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Spatial Justice and Healthcare Accessibility in a Pilgrimage Metropolis: A Multi-Criteria GIS-Based Analysis of Mashhad, Iran

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Abstract

Equitable healthcare access is essential for urban spatial justice, yet pilgrimage cities face unique pressures from fluctuating populations. This study assesses healthcare equity in Mashhad, Iran, by integrating GIS-based network analysis, TOPSIS, and spatial autocorrelation (Moran's I, Getis-Ord Gi*) within a Multi-Criteria Decision Support System (MC-DSS). Results reveal pronounced disparities: a significant negative correlation between population density and hospital bed availability ($r = -0.34$), and a clustered inequality pattern (Global Moran's $I = 0.44$, $p < 0.05$). Optimal access hotspots concentrate near the Holy Shrine (Districts 1 & 8), while peripheral districts (e.g., 6, 10, 12) are cold spots. Notably, geographical proximity alone (2000m buffer) does not ensure effective access, underscoring the need for multidimensional evaluation. Pilgrimage-driven urban development perpetuates spatial injustice. The proposed MC-DSS framework offers a replicable model for tourist and religious cities worldwide, guiding strategic decentralization and targeted investments to achieve equitable healthcare

Keywords: Spatial Justice, Healthcare Accessibility, GIS-MCDA, TOPSIS, Pilgrimage City, Urban Equity, Mashhad

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1. Introduction

Equitable access to healthcare services is a fundamental pillar of sustainable urban development and social justice (Sapkota et al, 2024; Xia et al, 2022), a principle consistently emphasized by international bodies like the World Health Organization (WHO), which defines access as the opportunity for individuals to obtain quality health services without physical, financial, or social barriers (WHO, 2021). Public hospitals serve as primary providers of essential medical care, particularly crucial for vulnerable populations in urban environments (Aljuaid et al, 2021; Arsenault et al, 2020; Fusheini et al, 2016). However, the unequal distribution of healthcare facilities in developing countries' metropolises has created substantial spatial disparities that directly affect public health outcomes (Du et al, 2024; Hu et al, 2019).

As Iran's second most populous metropolis and its foremost religious destination, Mashhad presents a unique case study where millions of annual pilgrims and migrants intersect with urban healthcare needs. The presence of the Holy Shrine of Imam Reza in the city center has established a distinctive urban morphology characterized by religious centrality, where economic, social, and cultural activities radiate from the religious core (Sabet Teimouri et al., 2022; Sarcheshmeh et al., 2020; Shirazi, 2017; Mahmood & Somayeh, 2018). This spatial organization has profoundly influenced the distribution of public services, with over 60% of medical facilities clustered within central zones adjacent to the shrine (Rosina, 2017; Hemmati, 2020). Conversely, western and peripheral districts face severe shortages of such infrastructure. The spatial inequity in healthcare distribution becomes particularly evident when considering that outlying areas are predominantly inhabited by low-income populations who are most dependent on public healthcare services. Furthermore, the pressure exerted by millions of pilgrims on the city's healthcare system has exacerbated these inequalities.

Rapid and disproportionate population growth in recent decades, coupled with unplanned physical expansion, has led to the formation of an unbalanced distribution pattern for health services. The challenge of inequitable access to public hospitals in Mashhad presents complex dimensions. On one hand, high population density in central areas, and on the other hand, horizontal urban expansion and the emergence of informal settlements in peripheral zones, have created serious challenges for the city's health system (Sadid et al, 2022). Preliminary studies indicate that access time to public hospitals exceeds 45 minutes in some peripheral neighborhoods, compared to less than 15 minutes in central districts. These disparities could have irreversible consequences during health emergencies and crises (Hashtarkhani, et al, 2019). Beyond spatial imbalances, additional factors such as hospital bed shortages and deficiencies in public transportation systems have further compounded accessibility problems. Statistics reveal that Mashhad's hospital bed-to-population ratio stands at approximately 1.5 per 1,000 people—below both national (2.5 per 1,000) and international (3 per 1,000) standards (Sadid et al, 2022; Reisi-Nafchy et al, 2014).

The spatial analysis of healthcare accessibility has been a significant focus of urban and medical geography research globally. Various methodologies have been employed to assess equity,

efficiency, and the impact of spatial distribution on population health outcomes. Early studies on healthcare access often relied on simple provider-to-population ratios within administrative boundaries (Joseph & Phillips, 1984). While useful for initial assessments, this approach was criticized for its inability to account for cross-boundary flow of patients, physical barriers, and varying transportation networks. The development of Geographic Information Systems (GIS) marked a paradigm shift, enabling a more nuanced, spatial understanding of accessibility.

A critical methodological advancement was the introduction of the Two-Step Floating Catchment Area (2SFCA) method by Luo and Wang (2003). This method effectively measures spatial accessibility by calculating the ratio of providers to the population within a catchment area, while also accounting for the demand from multiple catchment areas. Cui (2024) applied an enhanced version of this method (E2SFCA) in Melbourne metropolitan area, demonstrating its efficacy in identifying medically underserved areas. The work of Abubakar (2021) in Nigeria is particularly relevant; utilizing a sequential mixed methods approach, their socio-spatial analysis combined quantitative GIS techniques with qualitative insights to deeply understand small-area need and accessibility to primary healthcare, moving beyond pure spatial metrics to incorporate community perspectives.

