Analysis and Evaluation of the Accessibility and Inequality of the Spatial Distribution of Medical Resources in Jinan

Abstract: This paper analyzes the current spatial distribution of medical resources in Jinan City, Shandong Province, taking into account the hierarchical nature of medical resources and hospital levels, and reveals the spatial differences and regional characteristics of medical resource allocation.

This paper divides hospitals into three levels: First-degree, second-degree and third-degree, and measures the spatial distribution and accessibility of medical facilities at each level respectively. This paper evaluates the current status of medical resource distribution in Jinan by using indicators such as locational entropy, kernel density, standard deviation ellipse, HRAD and NNI. In this paper, Modified 2SFCA is selected as the method of accessibility measurement, and the distance decay function of gravity model is introduced to improve it, and different thresholds and decay coefficients are set for different levels of medical facilities to establish the accessibility measurement model. Finally, the Moran's I and LISA indicators are used to propose improvement ideas for the inequality and unreasonable distribution of medical resources in Jinan.

Key words: Accessibility; Inequality; Medical Resource; Spatial Distribution; 2SFCA

1. Introduction

With economic development and improvement of residents' living quality, their demand for urban public service facilities is continually increasing. As an important component of urban public service facilities, medical facilities provide residents with necessary medical services. But there is an increasing inconsistency between the multi-level medical and health demand and the apparent of medical facilities. Therefore, the spatial distribution, allocation and equalization of medical facilities have practical significance.

This article starts with the four aspects of the spatial distribution characteristics, spatial accessibility, inequality evaluation, and layout optimization of the existing medical resource allocation in Jinan. It also provides a scientific basis for the optimization of the layout of medical facilities and the rational allocation of resources in Jinan. Based on the analysis of the article, targeted countermeasures and suggestions are put forward for layout optimization.

1.1. Definition

A hospital is an institution that is mainly inpatient and medical, has a certain number of beds and facilities, has sound rules and regulations, is equipped with medical staff registered by health-related departments relative to its size, and has equipment such as medical devices.

Hospitals can be classified according to different criteria. According to the "General Hospital Management Standards" issued by the Ministry of Health in 1989, general hospitals can be classified as follows: according to the tasks and functions of general hospitals can be divided into First, Second, third levels, each level according to the hospital technology, quality, management, facilities conditions, etc. are further divided into three levels of A, B, C, three hospitals with additional special, so general hospitals are divided into three levels, ten levels; according to the scope of admission classification, can be divided into two categories of general hospitals, specialty hospitals; classification by ownership, can be divided into hospitals owned by the people, collective ownership of hospitals, hospitals owned by individuals, joint-stock hospitals, Sino-foreign joint venture hospitals. There are also classifications by level, task, management system, etc.

Table 1. Classification of Hospitals.

Classification	Content
Function	First-degree; Second-degree; Third-Degree
Management	For-profit Hospital; Non-Profit Hospital
Scope of treatment	General Hospital; Specialty Hospital
Levels	Provincial Hospital; City Hospital; County Hospital; Township Health Centers
Tasks	Military Hospital; Teaching Hospital; Research Hospital

1.2. Framework

Here is the procedure of this paper.

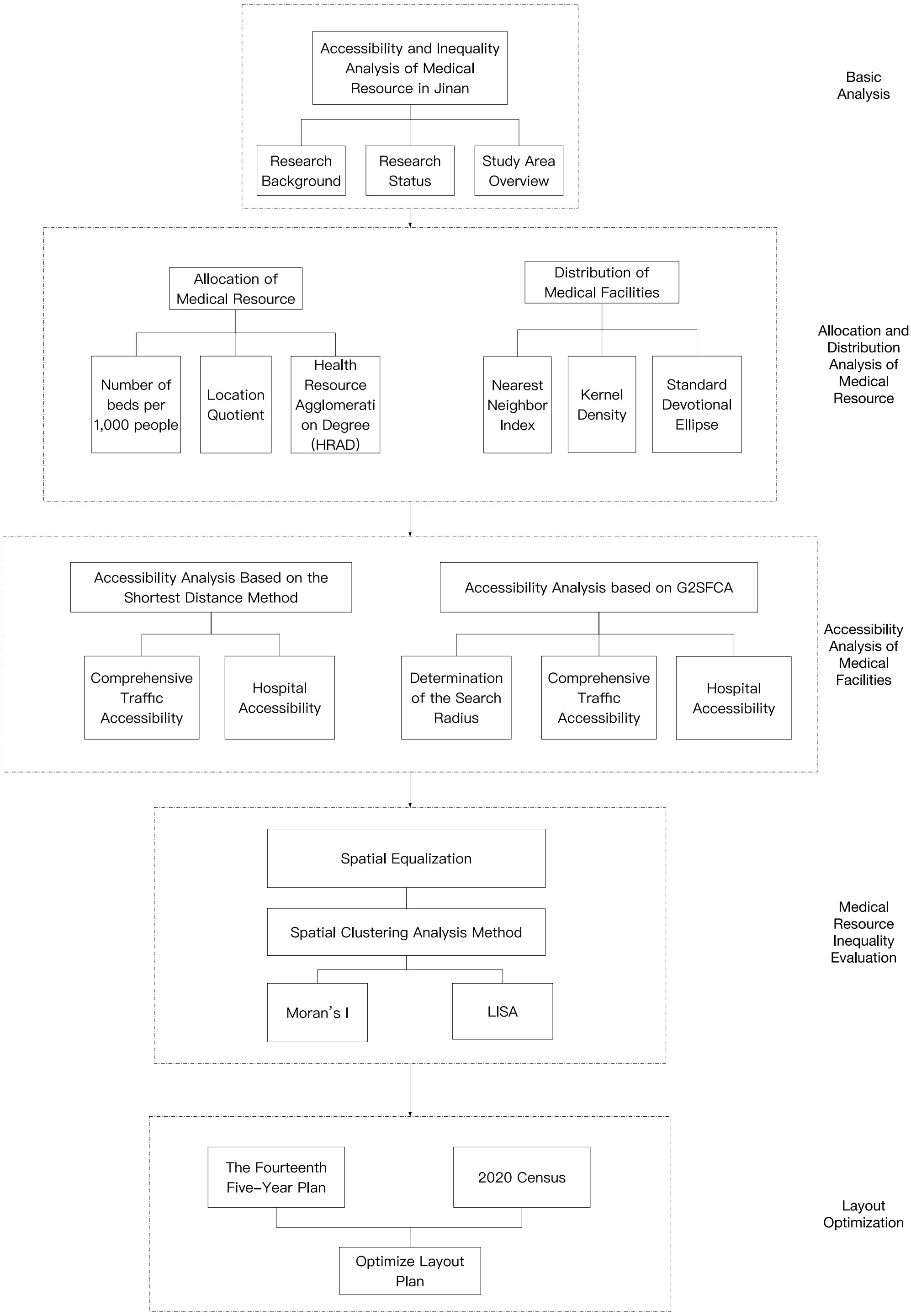


Figure 1 Framework.

2. Literature Review

2.1. Accessibility

The spatial accessibility is the most commonly used method to measure the inequality of the spatial distribution of public services. The methods used for facility accessibility studies have evolved over time, from initial qualitative analysis, to simple quantitative analysis, to later model analysis based on accessibility studies.

