International Journal of Strategic Property Management
ISSN: 1648-715X / eISSN: 1648-9179
2023 Volume 27 Issue 6: 362–378
https://doi.org/10.3846/ijspm.2023.20580

EVALUATION OF URBAN LIVABILITY BASED ON SPATIAL DISTRIBUTION AND FUNCTIONAL RADIUS OF LAND USES

Sarfaraz HASHEMKHANI ZOLFANI [1,*], Seyed Mostafa HEDAYATNEZHAD KASHI [2], Jurgita ANTUCHEVIČIENĖ [3]

[1] *School of Engineering, Universidad Catolica del Norte, Larrondo, 1281 Coquimbo, Chile*
[2] *Faculty of Geography and Environmental Planning, University of Sistan and Baluchestan, Babol, Iran*
[3] *Department of Construction Management and Real Estate, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania*

Received 9 October 2023; accepted 6 December 2023

Abstract. The present research has evaluated the spatial distribution and functional radius of land uses in the central district of Tehran city using objective and subjective methods. The findings showed; Land uses have a directional pattern with random distribution and a cluster. The functional radius also indicates a lack of desirable access for residents to land uses. On the other hand, the lack of per capita confirms the results of the functional radius of the land uses. Because the district is facing a per capita shortage in all uses and functional scales. The results of subjective evaluations also showed that residents lack ease of access to land uses. Also, the optimal access to land uses from the residents' perspectives has been contrary to the standards of urban development plans. What has been quite evident is that spatial injustice in the distribution of land uses and the presence of disparities in access to land uses have had a negative impact on the livability of the district. Our results underscore the importance of a comprehensive examination of livability based on the spatial justice of land uses. This necessitates simultaneous attention to distribution patterns, functional radii of land uses, and the involvement of residents' perceptions of that space.

Keywords: livability, land use, liveable city, quality of life, urban sustainability, residental sustainability, sustainable city.

Introduction

Given that the majority of the world's population (56%) currently resides in cities (Öncel & Levend, 2023), creating favorable living conditions has become a significant goal among governments and urban planners. Consequently, there has been considerable attention towards urban livability in recent years (Sochacka et al., 2021). Urban livability refers to the overall quality of life and well-being of the residents in a city or urban area (Paul & Sen, 2020; Al-Thani & Furlan, 2020). It signifies a city's ability to provide a conducive environment for its inhabitants to live, work, and prosper. Kovacs-Györi et al. (2019) argue that livability, as the quality of the relationship between individuals and the environment, is interpreted based on what the environment provides and how it meets the needs and expectations of residents. However, according to the majority of researchers, livability is a combination of factors that enhance the quality of life in a community, including built and natural environments, economic well-being, social stability and equality, educational opportunities, cultural facilities, and recreational and welfare amenities (Allen & O'Donnell, 2020; Hashemkhani Zolfani et al., 2022; Andrade et al., 2022).

One key consideration in evaluating livability is the spatial distribution and functional radius of land uses within an urban area, referring to the arrangement of different land uses and their proximity to residential areas (Ghasemi et al., 2018; Paap, 2022). Spatial distribution and functional radius relate to the distance at which individuals can access essential services, amenities, and necessary facilities for their daily lives (Zhang et al., 2023; Oh et al., 2007). This includes a wide range of destinations that can be easily, efficiently, and sustainably reached, such as employment centers, educational institutions, healthcare facilities, recreational areas, and public transportation (Fu et al., 2019; Tu et al., 2021). Therefore, evaluating urban livability based on the functional radius

*Corresponding author. E-mails: *sa.hashemkhani@gmail.com; sarfaraz.hashemkhani@ucn.cl*

of land uses enables a comprehensive understanding of a city's accessibility and inclusiveness for its residents (Furlan et al., 2021; Lang et al., 2020). This assessment approach emphasizes that livability is not solely determined by the presence of individual elements or amenities but also by their accessibility and connectivity (Istrate & Chen, 2022).

Evaluating livability based on the spatial distribution and functional radius of land uses involves assessing the effectiveness of urban planning in meeting the needs of residents and enhancing their quality of life. This process requires analyzing patterns of land use distribution, examining the accessibility and connectivity of amenities and services, and considering the functional distances that residents must travel to carry out their daily activities. Planners and policymakers, by evaluating the level of alignment between spatial organization and the preferences and needs of residents, can identify strengths, weaknesses, and opportunities for improving livability.

Studies have examined the livability based on the spatial distribution and functional radius of land uses in urban areas. Some of the notable studies in this area include (Ghasemi et al., 2018; Liang et al., 2020; Yang et al., 2021; Furlan et al., 2021; Jiang et al., 2022; Kourtit et al., 2022). The main focus of these studies has been on the distribution patterns, the direction of distribution, and the functional radius of public transportation stations. The findings of these studies have been valuable as they effectively articulate the concept of livability in terms of the spatial distribution and functional radius of public transportation stations. However, despite multiple efforts, research gaps still exist. These gaps can be attributed to the lack of simultaneous attention to spatial dispersion patterns (distribution type and direction) and the neglect of the functional radius of other land uses. Examining the functional radius of land uses is important because it assesses residents' access from the perspective of spatial justice. This is exactly the important issue that has been neglected in these studies. Especially access to land uses that have more vitality than other land uses and have a selective and voluntary nature (such as green, sports, religious uses). Furthermore, an important consideration in these studies is the scale of the study, which hase focused on the city level and less emphasis has been placed on livability at the regional scale. While, the functional characteristics of different areas may shape distinct physical needs, and the livability of regions can vary based on their performance.

In line with the gaps mentioned in similar studies, the present research has attempted to examine the spatial patterns and functional radii of land uses. So, the main innovations of the present research include investigating the distribution patterns (to determine the type and direction of spatial distribution) and the functional radii of land uses (green spaces, recreational areas, sports facilities, and religious sites). Therefore, we have emphasized two objective and subjective methods to achieve the above goal. In the objective method, the spatial distribution and the status of the functional radius of land uses were studied based on the standards of urban development plans for the study area (District 6 of Tehran). In this method, the coverage/non-coverage status of land uses was calculated at the regional level. Additionally, the type of distribution (clustered, dispersed, random) and the direction of the distribution of land uses were evaluated. In the subjective evaluation method, residents' perspectives on access to land uses in District 6 were examined. The purpose of the subjective evaluation a better understanding of residents' preferences, expectations, and needs regarding access to land uses has been sought. Using this method, we have examined the standards considered in the plans for access based on the residents' perspectives.

The area under our study for evaluating urban livability based on the spatial distribution and functional radius of land uses was District 6 of Tehran. What caused us to emphasize this issue was the assessment of spatial justice, which is necessary to achieve a livable and sustainable city. But what has caused us to choose District 6 of Tehran city as the area of study was the performance and geographical location of the area, which has made the residents' livability face major problems. Because:

1. District 6 is located in the central area of Tehran. Its geographical location has led to its recognition as a hub of connectivity between different areas. According to reports from the municipality of District 6, over one million and five hundred thousand people travel to District 6 from other areas on a daily basis. On one hand, this has resulted in severe population density, pollution, and heavy traffic. On the other hand, in response to the need for intra-city travel, city officials have expanded the road network and increased the number of transportation stations. To the extent that the passages land use, at 27%, occupies the largest area after residential land use.
2. District 6 has educational, administrative, and commercial functions. The functionality of the district has led to the distribution of land uses with essential activities (residential, passages, administrative, industrial, medical, educational, transportation, etc.). Consequently, this has had a negative impact on the distribution of voluntary and selective land uses (green spaces, recreational/artistic, sports, and religious). According to statistics, only about 5% of the land uses in the district fall into the category of voluntary and selective land uses.

1. Theoretical framework

As mentioned in the introduction, the main focus of studies conducted on the relationship between land use distribution and livability has been on the distribution and direction of physical elements, as well as the functional radius of public transportation stations. For example, Kovacs-Györi et al. (2019) focused on evaluating

Table 1. Urban livability assessment methods based on spatial distribution and functional radius

Authors	Method used	Methodological limitations
Spatial distribution		
Ghasemi et al. (2018)	The directional distribution of biological services in the Tehran metropolitan area has been investigated using the standard deviational ellipse method	– Neglecting the spatial distribution pattern of land use – Ignoring the performance of different areas – Neglecting land uses that are voluntary or selective in nature
Liang et al. (2020)	They have examined the spatial distribution pattern of urban livability using the Moran's I spatial autocorrelation method for the years 2006–2016	– Not examining the spatial distribution pattern of livability indicators separately – Not considering the directional distribution of livability indicators
Yang et al. (2021)	They have examined the spatial distribution pattern of urban livability using the Moran's I spatial autocorrelation method for the years 2011 to 2025	– Not examining the spatial distribution pattern of livability indicators separately – Ignoring other spatial distribution patterns
Jiang et al. (2022)	The spatial autocorrelation binary model was used to examine the spatial distribution patterns of intense land use (ILU) and urban livability in the years 2002 and 2017	– The spatial distribution pattern of indicators is not entirely transparent
Functional radius		
Furlan et al. (2019)	Examining the functional radius of transportation stations within a 400-meter radius	– Not considering the functional radius of stations up to 800 meters – Ignoring user perspectives
Lang et al. (2020)	They have examined the livability status based on the relationship between the distribution of human activities around TOD within an 800-meter radius	– Considering the distance of all establishments from transportation stations within an 800-meter radius does not seem logical – Ignoring user perspectives in examining the relationship between livability status and social activities
Kourtit et al. (2022)	They have examined the accessibility radius to facilities using the Floating Catchment Method with a standard distance of 500 meters	– They have not provided a clear explanation for selecting a distance of 500 meters for facilities – Ignoring the performance of land uses

the accessibility to physical elements from the residents' perspective. Ghasemi et al. (2018), on the other hand, examined the spatial distribution of biological services in the mega-city of Tehran using the standard deviational ellipse method. Liang et al. (2020) and Yang et al. (2021) conducted their research by using the Moran's I correlation method to examine the distribution type of livability indicators in cities. Furthermore, studies that have investigated livability based on functional radius (Furlan et al., 2021; Al-Malki et al., 2022; Lang et al., 2020; Berawi et al., 2019; Furlan et al., 2019) have emphasized the Tod (transit-oriented development) model. Therefore, the focus of these studies has been on the functional radius of public transportation stations. However, the functional radius of other land uses has not been given much attention.

