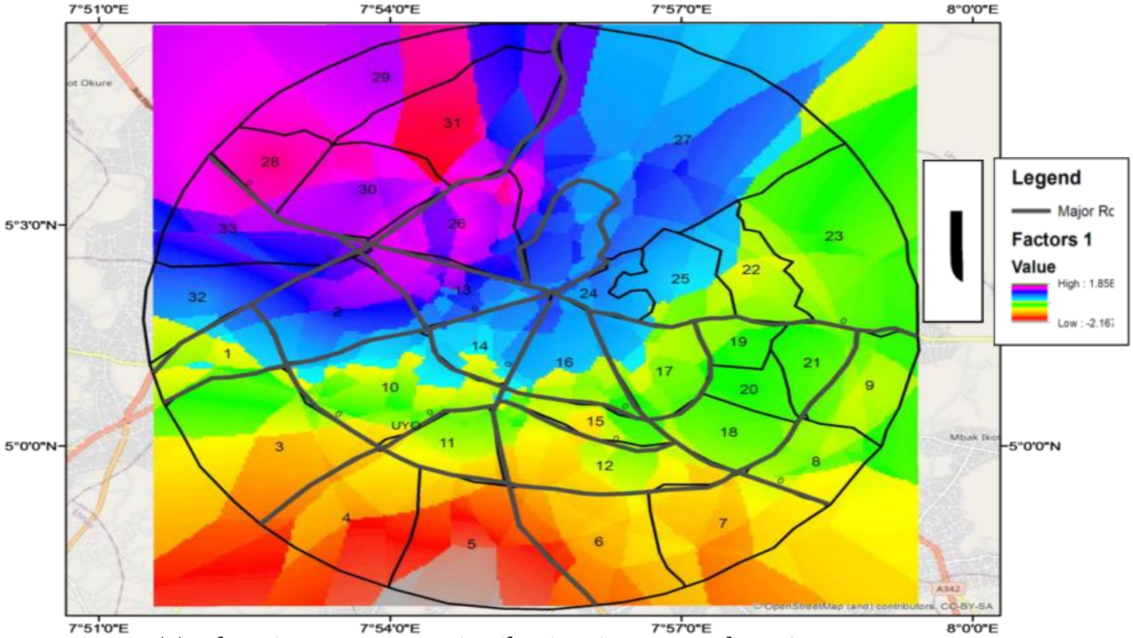

Figure (a): showing Factor 1 Distribution in Uyo Urban Area

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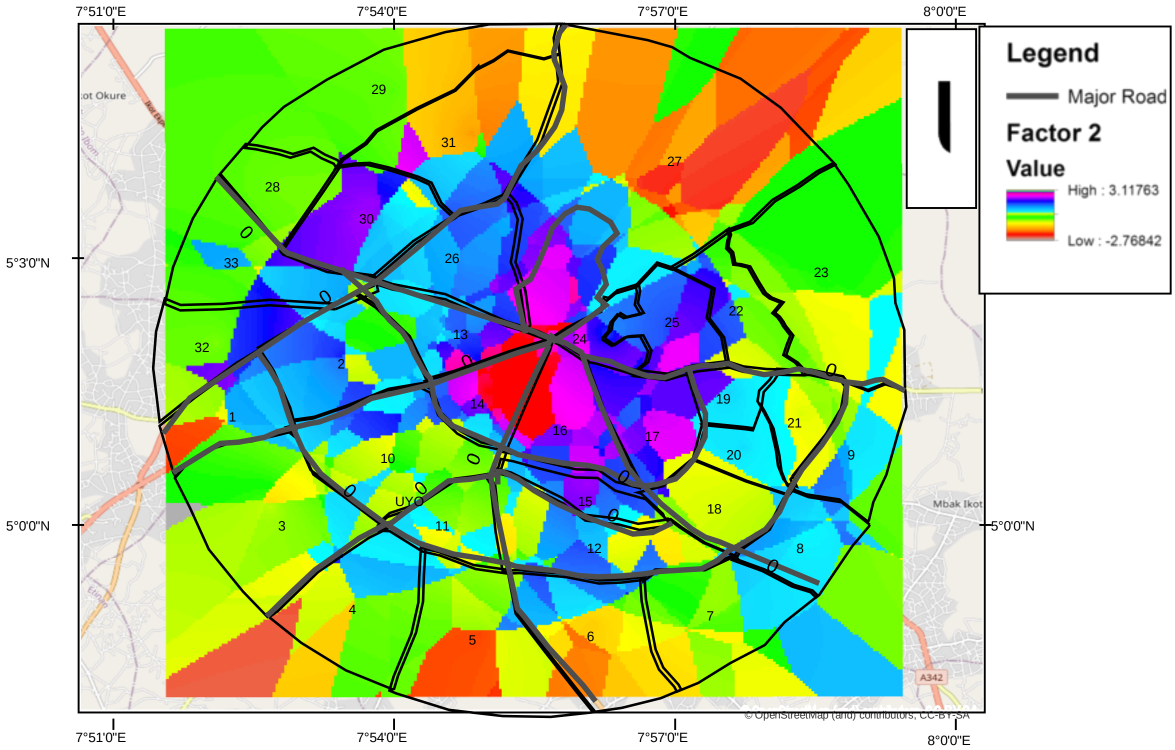