The concept of reachability and related theories were first introduced by Hansen [1] and defined as the ease of reaching a nearby point from any point in space. Based on this, Dalvi et al [2] added specific reachable objects and reachable modes, defining reachability as how fast it is possible to get from one point to another using a certain means of transportation.

With the development and research of many scholars, accessibility has been applied to the measurement of urban public service facilities, and the main research objects include: education resources, medical resources, green areas, parks, firefighting facilities, sports facilities, cultural facilities and emergency facilities, etc.

These accessibility measures include the shortest distance method, proportional method, spatial interaction-based methods (kernel density method, Hoover model, potential model), and opportunity-based cumulative methods (contour method, 2SFCA), which are widely used in measuring the accessibility of medical facilities.

Stentzel et al. measured the travel time to general practitioners and specialists for residents of Greifswald County, Mecklenburg-Vorpommernia, Germany, based on the minimum distance method [3]; Stentzel et al. used the core density method to assess the exploratory results of population coverage of health services in Nicaragua [4]; Luo et al. Luo et al. measured the spatial accessibility of primary care services in the Chicago area based on 2SFCA and gravity-based approach, which was useful in helping health departments identify areas with health professional shortages [5]; Wang et al. measured the accessibility of the primary health system in Illinois, USA based on 2SFCA [6]; Zhou Yuyang et al. measured the accessibility of public transportation based on a potential model [7]; Ai Tinghua et al.[8] measured the spatial accessibility of general hospitals in Shenzhen based on an isochronous model.

With the further development of accessibility theory, more and more scholars have improved the original methodological model to make it more suitable for the accessibility study of different public facilities. Pan et al. proposed a new integrated catchment area concept using orbital data from cabs, which utilizes an enhanced 2SFCA that incorporates actual human travel behavior to assess the accessibility of medical facilities in Shenzhen [9]. Mao et al. proposed an innovative way to incorporate transportation modes into accessibility estimation (multimodal 2SFCA) in a study of Floridan, USA, using a 2SFCA, and compared the accessibility results with those obtained by the basic 2SFCA, showing that the multimodal approach provided more realistic accessibility estimates by taking into account the heterogeneity of the population [10]. Luo et al. measured the accessibility of medical facilities in Wuhan based on Gaussian 2SFCA with elderly people as the target population [11] In a spatial accessibility study of primary care physicians in Albuquerque, USA, Lin et al. proposed an improved multimodal 2SFCA that introduced the concept of spatial access ratio into spatial access measurement, and showed that SPAR can significantly reduce the uncertainty associated with impedance coefficients.

Compared with the gravitational model, the 2SFCA overcomes the limitation of the administrative area boundary of the place of demand, and the calculation process is more convenient and intuitive, which is more convenient for practical operation, and is the most applied in the measurement of medical facility accessibility, and is considered by medical geographers as the most effective method to express the accessibility of medical facilities. Radke and Mu first used this method in the study of medical accessibility [12] Luo and Wang used GIS-based 2SFCA to evaluate the accessibility of basic medical facilities in Chicago and created a method to identify facility shortage areas [13] Since the 2SFCA does not consider the factor that the attraction of the supply side to the demander diminishes with increasing distance, some scholars have improved it, for example, McGrail's study improved the 2SFCA by considering the decay of distance and the influence of the study area, i.e., the method was improved by introducing a gravity model to the 2SFCA [14] There is also the optimization of the 2SFCA by adding the corresponding demand weighting factor, such as Andre and Philippe used such a method to do the accessibility study of medical facilities, which provides a scientific basis for planning the location and scope of building new facilities [15].

2.2. Inequality

The formulation of parity varies among scholars, but the concepts and understandings are basically the same. Parity refers to the equitable degree of access to public service facilities by residents in different zones and is an indicator characterizing parity [16]. Research on the parity of public service facilities in a region is conducive to revealing the degree of parity of public service facilities in the region and to promote the development of public service facility equity to a certain extent. The current research on parity mainly includes the following aspects:

First, the applicability assessment and measurement of public service facilities, and the main methods used include the concentration curve method, the extreme difference method, the Gini coefficient and the Lorenz curve. For example, Wang Qi used the Lorenz curve and Gini coefficient methods to evaluate the parity of medical facilities in Shanghai based on the number of beds and population in the region [25]; Ruiz et al. used the concentration index to assess the changes in five health and hygiene dimensions (health status, social health insurance coverage, health service utilization, quality, and health expenditure) in the Colombian health system [17].

Second, the parity of public service facilities is evaluated through a certain indicator or the construction of an indicator system. Currently, many scholars use the accessibility results as the basis for the evaluation of the parity of public service facilities as a measure of the equity of public service facilities in the region, so the accessibility measures as a tool for evaluating the parity of public service facilities have been the focus and difficulty of research [18] For example, Talen et al. evaluated the parity of playgrounds in Tulsa, Oklahoma, based on the results obtained from three accessibility measures: gravity model, average travel time, and distance to the nearest playground [19]; Zhao et al. evaluated the parity of medical facilities in Beijing based on the shortest travel time and spatial accessibility [20]; Xiong Juan et al. combined cluster analysis with accessibility analysis to measure the parity of medical facilities in Hubei Province Songzi City, Hubei Province, by combining cluster analysis with accessibility analysis to measure the level of service parity of medical facilities in different regions [21]; Liu Ansheng et al. used accessibility measures such as nearest distance and opportunity accumulation to evaluate the degree of inequality of educational facilities in urban and rural areas of Changzhou City, using educational facilities as the research object [22]; Guo Wenxiu et al. evaluated the parity of public service facilities in Changxing County, Huzhou City, Zhejiang Province, based on accessibility measures in an urban-rural context [23]; Wang Minmo evaluated the parity of basic health care, basic education, environmental protection, social security, public employment and infrastructure in six aspects, combined with relevant theories, to establish a comprehensive evaluation index system and further construct an evaluation model to evaluate the level of parity of the above six services in Jiangxi Province [24].

3. Methods

3.1. Accessibility

3.1.1. Shortest Distance Method

The shortest distance method is the cost of transportation from a residential point to the nearest facility point. It mainly measures the straight-line distance from people to the nearest facility point, and then quantitatively analyzes the nearest distance to evaluate the accessibility of the facility [26], and the nearest distance from residents to the facility can be accurately measured by using GIS. However, the nearest distance method is more single consideration, it only measures the distance between people and facilities, the smaller the distance, the better the accessibility, and lacks the comprehensive consideration of people, facilities and traffic.

3.1.2. Gravity Model

The gravity model method is derived from the law of gravity, and Stewart introduced the potential energy formula into geography [27] to measure the accessibility of all attractors beyond a point to the total potential energy of that point, where the distance decay function of the attractors to the force acting on that point is the focus of the gravity model [28]. The larger the force between them (the amount of the facility), the better the accessibility condition. The gravity model integrates the size of the supply of facilities and distance, but ignores the competition that exists for individual residents to obtain a supply. It also integrates the distance decay effect, but does not set the threshold range size, while in reality, people have a range of affordable distance to the facilities, and people will not choose the service facilities that are too far away in reality.