Based on the reviewed research, it can be said that studies focused on the spatial distribution of land use have mainly focused on the type of distribution (dispersed, random, clustered). However, the spatial distribution pattern is not limited to the distribution type, and it also includes factors such as direction, diversity, and spatial heterogeneity. So, the following is a summary of the methods used and the limitations of the cognitive approach in the mentioned studies, presented in Table 1.

2. Methodology

2.1. Study area

District 6 of Tehran is located in the central area of the city and is considered one of the relatively older districts due to its geographical position (Figure 1). This district holds special importance, as it accommodates 40% of government ministries and organizations, 30% of embassies, 50% of universities, and 30% of hospitals in Tehran (Information and Communication Technology Organization of Tehran Municipality, 2020).

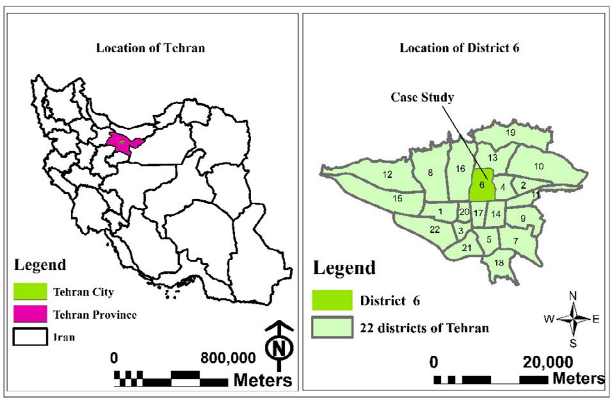


Figure 1. Location of Tehran in Iran and District 6 of Tehran

Table 2. Characteristic of District 6 of Tehran city (source: Information and Communication Technology Organization of Tehran Municipality, 2020)

District function	Educational-administrative-commercial
Geographical location in Tehran	Centerality
Region's extent	2137 hectares
Population	250753
Percentage of area from the city	3.47
Percentage of population	2.88
Population density per hectare	117
The percentage of land-uses with the nature of essential activities (residential, passages, administrative, industrial, medical, educational, transportation, etc.)	More than 95%

The performance and geographical location of the district have influenced the distribution of land uses. More than 95% of the land uses in the district are essential uses. As a result, over 1.5 million people commute daily from other areas of Tehran to District 6, while the resident population of the district is approximately 250753 people. Furthermore, the area of this district is 2,137 hectares (Information and Communication Technology Organization of Tehran Municipality, 2020). Table 2 presents the characteristics of the district.

2.2. Research question

As mentioned in the introduction, the aim of this research is to assess urban livability based on the spatial distribution and functional radius of land uses. In this regard, the main research questions are raised: Has spatial justice been paid attention to in the distribution of uses? Do the residents have desirable access to the land use?

To answer these questions, a comprehensive analysis of the distribution patterns and functional radius of land uses is necessary. Additionally, the opinions of residents should be considered as an evaluation criterion. This is because examining access to urban land uses is impossible without taking into account the users' perceptions of those spaces. The process of addressing the research questions is illustrated in Figure 2.

2.3. Data

The present study utilized the latest data from the Statistical Center of Iran and the Information Technology and Communication Organization of Tehran Municipality. The latest population data and statistical blocks (2016) were extracted from the Statistical Center of Iran. Additionally, the shapefiles of the land use in District 6 of Tehran City, resulting from the latest studies conducted by the Municipality in 2016 and 2020, were loaded in GIS and the required information was analyzed.

2.4. Methods

The current research employs both objective (quantitative) and subjective (qualitative)methods to evaluate urban livability. In the objective approach, the spatial distribution and functional accessibility of land uses were analyzed based on the detailed plan standards of District 6 in Tehran. The coverage status or lack of coverage of land uses at the regional level was calculated. The subjective evaluation method involved examining the residents' perspectives on the desirability or undesirability of accessing different land uses. To assess the residents' perspectives, a questionnaire was utilized. The statistical population of the present study consists of residents over 18 years old in District 6 of Tehran city. According to the latest census conducted by the Statistical Center of Iran in 2016, the population of District 6 was 250,753 individuals. The sample size was calculated using the Cochran formula, which resulted in a sample size of 383 individuals. The sample size was calculated using the Cochran formula, which resulted in a sample size of 383 individuals. The sampling method used in this study was multi-stage sampling. Considering the possibility of incomplete responses in some questionnaires, a total of 400 questionnaires were distributed. Also, the sampling method used in this study was multi-stage sampling.

The emphasized software in the quantitative GIS method is a Geographic Information System (GIS). Analytical tools within GIS, such as spatial statistics and network analysis, were employed. Spatial statistical tools included measures like the nearest neighbor index and standard deviational ellipse. The nearest neighbor index was used to determine the pattern of land use distribution (green spaces, recreational/artistic, sports, and religious) while the standard deviational ellipse method was used to identify the orientation of land uses. Network analysis tools were used to examine the functional accessibility radius of land uses. Additionally, population density was considered in evaluating the conformity or non-conformity of land use distribution by calculating land use ratios in functional scales.

In the subjective approach, the SPSS software was used to analyze the questionnaire data. The Kolmogorov-Smirnov test was applied to assess the normality distribution of the data. Furthermore, a parametric test (One Sample *t*-test) was employed to examine the desirability or undesirability of indicators based on the residents' perspectives. Also, the statistical population of the present study consists of residents over 18 years old in District 6 of Tehran city. According to the latest census conducted by the Statistical Center of Iran in 2016, the population of District 6 was 250,753 individuals. The sample size was calculated using the Cochran formula, which resulted in a sample size of 383 individuals.

$$n = \frac{(250753)\cdot(1.96)^2\cdot(0.5)\cdot(0.5)}{(250753-1)(0.06)^2\cdot(1.96)^2\cdot(0.5)\cdot(0.5)} = 383.57 = 383.$$

Considering the possibility of incomplete responses in some questionnaires, a total of 400 questionnaires were

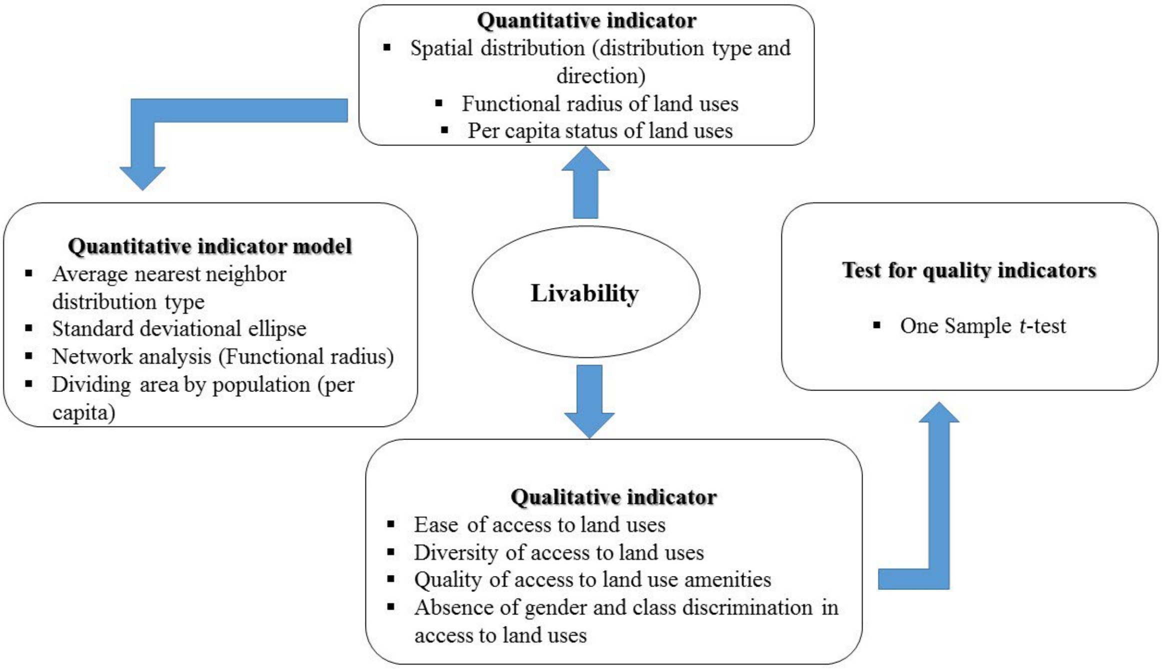


Figure 2. Methodological flowchart

distributed. The sampling method used in this study was multi-stage sampling. Initially, a number of blocks with population were randomly selected from the blocks in the region. Then, based on the population of each block, the number of questionnaires to be distributed was determined. The questionnaires were distributed based on calculated interval numbers. The distribution of questionnaires was also conducted randomly. Additionally, 12 individuals voluntarily participated in the questionnaire distribution and they were residents of District 6. It is worth noting that the questionnaires were interviewer-administered.

