

URBAN STREET TOPOLOGY, TRAFFIC FLOW AND MOBILITY RESILIENCE IN MEDIUM-SIZED NIGERIAN CITIES

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Abstract

This study examined street-network topology, traffic-flow characteristics, and transportation infrastructure in relation to mobility structure and emergency accessibility in medium-sized Nigerian cities. An integrated Geographic Information Systems (GIS) and graph-theoretical framework was applied to evaluate street-network connectivity, centrality patterns, traffic-flow characteristics, and infrastructure conditions in Ilesa and Iwo, southwestern Nigeria. Results revealed considerable spatial variation in mobility structure, with movement concentrated along a limited number of dominant corridors. Top-category streets accounted for 98% of observed traffic in Ilesa and 97% in Iwo, indicating a pronounced concentration of vehicular movement along higher-order streets. Strong positive relationships were observed between street length and degree centrality (Iwo: r = 0.856; Ilesa: r = 0.834), street length and betweenness centrality (Iwo: r = 0.813; Ilesa: r = 0.737), and degree and betweenness centrality (Iwo: r = 0.815; Ilesa: r = 0.749). Drainage deficiencies and deteriorating pavement conditions were evident along several highly utilized routes. The findings highlight the importance of street-network hierarchy, traffic concentration, route redundancy, and infrastructure functionality for mobility continuity, emergency-access planning, and urban transport resilience.

Keywords: Street-network topology; Emergency mobility; Urban accessibility; Transport resilience; Betweenness centrality; Geographic Information Systems (GIS)

1.0 Introduction

Urban transportation systems constitute one of the most fundamental components of spatial organization and socio-economic interaction within cities. The efficiency of urban mobility is strongly influenced by the structural configuration of street networks, the degree of connectivity among road segments, and the capacity of transport corridors to accommodate traffic flows under both normal and emergency conditions (Barthelemy, 2011; Boeing, 2021; Jiang & Claramunt, 2004). In rapidly urbanizing cities of developing countries, particularly in sub-Saharan Africa, population growth, uncontrolled land-use expansion, and inadequate transportation planning have intensified traffic congestion, reduced mobility efficiency, and heightened vulnerability to mobility disruption during emergencies and extreme events (UN-Habitat, 2022; United Nations, 2019). These challenges are especially pronounced in medium-sized cities where transportation infrastructure expansion frequently lags behind demographic and economic growth, thereby increasing pressure on existing road systems and mobility corridors (Adelekan et al., 2015; Cobbinah et al., 2015). Consequently, understanding the structural properties of urban street networks and their



relationship with traffic dynamics is important for sustainable urban transport planning, mobility resilience, and emergency-management strategies (Boeing & Ha, 2024; Crucitti et al., 2006).

Street networks are complex spatial systems whose morphology influences accessibility, traffic distribution, travel efficiency, and emergency movement (Porta et al., 2006a; Porta et al., 2006b). Their arrangement and interconnection determine the ease with which people, goods, and emergency services move across urban space (Marshall, 2005). Street connectivity describes the directness and density of links within a transportation network, while street hierarchy reflects the functional differentiation of roads according to their structural importance and mobility roles (Jiang, 2009; Xie & Levinson, 2007). Highly connected and centrally positioned streets frequently function as dominant mobility corridors, whereas fragmented street systems may generate bottlenecks, reduce route redundancy, and increase vulnerability to congestion and network disruption (Kirkley et al., 2018; Tang et al., 2022; Yadav et al., 2020).

Graph theory provides a quantitative framework for examining these structural characteristics of urban street systems (Barthelemy, 2011; Crucitti et al., 2006). In graph-theoretical representation, street intersections are treated as nodes and street segments as edges connecting the nodes (Jiang & Claramunt, 2004). Measures such as degree, betweenness, and closeness centrality enable the relative structural importance and accessibility of different components of a street network to be evaluated (Freeman, 1977, 1979). Degree centrality reflects local connectivity, betweenness centrality identifies nodes or corridors occupying strategic positions along shortest paths, while closeness centrality measures accessibility relative to other locations within the network. Together, these measures provide insights into street hierarchy, accessibility, and the structural organization of urban movement, while previous applications have demonstrated relationships between street-network characteristics and traffic-flow patterns (Jiang & Liu, 2009; Porta et al., 2006a; Wang et al., 2017).

The relationship between street-network structure and movement is also influenced by the spatial distribution of urban activities. Commercial districts, industrial zones, administrative centers, markets, and residential neighborhoods generate varying travel demands that affect traffic intensity and composition across urban space (Rodrigue, 2020). Corridors connecting major activity areas therefore tend to experience greater traffic concentrations and congestion pressure (Marshall, 2005). In rapidly urbanizing environments, these pressures may be intensified where increasing motorization is not accompanied by corresponding expansion and improvement of transportation infrastructure (UN-Habitat, 2022).

Urban mobility resilience is particularly important because transportation networks constitute critical infrastructure for emergency response, evacuation, and socio-economic continuity (Boeing & Ha, 2024; Morelli & Cunha, 2021). Mobility resilience describes the capacity of transportation networks to maintain functionality or recover from disruptions such as flooding, accidents, infrastructure failure, or other hazards (Henke et al., 2024). Network connectivity and route redundancy are therefore important because alternative routes may support movement when individual links are disrupted (Lu et al., 2025; Tang et al., 2022). Conversely,



dependence on a limited number of structurally important corridors may constrain movement continuity when those corridors are affected (Boeing & Ha, 2024; Morelli & Cunha, 2021). Identifying such critical corridors is consequently relevant to emergency preparedness, transport planning, and infrastructure prioritization (Roosta et al., 2022; Yadav et al., 2020).

These concerns are particularly relevant to African cities, where rapid urban growth frequently occurs without proportional infrastructure expansion (Cobbinah et al., 2015). Medium-sized Nigerian cities experience increasing transportation pressure within street systems that must accommodate expanding urban activities and travel demand. However, studies examining the topological structure of urban street networks and its implications for mobility resilience remain limited. Previous Nigerian transportation studies have provided important insights into transport conditions and mobility characteristics (Aderamo & Mogaji, 2010; Olawole & Aloba, 2014), while GIS-based approaches provide opportunities for more systematic evaluation of urban transport-network structure (Sahitya & Prasad, 2024). Greater attention is therefore required to how street connectivity, hierarchy, and centrality relate to the spatial organization of urban mobility and the capacity of street systems to support movement continuity.