Beyond simple distance, the role of multi-modal transportation networks is crucial. Kaur Khakh, Fast, and Shah (2019) developed a multimodal accessibility index in Calgary, Canada, which integrated various travel modes. Their study showed that car ownership dramatically increased accessibility scores, highlighting a significant socio-economic dimension to healthcare access.

To handle the complex, multi-dimensional nature of location-allocation problems, Multi-Criteria Decision Analysis (MCDA) integrated with GIS has become a powerful tool. Okundi and Varol (2024) employed a Maximum Covering Location Problem (MCLP) model to optimize the spatial coverage of primary healthcare services. The application of MCDA in complex urban environments is further supported by Tirkolaee and Torkayesh (2022), who developed a cluster-based stratified hybrid decision support model for sustainable facility location selection. Although applied to landfill siting, their model underscores the robustness of advanced MCDA frameworks for tackling public service allocation problems characterized by uncertainty and multiple conflicting criteria, a challenge directly applicable to healthcare planning.

Studies within Iran have also begun to leverage these advanced spatial techniques. Research in cities like Tehran and Isfahan has consistently revealed a central-peripheral divide in the distribution of healthcare facilities. However, specific research on Mashhad has often been limited. Previous studies have typically:

1. Focused on descriptive analyses of distribution without employing advanced spatial statistics.

2. Used single-method approaches, failing to capture the multi-faceted nature of accessibility.

3. Overlooked the unique and critical variable of pilgrimage-driven demand. Mashhad's status as a religious metropolis generates a massive, fluctuating non-resident population, a factor rarely incorporated into existing models.

Despite these methodological advances, a critical gap persists in applying these frameworks to the unique context of religious pilgrimage metropolises. In cities like Mashhad, the dual demand system from permanent residents and millions of annual pilgrims creates a dynamic that fundamentally distorts service allocation and accessibility patterns. Previous studies have either neglected this demographic fluidity or employed single-method approaches insufficient to capture the multi-faceted spatial injustice. Specifically, no study has yet: (1) integrated pilgrimage-driven demand into a comprehensive accessibility model for Mashhad; (2) synthesized multi-modal network analysis with an MCDA technique like TOPSIS within a unified MC-DSS framework; and (3) employed advanced spatial autocorrelation to statistically validate and visualize the resulting equity patterns. This study aims to bridge these gaps by three primary objectives:

1. To develop and apply an integrated GIS-MCDA (TOPSIS) framework to assess and map multi-modal spatial accessibility to public hospitals in Mashhad.
2. To identify and statistically validate spatial clusters (hotspots/coldspots) of healthcare accessibility and analyze their relationship with the city's pilgrimage-oriented urban structure.
3. To derive evidence-based, spatially explicit policy recommendations for reallocating resources and planning future infrastructure to mitigate spatial inequities, providing a model for similar cities.

2. Research Methods

2.1. Methodology Overview

This study adopts a descriptive-quantitative and analytical approach, focusing on the 13 municipal districts of Mashhad as its statistical population. Data for the year 2024 was sourced from the Mashhad Municipality.
The research process involved five key steps:

1. Indicator Selection & Development: Five key indicators were developed to assess accessibility (Fig.1).
2. Multi-Criteria Decision Analysis (MCDA): The TOPSIS technique, implemented in SPSS, was used to rank the districts based on the selected indicators. Indicator weights were determined through expert judgment, utilizing a structured questionnaire (n=20) based on pairwise comparisons (Ming way & Hsu, 2014). The final weights were derived by calculating the geometric mean of expert responses, ensuring a consensus-based weighting scheme.

3. Network Analysis (GIS): Service areas for public hospitals at 1000m, 1500m, and 2000m distances were precisely delineated using network analysis in ArcGIS. This method calculates coverage based on the actual road network, providing a realistic measure of geographical accessibility.

4. Spatial Autocorrelation Analysis: Global and local techniques identified significant spatial patterns

    - Global Moran's I was used to measure the overall clustering pattern of accessibility values across the study area, which is expressed as:

$$I = \frac{n}{s} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\overline{x})(x_j-\overline{x})}{\sum_{i=1}^{n}(x_i-\overline{x})^2}$$

Where:

- x_i and x_j are the attribute values for districts i and j
- $\bar{x}$ is the mean of the attribute values
- n is the number of urban districts
- s is the sum of all coefficients
- $w_{ij}$is the spatial weight between which ranges from -1 to +1. -1 indicates negative spatial interaction and +1 indicates positive spatial interaction. If there is no spatial interaction, Moran's coefficient is zero.

