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Research on the Matching Relationship between Supply and Demand of Medical Resources Based on Accessibility：A case study on Pudong New Area District in Shanghai

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Abstract. Scientific evaluation of the spatial accessibility of medical facilities can effectively measure the relationship between the supply of medical resources and the needs of residents. Taking Shanghai Pudong New Area as an example, with the help of ArcGIS analysis tools, the community is used as the smallest research unit, considering the size of medical facilities, travel time and other factors, the improved Gaussian two-step mobile search method is used to analyze the spatial accessibility of medical facilities in Pudong New Area, and adopted Spatial autocorrelation analyzes the matching relationship between the supply of medical resources and the needs of residents. The results show that the accessibility of medical resources in Pudong New Area is unevenly distributed, presenting a dual-core spatial distribution, and the accessibility value is greatly affected by secondary and tertiary medical facilities; there is a positive relationship between the accessibility of medical facilities in Pudong New Area and the needs of residents The main urban area of Pudong New Area is rich in population density and medical resources, but there is still a shortage of medical resources. The southern region is lack of medical resources and the population density is low. In the future, we can optimize and optimize the stock of medical resources. Incremental site selection and improvement of the transportation network promote the rational distribution of medical resources.

Keywords: medical facilities; accessibility; Gaussian two-step mobile search method; supply and demand matching

1. Introduction

In recent years, China's health services have achieved full development, and the equalization of urban medical resources is an important foundation for improving the people's happiness index and building a moderately prosperous society in all respects. The essence of the equalization of public services is to solve the problem of social equity [1]. As one of the public service facilities closely related to residents' lives, the equalization of medical facilities has become an important topic in the field of health equity research. In the context of limited spatial resources, the study of the spatial distribution of medical facilities and the matching relationship between residents' needs and medical facilities is conducive to the improvement of the quality of medical facilities stock, the equity of incremental distribution, and the promotion of social equity and justice.

Spatial accessibility was first proposed by Hansen[2], and then widely used in the allocation evaluation of public service facilities, as an important index for fairness evaluation [3]. Two-step mobile search method (2SFCA) is based on the facility supply point and the residents' demand point as the center to search back and forth twice to determine the supply and demand ratio. By setting the threshold value, it can better simulate the actual situation and better identify the areas with low accessibility value [4], so it has been widely used in the evaluation of public service facilities. Since 2SFCA does not consider the impact of distance decay on accessibility, scholars have introduced distance decay functions on the basis of 2SFCA, including gravity model [5], kernel density function [6] and Gaussian function [7], to overcome this defect. In the current studies using 2SFCA to study the accessibility of medical facilities, the effects of different levels of medical facilities and multiple travel modes on accessibility are rarely considered. China implements a hierarchical medical system, and medical facilities with large scale and many beds have larger service radius

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and service capacity. Different travel modes have different impacts on accessibility. Some scholars only consider a single travel mode in their research. For Shanghai, a city with a developed transportation network, multiple travel modes consisting of rail transit and roads of different grades have an important impact on the accessibility results. In addition, most of the existing studies on medical resources focus on the accessibility of medical facilities, and lack of attention to the matching relationship between residents' needs and the supply of medical facilities.

In view of the above shortcomings, this study takes Pudong New Area as an example to analyze the demand for medical facilities by using Python to crawl the population data of the community, and establishes and improves the Gaussian two-step mobile search model by considering factors such as the scale of medical facilities, various transportation modes, and the degree of consistency between distance decay and the actual situation [8]. To analyze the primary, secondary and tertiary medical facilities and their overall accessibility in Pudong New Area, and to analyze the matching relationship between residents' demand and medical facilities supply at the street and town levels through spatial autocorrelation, so as to promote the rationality and fairness of medical resources distribution

2. The Research Methods

2.1 Gaussian Two-Step Mobile Search Method

In this paper, the Gaussian two-step mobile search method is selected and improved according to the research data to study the accessibility of medical facilities in Pudong New Area. The specific calculation process is as follows:

In the first step, with settlement i as the center, the travel distance threshold d0 was determined, and all medical facilities j falling within the search radius were searched, and the supply-demand ratio was calculated.

$$D_{ij} = \frac{S_j}{\sum_{i\in\{d_{ij}<d_0\}} P_i G\left(d_{ij},\ d_0\right)} \tag{1}$$

In the formula, Dij represents the supply-demand ratio within the search radius. Sj represents the supply of medical facility j, represented by the number of beds; Pi is the number of residents within the search radius; dij is the travel distance from residential area i to medical facility j; d0 is the travel distance threshold; G (dij, d0) is the Gaussian distance decay function, and the calculation formula is as follows:

$$G\left(d_{ij},\ d_0\right) = \begin{cases} \dfrac{e^{-\frac{1}{2}\times\left(\frac{d_{ij}}{d_0}\right)^2} - e^{-\frac{1}{2}}}{1-e^{-\frac{1}{2}}}, & d_{ij} \le d_0 \\ 0, & d_{ij} > d_0 \end{cases} \tag{2}$$

The second step is to calculate the accessibility Ai of settlement i:

$$A_{ij} = \sum_{j\in\{d_{ij}\le d_0\}} D_{ij}\, G\left(d_{ij},\ d_0\right) \tag{3}$$

$$A_i = \sum_{j=1} A_{ij} \tag{4}$$

In the formula, Aij represents the accessibility of settlement i to medical facility j, and Ai represents the overall accessibility of settlement i.

The third step, the traditional gaussian two-step mobile search method will distance as the travel cost computing accessibility, but in real life, people prefer to measured through time travel costs, so in this paper, the traditional gaussian two-step mobile search method was improved, replace the

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distance with time as the travel cost, the search radius dij instead of travel time, d0 for travel time threshold.

2.2 Spatial Autocorrelation

Moran's index can be divided into global Moran's I and local Moran's I. Firstly, the global bivariate Moran's I was used to analyze the spatial correlation between the accessibility of medical facilities and population density. The value of Moran's I was between -1 and 1, and its absolute value indicated the degree of correlation. The larger the absolute value, the higher the correlation, and a value greater than 0.2 was considered to have a higher degree of clustering [8]. Moran's I value greater than 0 indicates positive correlation, and less than 0 indicates negative correlation. Then, local Moran's I and LISA cluster maps were used to analyze the spatial heterogeneity among the accessibility of medical facilities and population density in each street and town. The results were divided into four categories: H-H, L-L, H-L, L-H.

3. Study Area and Study Data

3.1 The Study Area

The study area is Pudong New Area, located in the east of the Huangpu River, bordering Fengxian District and Minhang District in the south and the Yangtze River in the north. It is the largest district in Shanghai, with 12 subdistricts and 24 towns, covering an area of 1210km2. As of November 1, 2020, Pudong New Area has a permanent resident population of 5,681,512 people, 4,695 people per square kilometer, roughly the same as Shanghai's 3,923 people /km2, which is an urban area with low population density in Shanghai. At the end of 2019, the number of beds per 1,000 people in Pudong New Area was 4.42, which was lower than 6.03 per 1,000 people in Shanghai, and the medical resources in Pudong New Area were relatively scarce. Therefore, the study on the distribution of medical service resources in Pudong New Area has certain reference significance for other regions in the country.

3.2 Current Situation of Supply and Demand of Medical Facilities

3.2.1 The supply of medical facilities.

The accessibility of medical facilities is usually reflected by the number of beds and the number of medical staff [9]. In this study, the number of beds was selected to measure the supply of medical facilities and calculate the accessibility of medical facilities. The number of beds in medical facilities was obtained from the official websites of Shanghai Pudong New Area Health Commission and hospitals, and the spatial location data of medical facilities and road network were obtained through AmAP API interface. "Standard of hospital classification management" in China could be divided into tertiary hospital grade ten, etc., considering the grading system in our country, so this article research object for all common disease and frequently encountered disease that can handle the pudong new area of public health care facilities, medical facilities and be divided into three levels, respectively is a three-level medical facilities (including level 3 grade a, b, c three levels of hospitals) 14, 11,797 beds; 10 level-II medical facilities (including level-II A, B and C hospitals) with 3,933 beds; There are 165 level-I medical facilities (including community health service centers, community health service stations and township health centers) with 3,141 beds.