This limitation is particularly relevant to medium-sized cities such as Ilesa and Iwo in Osun State, southwestern Nigeria. These cities perform important regional commercial and administrative functions and are experiencing transportation pressures associated with urban expansion, population growth, and changing land-use patterns. Yet, there remains limited empirical understanding of how street-network structure relates to mobility concentration and critical corridor functionality within these urban environments. Identifying structurally significant streets and mobility corridors can provide useful evidence for transport planning, congestion management, emergency movement planning, and urban mobility resilience.

This study therefore examines the topological structure, street hierarchy, and traffic-flow dynamics of urban street networks in Ilesa and Iwo, Osun State, Nigeria. Specifically, the study evaluates street connectivity and centrality patterns, examines traffic-flow characteristics across street-hierarchy categories, and identifies critical mobility corridors relevant to emergency movement efficiency and urban transport resilience. By integrating graph-theoretical analysis with traffic-flow assessment, the study contributes to emerging discussions on transport-network resilience and mobility structure in medium-sized cities of developing countries.

2.0 Methodology

This study adopted an integrated Geographic Information Systems (GIS) and graph-theoretical analytical framework to examine street-network topology, hierarchy, traffic-flow dynamics, and mobility structure in the urban centers of Ilesa and Iwo, Osun State, southwestern Nigeria. The approach combined spatial-network analysis, traffic-flow assessment, and statistical analysis to evaluate the structural and functional characteristics of the urban transport systems. The integration of GIS and graph-theory techniques has been widely recognized as an effective method for analyzing transportation systems because it enables quantitative evaluation of street-network configuration, connectivity, centrality, and movement patterns

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within urban environments (Jiang & Claramunt, 2004; Porta et al., 2006a; Xie & Levinson, 2007).

As shown in Figure 1, Ilesa lies approximately between latitudes 7°36′00″N and 7°40′30″N and longitudes 4°41′00″E and 4°49′00″E, while Iwo is situated approximately between latitudes 7°32′54″N and 7°41′03″N and longitudes 4°07′33″E and 4°14′03″E. According to the 2006 Population and Housing Census, Ilesa East and Ilesa West Local Government Areas recorded populations of 105,416 and 106,809, respectively, giving a combined population of 212,225, while Iwo Local Government Area recorded a population of 191,348 (Federal Republic of Nigeria, 2009). In the southwestern Nigerian urban context, cities with populations exceeding 100,000 but below one million have been classified as medium-sized cities (Samuel et al., 2023). On this demographic basis, Ilesa and Iwo are treated in this study as medium-sized urban centres. Both cities perform important commercial, administrative, and transportation functions within the region. Road transportation constitutes the dominant mode of movement within the cities, thereby generating substantial traffic concentration along major urban corridors. Similar to many rapidly urbanizing cities in southwestern Nigeria, increasing population growth, urban expansion, and commercial activities have intensified transportation demand and mobility pressure within the urban street networks (Cobbinah et al., 2015; UN-Habitat, 2022). These characteristics make Ilesa and Iwo suitable for examining street-network topology, traffic-flow dynamics, and urban mobility structure within the context of transportation resilience and movement efficiency.

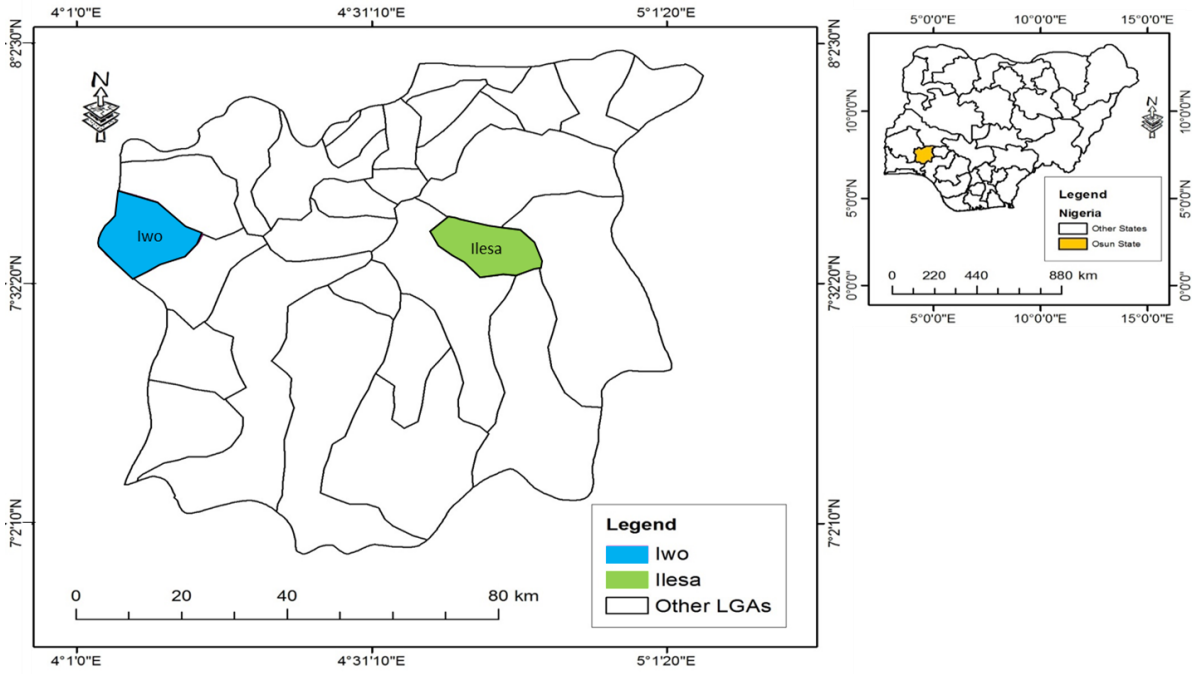


Figure 1: Location of the study areas (Ilesa and Iwo) in Osun State, southwestern Nigeria.

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Spatial data used for the study were derived from high-resolution satellite imagery, topographic datasets, and field observations. The urban road networks of the study areas were digitized within a GIS environment to produce spatially referenced transportation-network databases. Both tarred and untarred roads within the urban extents were incorporated into the analysis to ensure comprehensive representation of the transportation systems. The digitized road datasets were processed in ArcGIS Pro 3.2 where topological corrections were carried out to ensure spatial continuity and proper connectivity among street segments and intersections. GIS-based network extraction and topological correction are critical procedures in urban-network analysis because disconnected or improperly linked segments may distort network centrality and connectivity measures (Boeing, 2020; Jiang & Claramunt, 2004).

The processed road networks were converted into graph structures in which street intersections and terminal points were represented as nodes, while road segments were represented as edges connecting the nodes. Graph-theoretical representation has become increasingly important in transportation geography and urban network science because it provides efficient frameworks for understanding mobility structures and hidden spatial relationships within urban transportation systems (Barthelemy, 2011; Crucitti et al., 2006). The graph representation enabled the application of quantitative connectivity and centrality analyses to evaluate street-network structure and identify strategically important mobility corridors within the urban systems.