3.1.3. 2SFCA

The 2SFCA was firstly proposed by Mu and Radke [29]. The 2SFCA is a special form of the gravity model, which is more logically rigorous, but the 2SFCA is easier to calculate as well as more intuitive and practical, and therefore is most used in the accessibility measurement of medical facilities and has been improved by many researchers. It is developed from the mobile search method, which sets the distance (time) range of access to characterize the reality of people choosing facilities in close proximity across different areas, and can better evaluate the accessibility of facilities, and its measurement can provide a scientific decision basis for fair planning and layout of facilities, etc. However, it also has a disadvantage that it assumes that the distance decay does not exist within the threshold and the demand does not exist outside the threshold.

3.1.4. Modified 2SFCA

The 2SFCA first sets the service threshold of medical facilities, fully considers both supply and demand, moves the search twice centering on the supply and demand points respectively, and calculates the number of facilities or resources that residents can reach within the threshold range. The traditional 2SFCA treats the suppliers in the threshold range equally and does not consider the decaying effect of distance between the demand and supply points, but in fact, residents' access to medical care follows the principle of distance decay. Therefore, this paper introduces the distance decay function of the gravity model into the traditional 2SFCA for improvement, so as to solve this problem.

1. Step 1: Calculating the service capacity of medical facility sites.

For each supply point (hospital) j, search for all demand points (residences) k that are within distance j and within the threshold range d_0, count the population at these locations, calculate their supply-to-demand ratios, and discount them by considering distance decay.

$$R_j = S_j \Big/ \sum_{k\in\{d_{kj} \le d_0\}} P_k\, f\left(d_{kj}\right) \tag{1}$$

2. Step 2: Calculating the accessibility of demand points.

For each demand point *i*, search all supply points *j* within distance I and within the threshold range d_0, aggregate all supply-to-demand ratios, and discount them considering distance decay.

$$A_j = \sum_{j\in\{d_{ij} \le d_0\}} P_j\, f\left(d_{ij}\right) = \sum_{j\in\{d_{ij} \le d_0\}} \left[P_j f\left(d_{ij}\right) \Big/ \sum_{k\in\{d_{kj} \le d_0\}} P_k\, f\left(d_{kj}\right) \right] \tag{2}$$

3. Step 3: Determination of threshold value and attenuation coefficient.

Threshold: According to the *Construction Standards for General Hospitals (2015)*, in densely populated urban areas, a first-class hospital should enable residents to walk for about 30 min to be able to reach it. Considering the sparseness of population distribution in various regions of the city in actual situations, we set residents to reach community medical facilities for about 30 ~ 40 min, and according to the urban pedestrian walking speed of 5 km/h, we take the average 35 min The walking distance is 2,916 m, and the value is rounded to 3,000 m as the threshold of first-degree medical facility services.

The specific service distances for second and third-degree hospitals are not clearly defined, and experience has set a half-hour electric bicycle ride and a half-hour vehicle ride as the service radius, which is 10,000 m and 30,000 m.

Attenuation Coefficient: The distance decay effect is an important aspect of public service facility services. There is an interactive trend between the convenience of services and the increase in distance, and as distance increases, the convenience of access to services tends to diminish.

$$f(d) = d^{\alpha} \tag{3}$$

Where $-\alpha$ is the attenuation coefficient, and in the case of distance attenuation, $-\alpha < 0$. The higher the value of α, the faster the attenuation.

The magnitude of α varies depending on the type of service, road access conditions, and population characteristics [30], and it can even be said that there is a specific value for each specific type of supply and demand. Most scholars set a value for α empirically. If α is obtained based on practical investigation and calculation, it is costly in terms of labor and material resources, and the investigation and calculation results of individual cases are not suitable for application to other cases, so it is not very practical. Peeters and Thomas [31] summarized the views of previous scholars and found that the values of α are mainly concentrated in $[0.9\,, 2.29]$ [32], and the values taken in medical accessibility are mostly taken as 1 or 2.

In this study, for different levels of medical facilities, their decay rate with distance is different and the decay coefficients are different because the transportation mode to reach them, the scope of services, and the attractiveness of the facilities are different. High-grade medical facilities are attractive, people are not very sensitive to the transportation cost of visiting large hospitals, their influence by distance is smaller, and they generally arrive through motor vehicle travel, the decay rate is relatively slow, so the α is relatively small; while lower-grade medical facilities are less attractive, the service radius is smaller, and they can generally be reached by walking, their influence by distance is relatively large, and residents arrive at medical facilities with distance The decay rate of medical facilities with distance is faster, so α is relatively larger.

Table 2. Attenuation Coefficient.

Levels	Methods	Threshold	Attenuation
First Degree	Walk	3,000 m	-2
Second Degree	Ride	10,000 m	-1
Third Degree	Drive	30,000 m	-0/5

4. Analysis the Study Area

4.1. Study Area

Jinan, the capital of Shandong Province, has 10 districts and 2 counties, a total area of 10,244 Km², a built-up area of 760.6 Km², a resident population of 8,908,700. Because Laiwu District and Gangcheng District were merged into Jinan City in 2020, there is still a long-time lag between the two governments in terms of data merging, so this study does not involve Laiwu District and Gangcheng District.

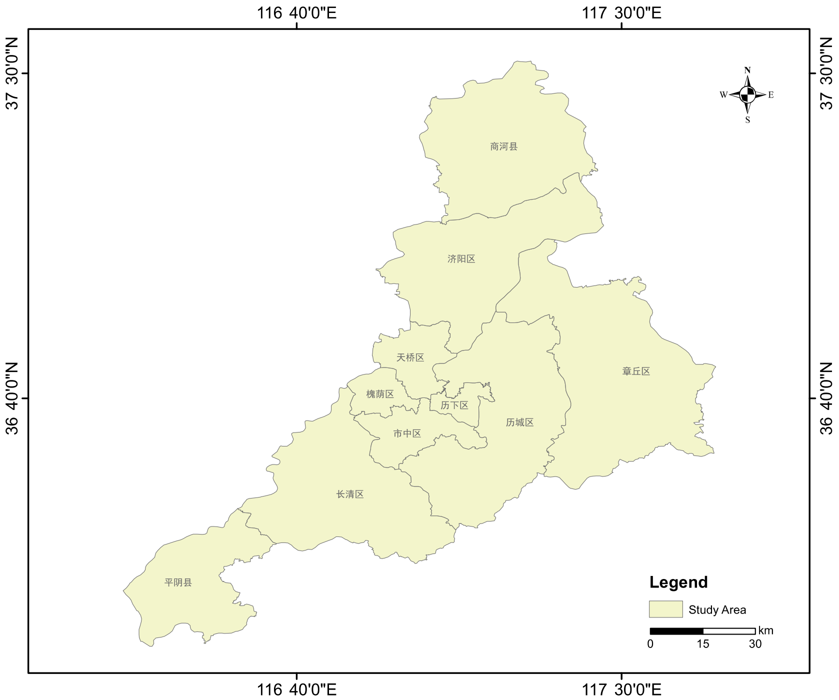


Figure 2. Study Area.

4.1.1. Hospitals

There are 296 hospitals in Jinan, 216 first-degree hospitals, 29 second-degree hospitals, and 51 third-degree hospitals. The graph shows the number of beds, doctors, nurses and health centers from the highest to the lowest in each district of Jinan and the spatial distribution of the hospitals.