2.5. Research indicators

The indices examined in the current research include both objective and subjective measures. The subjective indices encompass ease of accessibility, diversity of accessibility, quality of accessibility, and non-discrimination based on gender and class in access to land uses. The following are further explanations of these indices:

1. Ease of access to land uses: the ease of access indicator aims to determine whether the facility is accessible to residents or not. It also examines the time distance between residents and the facility (equivalent to a 5 to 10-minute walk).
2. Diversity of access to land uses: this indicator focuses on whether the facility offers a diverse range of options for residents to access.
3. Quality of access to land use amenities: indicator assesses whether residents can fully and unobstructedly utilize the amenities provided by the land use.
4. Absence of gender and class discrimination in access to land uses: does the presence of residents face any difficulties or discrimination in accessing the facility? This indicator refers to the existence of issues such as racial, gender, and class discrimination in accessing the facility.

The objective indices focus on the examination of land uses. The land uses examined in this study include green spaces, recreational/artistic, sports, and religious land uses (Table 3 presents the share of these four land uses in District 6). The reason for selecting these particular land uses is that they exhibit a higher level of livability compared to other land uses. These land uses involve a higher proportion of social and voluntary activities and have a

Table 3. The levels and area of land use in District 6 of Tehran (source: Urban Observatory of Tehran, 2017)

Land-use	Area (m^2)	Percentage of the district's area	The cumulative percentage
Park and green space	810165	3.79	6.61
Recreational and artistic	81611	0.38	95.04
Sport	31150	0.15	98.37
Religious	50964	0.24	98.61
Total	973891	4.56	----

stronger functional connection to the livability of urban spaces. Additionally, Considering the emphasis of the sixth district of Tehran's performance on the distribution of essential land uses, examining the status of voluntary land uses seems important.

2.6. Introduction of research tools and tests

2.6.1. Spatial pattern analysis

Analysis of spatial patterns is used to understand the overall patterns and trends present in spatial data and the distribution patterns of spatial dispersion. Generally, spatial distribution patterns can be classified into three states based on previous studies: clustered, dispersed, and random. The following describes the models (tools) used in the current research.

2.6.2. The average nearest neighbor model

This tool calculates the nearest neighbor index based on the average distance from each feature to its nearest neighbor. In this tool, if the features are linear, the centerline is considered, and if they are polygons, the centroid of the polygon is considered. The range of variation in the average distances between points can vary from a clustered to a dispersed pattern. If the calculated average distance is less than the average distance expected in a random distribution, it can be concluded that the distribution of the phenomenon is clustered. However, if it is greater than the expected average distance, it indicates that the features are dispersed in that area. The level of the neighbor index is expressed as the ratio of the observed average distance to the expected distance. The expected distance in this index is obtained through the analysis of the Z quantity, which is presented at three levels: clustered or regular with a Z-score ≥ 1.65, random with a Z-score between –1.65 and 1.65, and clustered pattern with a p-value < 0.05 (Mansour, 2016). The equations used to calculate the average nearest neighbor distance index are as follows:

The mean nearest neighbor distance:

$$d = \sum_{i=1}^{N} d_i / N, \tag{1}$$

where N is the number of points while d_i is the nearest neighbor distance for point i.

The expected value of the nearest neighbor distance in a random pattern:

$$E(d_i) = 0.5\sqrt{\frac{A}{N}} + (0.514 + 0.41) / \sqrt{N} \times B / N, \tag{2}$$

where A is the area and B is the length of the perimeter of the study area.

The variance:

$$Var(\partial) = \frac{0.070A}{N^2} + 0.037B\sqrt{\frac{A}{N^2}}. \tag{3}$$

2.6.3. Directional distribution. Standard deviational ellipse

The distribution of many geographical phenomena in space is such that it may be directional and cannot be represented by a circle. In these cases, the trend and distribution of phenomena in space can be shown by calculating the variance of X and Y separately and independently. The directional distribution tool shows whether the distribution of geographic features in space is done in a directional manner or not. Are some complications from a specific complication more distant than other complications in a certain direction? The standard deviation ellipse is so named because the standard deviation (SDE) of the X and Y coordinates are calculated from the central mean to determine the axes of the ellipse. These ellipses make it possible that if the distribution of space complications has a directional pattern (Ghasemi et al., 2018), the standard deviation ellipse is calculated as follows (Eq. (1)). In this regard, x_i is the coordinate of complication i, which is the average center of complications, and n is equal to the total number of complications in the analyzed layer. The standard deviation ellipse is calculated with three characteristics, including the standard deviation in both the x and y directions and its rotation angle. The standard deviation can be calculated in both directions, x and y, through Eq. (1) (Eck et al., 2005). Several methods have been suggested to calculate the SDE formula. Yuill's method (1971) was an improvement of Lefever's initial model (1926), although it faced some objections (Furfey, 1927).

The following steps can be taken in order to determine a standard deviational ellipse.

First, shift the reference point of the Cartesian coordinate system to the average center of the n objects under examination.

$$x = \frac{1}{n}\sum_{i=1}^{n} x_i,\ y = \frac{1}{n}\sum_{i=1}^{n} y_i; \begin{pmatrix} \widetilde{x_i} \\ \widetilde{y_i} \end{pmatrix} = \begin{pmatrix} x_i \\ y_i \end{pmatrix} = \begin{pmatrix} \tilde{x} \\ \tilde{y} \end{pmatrix}. \tag{4}$$

The coordinates of the n objects in the X-Y coordinate system are given by $\{(x_i, y_i), i = 1,\ldots,n\}$.

Next, introduce a rotation matrix $G = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$.

After rotating by the angle θ in a clockwise direction, as shown in Figure 3, all the observed sample points are converted to a novel planar coordinate system,

$$\begin{pmatrix} X_I \\ Y_I \end{pmatrix} = G\begin{pmatrix} \widetilde{x_i} \\ \widetilde{y_i} \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}\begin{pmatrix} \widetilde{x_i} \\ \widetilde{y_i} \end{pmatrix} = \begin{pmatrix} \widetilde{y_i}\sin 0 + \widetilde{x_i}\cos\theta \\ \widetilde{y_i}\cos 0 + \widetilde{x_i}\cos\theta \end{pmatrix}. \tag{5}$$

The estimator that maximizes the likelihood of the variance of the rotated samples produces,

$$\begin{cases} \sigma_x^2 = \frac{1}{n}\sum_{i=1}^{x}(x_i)^2 = \frac{1}{n}\sum_{i=1}^{x}\left(\widetilde{y_i}\sin\theta + \widetilde{x_i}\cos\theta\right)^2 \\ \sigma_y^2 = \frac{1}{n}\sum_{i=1}^{x}(y_i)^2 = \frac{1}{n}\sum_{i=1}^{x}\left(\widetilde{y_i}\cos\theta + \widetilde{x_i}\sin\theta\right)^2 \end{cases}. \tag{6}$$

As a result, the angles that produce the greatest and smallest standard deviations can be determined by setting any derivative of the variance estimators with respect to θ equal to zero, that is,

$$\frac{d\sigma_x^2}{d\theta} = \frac{2}{n}\sum_{i=1}^{n}\left(\begin{matrix}\widetilde{y_i}^{\,2}\sin\theta\,\cos 0 + \widetilde{x_i}\,\widetilde{y_i}\left(\cos^2\theta - \sin^2\theta\right) - \\ \widetilde{x_i}\,\sin\theta\cos\theta\end{matrix}\right) = 0. \quad (7)$$

The quadratic equation above has a general solution in accordance with Vieta's formulas, which is:

$$\tan\theta = \frac{\left(\sum_{i=1}^{n}\widetilde{x_i}^{\,2} - \sum_{i=1}^{n}\widetilde{y_i}^{\,2}\right) \pm \sqrt{\left(\sum_{i=1}^{n}\widetilde{x_i}^{\,2} - \sum_{i=1}^{n}\widetilde{y_i}^{\,2}\right)^2 + 4\left(\sum_{i=1}^{n}\widetilde{x_i}\,\widetilde{y_i}\right)^2}}{2\sum_{i=1}^{n}\widetilde{x_i}\,\widetilde{y_i}}. \quad (8)$$

One of these angles corresponds to the maximum deviation in the new coordinate system, while the other corresponds to the minimum deviation. By incorporating Eq. (4) into Eq. (3), it is possible to calculate the major and minor axes of the standard deviational ellipse, which can be used to evaluate the distribution of the original observations. It is important to note that rotating Eq. (3) around the mean center of the sample defines an implicit locus curve.

