Accessibility and Population Matching Analysis of Public Service Facilities Based on the Gaussian Mobile Search Method

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Abstract: Public service facilities are an essential index to measure urban infrastructure, people's livelihood and well-being and a necessary standard to evaluate public service management. Taking Daoli District and Nangang District of Harbin City as the study area, this paper calculates and analyzes the coverage and population distribution of 15-minute accessibility of public service facilities in the study area based on the Gaussian two-step mobile search method and ArcGIS Natural breaks. The results show that: 1) The overall layout of the study area is reasonable, but the spatial layout of public facilities such as cultural, sports, and medical facilities needs to be strengthened. 2) The data shows that the spatial layout of Daoli District is more reasonable. 3) Most residents can reach five types of public service facilities within 15 minutes.

1 INTRODUCTION

The construction of public service facilities is the basis of urban spatial layout and convenience for residents, which is also an important performance to measure the working ability of the government and fulfill the purpose and obligation of the government. The essence of public service facilities is to serve citizens, so we should pay attention not only to the increase in quantity but also to the quality of service.

There are abundant research results on the accessibility of public service facilities. In terms of research objects, some scholars pay attention to the accessibility of park green space (Chen 2020), while others pay attention to the accessibility of medical facilities (Xiao, Yuan, Xu 2009). It is relatively single, so this paper tries to construct a dual index for analysis. There are also many research methods, such as the nearest distance method (Fryer 2010), and the spatial interaction-based method (Spencer 2014, Luo 2004). Through comparison and careful consideration required in this paper, the Gaussian two-step search method (Tao 2016) is used for research and analysis. ArcGIS was used to transform the data into a plan to show the distribution of public service facilities and population, and the concept of the 15-minute life circle was introduced to evaluate the matching degree of the two.

2 OVERVIEW OF THE STUDY AREA

Harbin, the capital city of Heilongjiang Province, is the provincial capital city with the highest altitude in the country and is located in the center of Northeast Asia. By 2021, Harbin had jurisdiction over nine districts and seven counties, with a total area of 53,186 square kilometers and a permanent population of nearly 10 million. Nangang District and Daoli District, which were developed earlier, are taken as the research areas of this paper.

3 DATA SOURCES AND RESEARCH METHODS

3.1 Data Sources

The subjects included population, health care, education, commerce, sports, and public services such as parks. According to the latest yearbook of

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the local statistics department, as of October 2021, there were 2,488,109 people in the experimental area. Among, Daoli District 1097430 people, and Nangang District 1390679. Other data were obtained from local education, planning, civil affairs, and other relevant departments or government public information.

3.2 Research Methods

The mobile search method used in the early stage is based on the calculation of the census unit as the center, in a given radius of the search area supply and demand ratio to the target accessibility and two. Compared with the former, the Gauss two-step mobile search engine adopted in this paper has two advantages. First, it solves the problem that the distance between supply and demand is too long to be used. Second, it solves the problem of cross-regional supply of demand by suppliers. The Gaussian mobile search method is divided into two steps. First, the coordinates of public facilities are set as point J, and all residents within the threshold range of point J are searched. The weighted sum of the Gaussian function is used to obtain the resident data within the threshold range of the point where the facilities are located, and then the demand-supply ratio of facility J is calculated. The specific calculation formula is as follows:

$$R_j=\frac{s_j}{\sum_{i\in (d_{ij}\le d_0} G(d_{ij},d_0)p_i} \quad (1)$$

Where: Rj is the supply-demand ratio of facility point j, S_j is the scale (area) of facility point j, D_{Ij} is the distance between facility point j and settlement I (road network distance), D0 is the search threshold, P_i is the scale (population) of settlement I within the threshold, and G (D_{Ij}, D0) is the Gaussian function. The specific calculation method is as follows:

$$G_{(d_{ij},d_0)}=\begin{cases}\frac{e^{-\frac{1}{2}\left(\frac{d_{ij}}{d_e}\right)^2}-e^{-\frac{1}{2}}}{1-e^{-\frac{1}{2}}}, d_{ij}\le d_0\\ 0, d_{ij}>d_0\end{cases} \quad (2)$$

Step 2: Centering on residential area i, search all facility points within the threshold range, and calculate the supply and demand ratio of all facility points by weighting the Gaussian function. The specific calculation formula is as follows

$$A_i=\sum_{j\in(d_{ij}\le d_0)} G(d_{ij},d_0)R_j \quad (3)$$

Where: A_i is the accessibility of settlement I, R_j is the supply-demand ratio of facility point j, and G (D_{Ij},d0) is a Gaussian function. In this paper, the supply point and demand point are divided into a 50*50 meters grid, and the geographic center of the grid is used for a two-step mobile search. The practical significance of the representation of accessibility calculated based on the Gaussian two-step mobile search method is the number of public service facilities accessible to each person in the research unit. In this paper, the practical meaning of the representation is the number of public service facilities available to each person in the grid.

