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Analyzing the Spatial Dynamics of Urban Road and Transit Networks: Integrating Space Syntax and Spatial Autocorrelation for Pedestrian Accessibility

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ABSTRACT:
Pedestrian mobility, accessibility, and urban connectivity are highly influenced by urban road networks and public transportation systems. This paper aims to integrate space syntax analysis with spatial autocorrelation methods to investigate the spatial configurations of road networks and public transit accessibility, with a particular focus on pedestrian movement patterns. Moran's I highlight areas with high pedestrian activities clustered around high transit stop areas or accessible roads. Findings are used in comparative studies among different neighborhoods. The analysis outcomes suggest that both road network design and transit infrastructure play significant roles in enhancing or hindering pedestrian accessibility. The research aims to demonstrate that neighborhoods experiencing hotspots of transit stops provide improved pedestrian access and greater walkability. In contrast, neighborhoods with grid-like structures provide a more evenly distributed pedestrian flow. Space syntax analysis and spatial autocorrelation analysis integration offer useful insights for urban planners in optimizing roads and transit network configurations. Additionally, it will improve the pedestrian experience in terms of safety, accessibility, and urban mobility.
This multifaceted approach would offer a more nuanced understanding of urban dynamics, enabling more accurate predictions and informed decision-making in road rehabilitation planning. By incorporating these diverse data sources, the framework can better account for the complex interplay between infrastructure conditions, pedestrian behavior, and spatial factors, ultimately leading to more effective and efficient urban maintenance strategies. Such an in-depth investigation would provide valuable insights for predicting maintenance needs, optimizing rehabilitation scheduling, and understanding the relationship between road conditions and pedestrian behavior. This approach would ultimately lead to more informed decision-making in urban infrastructure management. This integration bridges the gap between spatial configuration and real-world spatial phenomena, offering a holistic understanding of urban road networks.

1. INTRODUCTION
In many countries, especially developing and underdeveloped countries, the scientific side of architecture and urban design is often ignored. Moreover, the increasing challenges of urban living, such as high population density, traffic congestion, and environmental pollution, have led to increased importance on enhancing urban livability which directly affects pedestrian behavior. This behavior can be measured through changes in average walking speeds and pedestrian flow rates (Abdulkareem Naji Abbood, 2023). Furthermore, pedestrian pathways can be integrated with public transportation hubs, as measured by accessibility metrics, typically resulting in higher pedestrian traffic volumes (Shawket, 2023). This integration enhances the overall effectiveness of the urban mobility network. It is imperative to understand the social and economic effects of designing urban networks. The challenge is to balance design with research that introduces basic tools for spatial analysis and their use in urban design (Van Nes, 2021). (Yong Liu,

2023) agrees that Improving traffic conditions and pedestrian facilities, along with enhancing safety perceptions through strategic measures, can lead to an increase in walking behavior within the neighborhood. These enhancements significantly boost pedestrian mobility, creating a more attractive environment for walking. Hence, optimizing network connectivity is essential for improving pedestrian movement.

Many techniques in literature have been used for predicting pedestrian movement patterns. These techniques aim to examine changes in pedestrian behavior. These tools allow for the precise quantification of different movement patterns and the identification of new pedestrian desire lines. The most widely used techniques are Moran's I and Space Syntax for spatial analysis. Moran’s I is a statistical tool that evaluates spatial autocorrelation, revealing whether adjacent geographic areas display comparable or contrasting values. When Moran's I is positive, it suggests a clustering of similar values, whereas a negative result indicates dispersion. This metric proves valuable for examining spatial trends in numerical datasets, with applications ranging from risk evaluation to asset performance analysis (Moran's I: Definition, Examples, n.d.). In contrast, Space Syntax is primarily employed to examine spatial layouts (Van Nes, 2021), finding its main applications in urban design and architectural planning (Aya Mohamed, 2023). This technique focuses on how the arrangement of spaces affects movement patterns, visibility, and accessibility. Unlike Moran's I, which provides a quantitative measure of spatial dependence, Space Syntax offers a more qualitative and structure-oriented analysis (Pilkington, 2020). Therefore, it is less appropriate for direct numerical correlations in industrial settings.

