

# Urban Street Network Porosity and Access to Recreational Spaces in Tashkent

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**Abstract:** *This study examines how street network porosity influences pedestrian accessibility to recreational spaces in Tashkent under conditions of rapid urban transformation and limited green space provision. Using GIS-based network analysis and OpenStreetMap data, accessibility was measured as the shortest network distance from urban block centroids to the nearest recreational space using a 500 m threshold. Street network porosity was quantified through intersection density and classified into high, medium, and low porosity categories. The results show that only 8.5% of analyzed urban blocks have access to a recreational space within 500 m walking distance, with accessibility significantly higher in areas characterized by more permeable and better-connected street networks. The findings indicate that street network structure is a key determinant of recreational accessibility and highlight the need for planning strategies that improve pedestrian connectivity in order to reduce spatial inequalities.*

**Keywords:** street network porosity, pedestrian accessibility, recreational spaces, urban morphology, walkability, spatial inequality, Tashkent

## 1. Introduction

Tashkent, the largest city of Uzbekistan, is undergoing rapid urban transformation accompanied by increasing pressure on public and recreational spaces. Although the city has an extensive transport network, the availability of urban green areas remains limited. Current green space provision of approximately 3 m<sup>2</sup> per capita, with plans to increase to 6 m<sup>2</sup>, remains below the World Health Organization's (WHO) recommended minimum of 9 m<sup>2</sup> per capita for sustainable urban living [1].

Under these conditions, the problem is not only the quantity of recreational spaces but also their everyday accessibility. Even where parks and green areas exist, fragmented street networks, large urban blocks, and weak pedestrian permeability may significantly reduce effective access. For rapidly developing cities, understanding how street network structure influences pedestrian access to recreational spaces is therefore an important planning issue.

Despite growing research on urban accessibility, walkability, and street network morphology, the relationship between street network porosity and pedestrian accessibility to recreational spaces remains insufficiently studied in Central Asian cities, including Tashkent. This is especially relevant in Tashkent, where Soviet-era microdistrict planning, major transport corridors, and fragments of historical urban fabric create a heterogeneous and often discontinuous pedestrian environment.

The aim of this study is to evaluate the influence of street network porosity on pedestrian accessibility to recreational spaces in Tashkent using GIS-based spatial analysis. To achieve this, the study measures block-level porosity, models network-based accessibility to recreational spaces, and compares accessibility outcomes across porosity classes. The main contributions of the study are as follows: (1) it operationalizes street network porosity as a measurable morphological characteristic of urban blocks; (2) it demonstrates the relationship between porosity classes and

pedestrian accessibility to recreational spaces at the city scale; and (3) it provides planning-relevant spatial evidence for improving walkability and reducing inequalities in recreational accessibility in Tashkent and other rapidly developing cities.

## 2. Literature Survey

Under conditions of limited green space provision, the spatial organization of the urban environment becomes critical for ensuring equitable access to existing recreational spaces. In this context, urban porosity has received increasing attention in contemporary urban studies as a property of openness, permeability, and connectivity that shapes movement patterns, environmental quality, and everyday social interaction within cities [2], [3]. Public spaces such as parks, squares, courtyards, and semi-public areas contribute to porous urban structures by creating transitional zones between private and public space and by supporting pedestrian movement and social activity [4] - [6].

One of the key physical dimensions of urban porosity is the structure of the street network. Street connectivity, intersection density, and block size significantly affect pedestrian mobility and the accessibility of urban functions, including recreational spaces. A fine-grained and well-connected street network generally improves walkability and reduces travel distance, thereby facilitating access to parks and other public destinations. In contrast, fragmented street networks with large blocks and limited pedestrian passages may substantially reduce effective accessibility even where recreational spaces are geographically nearby. Previous studies indicate that street network structure and urban form influence walkability, recreational walking, and broader patterns of urban activity [7], [8]. However, block-level relationships between street network porosity and accessibility to recreational spaces remain insufficiently studied in Central Asian cities.

GIS-based analysis provides an effective methodological basis for investigating the relationship between street network

structure and accessibility to public spaces. Geographic information systems make it possible to quantify street network characteristics such as connectivity and intersection density and to evaluate their influence on pedestrian access to parks and recreational areas [9], [10]. Empirical studies further show that higher levels of street connectivity are associated with more equitable access to urban green spaces, whereas fragmented street networks may limit the practical use of recreational areas regardless of their total size or proximity [9], [11].