4.1.2. Medical Beds

As of December 31, 2019, there were 66,623 beds in medical institutions in the city. Of which: 56,315 hospital beds (84.53%), 3,382 health center beds (5.08%), 3,791 community health service center (station) beds (5.69%), 33 outpatient department beds (0.05%), 1,444 maternal and child health center beds (2.17%), 1,658 specialty disease control hospital beds (2.49%).

4.1.3. Human Resources

There were 78,750 (64.35%) hospital employees on the job, up 3.69% year-on-year; 4,090 (3.34%) township health center employees on the job, up 10.01% year-on-year; 8,147 (6.66%) community health service center employees on the job, up 6.94% year-on-year; 7,806 (6.38%) professional public health institutions employees on the job, up 6.35% year-on-year; 2,179 (1.78%)

other institutions employees on the job, up 13.79% year-on-year. The number of employees in other institutions was 2,179 (1.78%), an increase of 13.79% year-on-year.

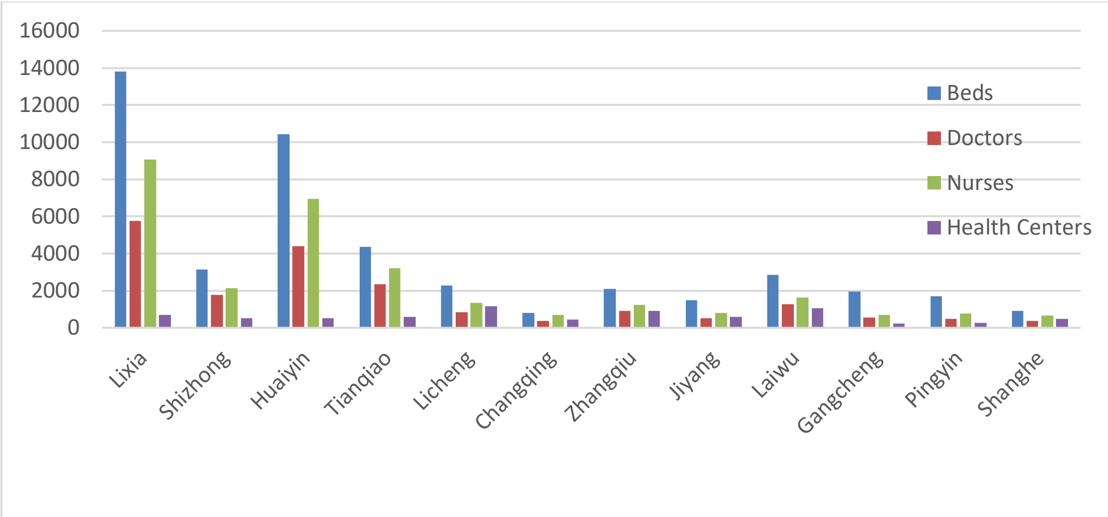


Figure 3. Overall View of Jinan Medical Resources.

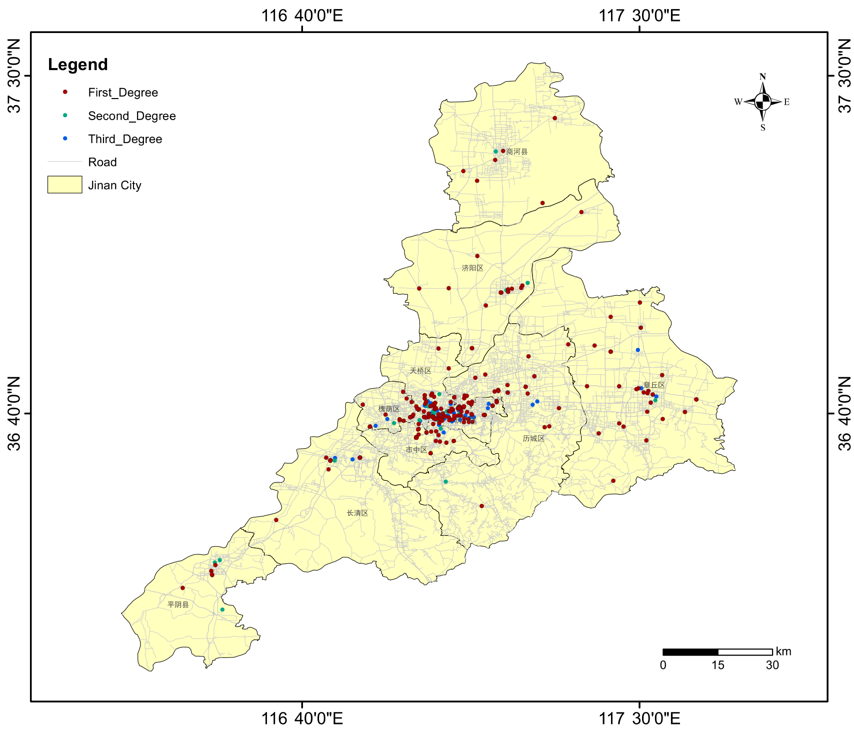


Figure 4. Hospitals Distribution.

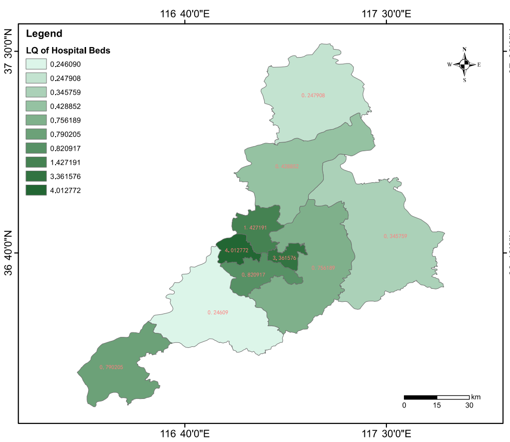
4.2. Location Quotient

The Location Quotient of medical service facility location is the ratio of the percentage of the scale of medical facilities in a certain cluster to the total scale of medical facilities in the municipality to the percentage of the population of the cluster to the total population of the municipality, which indicates the degree of concentration of medical service facilities in the cluster.

$$LQ_i = \frac{q_i}{p_i} \Big/ \frac{q}{p} \tag{4}$$

where q_i is the total number of general hospital medical resources in region i (the number of hospital beds, the number of practicing physicians, and the number of registered nurses, respectively); p_i is the total population in region i; q is the sum of general hospital medical resources in each cluster (the number of hospital beds, the number of practicing physicians, and the number of registered nurses, respectively); and p is the sum of the population in all regions.

The location quotient of medical resources in nine districts of Jinan can be seen through GIS statistics, and there are large differences in the spatial concentration of medical and health service resources in each district. The medical resources of Huaiyin District and Lixia District are particularly adequate, with the per capita level of medical resources exceeding the city average by three times, while the resources of Zhangqiu District and Shanghe District are relatively scarce, with only about 30% of the city average. Forming a strong contrast, the remaining areas values close to the city's average, the amount of distribution and the city-wide development of general hospitals in line with the current situation.