3.2.2 Demand for medical facilities.

This paper uses the population of the community to identify the demand for medical facilities. At present, the acquisition of urban population data is faced with problems such as difficulty in data collection and insufficient accuracy, and most of the population data used in studies are still at the street level. Therefore, this paper crawls the second-hand housing transaction network through Python to obtain the information of 2996 communities, including the spatial location data and the number of communities, and calculates the number of people in each community based on the

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average of 2.32 people per household in Shanghai obtained from the seventh population census. The number of people in each community is taken as the demand in the calculation of accessibility.

3.3 Search Threshold Versus Road Running Speed

Now all regions tend to have diversified travel modes. Considering that Shanghai is a city with abundant travel modes, this paper combines rail transit and ground transportation when determining travel modes. The operation speed of roads of different grades is determined according to the "2021 Annual Report of Shanghai Comprehensive Transportation Development", "2020 Annual Report of Shanghai Comprehensive Transportation Operation" and the data published on the official website of Shanghai Metro, as shown in Table 1.

Table 1. Different road speeds

Road type	expressway	Trunk road	Other road	orbital
speed（km/h）	42	18	5	37.5

4. The Results of the Study

4.1 Spatial Accessibility Analysis of Medical Facilities in Pudong New Area

The overall accessibility of first-level medical facilities in Pudong New Area is poor due to the limitations of residents' demand and willingness and small search threshold (Figure 1.a), and the accessibility values of most areas are in the areas with low accessibility values of Ⅰ-Ⅲ. In the northwest of the outer ring road, the accessibility of part of the main urban area shows a dual core spatial distribution. Lujiazui Street, Weifang Xincun Street and Zhoujiadu Street are the high value areas, and the concentration of medical facilities and transportation network is high in this area. A sub-core area is formed at the junction of Heqing Town, Kangqiao Town and Zhoupu Town. Although the distribution of medical facilities in this area is not dense, the subway line 2 effectively connects the facilities and improves the accessibility of medical facilities.

Secondary medical facilities are rich in medical resources, and residents have strong demand for them. Besides, secondary medical facilities are located near subway lines, and the search threshold is larger than that of primary medical facilities. Therefore, the accessibility level of secondary medical facilities is higher than that of primary medical facilities on the whole (Figure 1.b). Two obvious core areas are formed in Xincun sub-district, Zhoujiadu sub-district, Sanlin Town interchange and Huinan Town. Two and three secondary hospitals are clustered in these two areas respectively, and all of them are passed by subway, which has a great impact on accessibility. The areas with low accessibility values are mainly located in Gaoqiao Town, Gaodong Town, Gaohang Town, Zhuqiao Town, Wanxiang Town, Nicheng Town, Shuyuan Town and Nanhui New Town. On the one hand, there are few facilities in these areas, and on the other hand, they are affected by the lack of transportation network in these areas.

Tertiary medical facilities for medical resources, bigger and stronger service ability, intend to strong demand for its residents, less constrained by time, therefore, accessibility of three-level medical facilities as a whole is higher than the primary and secondary health care facilities, northwest urban area as the core to the southeast accessibility decreases step by step, about one-third of regional accessibility for high value (Figure 1.c). Pudong new area of medical facilities overall accessibility spatial distribution (Figure 1.d) and secondary similar accessibility of medical facilities spatial distribution characteristics, present a dual core spatial distribution, but influenced by three-level medical facilities accessibility, accessibility of medical facilities overall core area and the accessibility level compared with the secondary medical facilities has a lot to improve, This also indicates that the secondary and tertiary medical facilities have a greater impact on accessibility. Notable is that the mud towns, college town in the south of the pudong new area, Wan Xiang town

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new town, nanhui district, it's the first, second and tertiary health care facilities and the overall accessibility of health care facilities are at the lower end, and in this area is only a third class medical facilities and five primary health care facilities, facilities small scale, low traffic network is extremely sparse, It accounts for about a fifth of the area of Pudong, so the overall development of the area needs to be further improved.