    - Getis-Ord Gi* While Global Moran's I identify the type of spatial pattern, Hot Spot Analysis (Getis-Ord Gi statistic) is employed to illustrate the spatial distribution of degradation patterns. The calculated Z-score indicates areas where high or low values are clustered. This index evaluates each feature in the context of its neighboring features, implying that for a feature to be classified as a statistically significant hot spot, both the feature and its neighbors must exhibit high values (Pattanasak, 2023; Bharti & Minz, 2022). The Getis-Ord Gi statistic is calculated as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij}\, x_j - \bar{x}\sum_{j=1}^{n} w_{ij}}{s\sqrt{\frac{n\sum_{j=1}^{n} w_{ij}^2 - (\sum_{j=1}^{n} w_{ij})^2}{n-1}}}$$

In this formula:

- x_iIs the attribute value for feature j
- w_{ij} is the spatial weight between features i and j
- n is the total number of features

$\bar{x}$ Is expressed as: $\bar{x} = \frac{\sum_{j=1}^{n} x_i}{n}$ And S is expressed as: $s = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{2}} - (\bar{x})^2$

5. Synthesis and Mapping: Integrated visualization presented final accessibility classifications.

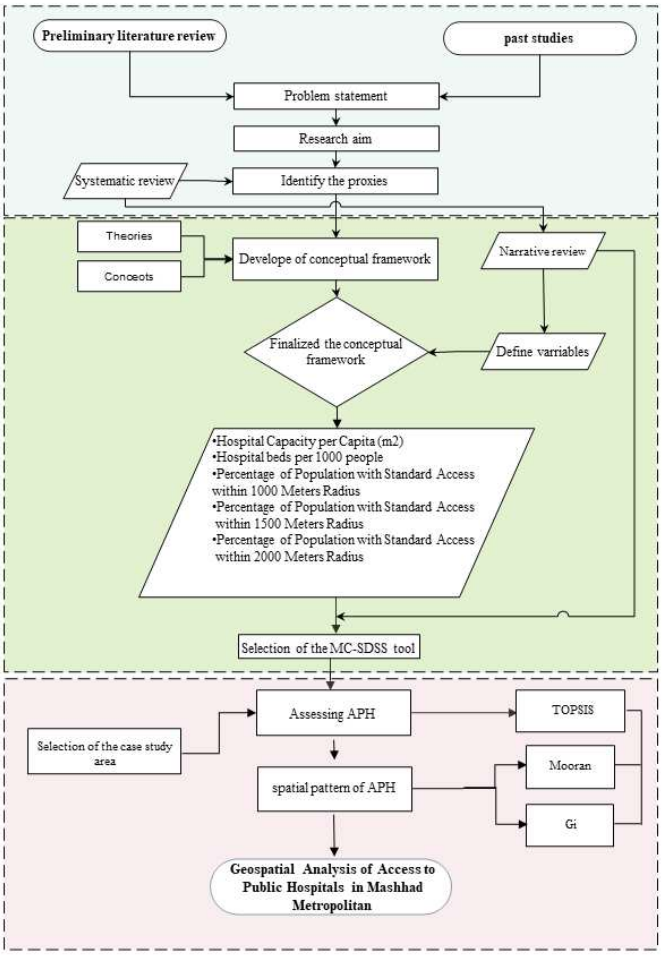


Fig. 1. Research Framework

2.2. Field site

Mashhad (36.2605° N, 59.6168° E), as the capital of Khorasan Razavi Province, encompasses approximately 351 km² with a residential population exceeding 3 million. The city's religious significance attracts nearly 13 million annual pilgrims and tourists (Hedayati-Moghaddam et al,

2019; Sabet Teimouri et al., 2022), creating unique urban dynamics.

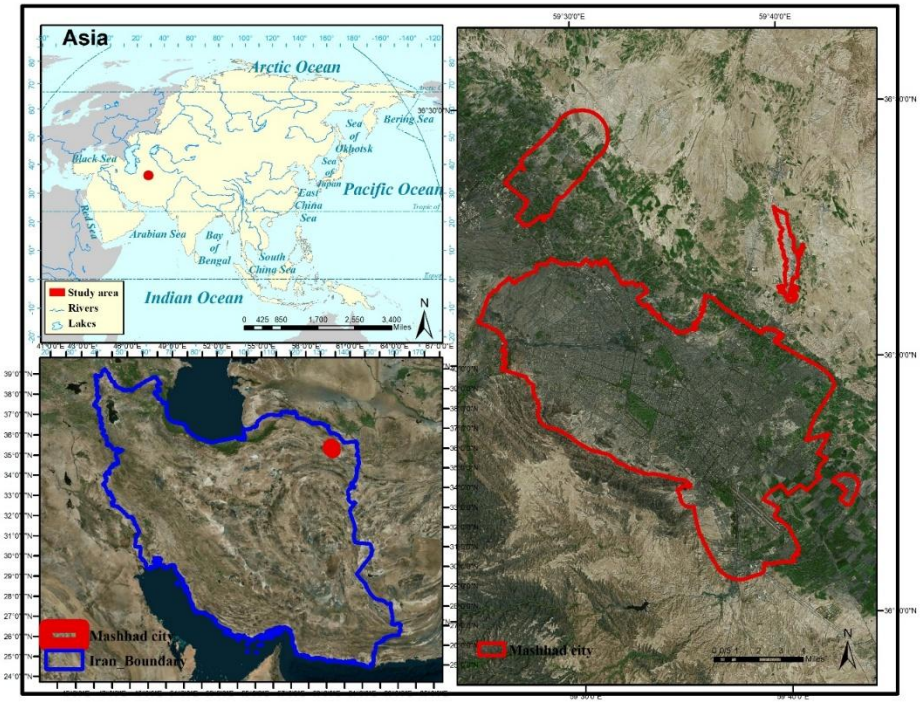


Fig. 2. Study area

Healthcare infrastructure analysis revealed concentrated distribution patterns. The city's 16 public hospitals (total area: 721,000 m²) demonstrate pronounced spatial inequality, with central Districts 9, 8, and 1 containing over 50% of facilities while Districts 5, 6, 10, 11, and 13 lack any public hospitals. This distribution pattern reflects the broader phenomenon of religious centrality shaping urban development (Figure 3).