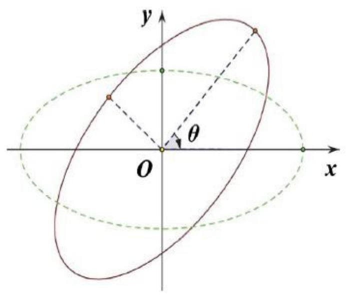


Figure 3. An ellipse that has been rotated by an angle θ in a clockwise direction (Ghasemi et al., 2018)

2.6.4. Network analysis

Networks are a special type of vector data that are mainly composed of edges, connections, and nodes. The network data set is used for route selection (Silalahi et al., 2020). Network analysis is widely used in geographic information system analysis. This analysis is a version of proximity and proximity analysis that takes place on layers that have a vector system and is used to determine and find the boundaries of points in different ways to find the best and fastest route to travel between the origin and the destination. ArcGIS Network Analyst is a powerful extension that provides network-based spatial analysis, including routing, travel routes, nearest facilities, and service area analysis. ArcGIS Network Analyzer enables users to dynamically model real-world network conditions, coding landmarks, best routes, finding nearest facilities, and assigning facilities. Understanding network elements in relation to each other forms the overall structure of the network (Karadimas et al., 2007; Comber et al., 2008).

As mentioned in the methodology section, this tool is used in the current research to investigate the functional radius of land uses at the regional level.

2.6.5. One sample *t*-test

The One Sample *t*-test is used to determine if there is a significant difference between the mean of a single sample and a specified constant value (hypothesized value). It is a parametric statistical method and falls under the category of population mean tests (Gerald, 2018). The mathematical formula for the One Sample *t*-test in SPSS is as follows:

$$t = (M - \mu) / (s / \sqrt{n}), \quad (9)$$

where t represents the t-value, which measures the difference between the sample mean (M) and the population mean (μ), scaled by the standard deviation (s) divided by the square root of the sample size.

3. Results

3.1. Land uses distribution

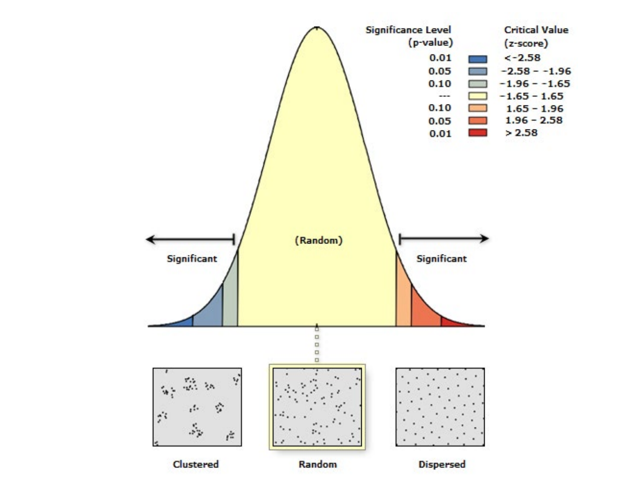
The provision of urban services to residents can be examined from three perspectives: 1) Distribution of land uses and services, referred to as the distribution of land uses, 2) The distance and location within the service area, known as the functional radius, and 3) The responsiveness of services to the urban population, examined through density of service provision. In the current article, all three perspectives have been considered.

3.1.1. Examining the distribution of land uses using the Mean Nearest Neighbor model

In this section, the distribution of land uses using the Mean Nearest Neighbor model is examined. Figures 4 to 7 present the distribution types based on the provided neighbor unit pattern. As observed, the land uses are clustered and random in their distribution. Figures 4, 5, and 6 respectively depict the distribution of sports, religious, and recreational-artistic land uses. All three exhibit a random pattern. Additionally, according to Figure 7, the distribution of green spaces shows a clustered pattern.

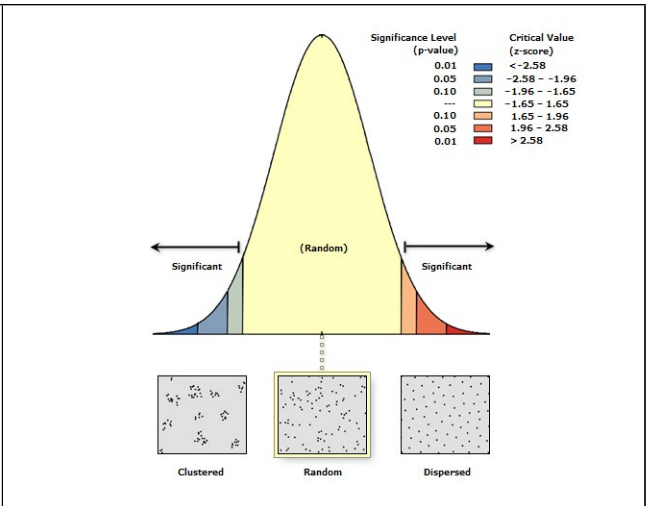
3.1.2. Investigating the orientation of land use distribution using the Standard Deviational Ellipse model

As indicated by the Average Nearest Neighbor model, land uses are scattered in a clustered and random manner. However, the noteworthy point is the orientation of land use distribution. In other words, the clustered and random distribution implies that the spatial distribution of land uses exhibits a directional pattern at the regional level. The Standard Deviational Ellipse model was used to examine the orientation of land use distribution. As seen in Figure 8, all land uses demonstrate a directional



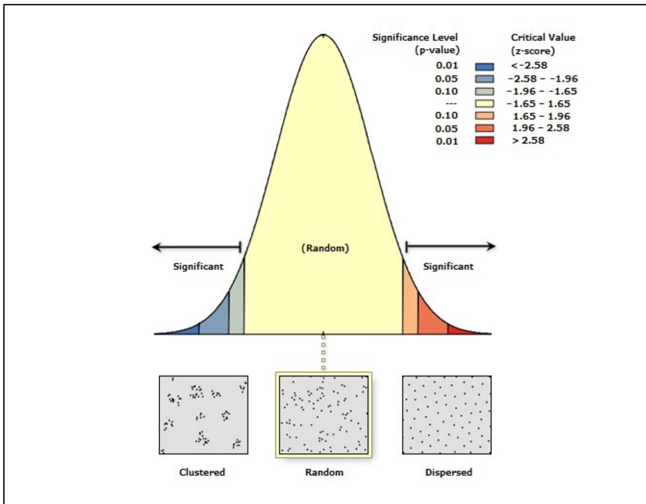
Observed mean distance: 391.779190
Expected mean distance: 353.422461
Nearest neighbor ratio: 1.108529
z-score: 1.296614
p-value: 0.194764

Figure 4. The distribution of religious usage using the mean nearest neighborhood



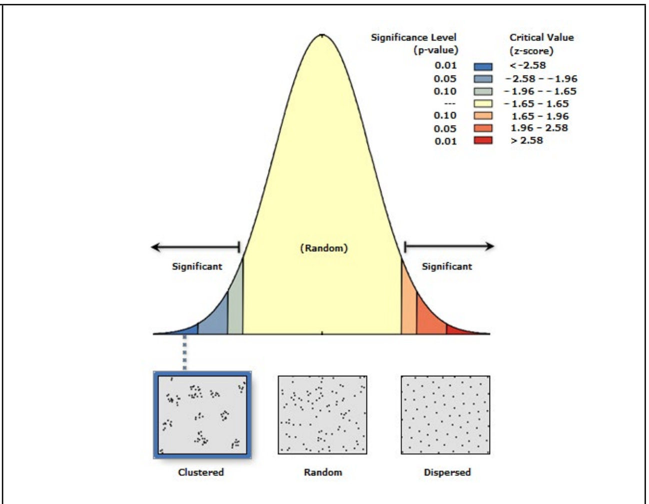
Observed mean distance: 339.902658
Expected mean distance: 325.468966
Nearest neighbor ratio: 1.044347
z-score: 0.569121
p-value: 0.569274

Figure 5. The distribution of sports land-use using the mean nearest neighborhood



Observed mean distance: 275.818721
Expected mean distance: 268.122936
Nearest neighbor ratio: 1.028702
z-score: 0.399749
p-value: 0.689341

Figure 6. The distribution of recreational-artistic land-use using the average of the nearest neighborhood



Observed mean distance: 91.829169
Expected mean distance: 137.154877
Nearest neighbor ratio: 0.669529
z-score: −10.895382
p-value: 0.000000

Figure 7. The distribution of the green space land-use using the mean nearest neighborhood

pattern. The rotation of the curves also indicates the directional nature of land uses. The dominant direction of recreational and artistic land use (Figure 8a) is from east to south, primarily concentrated in the central, eastern, and southern parts. This indicates a random distribution pattern as well. In Figure 8b, the orientation of park and green space land use is depicted. The dominant direction of this land use is from the center towards the north. The concentration of green spaces in the northern part clearly reveals a clustered distribution pattern. The dominant direction of sports land use (Figure 8c) is from south to north, and with a random distribution, the eastern and western parts do not have equal sports facilities. The same applies to religious land use (Figure 8d), with the exception that besides the eastern and western parts, the northern part of the area is also devoid of religious land uses. Considering that the dominant direction of religious land use is from south to north, most religious land uses are scattered in the central area of the district.