Street-network connectivity was evaluated using the Alpha Index (α), Beta Index (β), and Gamma Index (γ), which are among the most widely used graph-theoretical measures for assessing transport-network structure and efficiency (Kansky, 1963; Xie & Levinson, 2007). The Alpha Index was used to measure the level of circuit connectivity and route redundancy within the network and was computed as:

$$\alpha = \frac{e - v + p}{2v - 5}$$

where e represents the number of edges, v denotes the number of vertices, and p represents the number of subgraphs within the network. Higher alpha values indicate greater route redundancy and stronger interconnectivity within the transport system.

The Beta Index was used to evaluate the ratio between the number of edges and vertices within the network and was calculated as:

$$\beta = \frac{e}{v}$$

Higher beta values generally indicate more complex and better-connected transportation systems. The Gamma Index was employed to determine the proportion of observed edges relative to the maximum possible number of edges in the network and was computed as:

$$\gamma = \frac{e}{3(v - 2)}$$

The Gamma Index ranges between 0 and 1, with higher values indicating stronger connectivity and network integration (Kansky, 1963).

Street hierarchy and structural importance within the networks were further examined using graph-theoretical centrality measures including degree centrality, betweenness centrality, and closeness centrality. Centrality analysis has become an important technique in transportation-network studies because it enables identification of

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strategically important nodes and corridors that facilitate urban mobility and traffic concentration (Freeman, 1977; Porta et al., 2006b). Degree centrality was used to measure the number of direct connections associated with individual nodes and street segments within the network. Streets exhibiting high degree values were interpreted as locally important connectors with greater interaction potential. Degree centrality was computed as:

$$d(v_i) = \sum_{j=1}^{n} a_{ij}$$

where $d(v_i)$ represents the degree centrality of node v_i, a_{ij} equals 1 if two nodes are connected and 0 otherwise, while $n$represents the total number of nodes within the network.

Betweenness centrality was used to identify strategic mobility corridors functioning as intermediaries along shortest movement paths within the urban street systems. Streets exhibiting high betweenness values were interpreted as critical corridors likely to attract substantial traffic concentration and movement flow. Betweenness centrality was computed as:

$$Bet(v_i) = \sum_{j<k} \frac{g_{jk}(v_i)}{g_{jk}}$$

where g_{jk} represents the number of shortest paths between nodes j and k, while $g_{jk}(v_i)$ represents the number of shortest paths passing through node v_i. Betweenness centrality has been widely used in transportation and resilience studies because it identifies dominant mobility corridors and urban chokepoints whose disruption may significantly affect network-wide movement efficiency (Kirkley et al., 2018; Tang et al., 2022).

Closeness centrality was employed to evaluate the accessibility efficiency and spatial integration of nodes within the street network. Streets exhibiting high closeness values were interpreted as highly accessible and well-integrated corridors within the urban system. Closeness centrality was computed as:

$$Clos(v_i) = \frac{1}{\sum_{j=1}^{n} d(v_i, v_j)}$$

where $d(v_i, v_j)$ represents the shortest-path distance between nodes $v_i$and v_j. The centrality measures were computed within the GIS and network-analysis environment to identify structurally important streets and critical mobility corridors within the study areas.

Traffic-flow analysis was conducted to examine the functional performance of the street networks and determine the relationship between traffic intensity and street-network structure. Traffic counts were undertaken at strategically selected corridors and intersections representing different levels of street hierarchy and centrality. The survey captured traffic volume and traffic composition characteristics across the selected streets. Traffic composition analysis considered the relative proportions of motorcycles, cars, minibuses, buses, tricycles, and heavy-duty vehicles operating along the selected corridors. Similar approaches have been widely adopted in transportation studies to evaluate mobility patterns and traffic-flow dynamics within urban systems (Jiang & Liu, 2009; Rodrigue et al., 2020).

Descriptive statistical techniques were used to summarize traffic-flow characteristics and street-network properties, including centrality measures and connectivity indices. Pearson correlation analysis was employed separately to examine



relationships among street topological properties, including street length, degree centrality, betweenness centrality, and closeness centrality. For the traffic-flow assessment, streets were classified according to degree-centrality hierarchy, and traffic volumes were compared between selected top- and bottom-category streets. Traffic counts were summarized by average hourly volume and Passenger Car Unit (PCU) to characterize the volume and composition of vehicular movement across the street hierarchy.

The analytical integration of street topology, traffic flow, and mobility resilience was undertaken sequentially. First, street topology was characterized using degree, betweenness, and closeness centrality to identify variations in connectivity, intermediary function, and network accessibility. Second, observed traffic volume and composition were examined across the degree-centrality-based street hierarchy to determine whether vehicular movement was concentrated on structurally higher-order streets. Third, the implications of the resulting structural and traffic patterns for mobility resilience were evaluated in terms of corridor dependency, route redundancy, alternative-route availability, and observed infrastructure conditions. In this framework, mobility resilience was not measured as post-disruption recovery or actual emergency-response performance; rather, it was assessed in terms of structural conditions that may support or constrain movement continuity during disruption. Accordingly, streets combining high structural importance with substantial traffic concentration were interpreted as critical mobility corridors whose disruption could have wider implications for network continuity, particularly where alternative routes or supporting infrastructure were limited (Boeing & Ha, 2024; Tang et al., 2022; Yadav et al., 2020)

3.0 Result and Discussion

Street-Network Structure and Hierarchical Characteristics

The analysis of the street-network structure revealed considerable spatial variation in the hierarchical organization and topological characteristics of the urban transport systems in Ilesa and Iwo. The street networks in both cities exhibited distinct structural patterns characterized by concentration of highly connected corridors within the urban cores and progressively weaker network integration toward peripheral districts. This uneven spatial distribution of network hierarchy indicates that movement activities and traffic interactions are concentrated mainly along structurally dominant corridors within the central urban areas.

The graph-theoretical analysis further revealed variations in the degree and betweenness characteristics of the street networks. Degree centrality analysis showed that a relatively small proportion of streets accounted for the highest levels of network connectivity within the urban systems, while a larger proportion of streets functioned primarily as local-access corridors with limited structural influence. Streets exhibiting high degree values were concentrated mainly within commercial and transportation-intensive sections of the cities, suggesting stronger spatial integration and greater interaction potential within these corridors. Similar hierarchical concentration of connectivity within urban street systems has been widely reported in transportation-network studies where central corridors generally function as dominant movement channels within the urban structure (Jiang & Claramunt, 2004; Porta et al., 2006a).