In the context of merging spatial autocorrelation, space syntax, and pedestrian behavior in urban roadways, this research examines the various attributes of traffic data generated by urban road networks. It develops complex networks by utilizing correlation coefficients and different space syntax measures. Spatial autocorrelation assesses the degree to which nearby spatial elements resemble one another. Integrating this calculation into space syntax analysis helps identify patterns of similarity or clustering in the spatial data, ensuring that the results are not skewed by random distribution. Additionally, spatial autocorrelation can reveal how local spatial relationships influence global network measures like centrality. For instance, a street with high betweenness centrality might also exhibit strong spatial clustering, indicating its role as a local and global connector. Another perspective is that incorporating spatial autocorrelation ensures that the analysis accounts for spatial dependencies, leading to more nuanced and reliable conclusions about urban dynamics and pedestrian behavior.

Research Goal and Objective

This paper proposes an integration of Space Syntax analysis with spatial autocorrelation analysis to provide valuable insights for urban planners in optimizing road and transit network configurations. This integration aims to enhance the pedestrian experience by improving safety, accessibility, and urban mobility. Two case studies of urban road networks are used to support the integration model of spatial autocorrelation evaluation and the Space Syntax analysis using different measures related to connectivity and road networks.

2. LITERATURE REVIEW

Using effective design techniques for pedestrian movement on urban roads is crucial for encouraging walking, promoting physical activity, and reducing the risk of lifestyle-related aspects. Additionally, by making walking a viable option, cities can reduce reliance on cars, leading to less traffic congestion and lower emissions. This, in turn, contributes to lower pollution levels, as fewer vehicles on the road means reduced greenhouse gas emissions.

2.1 Space Syntax in Construction

The Space Syntax Space Syntax was developed in the 1970s by Bill Hillier (Van Nes, 2021). Space Syntax is a technique that has been widely employed in analyzing and interpreting spatial qualities (Aya Mohamed, 2023). Essentially, space syntax includes various techniques that can be used either separately or collectively, depending on the specific questions in research or urban planning. These techniques help find spatial solutions by calculating how spaces are arranged in the built environment. This methodology can offer valuable insights into how different cultures organize their settlements by showing how buildings and spaces influence social interactions.

Space syntax evaluates how each public space or street segment in a built environment connects to all other public spaces (Van Nes, 2021). It measures two main aspects: the "to-movement" potential, or closeness, which assesses how easily one can reach a street segment from all others, and the "through-movement" potential, which evaluates how often a street segment is used as a route between other segments (Pilkington, 2020) (Aya Mohamed, 2023). These correlation patterns can be weighed

using three types of distance. Metric distance measures the street network as a system of shortest-length paths. Topological distance calculates it as a system of fewest-turn paths. Geometrical distance views it as a system of least angle-change paths. (Yong Liu, 2023) added the significance of including pedestrian behavior in urban design. Walkability measures how pedestrian-friendly an area is and how well it encourages walking. This concept is crucial for urban and transportation planners aiming to create more pedestrian-friendly cities. Enhancing walkability encourages residents to walk more, benefiting their physical and mental health. Therefore, studying walking accessibility is important. Other researchers have used the walkability index to analyze walkability and provide insights for future urban development and transportation planning. Walkability and connectivity are closely related concepts in urban planning. Walkability measures how friendly an area is to pedestrians, while connectivity refers to how well different parts of the urban environment are linked (Claudia Yamu et al, 2021). Improving walkability often involves enhancing connectivity. For example, a well-connected street network with many intersections and pathways makes it easier for pedestrians to navigate and reach their destinations. This interconnection encourages walking by providing direct and convenient routes, reducing the need for long detours. In designing urban networks, high connectivity supports the creation of walkable environments by integrating various services, such as shops, parks, and public transportation, within easy walking distance. This integration enhances the road networks, as pedestrians have access to multiple destinations and services along their routes.
Streets have long been regarded as vital components of urban spaces (Mahdzar, 2019), offering comfort, safety, and accessibility for travel. In recent years, there has been a mutual effort to separate pedestrian zones from vehicular traffic to enhance safety and convenience. From a socio-historical perspective, the design and layout of streets mirror the surrounding communities and people naturally move towards walking paths that offer the most comfort and accessibility. A study has been developed by (Abdulkareem Naji Abbood, 2023) focusing on pedestrian traffic flow and the facilities for their crossings and movements. Noticing that most designs typically address road paths, cross and longitudinal sections, and alignment, but often overlook pedestrian considerations. In that study, the developed methodology aims to highlight pedestrian issues and propose options and solutions to improve safety, efficiency, and convenience. The methodology evaluates the impact of pedestrian characteristics, traffic flow, and walking speed on the efficiency of the pedestrian level of service (LOS) within the study area. By employing statistical and traffic models, the results demonstrate the extended impact of various factors on pedestrian traffic flow efficiency. It also proposes solutions for existing sidewalk and walkway designs in the study area and examines the efficiency of at-grade and stairway crossings in other locations within the area.