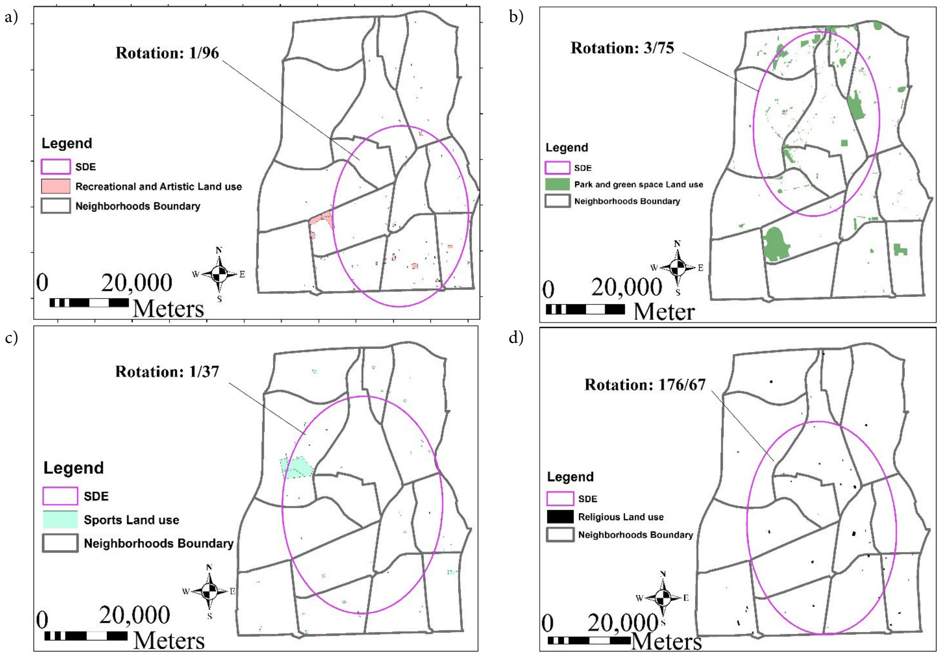


Figure 8. The SDE of the distribution of land uses

3.2. Investigating the functional radius of land uses in the neighborhood, local, district, region, and city scales

Each land use in a city has a specific function referred to as the functional threshold (or functional radius). According to this characteristic, an area of the city is allocated to the activities of that land use. In other words, the area in which a land use can provide its services is called its functional radius. This characteristic varies from one city to another based on social, economic, and recreational characteristics of the studied region. Therefore, investigating the functional radius of land uses is important in determining the coverage status of land uses and the level of residents' access to them.

In the current study, the distance of the functional radius of land uses has been determined based on the criteria of the detailed plan, land use plans, and the study patterns of the sixth district of Tehran.

Since land uses have different functional scales based on their area, in the 6th district, they are divided into the following categories: neighborhood unit, neighborhood, district, region, city, and sub-urban. Land uses with the smallest area have a neighborhood unit-scale functional radius. As the area increases, the functional radius becomes different. Therefore, land uses with the largest area have a sub-urban-scale functional radius. It should be noted that the functional radius of land uses varies depending on the type of land use, population, and area. Table 4 shows the standards of the functional radius of land uses.

In this study, GIS tools were used for accurate calculation of the area of land uses. By examining the area of land uses, it was found that among the four land uses investigated (sports, recreational, religious, and green spaces), there are no land uses with a sub-urban-scale functional radius. Additionally, by examining the area of land uses, it was determined that among the four categories of land uses studied (sports, recreational, religious, and green spaces), there is no land use with a suburban functional scale. As observed, sports and green spaces have the highest functional scales among the studied categories.

Figures 9 to 12 present the functional radius of land uses, which takes into account the scales of land uses, including neighborhood, local, regional, district, and urban scales. In addition, Table 5 provides information on the

Table 4. Functional radius standards of uses in different scales (source: detailed plan, land use plan and study plans of District 6 of Tehran city)

Land-use	Scale	Functional radius standards (meter)
Sport	Neighborhood	500
	Local	1000
	District	3000
	Regional	4500
	City	6000
Recreational and artistic	Local	1000
	District	1500
	City	5000
Religious	Local	400
Park and green space	Neighborhood	200
	Local	750
	Regional	2000
	City	6000

population coverage and the number of people without coverage across different functional scales. As observed in Figure 8, the functional radius of land uses does not cover the entire district. Among the four studied land uses, sports (Figure 9) and green spaces (Figure 12) have a more desirable functional radius, while religious land use (Figure 11) has a less desirable functional radius. Continuing on, the population coverage/coverage gap in different functional scales of land uses are addressed.

According to Table 5, the percentages of the population lacking access to sports land use vary across different functional scales. For the neighborhood scale, 23.84% of the population lacks access, for the local scale, 28.47% lacks access, for the regional scale, 77.84% lacks access, for the metropolitan scale, 15.66% lacks access, and for the urban scale, 13.96% lacks access.

According to Table 5, approximately 35% of the population in the region are deprived of access to religious land uses.

The functional radius of recreational and tourist uses (Figure 10) has been examined at the local, regional, and urban scales. The local functional radius indicates that approximately 38.23% of the population does not have access to recreational and tourist activities. For the regional scale, this figure is around 43.38%, meaning that 109,000 people in this scale are deprived of access to these uses. However, the situation is different at the urban scale, where 72% of the area has access to these activities.

The functional radius of green space uses is demonstrated at the neighborhood, local, regional, district, and urban scales. In this use, the functional radius is very desirable at the neighborhood and urban scales, with over 85% of the population in the area covered by the functional radius. However, at the local scale, 46.86% of the population is deprived of access to these uses, and at the regional scale, 86.15% of the population is deprived of access to them (Table 5).

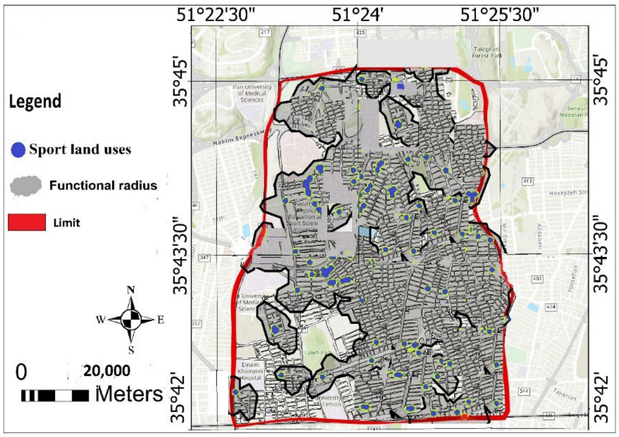


Figure 9. Functional radius of sports land uses

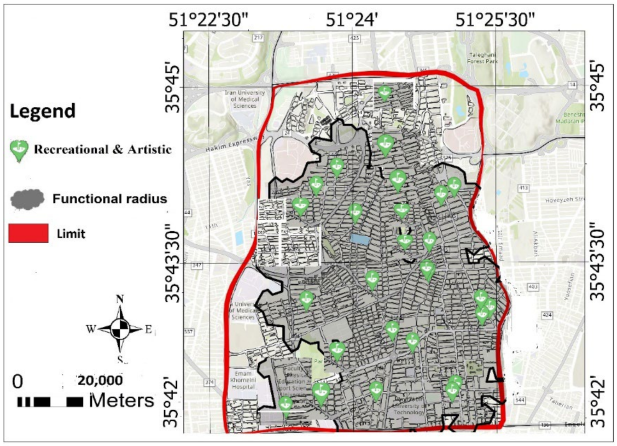


Figure 10. Functional radius of recreational and artistic land uses

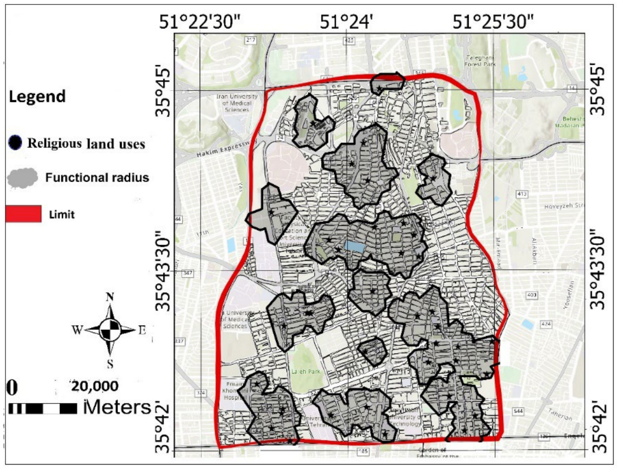


Figure 11. Functional radius of region land uses

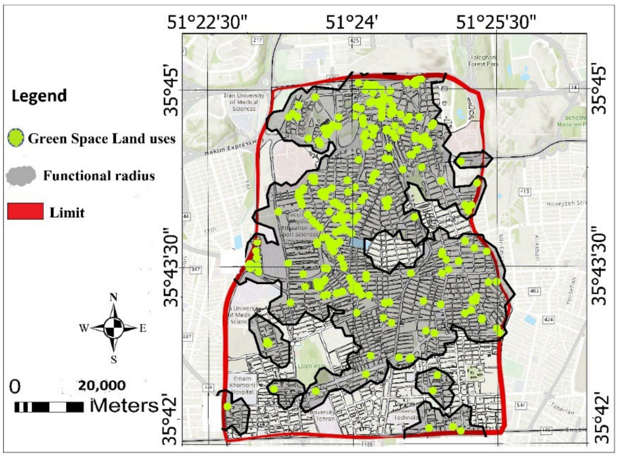


Figure 12. Functional radius of green space land uses

Table 5. The amount of population coverage/non-coverage in different functional scales of land uses

Land-use	Scale	Population with standard access	Percentage of population with standard access	The number of people without access	The percentage of the population without access
Sport	Neighborhood	190978	76.16	59775	23.84
	Local	179364	71.53	71389	28.47
	District	55576	22.16	195177	77.84
	Regional	211474	84.33	39279	15.66
	City	215744	86.03	35009	13.96
Recreational and artistic	Local	154872	61.76	95881	38.23
	District	141977	56.62	108776	43.38
	City	182366	72.72	68387	27.27
Religious	Local	163165	65.07	87588	34.93
Park and green space	Neighborhood	213485	85.14	37268	14.86
	Local	133261	53.14	117492	46.86
	Regional	34721	13.85	216032	86.15
	City	218264	87.04	32489	12.95

3.3. Investigating the per capita status of land uses at the scales of neighborhood, local, district, regional, and urban

To conduct a more in-depth study on the relationship between population density and access to land uses, an assessment of the per capita status of land uses was also undertaken. This is because the per capita allocation of land uses plays a crucial role in spatial organization, facilitating activities, and meeting the needs of urban dwellers. The per capita use is considered one of the physical and quantitative (objective) indicators of livability. The concept of per capita, derived from dividing the total area by the population, refers to the land area allocated to accommodate specific land uses in order to provide accessible services. Therefore, per capita represents the level of access to land uses in relation to the population. The relationship between per capita land uses and urban livability is complex and can vary depending on various factors. This relationship can be observed through the lens of accessibility and distribution. If per capita is not properly managed and allocated, it can have a detrimental impact on functional Radius and accessibility. As a result, per capita of land uses has a close correlation with their functional scale in the planning process.