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Betweenness centrality analysis revealed additional variation in the structural importance of street corridors within the study areas. As presented in Table 1, streets with the highest betweenness values functioned as major intermediary corridors facilitating movement between different sections of the urban networks. These streets are structurally important because they accommodate substantial proportions of shortest-path movement within the transport system. In contrast, streets characterized by low betweenness values function mainly as peripheral or localized routes with comparatively lower movement mediation roles.

Table 1: Street Segments and Betweenness Value

	Ilesa	**Iwo**
Street segment	2267	1245
Total Betweenness value	17179782.1	4551933.46
coverage Area (km^2)	108.84	61.75
Average Betweenness	7578.20	3656.17
Minimum Betweenness Value	0	0
Maximum Betweenness Value	1153167.1	420555.9

The spatial distribution of street hierarchy based on betweenness centrality is illustrated in Figure 2a and Figure 2b. The figures show that streets exhibiting high betweenness concentration are clustered predominantly within the central districts of both cities, particularly along major commercial and transportation corridors. Peripheral sections of the street networks displayed relatively lower betweenness concentration, indicating reduced intermediary importance within the overall movement structure. This pattern suggests that urban mobility within both cities is strongly dependent on a limited number of structurally dominant corridors that facilitate interconnectivity across the transport systems.

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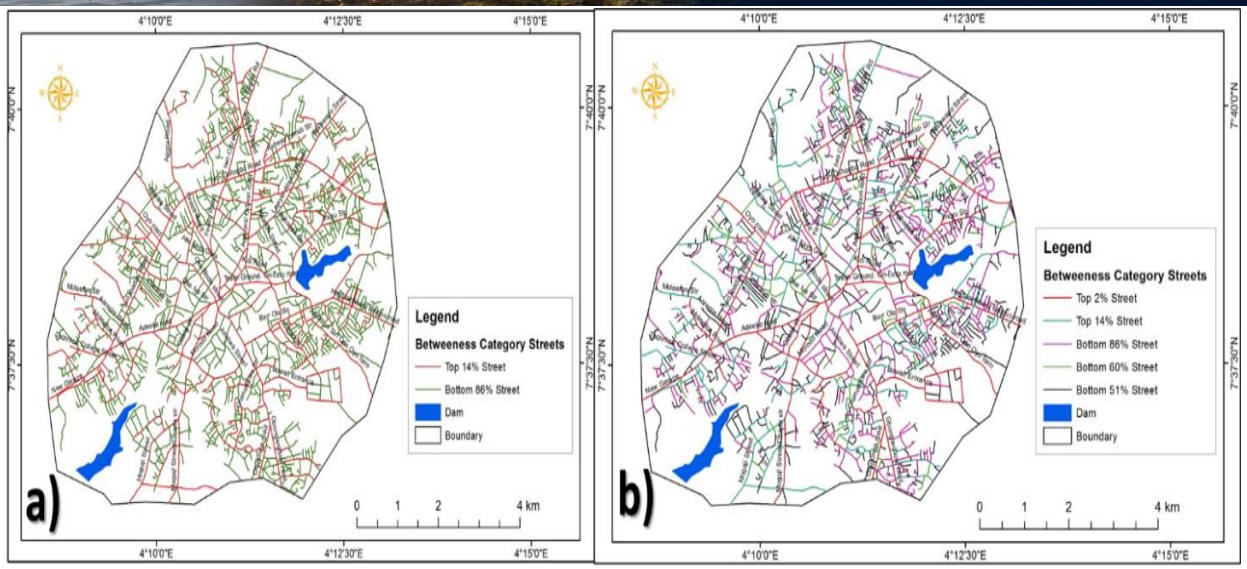


Figure 2: Spatial distribution of street hierarchies based on betweenness centrality of streets in a) Iwo and b) Ilesa

The observed concentration of hierarchical dominance within central urban corridors further indicates that transportation activities in both cities are spatially structured around a relatively small number of strategically important streets. Such concentration of movement along dominant corridors may increase traffic pressure and movement dependency within these sections of the network, particularly during periods of peak transportation activity. Previous studies have shown that urban transport systems characterized by concentrated movement dependency on a few strategic corridors often exhibit greater sensitivity to localized traffic disruption and congestion (Crucitti et al., 2006; Kirkley et al., 2018).

The hierarchical structure observed in the street networks also reflects the influence of urban growth patterns and land-use concentration within the study areas. Streets located within major commercial districts and transportation nodes generally exhibited stronger centrality characteristics due to their greater accessibility and connectivity functions within the urban systems. Conversely, peripheral residential streets displayed comparatively weaker structural influence and lower levels of movement concentration. These variations in street hierarchy provide an important basis for understanding the spatial organization of traffic-flow dynamics and mobility concentration within the study areas.

Street Connectivity and Urban Facility Concentration

The spatial relationship between street connectivity and urban facility concentration revealed that highly connected streets and structurally dominant corridors were closely associated with areas characterized by intensive commercial, institutional, and transportation activities within the two cities. Streets exhibiting stronger connectivity and centrality characteristics generally corresponded with sections of the urban areas containing higher concentrations of public facilities, commercial establishments, markets, and transportation nodes. This pattern suggests that urban activities and transportation interactions within the study areas are strongly influenced by the hierarchical organization of the street networks.

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The distribution of urban facilities along highly connected corridors further indicates that accessibility and movement efficiency play important roles in shaping the spatial organization of urban activities within the cities. Areas characterized by stronger street integration exhibited greater concentration of transportation-related and commercial activities because such locations provide improved accessibility and facilitate easier movement across different parts of the urban systems. Similar relationships between street-network integration and urban activity concentration have been widely reported in urban-network and spatial-accessibility studies, where highly connected streets generally attract greater economic and transportation activities because of their superior accessibility characteristics (Porta et al., 2006b; Boeing, 2020).

The spatial distribution of connectivity and facility concentration patterns is illustrated in Figure 3a and Figure 3b. The figures show that highly integrated corridors are concentrated predominantly within the central districts of both cities, where commercial and institutional activities are most intensive. In contrast, peripheral sections characterized by weaker street connectivity exhibited comparatively lower concentrations of urban facilities and transportation activities. This uneven distribution further demonstrates the influence of street-network structure on the spatial organization of urban land-use activities within the study areas.