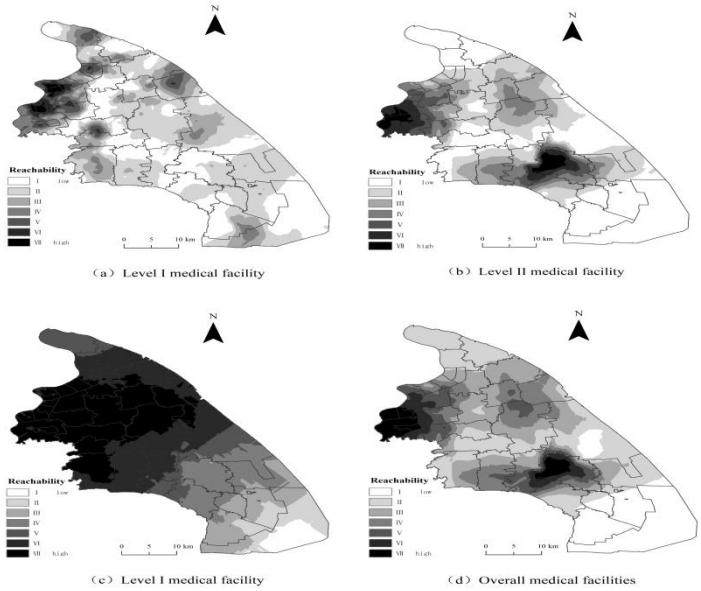

Figure 1. Accessibility of medical facilities

4.2 Analysis of Matching Relationship Between Supply and Demand of Medical Resources

Further, global bivariate spatial autocorrelation was used to analyze the correlation between accessibility of medical facilities at all levels and population density in Geoda1.18 software, and local bivariate spatial autocorrelation was used to analyze the relationship between accessibility of medical facilities at street level and town level and population density.

According to the calculation of the global bivariate Moran's I value of medical facilities and population density at all levels in Pudong New Area, all of them are greater than 0 (Table 2), indicating that there is a positive correlation between accessibility of medical facilities at all levels and population density in Pudong New Area, and there is a certain spatial agglomeration.

Table 2. Global bivariate Moran's I

	Level I medical facility	Level I medical facility	Level I medical facility	Overall medical facilities
Moran's I	0.399	0.138	0.196	0.181

In LISA diagram of level 1 medical facilities (Figure 2), there are 8 H-H cluster areas, in which medical resources can meet the needs of residents. L-H clustering area has Shanggang New Village, Hudong new village and so on a total of 5 streets, the five street health resources in short supply, because the area is located in the downtown area, limited land resources and the development is difficult, to improve the way should give priority to with inventory optimization, based on existing facilities can add beds, meet the needs of residents; Huinan town, Shuyuan town, Wanxiang town, and other 6 towns is L-L clustering area, medical resources supply is less, low population density, but the medical resource supply still exists a certain gap, can be from two aspects of inventory optimization and incremental layout, promoting the regional medical resource supply.