In Table 6, the standard per capita, the current per capita, and the deficiencies in land use areas were calculated for District 6 of Tehran city. As observed, District 6 faces a scarcity of per capita in all land uses and functional

Table 6. The per capita status of land uses on the neighborhood, local, district, regional, and urban scales

Land-use	Scale	Standard per capita	Areas of the status quo	Per capita of the status quo	Shortage/surplus of land use area
Sport	Neighborhood	1.00	6557.59	0.03	–184420.41
	Local	1.40	34674.56	0.19	–216435.04
	District	1.50	9815.33	0.18	–73548.67
	Regional	1.60	26795.89	0.12	–339826.51
	City	2.00	171238.44	0.69	–327405.56
Recreational and artistic	Local	0.15	17867.54	0.07	–19067.56
	Zonal	0.25	4761.25	0.03	–30733
	City	0.80	91502.53	0.36	–109099.87
Religious	Local	0.75	38622.36	0.24	–83751.4
Park and green space	Neighborhood	1.50	192488.70	1.11	–83455.96367
	Local	2.00	303208.90	0.44	–207953.4879
	Regional	2.50	119642.45	0.29	–76726.24495
	City	6.00	257404/.32	0.97	–1260244.45

scales. Among the land uses, the per capita status of sports facilities is the least desirable, followed by green spaces. Additionally, the shortage of per capita confirms the findings obtained from the analysis of functional radius, indicating that not all residents have equal access to these land uses and are deprived of their services. Consequently, this shortage adversely affects the livability for a significant percentage of the residents.

3.4. Investigating the residents' perspectives using a questionnaire

The general public is considered the ultimate judge in evaluating urban spaces (Mahmoudi et al., 2015). Therefore, assessing the accessibility of urban amenities without considering users' perceptions of those spaces is impossible. Hence, in the next stage, questionnaires were specifically designed for District 6 of Tehran city. The purpose of this survey was to examine the residents' (users') perspectives on access to land uses. Residents were asked about the desirability/undesirability of accessing land uses. The Likert scale with five options (very low, low, moderate, high, very high) was used to measure individuals' perspectives.

To estimate the initial reliability, a sample of 30 questionnaires was considered, and Cronbach's alpha coefficient was calculated, resulting in 0.830, indicating high questionnaire reliability. After verifying the reliability, as mentioned a total of 400 questionnaires were distributed. Since 12 questionnaires were incomplete, data from 388 questionnaires were entered into SPSS. The next step involved examining the normality distribution of the data, which was assessed using the Kolmogorov-Smirnov test. The results of this test indicated that the data were normally distributed. Therefore, in this study, a parametric test (One Sample *t*-test) was used to examine the desirability/undesirability of indicators from residents' perspectives.

The demographic information section of the questionnaire included four questions regarding gender, age, education, and length of residency in the study area. Respondents over 18 years old were categorized into three groups: youth (18–35), middle-aged (36–49), and elderly (50 or above). This categorization was done without creating differentiation based on gender, ethnicity, or race. Table 7 presents the demographic and descriptive characteristics of the questionnaire. Among the respondents, 48% were male, and 52% were female. Approximately 55% of the respondents had a bachelor's degree. Additionally, 40% of the respondents had a residency of more than 20 years. The largest age group among the respondents was in the 18–35 age group, comprising 246 individuals (63.4% of the total).

In the next section of the questionnaire, the status of accessibility to Land uses was assessed. The accessibility index was divided into the following sub-indices: ease of access, diversity of access, quality of access, and absence of gender and class discrimination in access to Land uses. For each of these indicators, 3 to 5 questions were considered.

Table 7. The demographic and descriptive characteristics of the questionnaire for District 6 of Tehran city

Demographic and descriptive characteristics		Frequency	%
Gender	Man	190	48
	Female	198	52
Education	Primary education to diploma	95	24.4
	Bachelor degree	216	55.6
	Masters	59	15.2
	P.H.D	18	4.6
Staying time	Less than 5 years	45	11.6
	5_10	91	23.5
	10_20	96	24.7
	More than 20 years	156	40.2
Age	18–35	246	63.4
	36–49	102	26.2
	More than 50 years	40	10.3

3.5. The results of *t*-test (One-sample statistics)

To assess urban livability from the perspective of residents, a one-sample *t*-test (One-Sample Statistics) was used. Since the significance level (Sig.) for all indicators is less than 0.05, it indicates a significant relationship between the research indicators and livability. The next step is to examine the mean values of the indicators. Considering that a 5-point Likert scale (1 to 5) was used to answer the questionnaire items, the average threshold (Test Value) is considered to be 3. Therefore, if the mean of the indicators is greater than 3, it represents a favorable situation, and if it is less than 3, it indicates the undesirability of livability in the research indicators.

According to Table 8, the indicators of access to sports facilities (2.87), recreational and artistic facilities (2.95), and religious facilities (2.64) are in an undesirable situation. Among the indicators, only the indicator of access to green spaces and parks (3.47) is in a favorable situation.

Table 8. Ease of access to land uses

Land uses	One-sample statistics				
	N	Mean	Std. Deviation	Sig. (2-tailed)	*t*-test
Sports	388	2.87	0.802	0.000	−10.46
Recreational and and artistic use	388	2.95	0.777	0.009	−10.37
Religious	388	2.64	0.762	0.003	−18.08
Green spaces and parks use	388	3.47	0.714	0.000	14.3

Table 9 shows the Diversity of Access to Land Uses index. The findings indicate a lack of diversity in access to land uses, as the average index score for the land uses is less than 3. This suggests that the land uses under study do not have a diverse distribution, and residents have limited diversity in accessing land uses.

Table 9. Diversity of access to land uses

Land uses	One-sample statistics				
	N	Mean	Std. Deviation	Sig. (2-tailed)	*t*-test
Sport	388	2.71	0.671	0.001	−12.34
Recreational and artistic	388	2.66	0.599	0.000	−19.01
Religious use	388	2.02	0.697	0.007	−11.41
Green spaces and parks	388	2.73	0.586	0.004	−15.03

Table 10 shows the Quality of Access to Land Use Amenities index. The average scores for religious land use (3.22) and green spaces (3.44) indicate desirable quality of access to amenities from the residents' perspective. However, the quality of access to sports facilities (2.81) and recreational facilities (2.89) has not been evaluated as desirable.

Table 10. Quality of access to land use amenities

Land uses	One-sample statistics				
	N	Mean	Std. Deviation	Sig. (2-tailed)	*t*-test
Sport	388	2.81	0.612	0.000	−13.01
Recreational and artistic	388	2.89	0.693	0.009	−14.64
Religious use	388	3.22	0.447	0.006	12.21
Green spaces and parks	388	3.44	0.603	0.001	17.61

Table 11 shows the Gender and Class Discrimination in Access to Land Uses index. The findings indicate the presence of discrimination in accessing sports facilities (3.22) and recreational facilities (3.14). They have attributed the reasons for gender discrimination in access to sports and recreational facilities to societal culture, the absence of sports programs, and gender attitudes towards sports. Therefore, residents face limitations and issues such as racial, gender, and class discrimination when accessing sports and recreational facilities. However, residents do not face discrimination in accessing amenities and services in religious facilities (2.97) and green spaces (2.77). Thus, the status of these land uses is evaluated as desirable from the residents' perspective in this index.