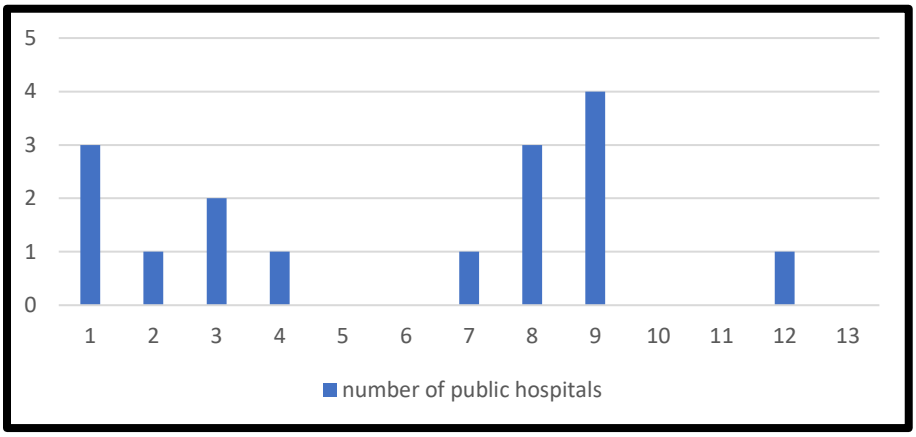


Figure 3: The spatial distribution and number of public hospitals

3. Findings

3.1. District Accessibility Ranking

TOPSIS analysis revealed substantial disparities in healthcare accessibility across districts:

- District 8 (CLI: 0.8907) demonstrated optimal access with comprehensive infrastructure
- Districts 1 (CLI: 0.4950) and 13 (CLI: 0.4351) showed satisfactory accessibility levels
- Districts 4 (CLI: 0.2804) and 9 (CLI: 0.2575) required significant infrastructure improvement
- Districts 5 (CLI: 0.0777), 6 (CLI: 0.0205), and 10 (CLI: 0.0000) exhibited severe deprivation

Intermediate districts (11, 12, 2, 3, 7) required targeted interventions to address specific accessibility challenges.

Table 1: Levels of Access to Public Hospitals in the Districts of Mashhad Based on TOPSIS Model Output

Rank	District	Closeness Index (CLI)	Access Level	Status
1	District 8	0.890684492	Very High	Optimal
2	District 1	0.495000767	High	Satisfactory
3	District 13	0.435133277	High	Satisfactory
4	District 4	0.280390466	High	Satisfactory
5	District 9	0.257471779	High	Satisfactory
6	District 2	0.209138029	Medium	Requires Improvement
7	District 3	0.186592205	Medium	Requires Improvement
8	District 7	0.176375968	Medium	Requires Improvement
9	District 11	0.151864667	Medium	Requires Improvement
10	District 12	0.1427383	Medium	Requires Improvement
11	District 5	0.077663058	Low	Deprived
12	District 6	0.020549714	Low	Deprived
13	District 10	0	Very Low	Severely Deprived

Note: The Closeness Index (CLI) ranges from 0 (worst) to 1 (best).