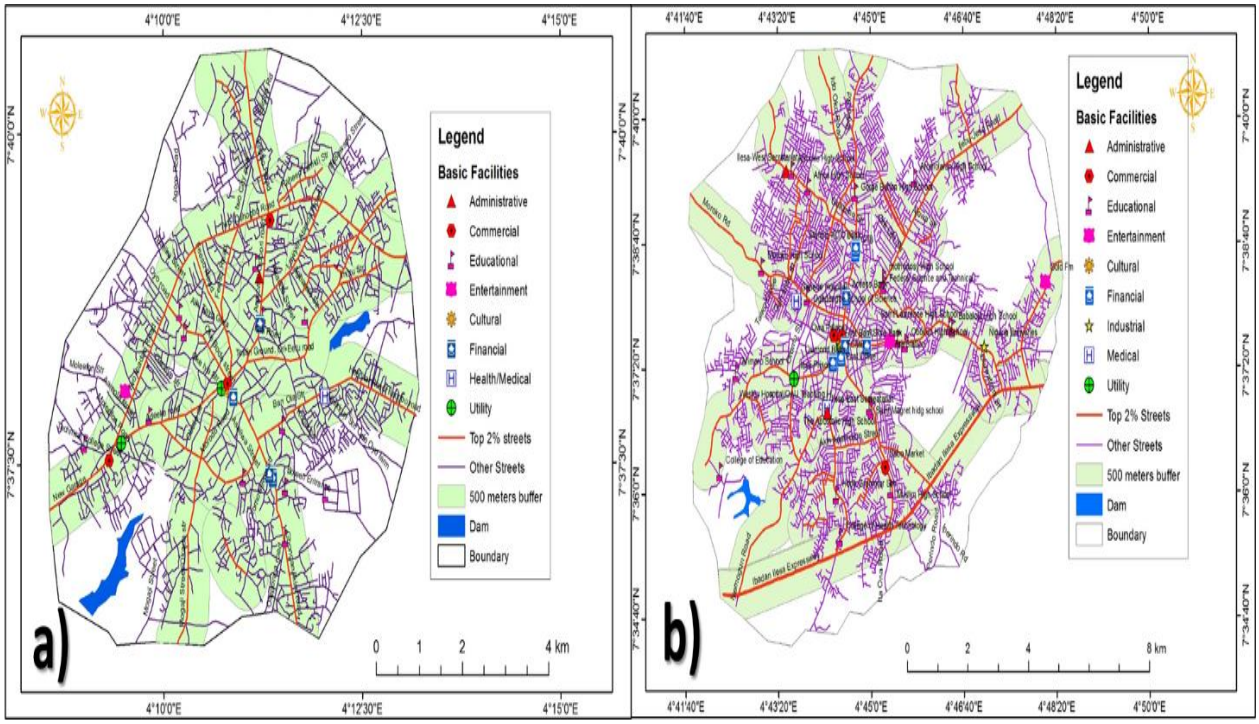


Figure 3: Spatial Distribution of Street Connectivity and Urban Facilities in a) Iwo and b) Ilesa

The observed concentration of urban activities along highly connected streets also suggests increased movement pressure within these corridors. Streets functioning as principal mobility routes are likely to accommodate substantial proportions of intra-urban traffic



movement because of their accessibility advantages and strategic spatial positions within the network. Such concentration of movement and activities along dominant corridors may contribute to localized traffic congestion and increased transportation pressure during periods of peak urban activity. Previous studies have shown that transportation corridors characterized by high accessibility and strong network integration commonly experience greater movement concentration and traffic intensity within rapidly urbanizing urban systems (Jiang & Liu, 2009; Rodrigue et al., 2020).

Furthermore, the results indicate that urban facility concentration within the two cities is not randomly distributed but is closely associated with the structural characteristics of the street networks. Streets exhibiting greater connectivity and centrality appear to function as important spatial organizers of urban activities and mobility interactions. This relationship between street-network structure and urban activity concentration provides important insight into the spatial dynamics of movement patterns and transportation functionality within medium-sized urban centers.

Street Hierarchy and Traffic-Flow Characteristics

Traffic-flow analysis revealed a pronounced concentration of vehicular movement on streets occupying the upper degree-centrality category in both study areas. Traffic counts were conducted on eight selected streets in each city, comprising four streets from the top and four from the bottom degree-centrality categories. As presented in Table 2, substantial differences were observed in traffic volume and Passenger Car Unit (PCU) between the two street-hierarchy categories. Top-category streets accounted for 98% of the observed traffic in Ilesa and 97% in Iwo, compared with only 2% and 3%, respectively, on bottom-category streets.

Table 2. Traffic-Flow Characteristics by Street-Hierarchy Category in Ilesa and Iwo

Traffic characteristic	Ilesa: Top	Ilesa: Bottom	Iwo: Top	Iwo: Bottom
Average hourly traffic count	2,688	50	1,403	39
Share of observed traffic (%)	98	2	97	3
Average hourly PCU	1,709	42	882	34

The differences between the street-hierarchy categories were also evident in the magnitude of average hourly traffic. Top-category streets recorded 2,688 vehicles per hour in Ilesa and 1,403 vehicles per hour in Iwo, compared with 50 and 39 vehicles per hour, respectively, on bottom-category streets. The PCU analysis exhibited a similar pattern, with average hourly values of 1,709 and 882 on top-category streets in Ilesa and Iwo, respectively, compared with 42 and 34 on bottom-category streets. The consistency of the traffic-count and PCU results indicates that observed vehicular movement was strongly concentrated on streets occupying the upper degree-centrality category in both urban networks.

Traffic composition was dominated by motorcycles in both cities, although their relative contribution was higher in Iwo. Motorcycles constituted approximately 87% of the observed traffic in Iwo and 81% in Ilesa, while private cars accounted for approximately 7% and 15%,

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respectively. Other vehicle categories constituted comparatively small proportions of observed traffic in both cities. Taken together, the traffic-volume, PCU, and vehicle-composition results provide empirical evidence of a strong correspondence between the degree-centrality-based street hierarchy and the spatial concentration of vehicular movement within the study areas.

Street Infrastructure Characteristics and Mobility Constraints

The analysis of street infrastructure characteristics revealed that mobility conditions within the urban transport systems of Ilesa and Iwo are influenced not only by street-network hierarchy and connectivity patterns but also by the operational quality of transportation infrastructure. Variations in drainage condition, pavement quality, pedestrian accessibility, and traffic-management facilities contribute to differences in movement efficiency across the street networks.

Road-surface assessment showed that although a substantial proportion of the streets in both cities are bituminous, many corridors exhibit deteriorating pavement conditions characterized by potholes and uneven surfaces. As illustrated in Figure 4a and Figure 4b, a considerable proportion of streets in both study locations were observed to possess rough surface conditions and multiple bad spots, particularly along highly utilized corridors. These conditions are capable of reducing traffic-flow efficiency by constraining vehicular movement and increasing travel delay within the urban transport systems. Previous studies have shown that deteriorating pavement conditions significantly affect urban mobility by reducing operating speed, increasing travel discomfort, and limiting transportation efficiency along major urban corridors (Hashim et al., 2023; Pregnolato et al., 2017).