Table 11. Gender and class discrimination in access to land uses

Land uses	One-sample statistics				
	N	Mean	Std. Deviation	Sig. (2-tailed)	*t*-test
Sport	388	3.22	0.464	0.002	17.71
Recreational and artistic	388	3.14	0.784	0.007	12.21
Religious use	388	2.97	0.502	0.007	−13.76
Green spaces and parks	388	2.77	0.767	0.000	−15.47

4. Discussion

The results indicate that the distribution of land uses is clustered and random. Since the population of District 6 is scattered throughout the area, none of the land uses follow a regular distribution. The dominant direction of land use also confirms the unequal distribution of land uses because if the distribution were scattered and regular, the distribution would be closer to circular. However, the distribution of all land uses in District 6 is elliptical. Therefore, the distribution of land uses in one or more specific directions has caused the concentration of land uses in those directions. Therefore, the pattern of distribution of all "green space, recreational -artistic, sports, and religious" land uses in District 6 is unfair and unequal. This has caused many parts of the district to lack desirable access to land uses. The distribution of land uses stems from profit-oriented thinking and the centralized economic structure of Tehran's urban management, which guides the allocation of spaces for land uses alongside urban development plans. The result obtained indicates that the distribution of urban land use in District 6 of Tehran city, which is prepared based on proposed regulations and urban development plans, has managerial and structural problems. The distribution of land uses in Tehran stems from profit-driven ideologies and the centralized economic structure of city management, which does not take into account the performance of different districts. Furthermore, the interest of both the government and the private sector in investing in land uses that offer high economic benefits (such as administrative, educational, and healthcare uses) has a significant impact on land use distribution. As a result, investment in these land uses has, on the one hand, led to the development of essential land uses, and on the other hand, contributed to the inequity in the distribution of voluntary and social-natured land uses.

The results showed that inequality in the region is not limited to the distribution of land uses. The analysis of the functional radius of land uses based on network analysis at different scales (neighborhood, district, region, city) also indicates unequal access. In functional scales (neighborhood, district, region, city), the percentage of the population who have access to land uses varies. None of the land uses have been able to cover the entire population of District 6 with their services. Land uses with regional and urban functional scales (due to their large area) are defined with a larger functional radius. Therefore, they have included a greater portion within their own functional radius. However, given the limited number of such land uses within the 6-city region of Tehran, residents must spend significant time and expense to access them. The shortage per capita confirms the results of the functional radius. The fact that not all citizens have access to land uses at different scales and are deprived of land use services is because all land uses at functional scales are facing shortages.

The key point of the network analysis was that, although none of the land uses were able to cover the entire population of District 6 with their services, a significant population was covered by their functional radius. In other words, a large population has access to land uses. To examine the accessibility index more accurately, the residents' perspective was taken into account. The most important result of the residents' perspective was that the accessibility index for sports, recreational, and religious land uses was evaluated as undesirable. According to the residents' opinion, these land uses are not easily accessible. Also, the travel time to reach land uses was evaluated as more than 10 minutes (walking). Therefore, the residents' perspective does not confirm the results of the functional radius of land uses, which indicates that a significant portion of the population lacks easy access to land uses. This was an unexpected result.

What is surprising is that land uses lack diversity in accessibility. Residents do not have diverse options for accessing land uses. Since diversity in access to land uses is essential in creating liveable cities, the situation of this indicator is evaluated as undesirable from the residents' perspective. Another important finding is related to the quality of access to land use facilities. According to the residents' perspective, the quality of access to religious and green space facilities is desirable. However, the quality of access to sports and recreational facilities has not been evaluated as desirable. This finding indicates that residents use religious and green space facilities completely and without any barriers.

Another interesting finding in this study is the examination of gender and class discrimination in access to land uses. The findings indicate the existence of discrimination in sports and recreational land uses. They have attributed the reasons for gender discrimination in access to sports and recreational facilities to societal culture, the absence of sports programs, and gender attitudes towards sports. The details of these reasons are as follows:

1. Society's culture: one of the influential factors in gender discrimination in access to sports facilities in the study area is society's culture. In some social settings, women are often considered the weaker gender and are not allowed to access some sports facilities such as gyms and other sports venues.
2. Lack of suitable sports programs for women: some sports facilities in the study area are not suitable for women, and they do not have a suitable space for sports and recreation. For example, some gyms are exclusively for men, and women cannot benefit from them. Also, many sports and recreation halls have designated only one day of the week for women to use.
3. Income inequality: many people may have less access to facilities due to income inequality. For example, some people cannot access facilities due to financial constraints. This constraint is more pronounced for religious women because, from the perspective of religious people (Muslims) in the study area, women should not be employed. Therefore, the lack of financial independence has an impact on reducing access to facilities.
4. Gender-based attitudes toward sports: a percentage of society perceives sports as an activity for men, and they believe that most sports activities are not suitable for women. This gender-based attitude has led to gender discrimination in access to sports facilities. Therefore, residents face limitations and problems such as racial, gender, and class discrimination in sports and recreational land uses.

The clearest finding that emerges from the analysis is that spatial justice has not been considered in the distribution of land uses. Additionally, residents do not have desirable access to land use amenities. An interesting point about the findings is that the results of residents' perspectives confirm the spatial distribution pattern, but challenge the results of the functional radius of land uses.

The findings of the present study regarding the direction of distribution land uses are consistent with the study by Ghasemi et al. (2018). They have concluded in their studies that different areas of Tehran metropolis do not have similar access to biological services, and the distribution pattern emphasizes an unfair dispersion of services. Furthermore, the findings of the present study have shown that the distribution type of land uses in the studied area follows a random and clustered pattern. Therefore, the distribution type has led to an unjust access to land uses. Also, this finding is consistent with the findings of Jiang et al. (2022), Liang et al. (2020), and Yang et al. (2021) who have concluded in their studies that clustered distribution of amenities highlights inequality in access. This is because there is a significant positive correlation between the distribution of amenities and access as well as the improvement of livability.

The findings from the functional radius of land uses in this study emphasize the importance of accessibility. These results further support the idea that adherence to functional radius standards is crucial for easy access to land uses. This finding is consistent with studies that have evaluated the functional radius of public transportation stations based on the TOD model (Transit-Oriented Development) (Furlan et al., 2021; Al-Malki et al., 2022; Berawi et al., 2019). In their studies, they considered a functional radius of 400 to 800 meters for public transportation stations, which is equivalent to a 5 to 10-minute walking distance from a transportation station for an individual. These results reflect the findings from the residents' perspective in the present study, as the residents evaluated the ease of access to land uses within a distance of less than 10 minutes. The findings also revealed that access has a strong correlation with the livability of residents. This result mirrors the studies conducted by Adhikari and Roy

(2021), who emphasized that access is the most influential factor on urban livability.

Conclusions

One of the important concerns of urban managers and planners is the practical, quantitative, and qualitative evaluation of urban livability. This necessity is fully understood in the process of land use planning, which emphasizes spatial justice and access to land uses. Spatial justice evaluation, which deals with the distribution of physical elements according to urban planning standards and residents' access to facilities, is exactly what current livability research lacks. Therefore, this study has focused on evaluating land uses in various dimensions (type of distribution, direction of distribution, radial functional performance, per capita land use) and examining residents' perspectives on the accessibility indicator.

We have shown in objective evaluations that in order to check the spatial justice of, both the distribution patterns and the functional radius of the uses should be considered. Because on one hand, distribution patterns do not consider the dispersion of the population, while the functional radius takes this into account. However, on the other hand, the functional radius lacks an evaluation of the direction of service and land use distribution, whereas distribution patterns determine the direction of land uses. Therefore, for a more accurate examination of the spatial justice of land uses, it is necessary to investigate both distribution patterns and functional radius. Furthermore, in examining the functional radius, we have considered the type and area of land uses. Because we believe that the functional radius can vary depending on the type and area of land use. Another important issue we have considered in analyzing the functional radius is paying attention to the characteristics of the district. For this reason, we have referred to the development plans of the studied district to determine the standards for distances of access to land uses. Furthermore, to provide a more detailed analysis of the results obtained from the aforementioned objective assessments, we have not overlooked the importance of subjective evaluations (residents' perspectives on accessibility indicators to land uses). Therefore, we emphasize that in examining spatial justice and access to urban land uses, the involvement of users' perceptions of that space is highly important.

In this research, it was shown how the performance of the district has affected the distribution of land uses and that not paying attention to the residents' perspectives can play an important role in unequal access to uses. Inequality in access to land uses causes residents to be deprived of easy access to services. This issue can lead to significant differences in the quality of life for residents. Additionally, an unfair concentration of land uses in one part of the district can result in high population density and heavy traffic. This wastes residents' time and energy and negatively impacts their quality of life. Moreover, high density and traffic can lead to increased air and noise pollution, which can harm residents' health in the long run. Furthermore, the unfair distribution of land uses can increase the cost of living. Residing in areas with limited access to services and economic opportunities may result in increased transportation and access-related expenses. The aforementioned consequences can have negative effects on the quality of life for residents.

Therefore, this study has presented possible solutions to the existing challenges of sustainability, the most important of which are: 1) Fair distribution of land uses based on residents' needs. Considering that many residents are deprived of proper access due to the clustered and unequal distribution of land uses, Urban managers should take action in the distribution of land uses based on spatial justice. 2) Attention to the time dimension and addressing plan deficiencies. The standards considered for the radial functional performance of land uses in urban development plans are not responsive to the needs of residents. Since a significant amount of time has passed since the preparation of the plans, there is a need for review. 3) Attention to residents' opinions in plans. Urban plans can contribute to improving the livability of residents, increasing plan acceptance, enhancing transparency and participation, and increasing plan effectiveness. Therefore, residents' opinions and suggestions in urban planning are very important and vital.

Limitations

Every research is usually faced with problems and obstacles during implementation, the present study is not an exception and has faced problems and limitations. In this study, consideration of other dimensions of livability (economic, social, environmental) was ignored. Among the reasons for not paying attention to other dimensions of livability, the following can be mentioned:

1. The geographical location and specific function of the 6th district in Tehran made it more necessary to examine the indicators in the physical dimension.
2. Obtaining statistics and information on indicators requires extensive financial support. Furthermore, examining indicators in various dimensions necessitates significant human resources and expenses.