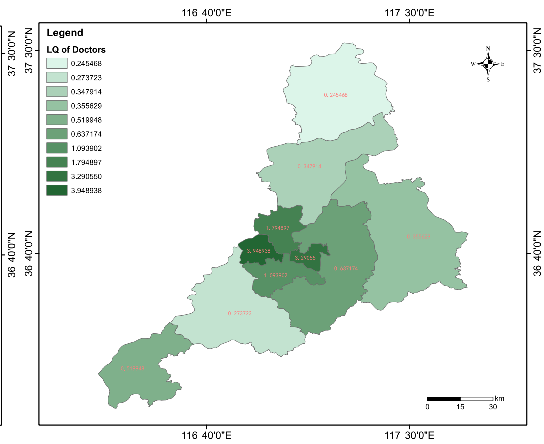
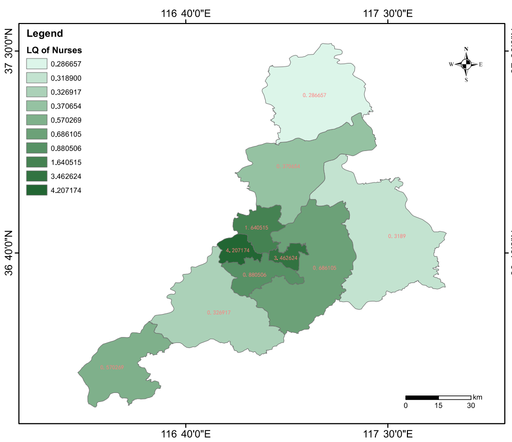


Figure 5. Location Quotient of Medical Beds. Figure 6. Location Quotient of Doctors.



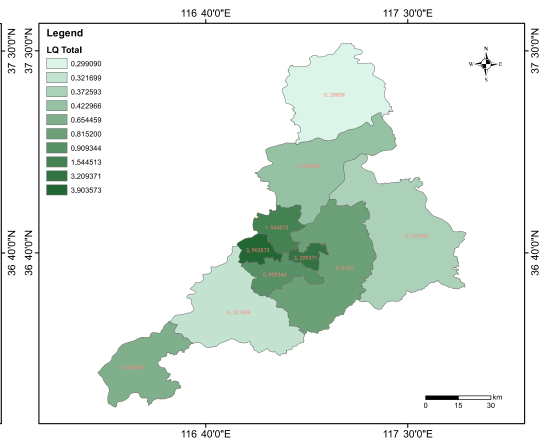


Figure 7. Location Quotient of Nurses. Figure 8. Location Quotient of Total Medical Resources.

4.3. HRAD

The evaluation of health resource allocation equity is one of the important elements of health system research. The concept of **Health Resource Agglomeration Degree (HRAD)** and **Population Agglomeration Degree (PAD)** was developed by introducing the concept of agglomeration in the field of economics into health resource allocation evaluation [33].

$$HRAD_i = \frac{HR_i/HR_n \times 100\%}{A_i/A_n \times 100\%} = \frac{HR_i/A_i}{HR_n/A_n}$$
$$PAD_i = \frac{P_i/P_n \times 100\%}{A_i/A_n \times 100\%} = \frac{P_i/A_i}{P_n/A_n} \quad (5)$$

A_i is the geographical area of each district, A_n is the geographical area of the city, HR_i is the number of medical resources swimming in district i, and HR_n is the total number of medical resources in the province. P_i is the number of population in district i, and P_n is the total population of the city.

When $HRAD_i = 1$, the allocation by geography is in absolute equity, when $HRAD_i > 1$, the equity is higher, and when $HRAD_i < 1$, the equity is worse.

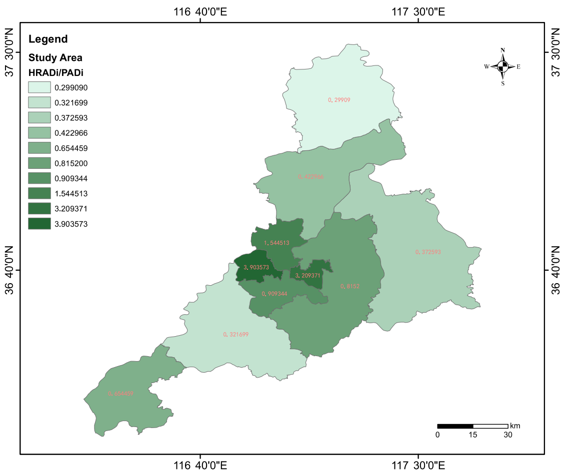


Figure 9. HRAD of Jinan.

The central area of Jinan is rich in medical resources and has a high degree of aggregation.

First of all, Lixia District, Shizhong District and Huaiyin District are the earliest developed areas in Jinan, and the initial allocation of medical resources started from this area, so they have a historical advantage.

Second, this area is the core area of Jinan's political and economic development, and has policy advantages in the allocation of service facilities, so it is rich in medical and health resources.

Although the total amount of medical resources of general hospitals in Zhangqiu District is not high, the per capita possession is high, mainly because the population is relatively small, and its development positioning is the comprehensive service center of the eastern development axis, so in the planning and construction process to improve the allocation of public service facilities, medical and health services are also attached importance, so the level of per capita medical resources is higher.

In contrast, the reason for the lower level of medical resources per capita in general hospitals in Shanghe District is that the location is more remote, the development of the region started late and is still in its initial stage, and the economy and population are growing slowly, so the relevant urban supporting facilities have not yet been perfected.

4.4. Medical Resource Demand

4.4.1. Density

The kernel density estimation method is mainly applied to the spatial distribution of point-like elements, and the density distribution of the element in a certain area is measured according to the spatial distribution and value of the element, and the formula is shown as follows.

$$f_n(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right) \quad (6)$$

where $f_n(x)$ is the kernel density of point element x, n is the number and the number of studied point elements, h is the search radius, and the radius of different searches. The results are also different, and $(x - x_i)$ is the distance between any two points.

By superimposing the attributes of the number of general hospital beds, hospital grade, population density and traffic road network, the following results were obtained: the overall spatial layout of hospitals in Jinan is well coupled with the characteristics of population density distribution within the city. The denser distribution of general hospitals can be clearly seen in the central area, the eastern area and the area with higher population density in the southwest border.

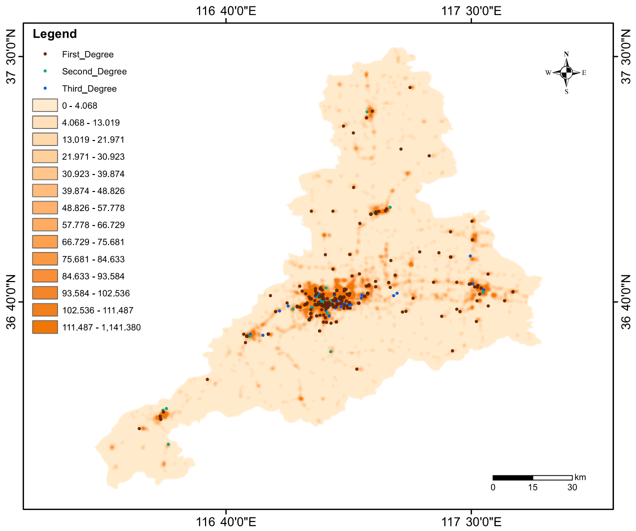


Figure 10. Population Density of Jinan.