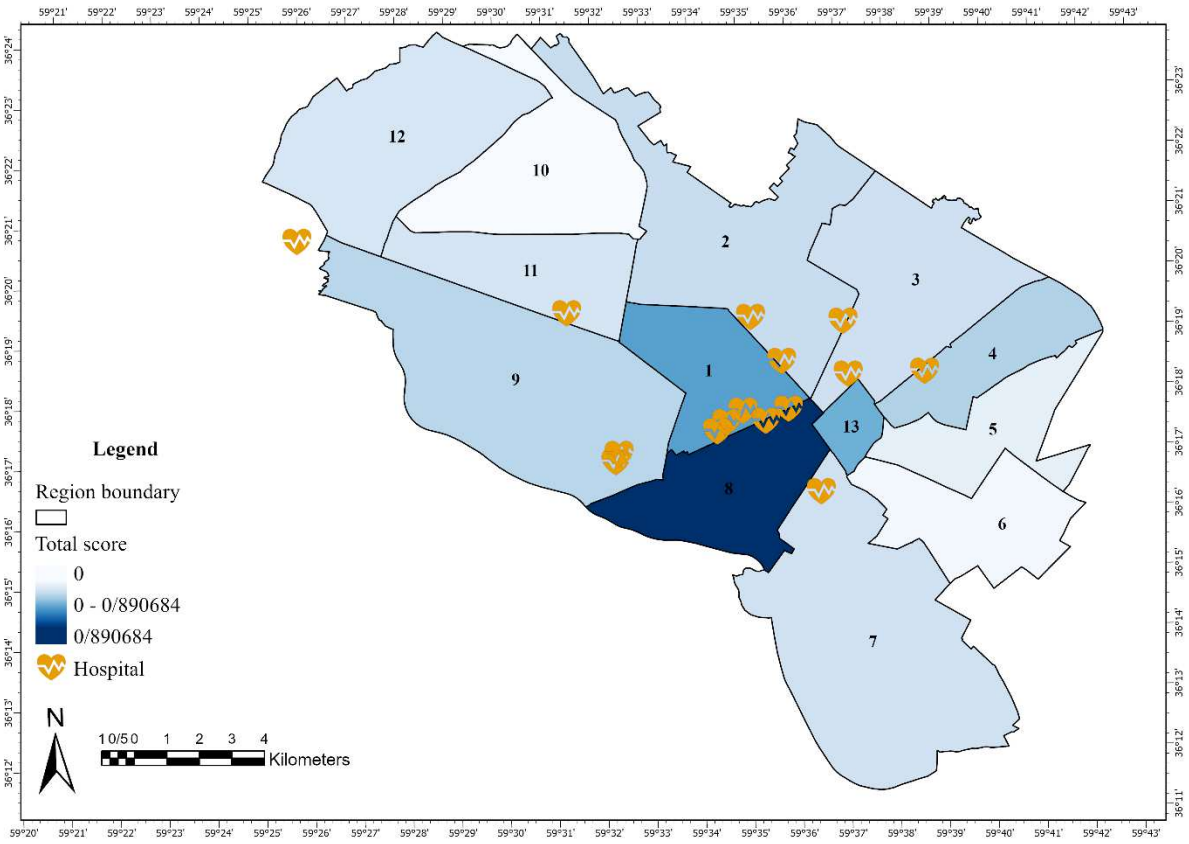


Figure 4: Spatial Classification of the 13 Districts of Mashhad Based on Accessibility to Public Hospitals

3.2. Spatial Pattern Analysis

The results obtained from the application of Moran's Index to the spatial distribution of accessibility yield a value of Moran's I = 0.443716. Given that this value is positive and close to 1, it can be concluded that the data exhibit significant positive spatial autocorrelation. Furthermore, the calculated z-score = 2.422576 exceeds the critical value of 1.65 at the 95% confidence level. Based on the Global Moran's I result, it can be inferred that access to public hospitals in the districts of Mashhad follows a clustered pattern, meaning that areas with high or low access tend to be located near each other (Figure 5). This spatial clustering highlights the presence of clear hotspots and cold spots in the distribution of healthcare accessibility across the city, reinforcing the disparities identified through the TOPSIS analysis and underscoring the need for targeted spatial planning interventions to address the concentrated inequalities.

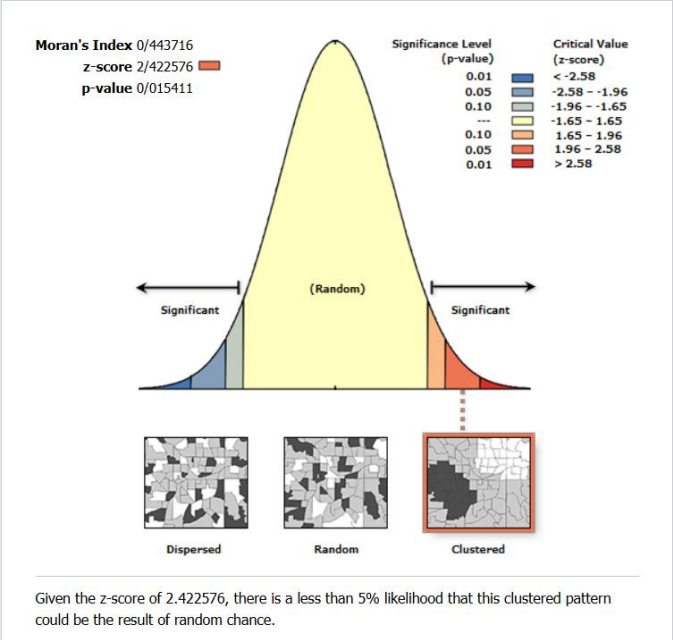


Figure 5: Statistical Results of Moran's Test in Evaluating the Spatial Pattern of Green Space Distribution

3.3. Urban Indicators and Healthcare Accessibility

In the context of analyzing clustering and concentration in access to public hospitals across urban areas of Mashhad, the calculated Getis-Ord General G statistic of 0.118748 indicates a relatively high degree of spatial concentration, suggesting the presence of hotspot and cold spot patterns in certain areas. Although this value is relatively moderate and does not indicate extreme concentration, it demonstrates that access to hospitals is concentrated in specific parts of the city, albeit in a limited and relative manner.

The results reveal that:

- Districts 1 and 8 show better access and form statistically significant hotspots, indicating spatial clustering of higher-than-average accessibility values.
- Districts 6, 10, and 12 form significant cold spots, demonstrating substantially lower accessibility values compared to the overall data average, with this difference being statistically significant. These areas represent zones with below-average activity and characteristics related to hospital access.
- The remaining districts do not follow a specific spatial pattern (Figure 7), meaning they are neither identified as hotspots (with high indicators and significant activity) nor cold spots (with low indicators and reduced activity). These areas are generally at par with the average or show no statistically significant difference from other regions.