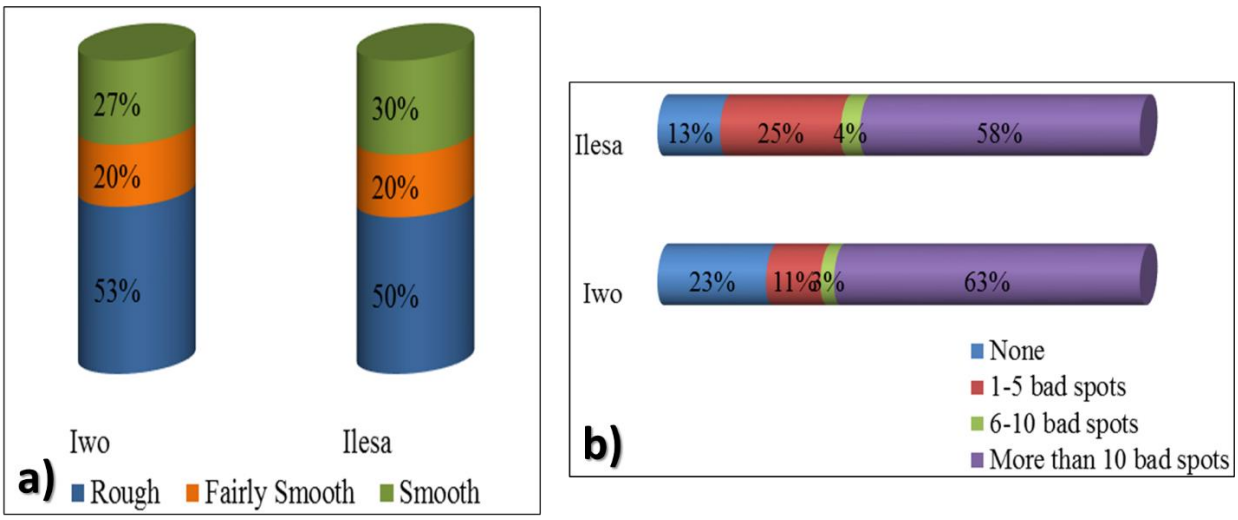


Figure 4: a) Road Surface Condition and b) Bad Spots on the streets in both Iwo and Ilesa

Drainage condition and flood susceptibility further revealed important mobility constraints within the study areas. The results presented in Figure 5 indicate that several streets either lacked

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drainage infrastructure or possessed drainage systems characterized by blockage, collapse, bush encroachment, or insufficient carrying capacity. Streets exhibiting poor drainage conditions also displayed higher susceptibility to flooding during rainfall events. Such conditions were more frequently observed along heavily utilized corridors and flood-prone sections of the urban transport networks. The results further indicate that streets characterized by drainage deficiencies generally exhibited higher levels of flood susceptibility within the study areas. The functional assessment of drainage condition was conducted only for streets where drainage infrastructure was present.

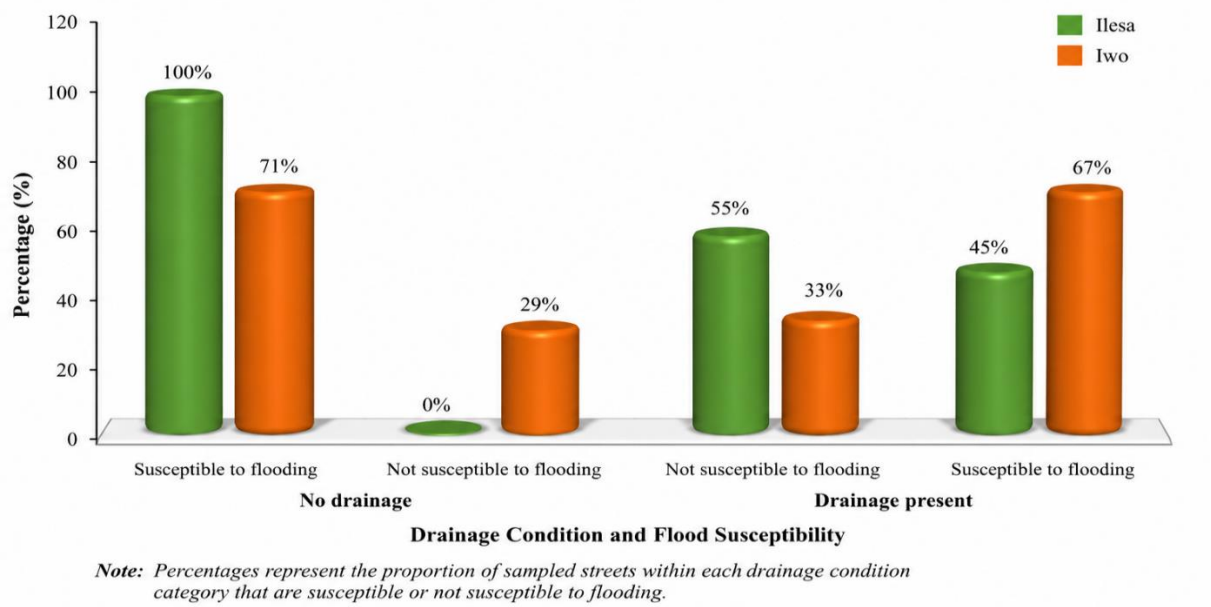


Figure 5. Nature of drainage and road susceptibility to flooding

The assessment of pedestrian and traffic-management infrastructure also revealed operational limitations capable of affecting urban mobility conditions. As shown in Figure 6a, Figure 6b, Figure 6c, and Figure 6d, several streets within the two cities lacked functional street lighting, pedestrian-support facilities, and formal traffic-control infrastructure. The limited presence of traffic wardens and the absence of traffic-light systems across major junctions indicate reduced traffic-management capability within sections of the urban transport networks. Similarly, narrow pedestrian shoulders observed along several streets may constrain pedestrian movement and increase interaction conflicts between vehicular and pedestrian traffic. Such infrastructural limitations may reduce overall transportation efficiency, particularly within highly active commercial corridors characterized by intense movement interactions.