4.4.2. NNI

The spatial distribution pattern is the basic characteristic of spatially distributed points, which can be mainly classified into three types: aggregation pattern, dispersion pattern and random pattern by using the nearest neighbor index (NNI) method to measure the distribution characteristics of spatial points.

When$0 < NNI < 1$, the data distribution mode is aggregation, and the nearest neighbor index is closer to 0, the higher the aggregation of data; when $NNI = 1$, the data is random distribution mode;

when $NNI > 1$, the data is dispersed distribution, and the larger the nearest neighbor index, the higher the dispersion.

4.4.3. Standard Deviational Ellipse

The standard deviation ellipse analysis is a method to analyze the spatial distribution characteristics and directions of point-like elements, which can accurately measure the distribution centers, directions and discrete trends of point-like elements in space, and is a common method for spatial point pattern analysis [34].

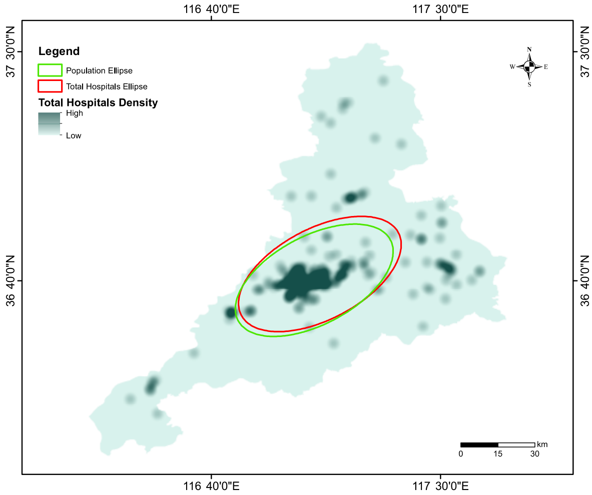


Figure 11. Standard Devotional Ellipse of Jinan.

According to the standard deviation ellipse results, the standard deviation ellipse diffusion angle of medical facilities in Jinan is 48°, and the standard deviation ellipse diffusion angle of residential neighborhoods is 56°. The diffusion direction of medical facilities is roughly in the northeast-southwest direction, which is roughly the same as the extension direction of residential neighborhoods, indicating that the development direction of residential neighborhoods and medical facilities is the same, which also coincides with the spatial expansion direction of Jinan city, indicating that the current distribution of medical resources is in line with the population distribution.

Table 3. Results of NNI.

Levels	Observed Mean Distance	Expected Mean Distance	Nearest Neighbor Index (NNI)	Z-score	P-value
First-Degree	1498.5597	3647.4644	0.41085	-16.565	0
Second-Degree	6070.9531	8691.8993	0.698461	-3.1065	0.001893
Third-Degree	1236.3063	2183.7582	0.566137	-5.9275	0
Total	771.8716	2059.2537	0.374831	-31.823	0

4.5. Accessibility

This paper measures the accessibility of medical facilities at four levels: first-degree hospitals, second-degree hospitals, third-degree hospitals, and all hospitals. The accessibility of each level represents a relative situation in each region of the city, and does not represent the absolute accessibility.

The number of first-degree hospitals in the city is high and scattered. In general, the accessibility distribution is more balanced. The high accessibility area almost covers the central urban areas such as Lixia District, Shizhong District and Huaiyin District. Changqing District is less accessible to the south, mainly because Jinan is adjacent to Tai'an, and the junction is where Mount Tai is located, with more hilly terrain, lower population density and fewer medical facilities.

The number of second-degree hospitals in the city is small, and their distribution is mainly concentrated in the central city of Jinan, so the accessibility of second-class hospitals in each district is generally low, and the accessibility of Licheng District and Zhangqiu District is poor.

The number of third-degree hospitals in the city is large, the spatial distribution is highly aggregated, almost all of them are located in the central city, the accessibility distribution shows an east-west strip distribution, and there is almost no accessibility in the remote areas in the north and southwest, especially in the northern Shanghe district, which needs to cross the whole Jiyang district to find the nearest tertiary hospital. Although the population density in these places is high, the economic conditions are poor and the development is slow, so the distribution of medical resources is poor.

The summary of all medical resources shows that Jinan has good accessibility to medical resources in all districts. In general, the comprehensive accessibility of medical resources in Jinan shows a spatial clustering distribution pattern, with each hospital densely distributed area as the center of aggregation, and gradually decreases with increasing distance, with the most obvious in Lixia District, Shizhong District and Huaiyin District.

There are historical reasons for the large gap between the accessibility distribution of the central city and other areas. Early Jinan city districts were gathered in Lixia District, Licheng District and Shizhong District, etc. Later, policy changes were made and areas such as Zhangqiu District and Laiwu District were merged under the jurisdiction of Jinan City Government, so the connection between the regions was not very strong. At the same time, the number of population and economic conditions vary greatly, so the current situation of accessible distribution is formed.

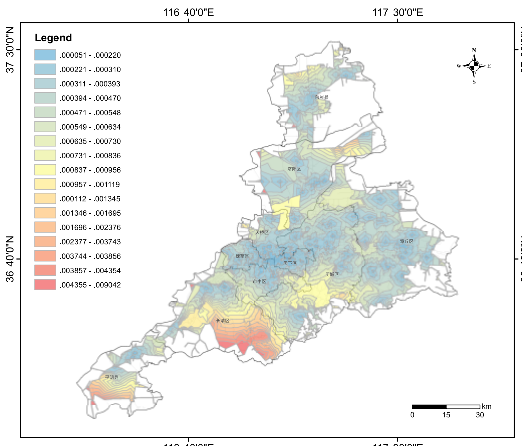


Figure 12. Accessibility of First-Degree Hospitals.

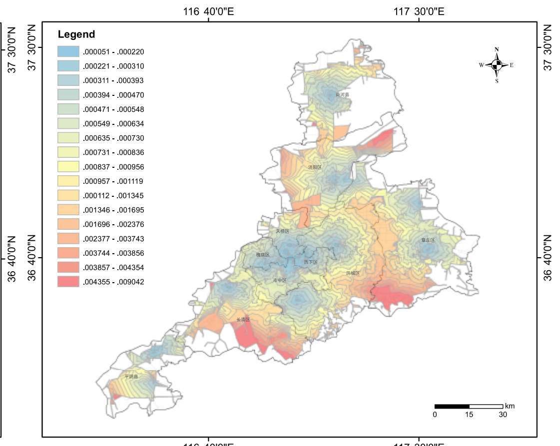


Figure 13. Accessibility of Second-Degree Hospitals.

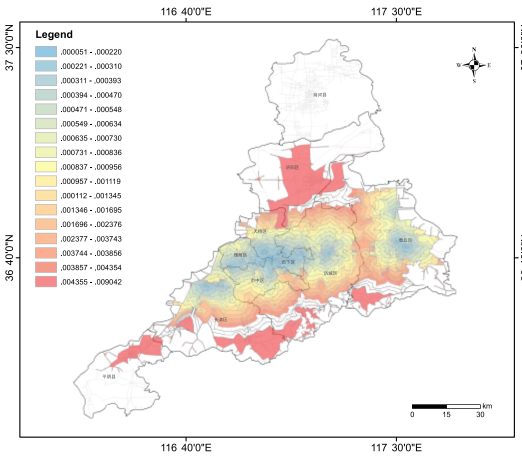


Figure 14. Accessibility of Third-Degree Hospitals.