The spatial analysis confirms the existence of significant disparities in hospital accessibility across Mashhad, with clear spatial clustering patterns. The presence of both hotspots and cold spots indicates an uneven distribution of healthcare resources, requiring targeted policy interventions to address the spatial inequalities in service provision.

The observed patterns are statistically significant at the 95% confidence level, confirming the reliability of the identified spatial clusters and supporting the need for spatially-focused urban healthcare planning strategies.

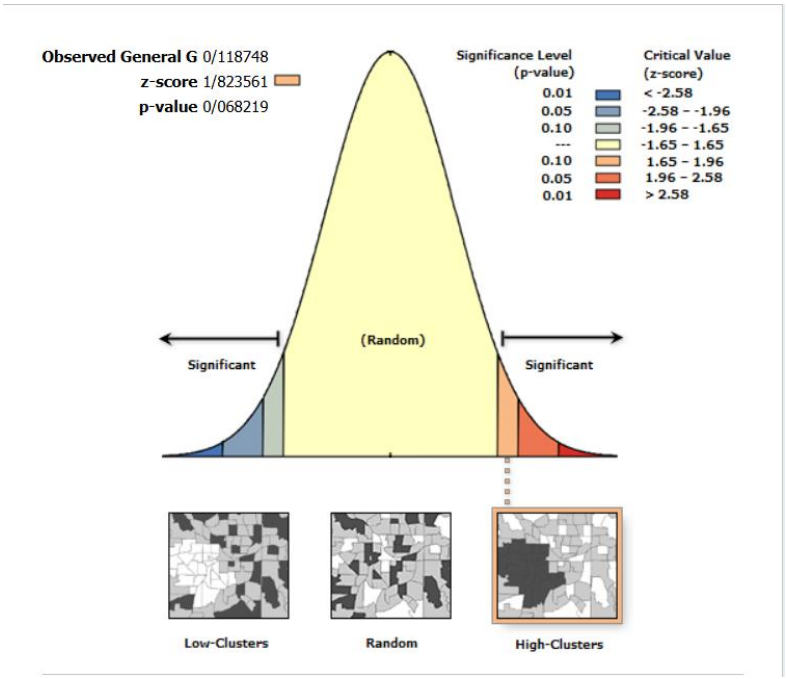


Figure 6: Statistical Results of the Getis-Ord G* Test in Evaluating the Spatial Pattern of Access to Public Hospitals