2.2 Spatial Autocorrelation in Construction

Spatial autocorrelation analysis involves statistically studying and quantifying how closely related values or features of spatially referenced data exhibit similar patterns, whether they are grouped, scattered, or randomly distributed across a geographical area (Ce Zhang, 2023). This analysis aims to identify and measure the degree of spatial dependency or interdependence between neighboring locations or entities within a defined area. It reveals underlying spatial patterns, relationships, and the presence of spatial clustering or randomness in a dataset. It has been extensively utilized in academic literature for a variety of purposes.
A model developed by (Haizi Wang, 2021) focuses on the demolition waste disposal industry. The model examines both internal and external factors that influence the industry's economy, collectively termed as influencing factors. By using Moran’s I, the model demonstrates the presence of spatial autocorrelation within the industry. This means that the disposal sites and their economic impacts are not randomly distributed but show a pattern of clustering or dispersion. The model helps in understanding how these factors interact spatially, which can inform better waste management practices and policy decisions.
Another model was developed for investigating spatial autocorrelation using key variables such as resources, environment, economy, and society (Lu, 2019). The model aims to understand how these variables are spatially related and how they influence each other. By applying Moran’s I, the model identifies patterns of spatial dependency, revealing areas where these variables are either clustered or dispersed. This analysis helps in understanding the spatial dynamics of sustainable development and can guide policy-making to promote balanced growth across different regions. An assessment system designed by (Hongqiang Wang, 2023) to evaluate the spatial autocorrelation of resources, environment, and economy within China's regions. The model uses a coupling coordination degree (CCD) and spatial autocorrelation analysis to measure how well these three systems are integrated and coordinated. The results show a significant spatial clustering of these variables, with coastal areas generally having higher degrees of

coordination compared to inland areas. This model provides insights into the spatial distribution of sustainable development and helps in formulating policies that encourage balanced regional development. These models collectively highlight the importance of spatial analysis in understanding and managing various aspects of urban and regional development. They provide valuable tools for policymakers and planners to make informed decisions based on spatial patterns and dependencies.
Using Global Moran's I for spatial autocorrelation analysis in road network design can provide valuable insights into the spatial relationships within the network (Pilkington, 2020). This methodology helps urban planners and designers understand how different segments of the road network are interconnected, anticipate potential issues, and improve the overall design process (Hussain, 2025). By identifying areas with high spatial dependency, planners can make informed decisions about facilities and services' optimal locations, ensuring that the road network is efficient and well-connected (Leonardi, 2023).
Furthermore, this approach can enhance decision-making in road network planning by providing a clearer vision of spatial dependencies (Westerholt, 2023). It can also improve the performance of the road network by optimizing connectivity and accessibility. By detecting similar issues in different locations, targeted interventions and corrective measures can be implemented, leading to a more robust and resilient road network design.

(Yoav Lerman, 2014) has explored how space syntax can be used to predict pedestrian movement and incorporates spatial variables to analyze urban networks. The research emphasizes that pedestrian movement patterns are mainly influenced by the spatial characteristics inherent to the street network. Given that changes to the network's structure are infrequent, significant shifts in pedestrian movement are unlikely to occur in the future. Additionally, by integrating models for pedestrian flow, motorized traffic, public transit, and bicycle networks, focus can be directed toward areas where interactions and potential conflicts among various road users, such as pedestrians, cyclists, transit vehicles, and private cars, are most likely to arise.

3. RESEARCH MOTIVATION AND OBJECTIVES

This research aims to develop an innovative framework for urban road design incorporating spatial autocorrelation analysis using Moran's I as a statistical measure and the Space Syntax concept. By integrating Moran's spatial autocorrelation and Space Syntax principles, the model can quantify spatial relationships and patterns within the urban road network and evaluate the movement patterns.
Adopting the proposed integrated approach allows for a richer understanding of urban dynamics, facilitating more accurate predictions in urban network planning as well as maintenance for existing networks. By integrating diverse data sources, this framework can better capture the intricate relationships between infrastructure conditions, pedestrian behavior, and spatial factors. This comprehensive analysis leads to more effective and efficient urban planning strategies that provide crucial insights for understanding how road and traffic conditions impact pedestrian behavior. Ultimately, this integrated framework enhances decision-making in urban infrastructure management, ensuring more strategic and informed planning.