Secondary medical facilities matching supply and demand relations and the level of medical facilities matching relationship between supply and demand are basically the same, the difference is

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that Weifangxincun street from H-H clustering into L-H clustering, Huinan town by L-L clustering area into a H-L clustering area, the reason may be that there is no secondary hospitals in the region and the secondary hospital nearby in the search domain inaccessible, The latter may be mainly due to the presence of three level II medical facilities in Huinan Town, which has significantly increased the supply of medical resources in the region. There are 7 L-H cluster areas of tertiary medical facilities, which is the most among the three levels of medical facilities, indicating that people have a great demand for high-quality medical resources, but the existing high-quality medical resources cannot meet the demand. There is a level III medical facility in Huinan Town, which is well supplied and can better meet the needs of residents in the area. Overall situation of medical facilities supply and the secondary medical facilities supply situation is roughly same, but Huinan town by the level of health resources in short supply to the whole medical resource supply, the secondary and tertiary health care facilities can better improve the supply of medical resources, should be to spread beyond the regional health resources, driving the development of regional health resources around.

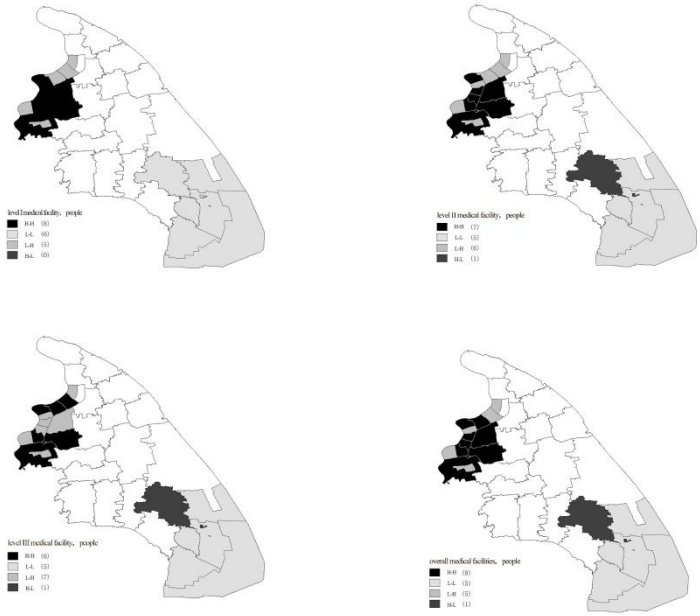

Figure 2. LISA cluster map of the correlation between medical facility accessibility and population density

5. Conclusion

In this paper, the ArcGIS spatial analysis tool is used to take the community as the minimum research unit. Considering the characteristics of the transportation network in Pudong New Area of Shanghai, the service capacity of different levels of medical facilities and the needs of residents, a three-level time threshold is designed, and the traditional Gaussian two-step mobile search method is improved to evaluate the accessibility of medical facilities in Pudong New Area. The matching relationship between medical resources supply and residents' demand in Pudong New Area was analyzed from the perspectives of supply and demand.

The results showed that: (1) The accessibility of medical facilities in Pudong New Area was unevenly distributed and the spatial concentration of medical resources was obvious through Gaussian two-step mobile search analysis. On the whole, there are two high value areas in the main city and the middle of the northwest, and they have an obvious outward downward trend. There is a large area of low values in the south. From the street level, medical facilities in Lujiazui Street, Weifangxincun Street, Tangqiao Street, Huinan Town and other areas are densely distributed and have a large scale and high accessibility. Regional medical facilities in Nanhui New Town, Nicheng

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Town, Shuyuan Town and Wanxiang Town are sparse and small in scale, with poor accessibility. Appropriate increase in the size of secondary and tertiary medical facilities and the intensity of the transportation network can effectively improve the accessibility of all regions. (2) The bivariate spatial autocorrelation analysis between the accessibility of medical facilities at all levels and the population density in Pudong New Area showed that there was a positive correlation between the accessibility of medical facilities at all levels and the population density in Pudong New Area, and there was a certain spatial aggregation. The study on the matching relationship between medical resources supply and residents' demand in Pudong New Area shows that there are a large number of areas in Pudong New Area with L-L cluster and L-H cluster, and the supply of medical resources is relatively insufficient. It is necessary to optimize the stock and incremental layout of existing medical facilities.

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