Recent studies from Uzbekistan further highlight the local relevance of this issue. Research on Tashkent documents the city's ongoing spatial transformation and heterogeneous urban structure [12], while transport-related studies point to persistent challenges in street network development and pedestrian accessibility [13], [14]. At the same time, studies on urban green spaces in Tashkent emphasize their environmental importance, particularly their role in mitigating urban heat [15], [16], while broader research on Uzbekistan and remote-sensing-based monitoring points to increasing pressure on urban green infrastructure under conditions of rapid urbanization [17].

Although previous research has examined urban porosity, street connectivity, and park accessibility, limited attention has been paid to their combined spatial relationship at the block level in post-Soviet and Central Asian urban contexts. This gap is particularly relevant for Tashkent.

### 3. Methods

#### 3.1. Research Design

This study applies a GIS-based analytical framework to examine how street network porosity influences pedestrian accessibility to recreational spaces in Tashkent. The methodological approach combines block-level morphological assessment of the street network with network-based accessibility modeling in order to identify spatial inequalities in everyday access to parks and green spaces. GIS-based methods enable the construction of topologically correct pedestrian networks and support the evaluation of connectivity and spatial permeability within the urban environment [18], [19].

#### 3.2. Accessibility analysis

Pedestrian accessibility to recreational spaces was evaluated using a network-based distance approach. The analysis calculated the shortest walking distance along the street network between urban block centroids and the nearest recreational space. To reduce computational complexity, a 1000 m Euclidean pre-selection buffer was applied before network calculation. This buffer only identified candidate destinations and did not replace network-based measurement. Accessibility was assessed using a 500 m walking distance threshold, commonly interpreted as a neighborhood-scale distance (approximately 5–7 minutes) in recreational accessibility studies. This threshold was selected as a neighborhood-scale walking distance commonly used in GIS-based accessibility studies of parks and public spaces. Although 500 m was used as the main threshold, it should be

interpreted as an analytical benchmark rather than a fixed behavioral boundary. A binary accessibility indicator was applied: blocks with a shortest network distance of 500 m or less were classified as accessible (value = 1), while those exceeding this threshold were classified as non-accessible (value = 0).

Network-based service areas were generated using GIS tools and routing services. The analysis relied on OpenStreetMap (OSM) data, OpenRouteService algorithms, and QGIS plugins such as QNEAT for accessibility calculations [20], [21]. Park entrance locations were also considered, as measuring accessibility only to park centroids or boundaries may overestimate actual pedestrian access.

The network included mapped streets and pedestrian-accessible paths available in OpenStreetMap. However, informal or unmapped routes could not be fully captured, which may lead to slight underestimation of accessibility in some areas.

#### 3.3. Urban Block Delineation and Data Sources

Urban blocks were derived from OpenStreetMap land-use polygons and used as the primary unit of analysis because block structure reflects the spatial morphology through which pedestrian access is organized. Polygons smaller than 1 hectare were excluded to ensure analytical consistency and to omit units too small to represent meaningful block-scale morphology. Where necessary, polygons were checked and cleaned to improve spatial consistency prior to analysis.

Spatial data were obtained from open geospatial datasets. The street network and pedestrian routes were derived from OpenStreetMap (OSM), which provides detailed information on urban road networks and pedestrian infrastructure. Polygons representing parks and recreational green spaces were also extracted from OSM. The spatial distribution of the main recreational and blue-green infrastructure elements used in the analysis is presented in Figure 1.

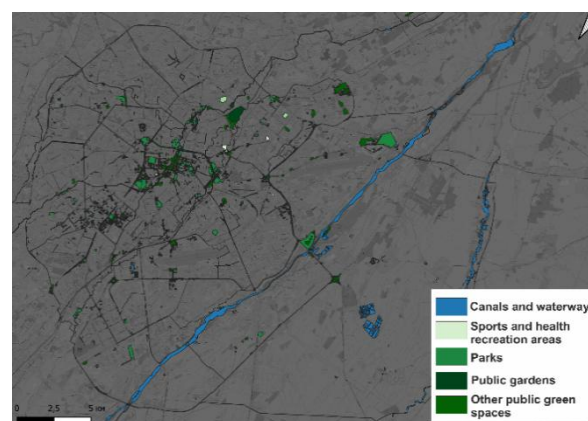


Figure 1: Spatial distribution of recreational spaces and waterways in Tashkent.