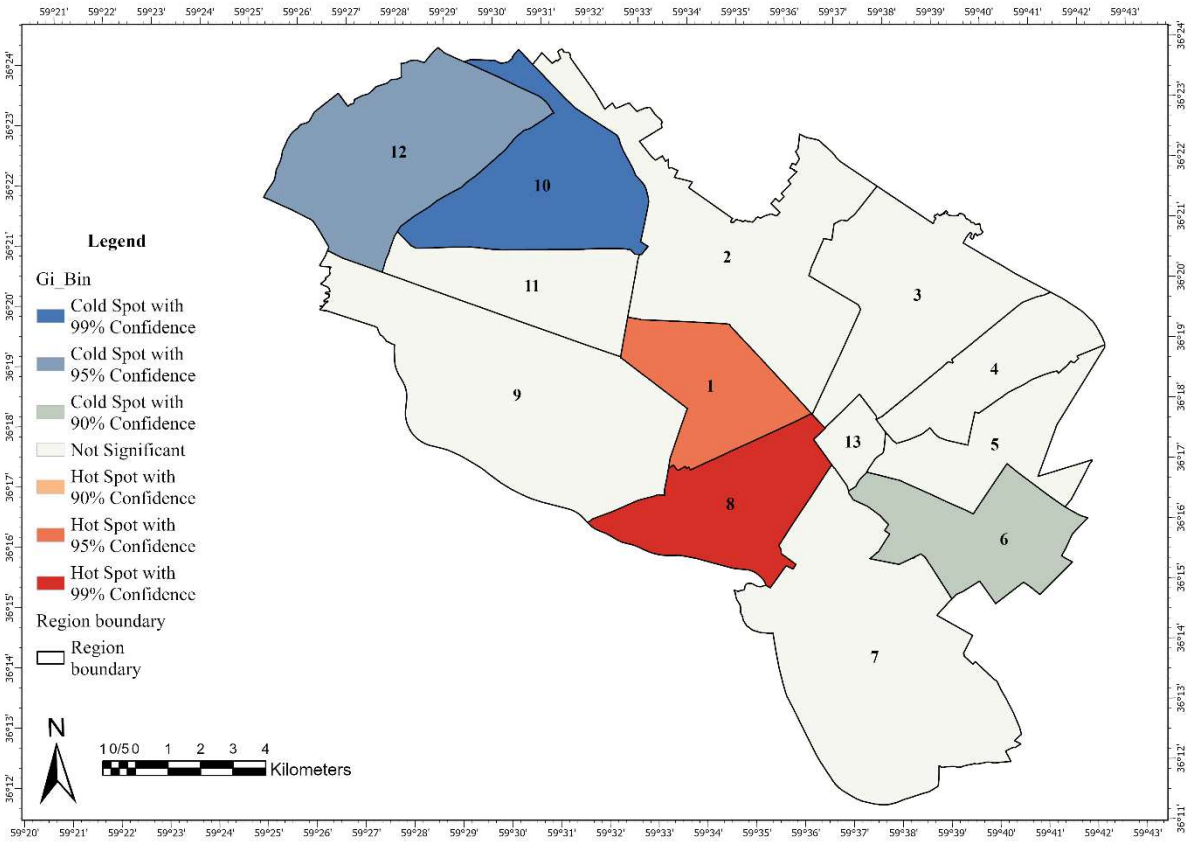


Figure 7: Spatial Autocorrelation Clusters of Public Hospital Accessibility

3.3. Relationship between Hospital Bed Density and Urban Indicators

This section examines the relationships between three key urban indicators: population density, aging index, and population access within a 2000-meter buffer, and their impact on the number of hospital beds per 1,000 people.

The correlation analysis between urban indicators and access to public hospitals in Mashhad revealed the following patterns:

1. Population Density: A significant negative correlation was observed with hospital bed density ($r = -0.34$, $R^2 = 0.12$), indicating service shortages in high-density areas.
2. Aging Index: A weak positive correlation was found ($r = 0.48$, $R^2 = 0.23$), suggesting relative attention to areas with older populations.
3. Geographic Access (2000m buffer): No significant relationship was detected ($r = 0$, $R^2 = 0$), demonstrating that physical proximity alone does not guarantee effective access.

3.4. Spatial Distribution Analysis

The spatial distribution of hospital infrastructure revealed substantial inequalities:

- Disproportionate concentration of resources in certain districts (e.g., District 8 with 3.02 m^2 infrastructure per capita)
- Complete deprivation in other districts (Districts 5, 6, and 13)
- Only 36.7% of the population resides within standard access radius (2000 meters)

The analysis of spatial distribution reveals profound inequities in healthcare infrastructure allocation, leading to several critical implications for urban health policy. First, the inverse relationship between population density and bed availability underscores a fundamental misalignment in resource distribution, creating critical service gaps in the most densely populated urban areas. Second, while the weak positive correlation with the aging index suggests some policy attention to elderly care needs, this response remains insufficient to address the scale of demographic challenges. Third, the complete absence of a relationship with mere geographic proximity demonstrates conclusively that physical distance alone cannot serve as an adequate measure of healthcare access, necessitating more sophisticated multi-dimensional assessment frameworks. Most significantly, the spatial analysis provides unequivocal evidence of systematic inequities in healthcare resource allocation, with disproportionate concentration in certain privileged districts and complete deprivation in others, resulting in exclusion of nearly two-thirds of the population from standard healthcare access thresholds. These findings collectively highlight the urgent need for transformative policy interventions that address both the spatial and social determinants of healthcare equity in urban environments.

Table2: Correlation Summary between Urban Indicators and Hospital Bed Density

Indicator	Correlation (r)	R-squared	Significance	Interpretation
Population Density	-0.34	0.12	$p < 0.05$	Significant negative relationship
Aging Index	0.48	0.23	$p < 0.05$	Weak positive relationship
Geographic Access (2000m)	0.00	0.00	NS	No significant relationship

**NS = Not Significant

These findings demonstrate the complex interplay between demographic factors, spatial distribution, and healthcare accessibility, emphasizing the need for integrated urban health planning approaches that address both spatial and social determinants of health access.

4. Discussion

The findings of this study provide robust empirical evidence that access to public hospitals in Mashhad is not randomly uneven but is systematically structured by the city's primary identity as

a pilgrimage destination. Correlation analysis between urban indicators and hospital bed density showed a significant negative relationship between population density and the number of hospital beds per 1,000 people ($r = -0.34$, $R^2 = 0.12$), indicating service shortages in densely populated areas. In contrast, the aging index showed a weak positive correlation ($r = 0.48$, $R^2 = 0.23$), suggesting relative attention to areas with older populations. However, geographical proximity (calculated within a 2000-meter radius) showed no significant relationship with bed distribution ($r = 0$, $R^2 = 0$), demonstrating that physical proximity alone does not guarantee effective access.

Spatial clustering analysis further confirms inequalities in service distribution. The global Moran's index of 0.4437 indicates significant positive spatial autocorrelation, meaning that areas with similar access levels are clustered together. Low-access areas (cold spots) are primarily located in western Mashhad, including Districts 10 and 12, showing significant infrastructure and service deficiencies. In contrast, high-access areas (hot spots) such as Districts 1 and 8 benefit from superior accessibility; District 8 enjoys high access concentration due to its proximity to the Holy Shrine of Imam Reza (AS) and central location, while District 1 demonstrates adequate access in central and commercial areas.

These results indicate that the low service concentration in certain peripheral areas, such as District 6, requires targeted policies for infrastructure development and service enhancement. Planning interventions should focus on reducing geographical distances and addressing unequal development, as these factors significantly impact health service distribution and access.

Recent studies emphasize the importance of spatial equity in health service access and propose solutions such as location-allocation models and multi-criteria analysis to improve spatial coverage (Okundi & Varol, 2024; Kaur Khakh et al., 2019). This study employed GIS technology and multi-criteria decision support systems (MC-DSS) to conduct a comprehensive analysis, revealing substantial inequalities in health service distribution in Mashhad. The results align with findings by Akakba and Lahmar (2023), who confirm the use of 2SFCA methods for measuring inequalities.