4. PROPOSED MODEL FRAMEWORK

The developed framework integrates spatial autocorrelation analysis using Moran's I as a statistical measure with the Space Syntax analysis measures. This comprehensive approach involves the following steps:

1. Select Space Syntax Measures: Identify the specific space syntax measures (e.g., integration, choice, connectivity) that will be analyzed for the study area.
2. Define Network Topology: Map out the network topology by identifying nodes (locations or points of interest) and edges (connections between nodes).
3. Construct Spatial Weights Matrix: For each measure, create a spatial weights matrix based on the network topology, considering the measure as the variable for Moran's I analysis.
4. Calculate Moran's I: Compute Moran's I to assess the overall spatial autocorrelation of relevant variables (e.g., traffic flow, accessibility indices) for different sequences.
5. Interpret Results: Analyze the results to determine optimal sequences that maximize positive spatial autocorrelation with desirable urban features

4.1 Spatial Autocorrelation

Efficient road networks are essential for economic growth, mobility, and public safety. The developed framework incorporates spatial autocorrelation analysis using Moran's I as a statistical measure as a first step through: constructing a spatial weights matrix based on the road network data and road distances according to the geographic locations; then, calculating Moran's I to assess the overall spatial autocorrelation of relevant variables (e.g., traffic flow, road condition, accessibility indices) for different sequences; finally, interpreting results to determine optimal sequences that maximize positive spatial autocorrelation with desirable urban features.

A spatial weight matrix is a key tool in spatial analysis that quantifies relationships between geographic units. It's essential for revealing spatial patterns and interactions across various fields, including urban planning and construction. Used in spatial statistics, these matrices provide critical insights into how spatial entities influence each other, forming the basis for understanding complex spatial dynamics.

Weights are calculated using the formula in equation (1).

[1] $w_{ij} = \{ f(d_{ij}) \ if \ i \neq j \ and \ d_{ij} \leq d_{\max} \ , otherwise \ 0\}$

Where:

w_{ij} are the spatial weights matrix between spatial units I and j,

f(d_{ij}) is the function of the distance d_{ij},

$dmax$ is the maximum distance threshold for considering spatial relationships,

Calculate Moran's I using equation (2)

[2] $\boldsymbol{I} = \frac{N}{W} * \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N} (xi - \bar{x})^2}$

Where:

N is the number of segments

x is the variable that we need to investigate

$\bar{x}$ is the mean of x

w_{ij} are the spatial weights matrix with zeroes on the diagonal

W is the sum of all w_{ij}

The results of Moran's I indicate whether a pattern exists based on the neighboring data of units, ranging from -1 (perfect dispersion) to 1 (ideal clustering), with *zero* indicating no spatial autocorrelation.

- Positive Moran's I (>0) proposes clustering or positive spatial autocorrelation, indicating that nearby locations tend to have similar values for the studied variable.
- Negative Moran's I (<0) proposes dispersion or negative spatial autocorrelation, indicating that nearby locations typically have dissimilar values.

4.2 Space Syntax Analysis

Space syntax is a methodology used to organize and connect spaces in urban planning and architectural design. Integration is one of the key measures, indicating how easily one can reach a particular location from a given starting point. High integration values suggest that the space is highly accessible and well-connected. Moreover, to examine how often a certain place is used as a route between other places the “betweenness” or choice measure is used, where the higher choice means a common pathway. Furthermore, the depth can be effectively utilized to determine the number of steps required to reach a destination from a starting point. The fewer steps needed, the more accessible the location is. Another method is connectivity, which shows the number of direct connections a certain place has to other places. Noting that more connections usually mean better accessibility. Other measures involve drawings and graph analysis such as Axial Analysis, and Visibility Graph Analysis are used in drawing the longest and fewest lines of sight and movement through a space to understand its layout in addition to measuring how well spaces can be seen from each other. These measuring tools help understand how visual connections affect movement. These measures help planners and designers create spaces that are easy to navigate and use.

5. COMPARATIVE ANALYSIS

The framework is developed using two distinct case studies for two areas (A and B) representing urban road networks in different neighborhoods. The gathered data from the two neighborhoods include node coordinates (x, y) and the road segments defined by From-Node, and To-Node junction.

5.1 Neighborhoods Under-Study

Neighborhood A is a vibrant, densely populated urban area with approximately 400,000 residents living within a 25-square-kilometer space. This neighborhood is known for its bustling commercial activities, traditional markets, and rich cultural and historical heritage. The streets are intricately dissected into key features and smaller components, highlighting both similarities and differences within the area.
In contrast, Neighborhood B is a more spacious, less densely populated area with around 30,000 residents spread across 40 square kilometers. This neighborhood is characterized by luxurious villas, a thriving café scene, chic malls by the sea, and a more grid-like street pattern. These features contribute to different pedestrian activity patterns compared to Neighborhood A, offering a distinct urban experience.