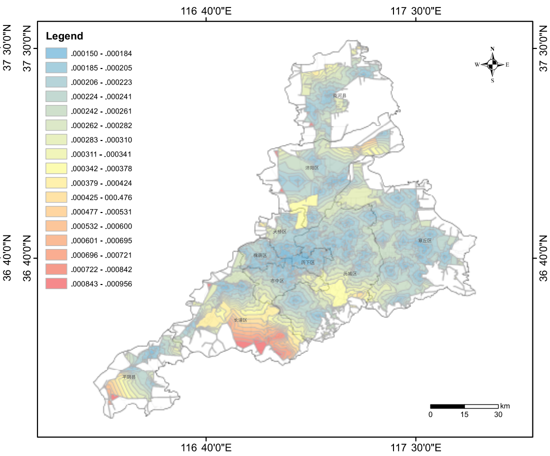


Figure 15. Accessibility of All Hospitals.

4.6. Moran's I

Spatial clustering analysis was performed on the accessibility standardized values obtained from M2SFCA. The results of spatial clustering of the standardized accessibility values of first-degree, second-degree and third-degree hospitals were obtained using Moran's I.

$Moran's\,I$ ranges from $[-1\,,1]$, when $Moran's\,I > 0$ it indicates that the attribute value is spatially clustered; when $Moran's\,I < 0$, it indicates that the attribute value is spatially tended to be discrete; when $Moran's\,I = 0$, it indicates that the attribute value is randomly distributed or there is no spatial autocorrelation.

From the Table 4, it can be seen that medical resources in Jinan are non-randomly distributed and have strong spatial correlation.

Table 4. Results of Moran's I

Levels	Moran's I	Z-score	P-value
Total	0.691935	3.893853	0.000099
First-degree	0.862633	3.822536	0.000132
Second-degree	0.053393	0.958712	0.337704
Third-degree	0.176788	2.470984	0.013474

4.7. LISA

Based on the standardization of accessibility, the LISA local association model was applied to primary, secondary, tertiary and all hospitals to calculate the degree of spatial local association. The results of the LISA local association model were in four categories, LH, HL, LL and HH, with the first two being outliers.

Visualizing the LISA local association model, HH clusters are distributed in the old urban areas and outliers are mainly distributed in remote peripheral urban areas.

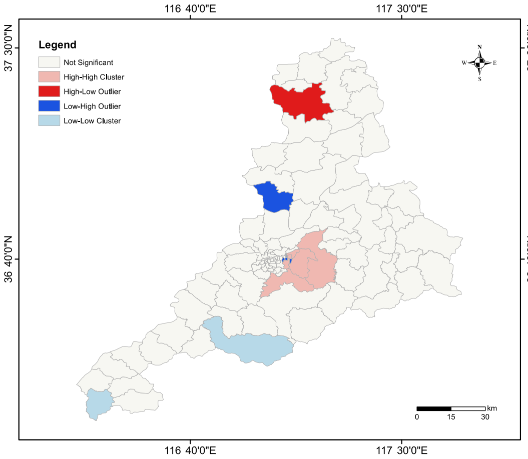


Figure 16. LISA of First-Degree Hospitals.

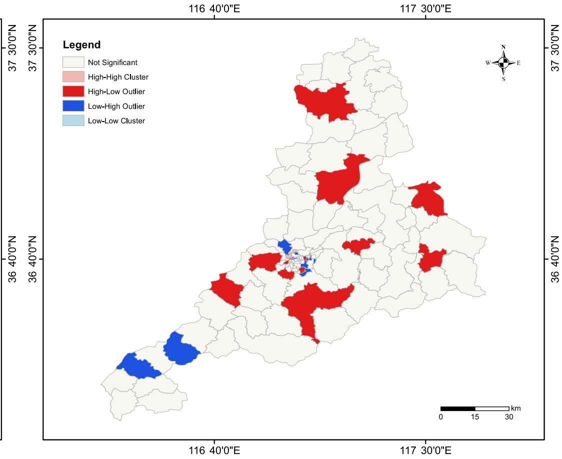


Figure 17. LISA of Second-Degree Hospitals.

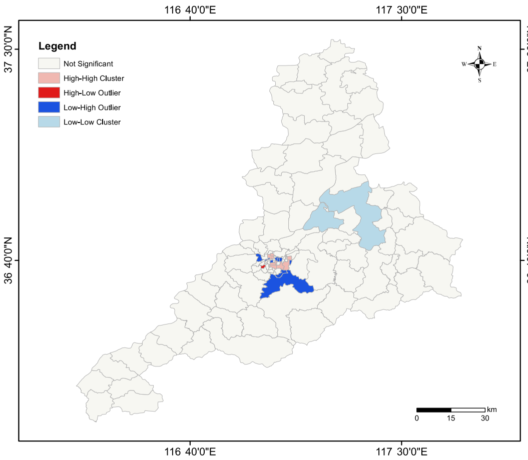


Figure 18. LISA of Third-Degree Hospitals.

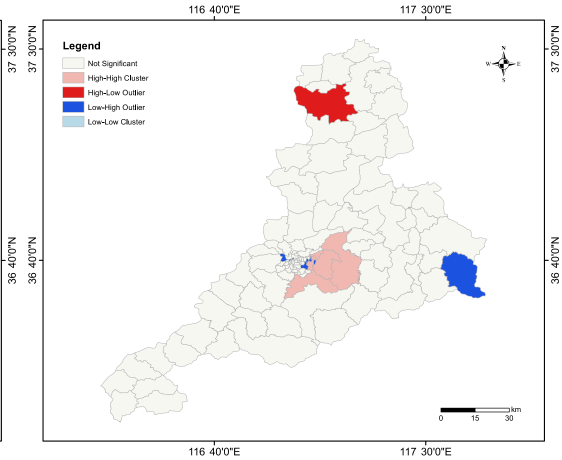


Figure 19. LISA of All Hospitals.

5. Summary

1. Spatial distribution characteristics of healthcare resources were measured in various ways.

The inequality in the distribution of existing medical resources in Jinan was analyzed by using location quotient, HRAD, NNI, kernel density, and standard deviation ellipse.

2. Accessibility measurement model developed based on medical facility hierarchy analysis.

Based on the analysis of medical facility levels, this paper improves the traditional 2SFCA, introduces a distance decay function, and sets different service thresholds and decay coefficients for different levels of medical facilities to establish a model to measure the accessibility of medical facilities at different levels.

3. Calculation of accessibility of each level medical facilities based on the accessibility measurement model.

In general, the comprehensive accessibility of medical resources in Jinan shows a spatial clustering distribution pattern, with each hospital densely distributed area as the center of aggregation, and gradually decreases with increasing distance, with the most obvious in Lixia District, Shizhong District and Huaiyin District, and less accessibility of medical resources in Shanghe District, Jiyang District and Pingyin District.

4. Spatial correlation of accessibility of medical facilities at each level by Moran’s I and LISA analysis.

Based on Moran's I, the spatial correlation of the accessibility of medical facilities in Jinan residential areas was analyzed, showing that the accessibility results of all three levels of hospitals were spatially correlated. Based on the LISA local correlation model, the local correlation phenomenon of accessibility of medical facilities were analyzed, and showed that the residential areas with high values of accessibility of medical facilities in Jinan are spatially clustered.