Figure 2(b): showing Factor 2 Distribution in Uyo Urban Area

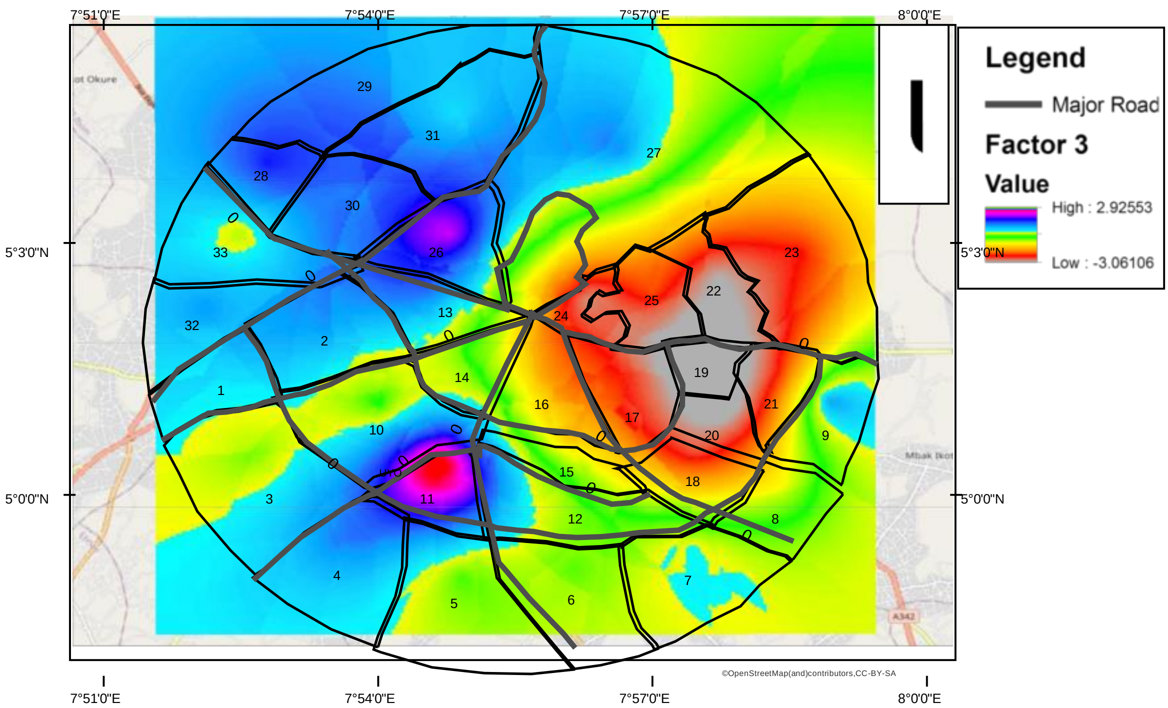

Figure (c):: showing Factor 3 Distribution in Uyo Urban Area

5.5 Composite Walkability Index Mapping

The Composite Walkability Index categorized the study area into Very Low, Low, Moderate, High, and Very High walkability zones. The spatial pattern demonstrated a clear core–periphery structure, with highly walkable areas concentrated within the central urban districts as in figure 3