Road Networks

Neighborhood A road network is shown in Fig. 1, from which a conventional network graph of nodes and links is abstracted. In total, there are 4,926 links and 2,501 nodes.

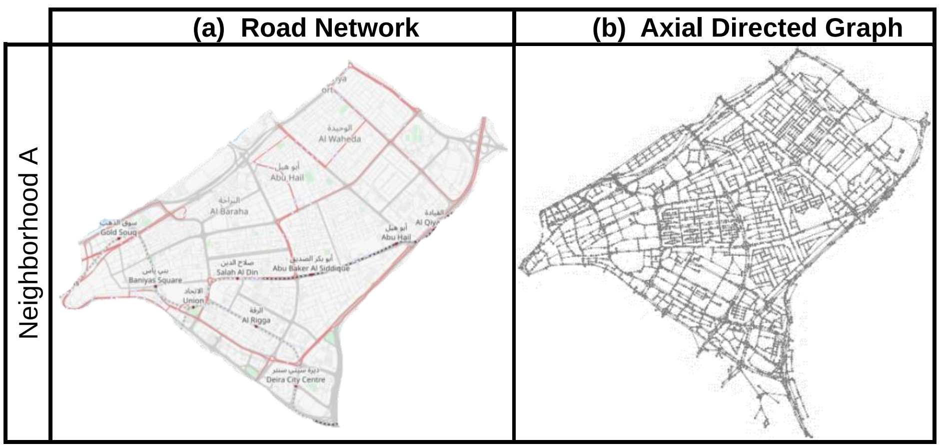


Fig. 1. Neighborhood A Road Network (a) mapped into Axial Directed Graphs (b)

Neighborhood B road network is shown in Fig. 2, from which a conventional network graph of nodes and links is abstracted. In total, there are 4,428 links and 2,097 nodes.

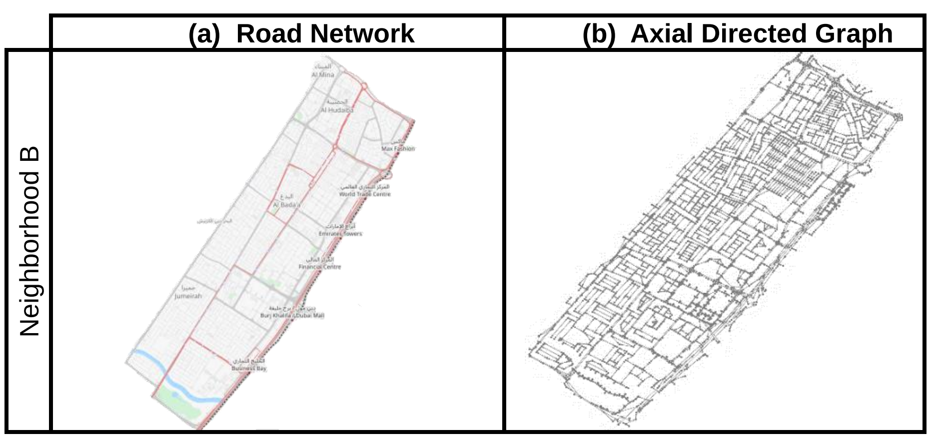


Fig. 2. Neighborhood B Road Network (a) mapped into Axial Directed Graphs (b)

N.B. Geographic coordinates and road network data for the two (2) neighborhoods were obtained through Open Street Map (https://www.openstreetmap.org/).

5.2 Analysis of Intersections and Junctions

Space syntax analysis forms the core of the methodological approach, providing a robust framework for investigating spatial configurations of the two selected urban road networks.

Space Syntax Measure: Closeness Centrality

This is a measure of how close a node (representing a junction or intersection) is to all other nodes in the network. It's calculated as the reciprocal of the sum of the length of the shortest paths between the node and all other nodes in the graph (MARSHALL, 2005). As shown in Fig. 3, the middle roads in both networks show high closeness centrality values, implying that these roads are relatively close to all other roads in the network. Hence, these roads might experience high volumes of traffic, as they provide efficient routes for travel within the network. In other words, they are centrally located within the network.