Furthermore, the results show that central and developed areas such as Districts 1 and 8 enjoy significantly better access, while western (District 12) and peripheral areas (District 6) face considerably lower access levels. These findings are consistent with the study by Khakh et al. (2019), which highlights the important role of transportation type and public transit facilities in determining access levels, particularly in a city like Mashhad with limited public transportation networks and unique geographical features, including distance from main centers and settlement patterns that influence regional access. Additionally, the findings underscore the necessity of paying special attention to cultural and demographic factors, such as the effects of pilgrimage and residence in religious cities, factors often overlooked in global studies (Khayal, 2019). Spatial analysis based on Mashhad's specific characteristics can provide more precise and effective policy solutions to reduce inequalities and ensure fairer distribution of health services.

Overall, utilizing place-based approaches and multi-criteria analyses is crucial for better understanding spatial inequalities in religious and less-developed cities and can address gaps in purely quantitative and conventional analyses.

This research demonstrates that access to medical facilities and public hospitals in Mashhad is heavily influenced by the city's role as a pilgrimage destination. Areas surrounding the Holy Shrine of Imam Reza (AS), such as District 8, benefit from high concentrations of health and hospital services due to the presence of pilgrims and economic activities related to religious tourism. This concentration reflects "pilgrimage demand-based development," meaning that medical centers and infrastructure in these areas are designed to meet the needs of both residents and pilgrims. In contrast, western and peripheral areas such as Districts 6 and 12 are less developed and have fewer services due to their distance from pilgrimage centers and lower pilgrim concentrations. This spatial inequality indicates that "uneven resource distribution" is largely linked to the city's pilgrimage function, and the concentration of services in high-traffic pilgrimage areas limits access for other populations.

Correlation and regression analyses in this study show that population density has a significant negative relationship with the number of hospital beds per 1,000 people, while the aging index has a weak positive relationship with this variable. However, purely geographical access (2000-meter radius) shows no significant impact on bed distribution, indicating that physical proximity alone does not ensure effective access.

5.Conclusion

This research aimed to conduct a spatial analysis of access to public hospitals in Mashhad metropolis using a Spatial Multi-Criteria Decision Support System (MC-SDSS), which revealed significant inequalities in the distribution of healthcare services across the city. The ranking of districts using the TOPSIS technique showed that District 8, with a priority coefficient of 0.890684492, ranked first with a "very good" status, benefiting from its proximity to the Holy Shrine and well-developed healthcare infrastructure. District 1 followed with a coefficient of 0.495000767, ranking second with a "relatively good" status. Districts 13 and 4 ranked third and fourth, showing "moderate" to "good" status, while Districts 5, 6, and 10, with low priority coefficients (0.077663058, 0.025549714, and 0, respectively), demonstrated "poor" to "very poor" status, indicating an urgent need for healthcare infrastructure development. The Global Moran's Index (0.443716) confirmed significant positive spatial autocorrelation in access patterns, indicating that areas with similar access levels tend to cluster together. Additionally, the Gi index (0.118748) revealed a relatively high concentration of healthcare services in specific clusters, primarily in central and developed areas.

The results demonstrate that the distribution of healthcare services in Mashhad is heavily influenced by the city's role as a pilgrimage destination. Areas close to the Holy Shrine, particularly District 8, benefit from excellent access due to high demand from pilgrims and related economic and service activities. In contrast, western and peripheral areas such as Districts 6 and 12, which

lack significant pilgrim populations, suffer from inadequate healthcare infrastructure and spatial inequalities. Furthermore, population fluctuations resulting from religious tourism significantly impact service demand and resource allocation.

The following evidence-based recommendations are proposed:

1. Targeted Infrastructure Development: Prioritize healthcare infrastructure investment in underserved districts (e.g., Districts 5, 6, and 10) to reduce spatial inequalities.
2. Decentralization of Services: Develop strategies to distribute healthcare resources more evenly across the city, reducing reliance on central areas.
3. Transportation Improvements: Enhance public transportation networks to improve accessibility for residents in peripheral areas, ensuring they can reach healthcare facilities efficiently.
4. Dynamic Resource Allocation: Implement flexible resource allocation models that account for population fluctuations caused by religious tourism, ensuring adequate service provision during peak periods.
5. Integrated Urban Planning: Incorporate healthcare accessibility as a key factor in urban planning decisions, particularly in developing areas, to ensure equitable service distribution.
6. Public-Private Partnerships: Encourage collaboration between public and private sectors to expand healthcare infrastructure in underserved regions.
7. Monitoring and Evaluation: Establish a systematic monitoring framework to track progress in reducing spatial inequalities and adjust policies as needed.

This study highlights the critical need for spatially-aware healthcare policy in religious metropolises like Mashhad, where traditional urban development patterns intersect with unique demographic challenges posed by religious tourism.

Note:

- This study was conducted in Mashhad metropolis, located in northeastern Iran (36°17′N, 59°36′E)”
- The authors declare no competing interests
- No funding was received for conducting this study
- The data supporting the findings of this study are available from the corresponding author upon reasonable request

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