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# Spatial Assessment of Accessibility to Public Healthcare Services: A Case Study on Accessibility to Hospitals in Shiraz

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**Abstract**

**Introduction:** Unfair distribution of healthcare services is one of the most important issues all over the world. The present study aimed to determine the distribution pattern of available hospital beds and the accessibility pattern to hospitals in Shiraz.

**Methods:** This was an analytical study. At first, spatial distribution pattern of available hospital beds was determined using Moran's Index (Moran's I). Then, the accessibility pattern to hospitals was determined using Euclidean distance and network travel distance metrics. All of the analyses were conducted using Arc GIS (10.3) software.

**Results:** The results revealed that available hospital beds had a random and unbalanced distribution pattern in Shiraz based on Moran's I (Moran's I=-0.05). Besides, according the achieved standard service areas for the existing hospitals, calculated by using Network analysis tools, 65.47% of Shiraz population was underserved in terms of accessibility. Furthermore, assessment of accessibility patterns resulted from both types of applied distances, indicating that in most cases hospitals were located in the central parts of the city.

**Conclusion:** According to the results of the present study, distribution of hospitals in Shiraz was unfair. Therefore, policymakers are suggested to plan in order to increase the number of Shiraz hospitals. They are also recommended that they should give priority to establishing new hospitals in areas without standard accessibility over areas with standard accessibility based on the results of the present study.

**Keywords:** Accessibility, Available bed, Hospital, Moran's index, Network analysis, Spatial pattern

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## Introduction

Inadequate access to healthcare services is one of the various determinants of social health inequities (1). Thus, equity in healthcare can be measured using the concept of accessibility (2). One of the most prominent dimensions of accessibility to health services is geographical accessibility (3, 4). In fact, distribution of healthcare services affects the individuals' accessibility level, and unequal accessibility levels can lead to unequal utilization of healthcare services (5). Geographical accessibility and disparities in access between different population groups can be described and understood using Geographical Information System (GIS) (6). In this context, geographical accessibility can be measured by indicators, such as distance and travel time or travel cost to a resource (7, 8). Distance and travel time are the most common indicators for defining geographical accessibility (9). Rosero-Bixby have used distance metric in order to evaluate spatial access to health care and its equity. They found that half of the Costa Ricans reside in less than 1 km away from an outpatient care facilities and 5 km away from a hospital; they also revealed substantial improvements in access and equity to outpatient care between 1994 and 2000. (10). Kalogirou and Mostratos have used distance metric for determining population access to Greek public hospitals. They found that almost two thirds of all people living in Greece have good accessibility (they are residing within 5 km straight distance from the nearest hospital). They also revealed that there are great inequalities between population age groups. People aged 65 and over are rather underserved than the total population in terms of accessibility to public hospitals (11). Pedigo and Odoi have used travel time metric in order to investigate disparities in geographic accessibility to emergency stroke and myocardial infarction care in East Tennessee. They found that approximately 8% and 15% of the study population did not have timely geographic accessibility to emergency stroke and MI care, respectively; also, underserved people in terms of access were living in rural areas (12). Up to now, different types of distance measures have been used in health researches. Euclidean distance is the most commonly used metric because of the ease of its calculations, while network travel distance (road travel distance) is the most reliable distance metric (13, 14) by considering real road infrastructure. Euclidean distance has been defined as the length of the straight line connecting two points, while network travel distance refers to the length of the shortest road connecting two points(15). Network analysis is a spatial analysis technique that calculates the distance between two points or nodes using network data, such as roads, railways, and rivers networks (16). Arc GIS network analyst tool is also a powerful extension help to model realistic network conditions by considering turn restrictions, speed limits, height restrictions, and traffic conditions (17).

Saving patients' traveling time to healthcare facilities in emergency situations, reducing traveling costs, and improving equity in health are some of the advantages of better accessibility to healthcare facilities. Therefore, equity in access to healthcare services plays a vital role in quality of life. Population growth, in turn, increases the demand for establishing new healthcare services. According to Iran's last census report (2011), Shiraz, the capital of Fars province, is the sixth most populous city in Iran and the main destination for immigrants from Fars and other provinces. Considering the fact that most individuals who migrate to Shiraz inhabit in the marginal parts of the city, the population of these parts is growing increasingly. Considering these problems, health policymakers should be aware of the distribution pattern of the existing health facilities in the city. Recognizing underserved population helps the policymakers to decide where to establish new health facilities in a rational and equal manner. Therefore, the present study aimed to determine the distribution pattern of available hospital beds and the accessibility pattern to hospitals in Shiraz.