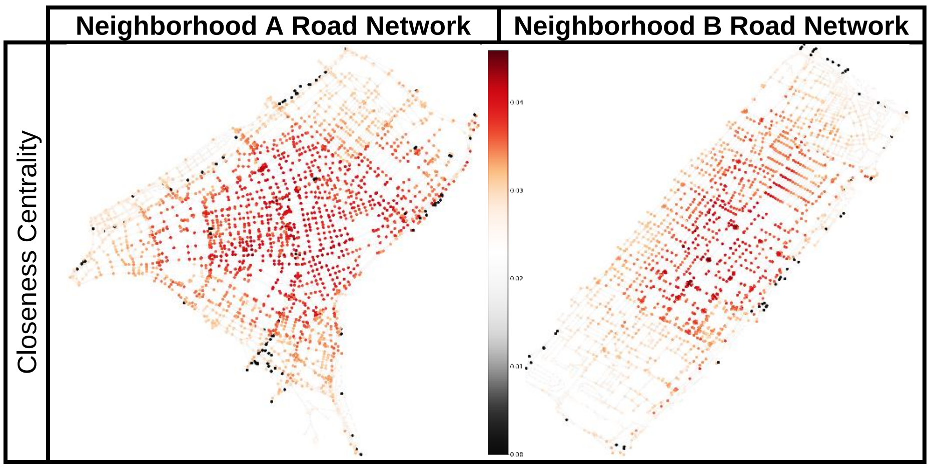


Fig. 3. Closeness Centrality Measure for the Two (2) Neighborhoods

Spatial Autocorrelation Analysis of Closeness Centrality

Spatial autocorrelation analysis of closeness centrality examines how the centrality of nodes within a network is spatially distributed, identifying patterns of clustering or dispersion. Closeness centrality quantifies how near a node is to all other nodes in the network, calculated as the reciprocal of the sum of the shortest paths between the node and all other nodes (Muhammad Sajid Mehmood, 2021).
Significance of this measure include:

- Network Efficiency: High closeness centrality indicates that a node can quickly reach all other nodes, suggesting efficient network connectivity.
- Accessibility: Nodes with high closeness centrality are more accessible, making them crucial for transportation, communication, and service delivery.
- Urban Planning: Understanding spatial autocorrelation of closeness centrality helps urban planners design more connected and accessible urban areas.
- Resource Allocation: Identifying central nodes can guide the allocation of resources and services to optimize accessibility and efficiency.
- By analyzing the spatial distribution of closeness centrality, planners and designers can make informed decisions to enhance the connectivity and functionality of urban networks.

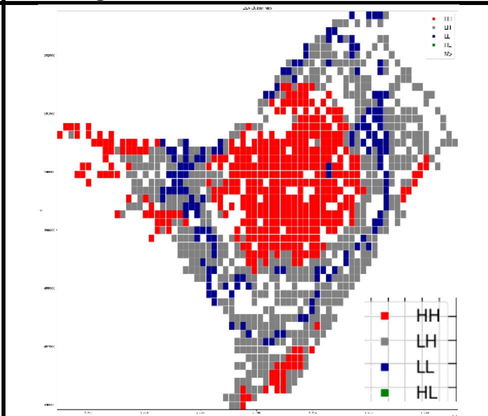
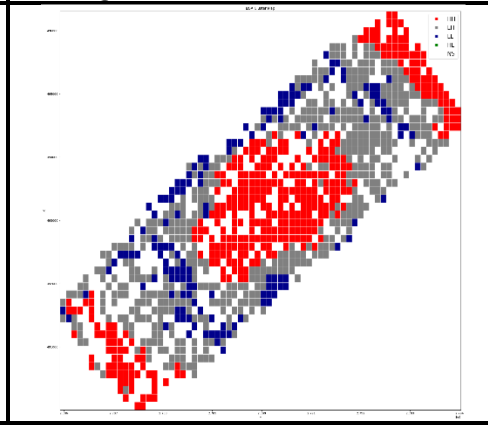
	Neighborhood A Road Network	Neighborhood B Road Network
Closeness Centrality		
	Global Moran's I	
	0.5	0.61

Fig. 4. Degree Centrality Moran's I for the Two (2) Neighborhoods

As shown in Fig. 4., the red area in the center of both study areas is a vibrant hub of activity, offering a variety of entertainment and shopping facilities. This area is characterized by its lively commercial centers, traditional markets, and modern shopping malls. These facilities provide a mix of retail options, from high-end boutiques to local shops, catering to diverse consumer preferences. Additionally, the area features many dining options, ranging from casual cafeterias to fine dining restaurants, enhancing the overall shopping experience. Moreover, the metro line running through the red area significantly enhances its accessibility. The well-connected metro stations provide convenient transportation options, facilitating easy movement within the area and to other parts of the city. This measure shows that the combination of diverse shopping and entertainment facilities, along with excellent metro connectivity, makes the center and areas close to it are dynamic and attractive part of the study areas. Moran's I results are positive and closer to 1 indicating that nearby locations tend to have similar values for the studied variable.