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Also, we regret that due to limitations, we are unable to provide data availability for this study.

Declaration of generative AI and AI-assisted technologies in the writing process

We have used Grammarly Premium to improve the language of the text.

References

Adhikari, A. K., & Roy, T. B. (2021). Latent factor analysis and measurement on sustainable urban livability in Siliguri Municipal Corporation, West Bengal through EFA and CFA model. *Computational Urban Science*, *1*(1), 23. https://doi.org/10.1007/s43762-021-00023-w

Allen, N., & O'Donnell, G. (2020). *Creating improved housing outcomes: medium-density housing liveability and wellbeing literature review*. BRANZ.

Al-Malki, A., Awwaad, R., Furlan, R., Grosvald, M., & Al-Matwi, R. (2022). Transit-oriented development and livability: the case of the Najma and Al Mansoura neighborhoods in Doha, Qatar. *Urban Planning*, *7*(4), 124–139. https://doi.org/10.17645/up.v7i4.5608

Al-Thani, S. M., & Furlan, R. (2020). An integrated design strategy for the urban regeneration of west bay, business district of Doha (State of Qatar). *Designs*, *4*(4), 55. https://doi.org/10.3390/designs4040055

Andrade, F. M. C., Ferreira, F. A. F., & Correia, R. J. C. (2022). Ranking residential neighborhoods based on their sustainability: a CM-BWM approach. *International Journal of Strategic Property Management*, *26*(6), 410–423. https://doi.org/10.3846/ijspm.2022.18310

Berawi, M. A., Ibrahim, B. E., & Miraj, P. (2019). Developing a conceptual design of transit-oriented development to improve urban land use planning. *Journal of Design and Built Environment*, *19*(1), 40–48. https://doi.org/10.22452/jdbe.vol19no1.4

Comber, A., Brunsdon, C., & Green, E. (2008). Using a GIS-based network analysis to determine urban greenspace accessibility for different ethnic and religious groups. *Landscape and Urban Planning*, *86*(1), 103–114. https://doi.org/10.1016/j.landurbplan.2008.01.002

Eck, J., Chainey, S., Cameron, J., & Wilson, R. (2005). *Mapping crime: understanding hot spots*. https://www.ojp.gov/pdffiles1/nij/209393.pdf

Fu, B., Yu, D., & Zhang, Y. (2019). The livable urban landscape: GIS and remote sensing extracted land use assessment for urban livability in Changchun Proper, China. *Land Use Policy*, *87*, 104048. https://doi.org/10.1016/j.landusepol.2019.104048

Furfey, P. H. (1927). A note on Lefever's "standard deviational ellipse". *American Journal of Sociology*, *33*(1), 94–98. https://doi.org/10.1086/214336

Furlan, R., Petruccioli, A., Major, M. D., Zaina, S., Zaina, S., Al Saeed, M., & Saleh, D. (2019). The urban regeneration of west-bay, business district of Doha (State of Qatar): a transit-oriented development enhancing livability. *Journal of Urban Management*, *8*(1), 126–144. https://doi.org/10.1016/j.jum.2018.10.001

Furlan, R., Zaina, S., & Patel, S. (2021). The urban regeneration's framework for transit villages in Qatar: the case of Al Sadd in Doha. *Environment*, *Development and Sustainability*, *23*, 5920–5936. https://doi.org/10.1007/s10668-020-00853-4

Gerald, B. (2018). A brief review of independent, dependent and one sample t-test. *International Journal of Applied Mathematics and Theoretical Physics*, *4*(2), 50–54. https://doi.org/10.11648/j.ijamtp.20180402.13

Ghasemi, K., Hamzenejad, M., & Meshkini, A. (2018). The spatial analysis of the livability of 22 districts of Tehran Metropolis using multi-criteria decision making approaches. *Sustainable Cities and Society*, *38*, 382–404. https://doi.org/10.1016/j.scs.2018.01.018

Hashemkhani Zolfani, S., Hedayatnezhad Kashi, S. M., & Baharvandi, S. (2022). The assessment of ecological livability for agricultural, pasture, forestry, residential, and tourism activities; study area: north of Iran. *Sustainability*, *14*(19), 12638. https://doi.org/10.3390/su141912638

Information and Communication Technology Organization of Tehran Municipality. (2020). *Statistical yearbook of Tehran city*. Information and Communication Technology Organization of Tehran Municipality.

Istrate, A. L., & Chen, F. (2022). Liveable streets in Shanghai: definition, characteristics and design. *Progress in Planning*, *158*, 100544. https://doi.org/10.1016/j.progress.2021.100544

Jiang, G., Luo, Y., Ma, W., Tian, Y., & Yang, L. (2022). *Compact and livable? Identifying and managing the relationships between intensive land use and urban livability: evidence from 336 cities in China*. https://doi.org/10.2139/ssrn.4120113

Karadimas, N. V., Kolokathi, M., Defteraiou, G., & Loumos, V. (2007, June 4–6). Municipal waste collection of large items optimized with ArcGIS Network Analyst. In I. Zelinka, Z. Oplatkova, & A. Orsoni (Eds.), *Proceedings of the 21st European Conference on Modelling and Simulation* (pp. 80–85), Prague. European Council for Modeling and Simulation. https://doi.org/10.7148/2007-0080

Kourtit, K., Nijkamp, P., Türk, U., & Wahlstrom, M. (2022). City love and place quality assessment of liveable and loveable neighbourhoods in Rotterdam. *Land Use Policy*, *119*, 106109. https://doi.org/10.1016/j.landusepol.2022.106109

Kovacs-Györi, A., Cabrera-Barona, P., Resch, B., Mehaffy, M., & Blaschke, T. (2019). Assessing and representing livability through the analysis of residential preference. *Sustainability*, *11*(18), 4934. https://doi.org/10.3390/su11184934

Lang, W., Hui, E. C., Chen, T., & Li, X. (2020). Understanding livable dense urban form for social activities in transit-oriented development through human-scale measurements. *Habitat International*, *104*, 102238. https://doi.org/10.1016/j.habitatint.2020.102238

Lefever, D. W. (1926). Measuring geographic concentration by means of the standard deviational ellipse. *American Journal of Sociology*, *32*(1), 88–94. https://doi.org/10.1086/214027

Liang, L., Deng, X., Wang, P., Wang, Z., & Wang, L. (2020). Assessment of the impact of climate change on cities livability in China. *Science of the Total Environment*, *726*, 138339. https://doi.org/10.1016/j.scitotenv.2020.138339

Mahmoudi, M., Ahmad, F., & Abbasi, B. (2015). Livable streets: the effects of physical problems on the quality and livability of Kuala Lumpur streets. *Cities*, *43*, 104–114. https://doi.org/10.1016/j.cities.2014.11.016

Mansour, S. (2016). Spatial analysis of public health facilities in Riyadh Governorate, Saudi Arabia: a GIS-based study to assess geographic variations of service provision and accessibility. *Geo-spatial Information Science*, *19*(1), 26–38. https://doi.org/10.1080/10095020.2016.1151205

Öncel, H., & Levend, S. (2023). The effects of urban growth on natural areas: the three metropolitan areas in Türkiye. *Environmental Monitoring and Assessment*, *195*(7), 816. https://doi.org/10.1007/s10661-023-11383-7

Paap, A. (2022). *Greening strategies, participatory planning and liveability* [Master's thesis, Utrecht University]. UU Theses Repository. https://studenttheses.uu.nl/handle/20.500.12932/42755

Paul, A., & Sen, J. (2020). A critical review of liveability approaches and their dimensions. *Geoforum*, *117*, 90–92. https://doi.org/10.1016/j.geoforum.2020.09.008

Silalahi, F. E. S., Hidayat, F., Dewi, R. S., Purwono, N., & Oktaviani, N. (2020). GIS-based approaches on the accessibility of referral hospital using network analysis and the spatial distribution model of the spreading case of COVID-19 in Jakarta, Indonesia. *BMC Health Services Research*, *20*(1), 1–20. https://doi.org/10.1186/s12913-020-05896-x

Sochacka, B. A., Kenway, S. J., & Renouf, M. A. (2021). Liveability and its interpretation in urban water management: systematic literature review. *Cities*, *113*, 103154. https://doi.org/10.1016/j.cities.2021.103154

Tu, F., Zou, S., & Ding, R. (2021). How do land use regulations influence industrial land prices? Evidence from China. *International Journal of Strategic Property Management*, *25*(1), 76–89. https://doi.org/10.3846/ijspm.2020.14051

Urban Observatory of Tehran. (2017). *Monitoring urban development in Tehran: zoning system and land use*. Tehran Municipality Information Technology and Communications Organization.

Yang, Y., Fang, S., Wu, H., Du, J., Tu, H., & He, W. (2021). Spatiotemporal trends and driving factors of urban livability in the Yangtze River Delta agglomeration. *Sustainability*, *13*(23), 13152. https://doi.org/10.3390/su132313152

Yuill, R. S. (1971). The standard deviational ellipse: an updated tool for spatial description. *Geografiska Annaler: Series B*, *Human Geography*, *53*(1), 28–39. https://doi.org/10.1080/04353684.1971.11879353

Zhang, S., Zhen, F., Kong, Y., Lobsang, T., & Zou, S. (2023). Towards a 15-minute city: a network-based evaluation framework. *Environment and Planning B: Urban Analytics and City Science*, *50*(2), 500–514. https://doi.org/10.1177/23998083221118570