5. Future

Quantitative analysis of the inequality in the distribution of medical resources in Jinan city by region. Machine learning using Particle Swarm Optimization algorithms can be attempted in the future. With the help of machine learning to explore the optimal solution for minimizing the variation in accessibility of healthcare resources and maximizing the equity of resource allocation.

6. Bibliography

[1]. Walter-G Hansen. How Accessibility Shapes Land Use[J].Journal of the American Institute of Planners,1959,25(2):73-76.

[2]. M-Q-DALVI-And MARTIN.The measurement of accessibility some preliminary results[J].Transportation,1976,5(1):17-42.

[3]. Ulrike Stentzel, Piegsa Jens, Fredrich Daniel, et al.Accessibility of general practitioners and selected specialist physicians by car and by public transport in a rural region of Germany[J].BMC health services research,2016,16(1):587.

[4]. John Spencer, Angeles Gustavo.Kernel density estimation as a technique for assessing availability of health services in Nicaragua[J]. Health Services and Outcomes Research Methodology,2007,7(3):145-157.

[5]. Wei Luo, Wang Fahui.Measures of Spatial Accessibility to Health Care in a GIS Environment:Synthesis and a Case Study in the Chicago Region[J].Environment and Planning B: Planning and Design,2003,30(6):865-884.

[6]. Fahui Wang, Luo Wei.Assessing spatial and nonspatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas[J].Health & Place,2005,11(2):131-146.

[7]. Zhou Yuyang, Tang Songtao, Chen Yanyan. Analysis of public transportation accessibility for medical travel based on potential model[J]. Transportation Technology and Economy,2019,21(04):12-15.

[8]. Ai T.H., Lei Y.Z., Xie P., et al. Spatial accessibility measurement analysis of Shenzhen general hospital supported by isochronous model[J]. Journal of Geoinformation Science,2020,2(1):113-121.

[9]. Xiaofang Pan, Kwan Mei-Po, Yang Lin, et al.Evaluating the Accessibility of Healthcare Facilities Using an Integrated Catchment Area Approach[J]. International Journal of Environmental Research and Public Health,2018,15(9): 2051.

[10]. Liang Mao, Nekorchuk Dawn.Measuring spatial accessibility to healthcare for populations with multiple transportation modes[J].Health & Place, 2013, 24115-122.

[11]. Jing Luo, Chen Guangping, Li Chang, et al.Use of an E2SFCA Method to Measure and Analyse Spatial Accessibility to Medical Services for Elderly People in Wuhan, China[J].International Journal of Environmental Research and Public Health,2018,15(7):1503.

[12]. Radke J. and Mu L. 2000. Spatial Decomposition, Modeling and Mapping Service Regions to Predict Access to Social Programs[J]. Geographic Information Sciences, 2000, 6 (2):105-112.

[13]. Luo W, Wang F. Measures of Spatial Accessibility to Health C are in a GIS Environment: S ynthesis and A C ase Study in the Chicago Region[J]. Environment and Planning B: Planning and Design, 2003, 30(6):865 -884.

[14]. Mcgrail M R. Spatial Accessibility of P rimary Health C are Utilising the Tw Step Floating C atchment Area M ethod: An Assessment of R ecent Improvements[J]. International

Journal of Health Geographics, 2012 , 11(1):50.
[15]. Ngui A N, Apparicio P. Optimizing the Two -Step Floating C atchment Are M ethod for M easuring Spatial Accessibility to M edical Clinics in Montreal[J]. Bmc Health Services Research, 2011, 11(1):166.
[16]. Liu Deji. The concept, institutional factors and realization path of equalization of public services: a review of the literature[J]. Shanghai Economic Research, 2008,(04):12-20.
[17]. Gomez-F Ruiz, Zapata Jaramillo-T, Garavito Beltran-L.Colombian health care system: results on equity for five health dimensions,2003-2008[J].Rev Panam Salud Publica,2013,33(2):107-115,6-107.
[18]. Luo Lei. Research on the accessibility and equalization of public medical services in rural Xiantao City, Hubei Province[D]. Huazhong Normal University, 2015.
[19]. L-Anselin E Talen. Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds[J].Environment and Planning A,1998,33(4): 595-613.
[20]. Meifeng Zhao, Liu Shenghe, Qi Wei.Spatial Differentiation and Influencing Mechanism of Medical Care Accessibility in Beijing: A Migrant Equality Perspective[J].Chinese Geographical Science,2018,28(2):353-362.
[21]. Xiong Juan, Luo Jing, Peng Jing, et al. Analysis of medical service equalization in counties based on accessibility: the case of Songzi City in Hubei Province[J]. Human Geography, 2012, 27(05): 25-29.
[22]. Liu Ansheng, Zhao Yihua. Research on the layout of basic public service facilities in rural areas of Changzhou City based on accessibility analysis: the example of education facilities[J]. Jiangsu Urban Planning, 2010,(06):6-8.
[23]. Guo Wenxiu. Research on the equalization of public service facilities in the county under the background of urban-rural integration[D]. Tianjin University, 2016.
[24]. Wang Minmo. Evaluation and Countermeasures of Equalization of Basic Public Services in Jiangxi Province[D]. Nanchang University,2011.
[25]. Wang Q. Analysis of medical service accessibility in Shanghai based on improved two-step mobile search method[D]. Wuhan University, 2019.
[26]. Guo Yaxin , Xu Jiangang . Study on the influence of pedestrian flow in commercial areas based on accessibility and spatial syntax analysis [J]. Journal of Shandong Normal University: Natural Science Edition, 2011, 26 (2): 95 -100.
[27]. Howard R. Kirby. Accessibility Indices for Abstract R oad Networks[J]Regional Studies, 1976, 10(4):479 -482.
[28]. Chen Jie , Lu Feng , Cheng Changxiu . A Review of Research Progress in Accessibility Metrics and Applications [J]. Advances in Geographical Sciences , 2007, 26(5): 100-110.
[29]. Radke J. and Mu L. 2000. Spatial Decomposition, Modeling and Mapping Service Regions to Predict Access to Social Programs[J]. Geographic Information Sciences, 2000, 6(2): 105-112.
[30]. Song Zhengna , Chen Wen , Che Qianjin , et al . Spatial accessibility of medical services based on improved potential model and determination of medical shortage areas in Rudong

County, Jiangsu Province [J]. Geoscience, 2010, 30 (2).

[31]. Peeters D, Thomas I. Distance P redicting Functions and Applie Location -Allocation M odels[J]. J ournal of Geographical Systems, 2000, 2(2): 167 -184.

[32]. Tao Z, Yang C, Dai T, et al. Spatial Optimization of R esidential C are Facility Locations in Beijing, China: M aximum Equity in Accessibility[J]. International J ournal of Health Geographics, 2014,13(1):33 .

[33]. Yuan Suwei, Gui Fengqing, Liu Wenwei, et al. A methodological exploration of using agglomeration to evaluate the equity of health resource allocation[J]. China Hospital Management, 2015(02):3-5.

[34]. By Mao Zhengyuan, Li Lin. Measurements of spatial patterns and their applications [M]. Beijing:Science Press,2004: 21-48.