5.3 Analysis of Roads and Streets

Space Syntax Measure: Betweenness Centrality

Betweenness centrality measures how often a node lies on the shortest paths between other nodes in a network. Nodes with high betweenness centrality have a significant influence because they control the flow of information or resources (MARSHALL, 2005). This measure is important for understanding network resilience, information flow, resource allocation, and identifying key players or critical points within the network. Betweenness centrality provides valuable insights into the structure and dynamics of a network, highlighting nodes/roads that are essential for maintaining connectivity, facilitating communication, and ensuring efficient operation. As shown in Fig. 5, both Neighborhood A and Neighborhood B have their main roads highlighted. This visualization helps in comparing the primary transportation routes and understanding the connectivity within each neighborhood. The highlighted main roads in Neighborhoods A and B provide a clear view of the key pathways that facilitate movement and access within these areas.

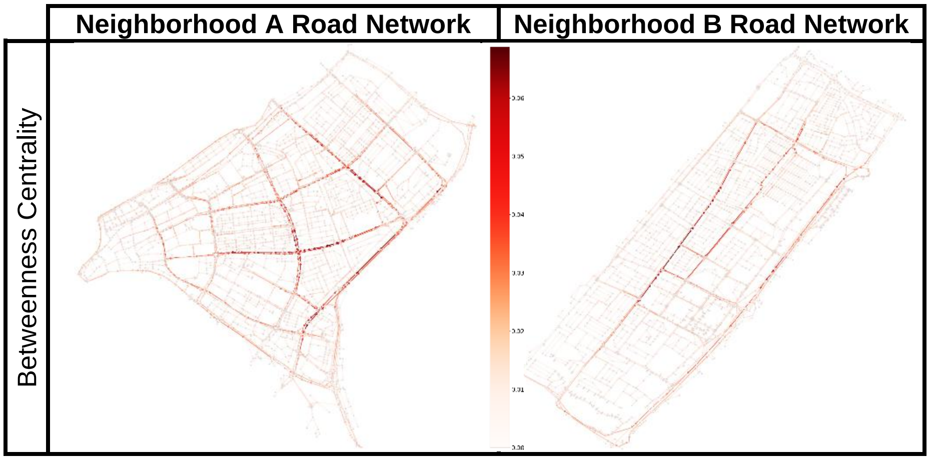


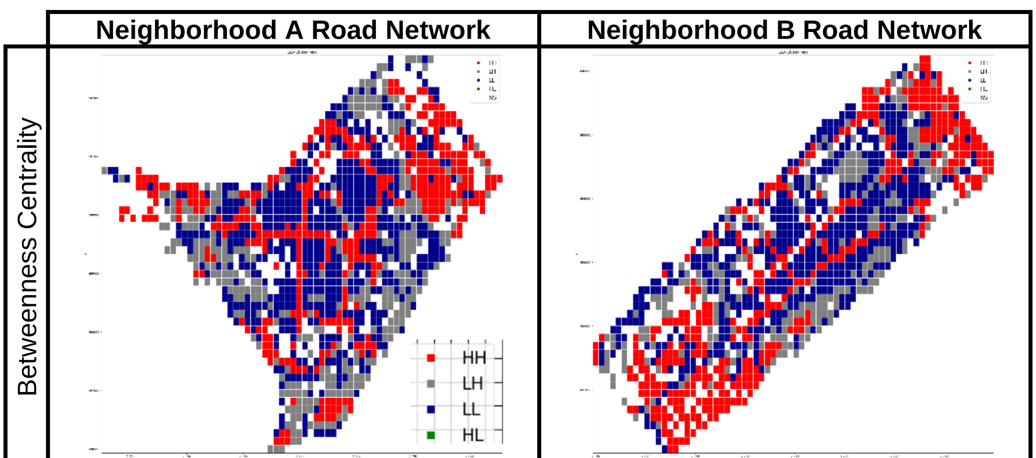
Fig. 5. Betweenness Centrality Measure for the Two (2) Neighborhoods

Spatial Autocorrelation Analysis of Betweenness Centrality

Main roads are vital for urban connectivity and efficiency, and their attractiveness can be analyzed using betweenness centrality. Roads with high betweenness centrality are crucial for maintaining traffic flow, enhancing accessibility, boosting economic activity, and aiding urban planning. These roads serve as key routes for vehicles, facilitate easy access to various destinations, attract businesses, and ensure a well-connected transportation network. By identifying and investing in these critical routes, urban planners can improve the overall functionality and appeal of the city's infrastructure.