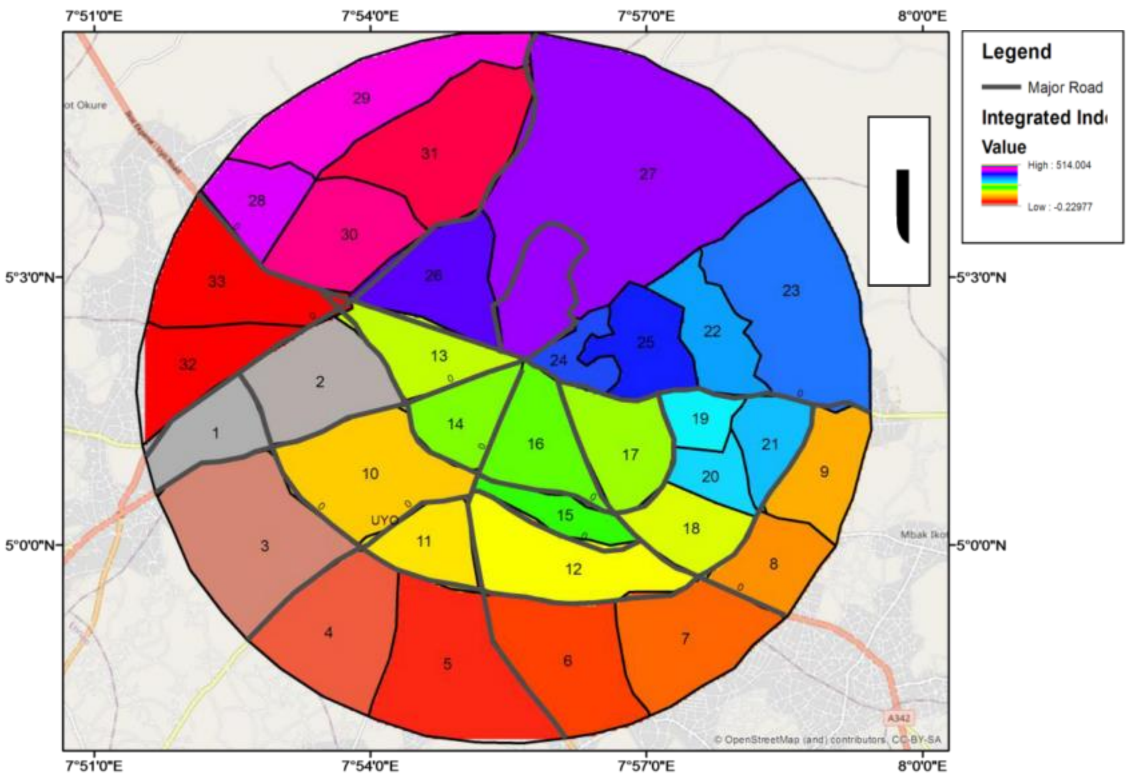

Figure 3: Final Composite Walkability Index (CWI) map of Uyo Urban

6 Discussion of Major Findings

The findings of this study show that walkability in Uyo Urban Area is determined by a combination of demographic concentration, land-use structure, street connectivity, accessibility, and environmental quality. The extraction of three principal components explaining 66.8% of the total variance confirms the multidimensional nature of walkability, consistent with Southworth (2005) and Sallis et al. (2004). The KMO value (0.527) and significant Bartlett's Test further confirm the adequacy of the dataset for factor analysis, in line with Frank et al. (2010), who demonstrated the interdependence of walkability indicators in urban environments. The first component (41.1% variance), representing demographic and facility density, indicates that population concentration and service availability significantly influence pedestrian movement. This supports Jacobs (1961), who emphasized that dense, mixed urban form promotes walking, and aligns with Ewing and Cervero (2010), who identified density and destination accessibility as key predictors of walking behaviour. Similar results were reported by Frank et al. (2006), confirming higher walking rates in dense neighbourhoods compared to low-density suburban areas.

The second component, capturing land-use mix and street connectivity, emerged as the strongest predictor of pedestrian traffic ($\beta = 0.472$, $p = 0.001$). This finding is consistent with the"3Ds"framework of Cervero and Kockelman (1997) and corroborates Frank et al. (2010) and Handy et al. (2002), who reported that integrated land use and connected street networks reduce travel distances and enhance walkability. In developing urban contexts, Bartzokas-Tsiompras and Photis (2021) similarly found that connectivity significantly improves pedestrian accessibility, aligning with the Uyo results.

