Research on the spatial distribution and accessibility of medical institutions in Wuhan based on GIS

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Abstract. To explore the rationality of the spatial distribution structure of medical institutions in Wuhan and provide a reasonable reference basis for the spatial layout of medical institutions. Using GIS spatial analysis methods to study the distribution characteristics and spatial accessibility in Guangzhou. Medical institutions in Wuhan have obvious spatial agglomeration characteristics and are concentrated in the central urban area. The spatial distribution of medical institutions in Wuhan is unbalanced and concentrated in the central urban area. The waste of health resources and the scarcity of health resources exist at the same time. The accessibility and fairness of medical institutions need to be improved, and reasonable planning and adjustment should be made.

1. Introduction
With the improvement of urban economic development level and residents' living standard, residents' demand for public health services is gradually increasing. At present, the service development of medical institutions lags behind the urban economic development, and the layout optimization of medical institutions is an important problem to be solved urgently. In recent years, with the development of geographic information science, GIS has gradually become one of the important research methods in the field of public health [1]. Wuhan is the central city in the central region of China, and it is also the core city of the Yangtze River Economic Belt. It is of great significance to study the spatial distribution of its medical institutions. Taking hospitals and community health service institutions in Wuhan as the research object, this paper discusses the spatial distribution characteristics and service level of medical institutions by using a variety of GIS spatial analysis methods, so as to provide reference for the layout and rational allocation of medical institutions in Wuhan.

2. Data sources and methods

2.1. Study area
Wuhan is taken as the research area in this paper. The total area of Wuhan is 8569.15km². By the end of 2019, there are 11.2 million permanent residents in Wuhan. Wuhan can be roughly divided into two circles: the central urban area and the outer suburban area. The central urban area includes Qiaokou District, Jianghan District, Hanyang District, Wuchang District, Qingshan District and Hongshan District.
2. Data sources

A total of 407 hospitals and 378 health service institutions in Wuhan in 2019 were selected as the research objects. The name data and category attribute data of various hospitals and community health service institutions are from the official website of Wuhan Health Commission. The population data of Wuhan comes from statistical yearbook, and the location of residential area is represented by administrative centre.

2.3. Research method

2.3.1. Analysis of spatial distribution characteristics. The methods used are mean nearest neighbour analysis and kernel density analysis. The mean nearest neighbour analysis can represent the spatial distribution characteristics of medical institutions by calculating the ratio R between the mean observed distance and the expected mean distance. When R < 1, it indicates that the spatial distribution of medical institutions is a cluster distribution mode. When R > 1, it is discrete distribution mode or competitive distribution mode. When R = 1, it is a random distribution pattern [2].

Kernel density analysis is a common spatial density analysis method, which can be used to calculate the density of each medical institution in its surrounding area and describe the spatial distribution characteristics of medical institutions.

2.3.2. Spatial accessibility analysis. The research methods used are Tyson polygon analysis and buffer analysis. Tyson polygon analysis can intuitively show the areas with the closest linear distance to the hospital to provide medical services, and these areas can be regarded as the service coverage of the sample points. The mathematical expression of buffer analysis is Bi=(x:d(xi, Oi)≤R), which can be used to calculate the number of medical institutions that can be selected in a residential area. Its characteristic is that it reflects the selectable ability of residents in the residential area.

3. Interpretation of result

3.1. Spatial distribution characteristics of medical institutions

3.1.1. Spatial distribution characteristics of major hospitals. Due to their comprehensive services, general hospitals and tertiary hospitals are often the hospitals that residents give priority to seek medical treatment. The number and average network density of general hospitals in Wuhan are higher than those of tertiary hospitals. In the analysis of average nearest neighbourhood, the average nearest neighbourhood distance of general hospitals and tertiary hospitals is 1809m and 2256m respectively, so the medical service of general hospitals is more convenient. The R values of the two are 0.546 and 0.678 respectively. The R values of the general hospital are smaller and have stronger agglomeration characteristics. As can be seen from Figure 1, the major hot spots of the general hospital are mainly distributed in the central and southern parts of Wuchang District, such as Jianshe Avenue and Huangpu Street in the south of Jiangnan District, and there is another small hot spot in the east of Qiaokou District. The hot spots of tertiary hospitals are in Jiefang Avenue in the south of Jiangnan District, Jianshe Avenue in the east of Jianghan District, Wusheng Road in the east of Qiaokou District, Baocheng Road and Baocheng Road, especially in the border area between Jianghan District and Jiangnan District, and also in the middle and south of Wuchang District. On the whole, the two types of medical institutions are similar in the distribution of intensive areas.
3.1.2. Spatial distribution characteristics of secondary hospitals. Compared with general hospitals, the number of secondary hospitals in Wuhan is relatively small. The average nearest neighborhood distance is 2659.24 meters, and the medical service is not very convenient. The R value is 0.578, showing strong agglomeration characteristics. It can be seen from Figure 3 that the major hot spots of secondary hospitals are mainly in Jianghan District, River Bank District and the area at the junction, followed by a small part of the area at the junction of Qingshan District and Wuchang District in the central and southern part of Wuchang District. Compared with general hospitals and tertiary hospitals, secondary hospitals have stronger spatial agglomeration, but fewer big hot spots.