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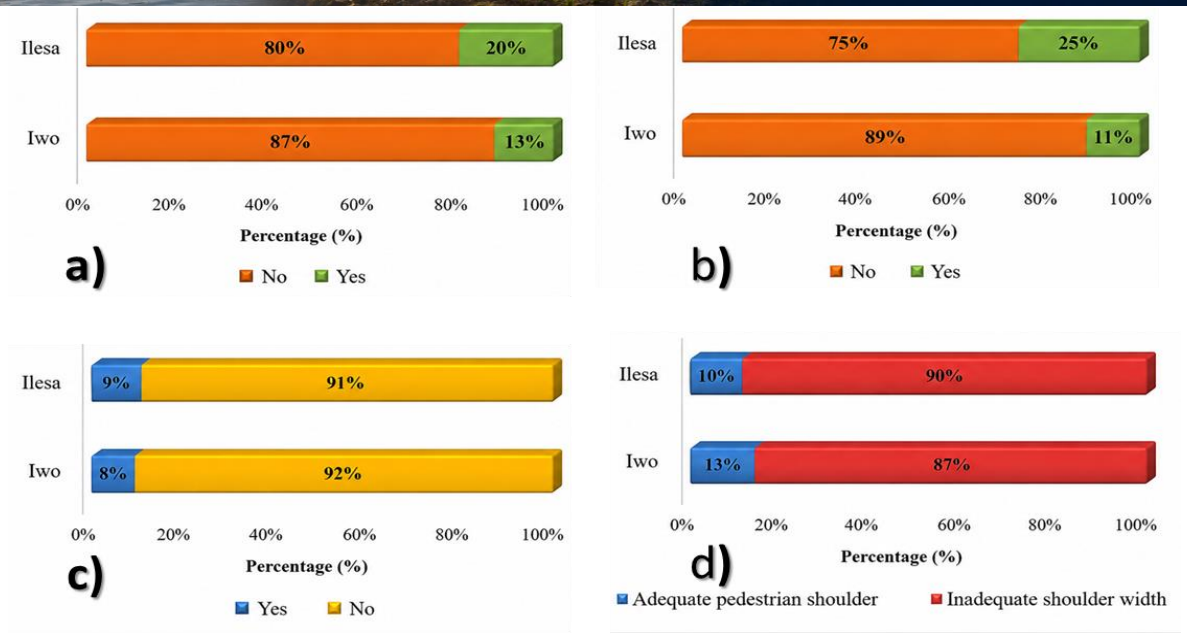


Figure 6: a) Street light availability, b) Functionality of Street Lighting, c) Availability of Traffic Wardens at Route Junctions and d) Pedestrian Shoulder Condition

The spatial variation in infrastructure quality further suggests that mobility conditions differ considerably across the urban transport systems. Streets located within highly commercialized corridors generally experience greater transportation pressure and pavement deterioration because of increased traffic concentration and continuous movement activities. Peripheral streets, although characterized by comparatively lower traffic intensity, exhibited infrastructural deficiencies associated mainly with poor drainage conditions and limited traffic-support infrastructure. These findings indicate that mobility performance within the study areas is influenced by the combined effects of street-network structure and transportation infrastructure quality.

Street Topology, Corridor Dependency and Emergency Mobility Structure

When considered together, the street-topology and traffic-flow results indicate that urban movement within Ilesa and Iwo depends disproportionately on a limited number of structurally important corridors. The concentration of observed traffic on top-category streets, together with the centrality patterns of the street networks, indicates that some corridors combine structural importance with substantial movement demand. As presented in Table 4, statistically significant relationships were observed among street length, degree centrality, betweenness centrality, and closeness centrality within both study areas, with streets characterized by stronger connectivity and intermediary functions occupying strategically important positions within the urban transport networks. The combination of structural importance and concentrated traffic demand has implications for mobility resilience because disruption along heavily utilized and structurally important corridors may constrain movement continuity, particularly where alternative connections are limited.



Table 4: Relationship Between Street Topological Properties in Iwo and Ilesa

City	Topological Relationship	Correlation Coefficient (r)
Iwo	Length and Degree	0.856
	Betweenness and Length	0.813
	Degree and Betweenness	0.815
	Length and Closeness	-0.333
	Degree and Closeness	-0.278
	Betweenness and Closeness	-0.215
Ilesa	Length and Degree	0.834
	Betweenness and Length	0.737
	Degree and Betweenness	0.749
	Length and Closeness	-0.239
	Degree and Closeness	-0.298
	Betweenness and Closeness	-0.192

All relationships are statistically significant at $p < 0.0001$.

Strong positive relationships were observed between street length and degree centrality in both cities. In Iwo, the correlation coefficient between street length and degree centrality was 0.856, while a similarly strong relationship of 0.834 was observed in Ilesa. Similarly, positive relationships were recorded between street length and betweenness centrality, with correlation coefficients of 0.813 in Iwo and 0.737 in Ilesa. These results indicate that longer streets generally exhibited stronger connectivity characteristics and greater intermediary movement importance within the transport systems.

The relationship between degree centrality and betweenness centrality also revealed strong positive associations within both study areas. Correlation coefficients of 0.815 in Iwo and 0.749 in Ilesa indicate that streets exhibiting higher levels of direct connectivity also tended to function as dominant intermediary movement corridors linking different sections of the urban systems. Streets characterized by high degree and betweenness values therefore constituted structurally important mobility corridors within the transport networks.

Negative relationships were observed between closeness centrality and the other topological variables within the study areas. The correlation coefficients between street length and closeness centrality were -0.333 in Iwo and -0.239 in Ilesa, while similarly negative relationships were observed between degree centrality, betweenness centrality, and closeness centrality. These findings indicate varying levels of spatial integration and accessibility across the urban street networks.

The observed topological relationships further revealed that movement concentration within the study areas was associated mainly with streets exhibiting stronger connectivity and intermediary movement functions. Such streets were concentrated predominantly within major commercial and transportation corridors where mobility interactions were relatively intensive. In contrast, streets characterized by lower centrality values generally functioned as localized access routes with comparatively limited movement influence within the broader urban transport systems.

In all, the results indicate that the hierarchical organization of the street networks plays an important role in shaping the spatial structure of mobility within the study areas. Streets characterized by stronger connectivity and

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intermediary movement functions provide important route continuity across different sections of the urban systems and therefore constitute strategically important mobility corridors within the urban transport networks.

Discussion

The concentration of urban movement around a relatively small number of structurally important corridors highlights the role of street-network hierarchy in organizing mobility within medium-sized cities. Rather than functioning as spatially uniform systems, the street networks of Ilesa and Iwo exhibit differentiated mobility roles in which some corridors assume disproportionate importance for network-wide connectivity and movement continuity. This pattern is consistent with previous urban-network studies showing that highly connected streets frequently function as principal mobility corridors and support greater spatial interaction within urban systems (Porta et al., 2006a; Crucitti et al., 2006). From a resilience perspective, such concentration creates both functional advantages and potential vulnerabilities because corridors that efficiently connect different parts of the city may also become critical points of dependency when disrupted.