## Methods

This is an analytical study conducted in Shiraz (2016). Shiraz, the capital of Fars province, is located in the southwest of Iran. According to the vice chancellor of treatment of Shiraz University of Medical Sciences, in 1395 Shiraz had 34 hospitals in total (20 governmental hospitals and 14 non-governmental hospitals). One of these hospitals was excluded from this study because it provided services to prisoners.

The applied data were prepared by collaboration of the Municipality Organization of Shiraz. The ethical commitment was given to the Municipality Organization of Shiraz for providing them with a copy of the results. Furthermore, confidentiality and privacy of information were also maintained in all steps of the study. Data were arranged in geographical layers and shape file format.

In this study, at first, in order to determine the distribution pattern of available hospital beds, we calculated the global Moran's Index (Moran's I), using Arc GIS 10.3. Moran's I developed by Patrick Alfred Pierce Moran is a measure of spatial autocorrelation (18, 19). This kind of autocorrelation is characterized by a correlation in a signal among nearby locations in space (20, 21). Spatial autocorrelation is a multi-dimensional and multi-directional autocorrelation and is consequently more complex compared to one-dimensional autocorrelation (20). Moran's I is defined as:

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij} (X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2} \quad (1)$$

Where N is the number of spatial units indexed by i and j, X is the statistical variable of interest, $\bar{X}$ is the statistical mean of X, and $w_{ij}$ is a spatial weights matrix element.

Moran's I can range from -1 to +1, with -1, 0, and +1, indicating dispersed, random, and clustered distribution patterns, respectively (22). Moran's I can be interpreted by Z-score, too. In this way, the null hypothesis states that there is no spatial autocorrelation between the spatial units. The variance can be calculated using the following equation:

$$Var\,(I) = \frac{NS_4 - S_3 S_5}{(N-1)(N-2)(N-3)(\sum_i \sum_j W_{ij})^2} - (E(I))^2 \quad (2)$$

Where the expected value is:

$$E\,(I) = \frac{-1}{N-1} \quad (3)$$

And

$$S_1 = \frac{1}{2} \sum_i \sum_j (w + w_{ji})^2 \quad (4)$$

$$S_2 = \sum_i (\sum_j w_{ij} + \sum_j w_{ji})^2 \quad (5)$$

$$S_3 = \frac{N^{-1} \sum_i (x_i - \bar{x})^4}{(N^{-1} \sum_i (x_i - \bar{x})^2)^2} \quad (6)$$

$$S_4 = (N^2 - 3N + 3) S_1 - NS_2 + 3(\sum_i \sum_j w_{ij})^2 \quad (7)$$

$S_5=(N^2-N)S_1$-2N$S_2$+6$(\sum_i \sum_j w_{ij})^2$ (8)

In the present study, considering the Arc GIS software default, P value (significant level) was considered equal 0.73.

Then, in order to determine the accessibility pattern to hospitals, we calculated the network travel distance and Euclidean travel distance, using Arc GIS software. The travel distance shows the distance that a patient must travel to a hospital. In order to calculate the network travel distance, we used GIS-based network analysis process. In this method, considering road network, the radius of 1500m around the center of every hospital (standard service area) was determined. The service areas were considered as the served areas, while other areas located out of these radiuses were considered as underserved areas. In the latter method, Euclidean distances of all residential land-uses from the nearest hospital were calculated, using GIS. Shorter distance indicates better accessibility; therefore, accessibility was divided into five levels based on the calculated distances, including very high (<1500m), high (1500m-3000m), middle(3000m-4500m), low(4500m-6000m), and very low(>6000m).