Although OSM data provide extensive spatial coverage, their completeness and level of detail may vary depending on the availability of volunteered geographic information [22]. To improve data reliability, the extracted spatial layers were visually checked for topological consistency and obvious omissions before analysis. Nevertheless, variations in OSM

completeness, particularly in pedestrian links and minor access routes, remain a limitation and may influence the estimated accessibility patterns.

The main spatial datasets and analytical layers used in the study are summarized in Table 1.

**Table 1:** Summary of spatial datasets and analytical layers

Dataset	Description	Source	Purpose in analysis
Street network	Road and pedestrian network including intersections and paths	OSM	Construction of routable pedestrian network and network distance calculation
Recreational spaces	Polygons representing parks and green recreational areas	OSM	Identification of destinations for accessibility analysis
Urban blocks	Land-use polygons representing urban blocks	OSM	Spatial units for porosity and accessibility analysis
Intersection nodes	Street intersections derived from the network	Derived from OSM	Calculation of street network porosity (nodes/ha)
Accessibility indicators	Shortest network distance between block centroids and recreational spaces	Calculated in QGIS (OpenRouteService, QNEAT)	Evaluation of pedestrian accessibility

### 3.4. Street Network Porosity Indicators

Street network porosity was assessed using intersection density as a morphological indicator of connectivity and permeability within the urban street structure. Intersection density was calculated as the number of street intersections per unit area:

$$P = N/A$$

where:

**P** — street network porosity (nodes per hectare);

**N** — number of street intersections (nodes);

**A** — area of the urban block or analysis unit (hectares).

Higher intersection densities indicate more permeable street networks with shorter and more direct pedestrian routes.

Porosity values were classified into three categories: low (0–5 nodes/ha), medium (5–15 nodes/ha), and high (>15 nodes/ha). These thresholds were used as analytical classes for planning-oriented comparison. This classification was used to compare pedestrian accessibility to recreational spaces across different urban morphological contexts and to reveal broad spatial patterns relevant for planning interpretation.

### 3.5. Analytical Procedure

The analytical workflow included the following steps:

- 1) extraction and preprocessing of street network data from OpenStreetMap;
- 2) identification and mapping of recreational spaces and park polygons;
- 3) construction of a routable pedestrian network using GIS tools;
- 4) calculation of network-based distances between urban blocks and recreational spaces;
- 5) classification of urban blocks according to street network porosity;
- 6) analysis of the relationship between porosity classes and accessibility indicators.

## 4. Results and Discussion

The spatial analysis reveals marked differences in pedestrian accessibility to recreational spaces across urban blocks with different levels of street network porosity in Tashkent. Overall, only 8.5% of the analyzed urban blocks larger than 1

hectare have access to a recreational space within a 500 m walking distance, indicating substantial spatial inequality in everyday access to urban green infrastructure.

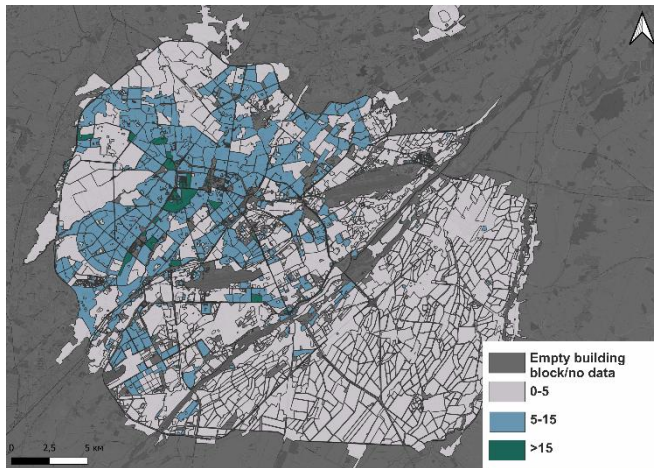
**Table 2:** Pedestrian accessibility to recreational spaces by street network porosity class

Porosity class	Number of blocks	% of blocks with access ≤ 500 m
High	61	36 %
Medium	612	17 %
Low	2056	5 %
Total	2729	8.5 %

Table 2 indicates a clear relationship between street network porosity and accessibility. Blocks with high porosity show the highest level of access, with 36% located within 500 m walking distance of a recreational space. In contrast, only 17% of medium-porosity blocks and 5% of low-porosity blocks meet this accessibility threshold. This pattern confirms that more permeable and better-connected street networks improve pedestrian access to parks and green spaces.