Moran's I is a measure of spatial autocorrelation, indicating how similar or dissimilar values are spatially distributed. In the context of analyzing the attractiveness of main roads using betweenness centrality, Moran's I help quantify the degree of clustering or dispersion of high centrality values. When Moran's I gives positive results but less than 0.5 as shown in Fig.6., it suggests a moderate level of spatial clustering. This means that roads with high betweenness-centrality are somewhat clustered together, but not to a very strong degree. In other words, there is a tendency for key roads to be located near each other, enhancing connectivity and accessibility, but this clustering is not extremely pronounced.

This moderate clustering can still be significant for urban planners, as it highlights areas where main roads are strategically positioned to facilitate efficient traffic flow and accessibility. It also indicates that while there are clusters of high-centrality roads, there is still a level of dispersion that prevents over-concentration, which can help in distributing traffic more evenly across the network.



	Neighborhood A Road Network	Neighborhood B Road Network
Global Moran's I	0.35	0.26

Fig. 6. Betweenness Centrality Moran’s I for the Two (2) Neighborhoods

6. CONCLUSIONS

This research incorporates Moran's I analysis as an innovative approach to urban network planning and design integrating Space Syntax measures. The integration of Moran's I analysis allows for a more complex understanding of the spatial relationships between road segments, considering factors such as traffic flow, pedestrian movement, and overall urban attributes. This approach not only enhances the efficiency of urban road planning but also contributes to improved urban mobility and quality of life for residents.

In this study, we utilized Space Syntax measures, specifically betweenness and closeness centrality, along with Moran's I to analyze the spatial configuration and spatial autocorrelation within our study area. The Space Syntax analysis provided insights into the connectivity and integration of different urban spaces, highlighting areas of high and low accessibility. Betweenness centrality revealed the importance of certain nodes in facilitating movement through the network, while closeness centrality identified nodes that are most efficiently accessible from all other nodes.

Moran's I, a measure of spatial autocorrelation, indicated how similar or dissimilar values are spatially distributed. In the context of analyzing the attractiveness of main roads using betweenness centrality, Moran's I helped quantify the degree of clustering or dispersion of high centrality values. When Moran's I gave positive results but less than 0.5, it suggested a moderate level of spatial clustering. This means that roads with high betweenness centrality are somewhat clustered together, enhancing connectivity and accessibility, but this clustering is not extremely pronounced. Additionally, Moran's I result closer to 1 indicated that nearby locations to the center of the area tend to have similar values for the studied variable.

The combination of these methods enabled us to gain a comprehensive understanding of the spatial dynamics at play. The Space Syntax measures revealed the structural properties of the urban layout, while Moran's I quantified the degree of spatial dependence. Together, these analyses demonstrated that spatial configuration significantly influences the distribution of urban phenomena, such as pedestrian movement and land use patterns. Integrating spatial autocorrelation assists in indicating that the corridor is part of a larger cluster of streets and facilitating cross-neighborhood movement in general.

Overall, our findings underscore the importance of considering both spatial configuration and spatial autocorrelation in urban planning and design. By integrating these analytical approaches, urban planners can make more informed decisions that enhance connectivity, accessibility, and overall urban functionality. They facilitate effective communication of the planned work progression and aid in coordinating with various stakeholders involved.

7. LIMITATIONS AND FUTURE RECOMMENDATIONS

This study, while comprehensive in its approach, acknowledges certain limitations stemming from funding constraints and restricted access to specific information. A notable limitation is the inability to fully validate the correlation between pedestrian behavior and road spatial autocorrelation in designing urban road networks. This gap in validation arises from:

- Limited real-time pedestrian movement data across the study area
- Insufficient historical data on pedestrian behavior changes during and after previous rehabilitation projects
- Challenges in segregating the effects of road conditions from other urban factors influencing pedestrian behavior

Despite these constraints, the study provides a robust foundation for understanding spatial autocorrelation and pedestrian dynamics. Future research, with access to more comprehensive data sets and extended observation periods, adding more measures to the Space Syntax analysis could further refine and validate the findings presented here.

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