3.1.3. Spatial distribution characteristics of community health service institutions. The number of community health service institutions in Wuhan is more than that of hospitals, with an average
network density of 0.0441 per square kilometer and an average neighbourhood distance of 1158.53 meters. Compared with secondary hospitals, tertiary hospitals and general hospitals, it is obvious that community health service institutions provide more convenient medical services. According to the mean spatial nearest neighbour analysis, the R value of the analysis is 0.532, and the Z value is -17.153, which has a significant clustering feature in the spatial distribution.

3.2. Space accessibility of medical institutions

3.2.1. Tyson Polygon Analysis. Using the Tyson polygon tool in ArcGIS to map the secondary and tertiary hospitals and general hospitals respectively, obtain the relative service scope of each hospital, and calculate the service population and area of each Tyson polygon area respectively (Figure 5, 6 and 7). The deeper the color in the picture represents the more the population serving the region, the secondary hospital serving the largest population reaches 500,700 people, the tertiary hospital serving the largest population is 624,600, and the general hospital serving the largest population reaches 407,900 people; However, it can be seen from the picture that whether in secondary hospitals, tertiary hospitals or general hospitals, some Tyson polygons of some hospitals do not cover the residential areas; The larger the area of Tyson polygon, the larger the area served by the medical institution serves, leading to the greater service pressure of the medical institution, and the relatively few choices of residents in the area[3].

Figure 5 Secondary Hospital Tyson Polygon

Figure 6 Tyson Polygon of tertiary Hospital

Figure 7 General Hospital Tyson Polygon
Figure 5, the black area is mainly concentrated in Jiangxia District in the southeast of Wuhan and part of the central Hanyang District and Hongshan District, indicating the large population needed by the medical institutions in the area; The single Tyson area with large polygons is mainly located in Huangpi District in the northwest, Xinzhou District in the northeast, Jiangxia District in the southeast and Caidian District in the southwest. Caidian District and Xinzhou District are relatively small. Although the service of medical institutions is relatively small, the service area is too large and not convenient for residents to seek medical treatment. Huangpi District and Xinzhou District show that medical institutions not only serve a wide range but also serve a large population.

Figure 6 is similar to Figure 5, which also presents a large difference of Tyson polygonal area, crowded urban hospitals, a large service scope of suburban hospitals and a large service population.

In Figure 7, the color distinction of each area is not obvious, but the white Tyson polygonal area has increased significantly, and the cluster of hospitals in the central urban area is more obvious, indicating that many general hospitals carry less service population, and the cluster of general hospitals in the central urban area has largely caused the waste of medical resources.

Combined with the statistical function of ArcGIS, the proportion of residents, population, and area served at each level after the service population stratification are calculated respectively (Table 1,2 and 3). From Table 2, the service area is only 2.62% of 164,993 ~ 249,879, while the service population reaches 17.09%; Of the service population of 363,599 ~ 624,630, it covers 54.55%, compared to only 25.15% of the service population. Of the class of service population 0 ~ 27,028, General hospitals serve 15.17%, compared to only 0.64% of the service population.

Table 1. Statistical Table of Space Distribution of Service Population of Secondary Hospital.

| Statistical indicators | Population (person) | 0~2238 | 22385~868 | 86882~1495 | 149567~2185 | 218592~3373 | 337364~5007 |
|------------------------|---------------------|--------|-----------|------------|------------|------------|------------|
| Share of the settlements (%) | 1.08 | 12.97 | 21.62 | 20.54 | 28.11 | 15.68 |
| Population ratio (%) | 0.36 | 9.47 | 17.77 | 25.71 | 28.19 | 18.50 |
| Area proportion (%) | 3.34 | 13.86 | 21.56 | 17.56 | 26.47 | 17.22 |

Table 2. Statistical Table of Space Distribution of Service Population in Level III Hospitals

| Statistical indicators | Population (person) | 0~2702 | 27029~9481 | 94814~1649 | 164993~2498 | 249880~3635 | 363599~6246 |
|------------------------|---------------------|--------|-----------|------------|------------|------------|------------|
| Share of the settlements (%) | 2.70 | 15.14 | 21.62 | 12.97 | 16.76 | 30.81 |
| Population ratio (%) | 0.99 | 10.04 | 23.92 | 17.09 | 22.8 | 25.15 |
| Area proportion (%) | 3.16 | 13.69 | 8.83 | 2.63 | 17.25 | 54.44 |