The spatial pattern shown in Figure 2 further supports this relationship. Higher levels of street network porosity are concentrated mainly in the central parts of the city, where the street network is denser and more interconnected. Peripheral areas are characterized by lower porosity values, reflecting larger urban blocks, fewer intersections, and weaker internal pedestrian connectivity. This center–periphery contrast strongly influences the geography of recreational accessibility across the city.

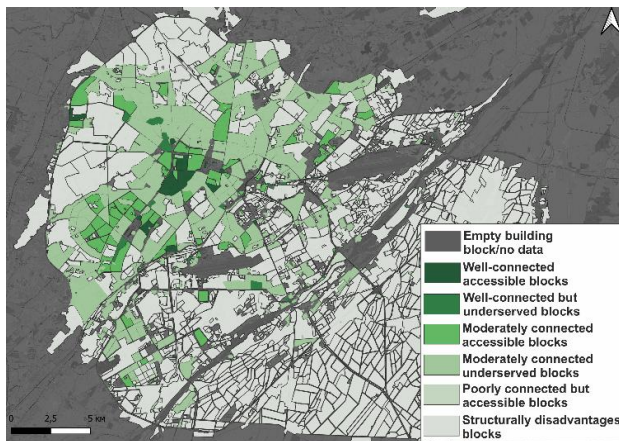
Blocks lacking access to recreational spaces tend to cluster in peripheral urban areas, where fragmented street networks and large block structures limit direct pedestrian movement. By contrast, central districts with smaller blocks and finer-grained street patterns demonstrate better access conditions. This finding suggests that the presence of recreational spaces alone does not guarantee accessibility; the effectiveness of access depends strongly on the permeability of the surrounding street network.



**Figure 2:** Spatial distribution of street network porosity in Tashkent

Street network porosity is measured as intersection density (nodes per hectare) and classified into three categories: low (0–5), medium (5–15), and high (>15). Higher porosity values indicate finer-grained street networks with greater connectivity and permeability.

As shown in Figure 3, urban blocks with access to recreational spaces within a 500 m walking distance are concentrated mainly in the more connected central parts of the city, whereas large peripheral blocks are predominantly characterized by limited access. The figure also shows that accessibility depends not only on the distribution of recreational spaces, but also on the configuration and permeability of the surrounding urban fabric.



**Figure 3:** Spatial configuration of urban blocks and access to recreational spaces within a 500 m walking distance

The map illustrates how the configuration and size of urban blocks, together with the distribution of recreational spaces, shape patterns of everyday accessibility across the city.

## 5. Conclusion

This study demonstrates that street network porosity is a key determinant of pedestrian accessibility to recreational spaces in Tashkent. Using GIS-based analysis, the results show that only 8.5% of urban blocks are within 500 m walking distance of recreational spaces, with significantly higher accessibility observed in areas with greater street connectivity. The findings reveal pronounced spatial inequalities between

central and peripheral areas, emphasizing that accessibility depends not only on the distribution of green spaces but also on the permeability of the surrounding street network. These results highlight the importance of enhancing street connectivity and pedestrian infrastructure as effective strategies for improving equitable access to recreational spaces. The study confirms the value of GIS-based approaches for supporting evidence-based urban planning in rapidly developing cities.

## 6. Future Scope

Future research may extend the proposed approach in several directions, including sensitivity testing with alternative walking distance thresholds. First, the analysis can be refined by incorporating qualitative characteristics of recreational spaces, including their size, functional diversity, and environmental quality, which may influence their actual use beyond spatial accessibility.

Second, future studies may account for physical and infrastructural barriers affecting pedestrian movement, such as major roads, railway lines, and limited crossing points, which are not fully captured in simplified network models.

Third, the integration of socio-demographic data would allow for a more comprehensive assessment of equity in access to recreational spaces, revealing how different population groups experience spatial inequalities within the urban environment.

Finally, the proposed GIS-based framework can be adapted for planning support by testing how additional pedestrian links, crossings, or network reconnections may improve access to recreational spaces.

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