The Euclidean distance between the points q and p refers to the length of the straight line connecting them ($\overline{qp}$). The distance is defined as:

d( p, q)=d(q, p)=

$$\sqrt{(q_1-p_1)^2+(q_2-p_2)^2+\cdots+(q_n-p_n)^2}=$$

$$\sqrt{\sum_{i=1}^{n}(q_i-p_i)^2} \quad (9)$$

In equation (9), p=($p_1$, $p_2$, …, $p_n$) and q=($q_1$, $q_2$, …, $q_n$) are two points in a n-dimensional space where (i, j, …, n) indicates the dimension's number.

## Results

The results of the calculation of Moran's I are presented in Table 1. Accordingly, Moran's I (-0.05) was approximately equal to zero. Thus, available hospital beds are dispersed randomly and in an unbalanced manner in Shiraz. P value and Z-score also approved the determined pattern.

**Table 1:** Distribution pattern of the hospital beds in Shiraz

| | |
|---|---|
| Moran's Index | -0.05 |
| Z-score | -0.3404 |
| P value | 0.7335 |

The accessibility patterns obtained from both applied distances indicated that the existing hospitals covered the central parts of the city more as compared to the marginal areas (Figure 1). In other words, the accessibility level got lower by moving towards the marginal parts of the city.

Considering the determined service areas, the hospitals with ID=27 covered the largest population (2.8% of total Shiraz population) compared to other hospitals. On the other hand, the hospitals with ID=3 covered the smallest population compared to other hospitals because it was not located in a residential area (Table 2).

Considering the hospitals' average Euclidean distance from all residential land-uses in the city, the hospitals with ID=19 had the highest accessibility level (Table 3).