The contrasting network structures of Ilesa and Iwo suggest different implications for route flexibility and mobility resilience. A more integrated network structure can provide greater opportunities for movement redistribution when individual links become congested or disrupted, whereas greater structural fragmentation may increase dependence on fewer connecting corridors. This interpretation is consistent with the proposition that connected and redundant street networks can enhance route choice and reduce vulnerability to localized disruption (Xie & Levinson, 2007; Boeing & Ha, 2024). The comparison therefore underscores the importance of considering not only the presence of roads but also their structural organization when assessing urban mobility resilience.

The correspondence between connectivity and intermediary network functions further emphasizes the strategic role of structurally central streets in maintaining movement continuity. Previous studies similarly identify high-betweenness corridors as important components of urban transport systems because they connect otherwise separated parts of the network and accommodate substantial movement interactions (Kirkley et al., 2018; Jiang & Liu, 2009). Their importance, however, also represents a potential source of vulnerability: disruption of a corridor upon which many shortest paths depend may have effects extending beyond the immediate location of the disruption. This reinforces the need to consider corridor redundancy alongside centrality when prioritizing transport-network improvements.

The pronounced concentration of observed traffic on higher-order streets provides a functional counterpart to the structural hierarchy identified through the network analysis. The agreement between the traffic observations and degree-centrality-based hierarchy suggests that structurally important streets also carry a disproportionate share of vehicular movement within the sampled corridors. This is consistent with previous studies linking street-network configuration with spatial accessibility, urban activity concentration, and traffic distribution (Porta et al., 2006b; Boeing, 2021). Nevertheless, this correspondence should not be interpreted as evidence that centrality alone determines traffic volume, since commercial activities, urban



facilities, land-use patterns, and other travel-generating functions may also contribute to traffic concentration along these corridors.

The infrastructure assessment indicates that network resilience cannot be understood solely from topological characteristics. Even structurally advantageous corridors may experience reduced operational performance where pavement deterioration, inadequate drainage, or deficient traffic-support facilities constrain movement. This interaction between network structure and infrastructure condition is particularly important for highly utilized corridors because physical deterioration or flooding can reduce the practical benefits of connectivity and route continuity. Similar concerns have been identified in studies showing that infrastructure condition can substantially affect transport-system functionality and vulnerability (Pregnolato et al., 2017; Litman, 2023). Thus, improving network connectivity without corresponding attention to infrastructure condition may provide only limited gains in mobility resilience.

Taken together, the network and traffic patterns have important implications for emergency mobility. Corridors combining structural importance with high movement concentration may serve as important components of emergency-access networks, but dependence on a limited number of such routes may also constrain movement continuity when flooding, traffic incidents, road obstruction, or infrastructure failure occurs. Greater route redundancy can provide alternative movement options under such conditions and reduce dependence on individual corridors (Tang et al., 2022; Boeing & Ha, 2024). These findings therefore support the incorporation of network centrality, observed traffic concentration, infrastructure condition, and alternative-route availability into emergency transport planning. However, because actual emergency-response or evacuation travel times were not directly measured in this study, these findings should be interpreted as identifying structural implications for emergency mobility rather than demonstrating observed emergency-response performance.

Overall, the findings indicate that street topology, traffic flow, and mobility resilience are interrelated dimensions of urban transport-network performance. Street-network structure establishes the connectivity and intermediary roles through which movement can be distributed, while observed traffic concentration across the street hierarchy indicates that particular components of the network accommodate disproportionate movement demand. The concentration of traffic on structurally higher-order streets has implications for movement continuity because disruption along important and heavily utilized corridors may have wider network effects, particularly where route redundancy and infrastructure functionality are limited. For medium-sized cities such as Ilesa and Iwo, transport planning should therefore extend beyond conventional road classification to integrate network centrality, observed traffic demand, alternative-route availability, and infrastructure condition when identifying critical corridors and prioritizing infrastructure improvements. Such an integrated approach can provide a stronger basis for congestion management, infrastructure prioritization, emergency-mobility planning, and interventions aimed at strengthening urban mobility resilience.



5.0 Conclusion

This study examined the hierarchical structure, topological characteristics, traffic-flow relationships, and mobility patterns of the urban street networks in Ilesa and Iwo, Osun State, Nigeria, using an integrated GIS and graph-theoretical analytical framework. The findings revealed considerable spatial variation in street-network connectivity, corridor hierarchy, and movement concentration within the two cities. Streets characterized by high degree and betweenness centrality values emerged as structurally dominant corridors facilitating substantial proportions of urban movement and spatial interaction across the transport systems.

The results further demonstrated that movement activities within the study areas are concentrated mainly along a limited number of strategically important mobility corridors associated with commercial activities, transportation nodes, and urban facility concentration. Ilesa exhibited relatively stronger street-network integration and route continuity compared with Iwo, indicating greater connectivity and movement flexibility within portions of the urban system. The correlation analysis also revealed significant relationships among street length, degree centrality, betweenness centrality, and closeness centrality, thereby demonstrating the strong influence of street topology on the spatial organization of urban mobility.

The infrastructural assessment further showed that mobility conditions within the study areas are influenced not only by street-network hierarchy but also by variations in transportation infrastructure quality. Drainage deficiencies, pothole occurrence, limited pedestrian-support facilities, and inadequate traffic-management infrastructure were more evident along several highly utilized corridors within the urban systems. These conditions were associated with sections of the transport networks characterized by increased traffic concentration and flood susceptibility.

The findings provide important insight into emergency mobility structure within medium-sized urban centers. Streets characterized by stronger connectivity and intermediary movement functions constitute strategically important corridors capable of supporting rapid accessibility and movement continuity across different sections of the urban systems. However, the concentration of mobility dependency along a limited number of dominant corridors may reduce route flexibility during periods of traffic disruption, flooding, road obstruction, or infrastructure failure. Urban transport systems characterized by stronger route redundancy and balanced connectivity distribution are therefore better positioned to sustain mobility continuity during periods of operational stress.

Overall, the study demonstrates that street-network topology, corridor hierarchy, and transportation infrastructure collectively shape the spatial organization of urban mobility within medium-sized cities. The study therefore highlights the importance of integrating street-network structure, corridor redundancy, and infrastructure functionality into urban transportation planning strategies aimed at strengthening emergency accessibility, sustaining movement continuity, and improving the resilience of urban mobility systems within rapidly urbanizing medium-sized cities.

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