Table 3. Space Distribution of Service Population in General Hospital

| Statistical indicators | Population (person) | 0~2702 | 27029~9481 | 94814~1649 | 164993~2498 | 249880~3635 | 363599~6246 |
|------------------------|---------------------|--------|-----------|------------|------------|------------|------------|
| Share of the settlements (%) | 3.24 | 15.14 | 28.11 | 23.24 | 23.78 | 6.49 |
| Population ratio (%) | 0.64 | 7.69 | 21.37 | 26.65 | 36.11 | 7.54 |
| Area proportion (%) | 15.17 | 6.81% | 32.69 | 24.22 | 13.73 | 7.38 |
3.2.2. Buffer Analysis. The non-integrated hospital buffer and the settlement are used for superposition analysis, and the number of secondary hospitals available within 1km, 2km, 3km, 4km, 5km of each settlement is calculated. According to the principle of nearby medical treatment, the large radius distance after 5km is not calculated. Within 2km, there are 111 settlements (accounting for 60% of the total residents of Wuhan City) and no secondary hospitals can choose. These settlements are relatively scattered in the outer suburbs of urban areas, and 20 settlements have more than 3 secondary hospitals to choose from, and these settlements are mainly concentrated in the central urban area. As the radius increased, no hospitals chose residents declined, 1~10 optional secondary hospitals gradually increased, with the search radius of 5km, 78 settlements (43%) had tertiary or above secondary hospitals available.

| The Distance: (km) | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
|-------------------|----|----|----|----|----|----|----|----|
| 1                 | 14 | 3  |    |    |    |    |    |    |
| 2                 | 11 | 2  | 1  |    |    |    |    |    |
| 3                 | 90 | 1  |    |    |    |    |    |    |
| 4                 | 78 | 1  | 6  | 1  | 1  |    |    |    |
| 5                 | 66 | 1  | 8  | 6  | 7  | 4  | 2  | 1  |

Table 4. Distribution of optional secondary hospitals within 1 km ~ 5 km

4. Conclusions

4.1. The medical institutions in Wuhan are centrally distributed in the central urban area
According to the results of the average nearest neighbor analysis and the nuclear density analysis, the distribution and agglomeration characteristics of medical institutions in Wuhan are obvious. On the one hand, Wuhan hospitals are concentrated in the central urban area, and the R value of the secondary hospitals, tertiary hospitals and general hospitals in the average nearest neighbor analysis is less than 1, which have strong spatial agglomeration characteristics, reflecting in the nuclear density analysis diagram, its hot areas are centrally distributed in the central urban area[4]. Community health service institutions are also concentrated in the central urban area, but compared with the distribution of hospitals, community health service agencies have more hot areas, the average network density is higher and the average nearest neighbor distance is shorter.

4.2. The accessibility and fairness of Wuhan medical institutions need to be improved
In the Tyson polygon analysis, part of the hospitals reached 500000, which has only 3~4 secondary hospitals in Xinzhou district and Huangpi district and are concentrated in the county area, and the suburban areas have a large population, 3~4 secondary hospitals cannot meet the needs of local residents for medical treatment. In these areas, on the one hand, it is necessary to increase the number of secondary hospitals to alleviate the demand of the existing small secondary hospital service carrying capacity. On the other hand, the service capacity of the corresponding secondary hospitals can be increased to meet the requirements of Grade II and Grade A. And some secondary hospital Tyson polygon covers the number of residents is 0~22384, which covers the population of 500000 secondary hospitals, query found that covers the population of the least of 10 Tyson polygons found to the corresponding Jianghan district, Qiao Kou district, riverbank district, hanyang district central district of the secondary hospitals, and the secondary hospitals in the area of hospitals is serious. The analysis results of Tyson polygonal of tertiary hospitals are basically the same as that of secondary hospitals. It is also a cluster of hospitals in the central urban area, resulting in the small population and the largest population of Tyson poly of tertiary hospitals in far suburbs covering more than 600,000,
and the gap is very huge. This shows that there is also a waste of medical resources and scarce medical resources in Wuhan. We must adjust the layout, limit the expansion of hospitals in the central city, and the development of the remote suburbs where medical institutions are scarce to reduce the overload of the existing remote suburban hospitals.

3km has 90 residents within the radius of no secondary hospital can choose, but there are 11 settlements have more than 6 hospitals can choose, shows the waste of health resources and health resources scarcity at the same time, should be the outer suburbs add hospital, should also take means to put an end to the waste of medical resources caused by some regional hospitals.

References
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