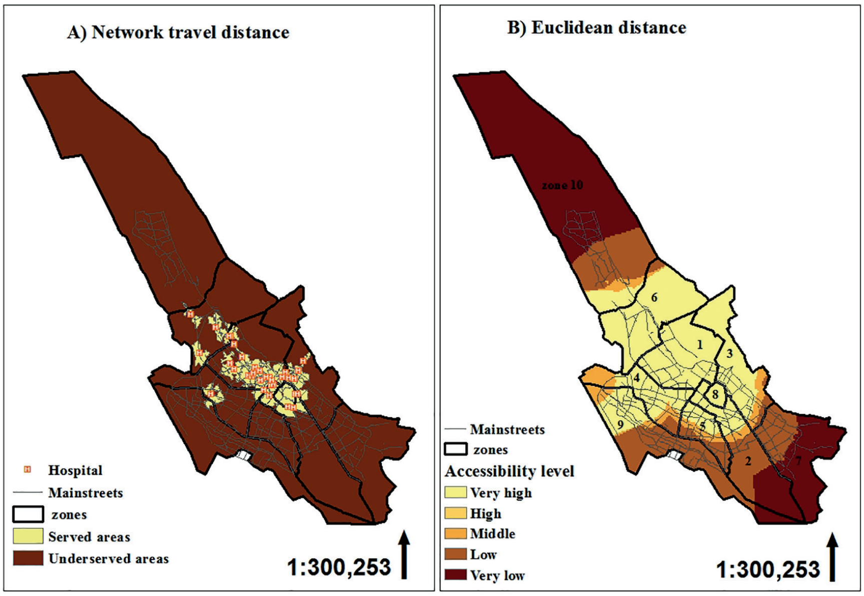


**Figure 1:** The accessibility pattern to Shiraz hospitals

**Table 2:** The population and area covered by the hospitals' standard service areas

| ID | Hospital Name | Covered Area (HA) | Covered population | Municipality zone |
|---|---|---|---|---|
| 1 | Army | 167.61 | 14004 | 1 |
| 2 | Ibn Sina | 124.94 | 16502 | 3 |
| 3 | Ordibehesht | 18.47 | 0 | 1 |
| 4 | Iran NAJA | 86.78 | 12274 | 2 |
| 5 | Ami oncology | 327.38 | 17269 | 6 |
| 6 | Besat | 160.87 | 24317 | 6 |
| 7 | Pars | 138.48 | 13997 | 1 |
| 8 | Jannat | 194.89 | 24689 | 4 |
| 9 | Rajaei | 11.41 | 218 | 1 |
| 10 | Hafez | 65.57 | 11693 | 1 |
| 11 | Zeinab | 97.42 | 17598 | 2 |
| 12 | AliAsqar | 71.49 | 5617 | 1 |
| 13 | Khodadost | 412.42 | 30417 | 1 |
| 14 | Khalili | 72.68 | 5677 | 1 |
| 15 | Az-Zahra | 247.25 | 39913 | 2 |
| 16 | Mir-Hoseini | 84.18 | 9727 | 3 |
| 17 | Mir | 250.49 | 20622 | 1 |
| 18 | Dena | 24.54 | 9265 | 1 |
| 19 | Shafa | 194.89 | 4985 | 1 |
| 20 | Shahryar | 119.07 | 10914 | 2 |
| 21 | Beheshti | 210.64 | 30748 | 3 |
| 22 | Chmaran | 393.88 | 8174 | 1 |
| 23 | Dastqeib | 104.33 | 13953 | 3 |
| 24 | Faqihi | 30.61 | 3581 | 1 |
| 25 | Alavi | 210.64 | 30000 | 3 |
| 26 | Farahmand | 43.59 | 6164 | 1 |
| 27 | Qotb-Oddin | 255.63 | 40461 | 2 |
| 28 | Kosar | 413.84 | 17212 | 6 |
| 29 | Alqadir | 68.8 | 456 | 3 |
| 30 | Shoshtary | 188.4 | 30192 | 1 |
| 31 | Markazy | 182.87 | 12571 | 1 |
| 32 | Moslemin | 92.81 | 9982 | 2 |
| 33 | Namazi | 145.9 | 11283 | 1 |

## Discussion

Hospitals provide the policymakers and those in charge of the reform in healthcare services with many challenges (23). One of such challenges is people's accessibility to health services and its equity. Health policymakers should be aware of the distribution pattern of the existing health facilities. Fast and easy access is one of the most important criteria in selecting hospital location (24). Recognizing underserved population helps the policymakers to decide where to establish new health facilities equitably when they intend to establish new hospitals. The findings of the present study can help the policymakers to recognize the pattern of the distribution of available beds in Shiraz, and to know which parts of the city are underserved in terms of access to hospitals. Population growth in Shiraz is on increase. Population growth, in turn, increases the demand for establishing new healthcare services. Thus, it is important to know which parts of the city are more underserved in terms of access to hospital services.

In the present study, based on the calculated Moran's I, available hospital beds were dispersed in an unbalanced manner in Shiraz. This unbalanced distribution can lead to disparities and inequity in the accessibility level of individuals who live in different parts of the city.

Considering the determined network-based accessibility pattern (Figure 1-A), four zones (5, 7, 9, 10) were located in underserved areas and they were completely deprived from accessibility to hospitals. Additionally, 6 zones (1-4, 6, 8) were partly deprived from accessibility. Overall, 34.57% of Shiraz population had standard accessibility and 65.47% of the population was completely deprived. Based on Euclidean distance (Figure 1-B), the lowest accessibility level was related to northwest, south, southeast, and southwest of Shiraz. Large parts