The third component reflects accessibility and environmental quality, where poor infrastructure and environmental conditions negatively affect walkability. This is consistent with Gehl (2010), who stressed the importance of safe and comfortable pedestrian environments, and Mulyadi et al. (2023), who reported that poor sidewalk quality and unsafe crossings discourage walking. The result is also supported by ecological behavioural theory (Bronfenbrenner, 1979) and empirical findings from Van Cauwenberg et al. (2014) and Krogstad et al. (2015), which highlight the role of perceived safety and environmental comfort in walking decisions.

The regression model ($R^2 = 0.498$) indicates that nearly half of the variation in pedestrian movement is explained by walkability components. This is consistent with Ewing and Cervero (2010), who reported explanatory power ranging from 40% to 60% in built environment–walking relationships. The stronger influence of land-use mix and connectivity further supports Frank et al. (2006), who found that design and diversity variables often outperform density in predicting walking behaviour.

Spatially, the study reveals a pronounced core–periphery pattern, with higher walkability concentrated in central areas and lower levels in peripheral zones. This reflects patterns observed in African cities by Turok (2016) and UN-Habitat (2020), where uneven infrastructure development and fragmented urban expansion generate accessibility disparities.

The Composite Walkability Index (CWI) further confirms spatial inequalities in pedestrian infrastructure and accessibility. This aligns with Reisi et al. (2019) and Zhang et al. (2023), who demonstrated the effectiveness of GIS-based composite indices in capturing spatial variation in urban walkability.

Generally, the findings are consistent with established literature (Jacobs, 1961; Cervero & Kockelman, 1997; Frank et al., 2010; Ewing & Cervero, 2010; Gehl, 2010), confirming that walkability is driven by the interaction of density, land-use mix, connectivity, accessibility, and environmental quality. However, this study extends existing knowledge by providing evidence from a medium-sized Nigerian city, showing that land-use mix and connectivity exert relatively stronger influence than density. It also demonstrates the effectiveness of integrating GIS and PCA for walkability assessment in data-limited urban contexts.

7. Policy Implications

The findings of this study carry important implications for sustainable urban planning and transportation policy in Nigeria.

1. Urban planners need to place greater emphasis on developing mixed land-use areas and improving street connectivity, as these elements help to enhance accessibility and shorten travel distances within the city.
2. Government agencies also have a key role to play in upgrading pedestrian infrastructure. This includes the provision of functional sidewalks, proper drainage systems, safe pedestrian crossings, and traffic calming measures that make walking safer and more comfortable.
3. In addition, the study highlights the importance of integrating GIS tools and open geospatial technologies into urban planning and transport decision-making processes, as they provide reliable support for spatial analysis and evidence-based planning.
4. The Composite Walkability Index developed in this research can also serve as a practical tool for identifying priority areas and guiding investment in pedestrian infrastructure.
5. Finally, there is a clear need for walkability assessment frameworks that are adapted to the realities of medium-sized African cities, especially those that operate within data-limited environments and require more flexible, context-sensitive approaches.

8. Conclusion

This study developed a GIS-based Composite Walkability Index for Uyo Urban Area by combining open geospatial datasets with field-based measurements. The results show that walkability in the area is strongly shaped by land-use mix, street connectivity, accessibility, the condition of pedestrian infrastructure, and environmental quality. Areas with mixed land uses, well-connected street networks, and better pedestrian facilities consistently recorded higher levels of pedestrian activity. The regression analysis also confirmed that these walkability components have a significant effect on pedestrian traffic volume across the study area.

The combination of OpenStreetMap data, GIS analytical techniques, spatial interpolation, and field observations proved to be an effective way of assessing walkability in a rapidly growing urban environment where data is often limited. Based on this, the Composite Walkability Index offers a practical tool that can support sustainable transport planning, improve pedestrian infrastructure development, and guide climate-responsive urban policy. The study adds to the ongoing discussions on sustainable mobility in African cities and highlights the usefulness of open geospatial technologies for assessing urban accessibility in developing contexts.

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