**Table 3:** The hospitals' Euclidean distance from the residential land-uses in Shiraz

| ID | Distance to the nearest residential land-use(m) | Distance to the farthest residential land-use(m) | Average distance to all residential land-uses of the city(m) |
|---|---|---|---|
| 1 | 89.67 | 1669.22 | 846.31 |
| 2 | 54.88 | 3723.66 | 2059.91 |
| 3 | 186.84 | 1740.80 | 920.01 |
| 4 | 25.10 | 618.42 | 321.24 |
| 5 | 27.20 | 2100.78 | 1129.19 |
| 6 | 118.58 | 11075.61 | 5792.53 |
| 7 | 19.73 | 841.67 | 386.35 |
| 8 | 56.93 | 5717.99 | 2288.69 |
| 9 | 102.12 | 1454.04 | 660.13 |
| 10 | 49.76 | 1658.09 | 526.93 |
| 11 | 87.79 | 11380.13 | 4667.31 |
| 12 | 17.28 | 878.29 | 386.06 |
| 13 | 13.97 | 2204.28 | 1009.01 |
| 14 | 22.89 | 565.20 | 284.46 |
| 15 | 96.01 | 5750.87 | 2539.22 |
| 16 | 17.50 | 901.38 | 360.78 |
| 17 | 15.40 | 2729.90 | 1287.53 |
| 18 | 435.22 | 1816.31 | 1263.37 |
| 19 | 25.27 | 671.16 | 279.69 |
| 20 | 43.00 | 606.81 | 319.66 |
| 21 | 63.50 | 1241.72 | 574.65 |
| 22 | 243.57 | 1747.43 | 1074.47 |
| 23 | 99.10 | 1671.82 | 708.29 |
| 24 | 96.65 | 1572.84 | 716.35 |
| 25 | 16.85 | 9425.04 | 2785.31 |
| 26 | 55.28 | 2060.51 | 695.92 |
| 27 | 23.81 | 5778.32 | 2298.77 |
| 28 | 284.50 | 2546.60 | 14296.17 |
| 29 | 1833.11 | 3758.59 | 2872.66 |
| 30 | 34.58 | 3967.95 | 1583.29 |
| 31 | 60.34 | 932.78 | 534.51 |
| 32 | 36.38 | 1236.32 | 659.84 |
| 33 | 167.48 | 1626.77 | 756.36 |

of five zones (2, 5, 7, 9, 10) were located in these deprived areas. Overall, 33.49% of the residential land-uses had standard accessibility, while 66.51% had no standard accessibility. In details, 33.49% of the residential land-uses had very high (standard) accessibility, 28.92% had high accessibility, 17.54% had middle accessibility, 7.15% had low accessibility, and 12.86% had very low accessibility. Considering the average Euclidean distance of the hospitals from all residential land-uses in the city, the hospital with ID=19 had the highest accessibility level. This hospital was located in zone 1 in the central part of the city. On the other hand, the hospital with ID=28 that was located in zone 6 had the lowest accessibility level.

Generally, using different accessibility metrics can yield different results (9). Hence, developing accurate accessibility metrics is important in health researches. One of the most commonly used metrics (Euclidean distance) and one of the most accurately used metrics (network travel distance) in health researches were applied in this study. Euclidean distance metric does not take topographic considerations such as rivers, railway or barriers which can influence the people's ability to access a facility into account. However, network distance metric takes such barriers into account (25). In the present study, based on the two applied methods, four zones (5, 7, 9, 10) were identified as areas with the least accessibility level using both methods. The present study findings revealed no equity in accessibility to hospital services in Shiraz. Various studies have also revealed that inequity in health services is a major problem in America (26, 27), Taiwan (28), India (29, 30), Italy (31), and Mexico (32, 33). Although inequity in utilization of health services is a global issue, several studies have indicated improvements in accessibility to health services in some countries, such as China (34, 35) and Costa Rica (10). Accordingly, policymakers are recommended to pay attention to underserved areas. The present study results can help healthcare policymakers make more efficient decisions because its findings indicated which parts of Shiraz were underserved in terms of access to hospitals. Saving the patients' traveling time to healthcare facilities in emergency situations, reducing traveling costs, and improving equity in healthcare are some of the advantages of better accessibility to healthcare facilities.

### *Study limitations and strengths*

Although geographical accessibility is so essential, it is not the only factor to assess accessibility to health facilities in a community. Accessibility is a complex concept and encompasses many dimensions, including availability, ethnicity acceptability, geographical accessibility, cultural accessibility, etc. However, it was not possible to evaluate all these aspects in this research. We hope to evaluate other aspects of accessibility to health facilities in other studies.

## Conclusion

The present study findings revealed no equity in accessibility to hospital services in Shiraz. Distribution of health services in Shiraz was unfair and according to the existing hospital standard service areas, 65.47% of Shiraz population was underserved in terms of accessibility. The present study recommends policymakers to give priority to establishing new hospitals in areas without standard accessibility over areas with standard accessibility when policy makers intend to establish new hospitals, based on Figure 1. Probably, policymakers can steer public participation in the direction of helping people residing in underprivileged areas if people intend to endow a piece of land to establish new hospitals.

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