4 DISTRIBUTION CHARACTERISTICS OF ACCESSIBILITY OF PUBLIC SERVICE FACILITIES IN THE STUDY AREA

4.1 Accessibility of Public Services

4.1.1 Accessibility of Educational Facilities

The maximum value of accessibility to educational facilities is 4196.04, and the minimum value is 0. Using the natural break point method in ArcGIS10.2, the accessibility of educational facilities in the grid of the study area was divided and calculated according to five levels. The results showed that there were 22,557 grids, and the accessibility of medical facilities for 2,455266 people was below 13.10. Units with per capita accessibility below 13.10 accounted for 98.68% of all grids and 96.24% of the total population. Again, the natural break point method was used to divide the grid with accessibility below 13.10. It can be seen that the accessibility of medical facilities is spatially "high in the northwest and low in the southeast".

4.1.2 Accessibility of Medical Facilities

The maximum value of accessibility to medical facilities was 95.75, and the minimum value was 0. Using the natural break point method in ArcGIS10.2, the accessibility of educational facilities in the grid of the study area was divided and calculated according to five levels. The results showed that there were a total of 20193 grids, and the accessibility of medical facilities for 218,724 people was below 0.83. Units with per capita accessibility below 0.83 accounted for 86.24% of all grids and 84.65% of the total population. Again, the natural break point method was used to divide the grid with accessibility below 0.83. It can be seen that the accessibility of medical facilities is spatially "high in the northwest and low in the southeast".

4.1.3 Accessibility of Commercial Facilities

Put the relevant data into the formula and calculate the maximum value of commercial facilities accessibility is 6769.29, and the minimum value is 0. By using the natural break point method in ArcGIS10.2, the accessibility of commercial facilities in the grid of the study area was divided and calculated according to five levels. The results showed that there were 22,728 grids, and the accessibility of commercial facilities for 2,733,165 people was below 41.41. The units with per capita accessibility below 41.41 accounted for 97.07% of all grids and 98.61% of the total population. Again, the natural break point method is used to divide the grid of accessibility under 41.41. It can be seen that the accessibility space of commercial facilities presents "high in the west and low in the east".

4.1.4 Accessibility of Cultural and Sports Facilities

By putting relevant data into the formula and calculating, the maximum value of accessibility to cultural and sports facilities is 1577.73, and the minimum value is 0. By using the natural break point method in ArcGIS10.2, the accessibility of educational facilities in the grid of the study area was divided and calculated according to five levels. The results showed that there were 23140 grids, and the accessibility of cultural and sports facilities for 2,649,426 people was below 10.27. Cells with per capita accessibility below 10.27 accounted for 98.83% of all grids and 99.13% of the total population. Again, the natural break point method is used to divide the accessibility grid at 10.27. It can be seen that the accessibility space of cultural and sports facilities presents "high in the middle and low around".

4.1.5 Accessibility of Park Facilities

The maximum value of accessibility to park facilities is 1806.51, and the minimum value is 0. Using the natural break point method in ArcGIS10.2, the accessibility of educational facilities in the grid of the study area was divided and calculated according to five levels. The results showed that there were 22,396 grids, and the accessibility of cultural and sports facilities for 2,785,771 people was below 14.72. Units with per capita accessibility below 14.72 accounted for 95.65% of all grids and 96.99% of the total population. Again, the natural break point method is used to divide the accessibility grid at 10.27. It can be seen that the accessibility space of park facilities presents "high in the northwest and low in the southeast".

4.2 Public Service Facilities and Population Analysis

Table 1: Accessibility of educational facilities and population coverage.

index	Nangang District	Daoli District
15-minute accessibility	2.34	1.18
Population coverage	95.82	97.73

As can be seen in Table 1, the accessibility of educational facilities in Daoli District is 1.18, and that in Nangang District is 2.34. The accessibility of Nangang District is nearly twice that of Daoli District. In terms of the population coverage of education facilities within 15 minutes, the population coverage rate of Daoli District is 97.73%, and that of Nangang District is 95.28%. The population coverage rate of Daoli District is about two percentage points higher than that of Nangang District.

Table 2: Accessibility of medical facilities and population coverage.

index	Nangang District	Daoli District
15-minute accessibility	0.34	0.68
Population coverage	78.93	92.34

As can be seen from Table 2, the accessibility of medical facilities in Daoli District is 0.68, and that in Nangang District is 0.34. The accessibility of Nangang District is nearly twice that of Daoli District. In terms of the population coverage of medical facilities within 15 minutes, the population coverage rate of Daoli District is 92.34%, and that of Nangang District is 78.93%. The population coverage rate of Daoli District is about 15 percentage points higher than that of Nangang District.

Table 3: Accessibility of commercial facilities and population coverage.

index	Nangang District	Daoli District
15-minute accessibility	9.19	3.31
Population coverage	98.25	99.24

As can be seen from Table 3, the accessibility of commercial facilities in Daoli District is 3.31, and that in Nangang District is 9.19. The accessibility of commercial facilities in Daoli District is less than half that in Nangang District. The accessibility of the Nangang district is nearly twice that of the Daoli District. From the perspective of the population coverage within 15 minutes of commercial facilities, the population coverage rate of Daoli District is 99.24%, and that of Nangang District is 98.25%. The gap between the two is not very large.

Table 4: Accessibility of cultural and sports facilities and population coverage.

index	Nangang District	Daoli District
15-minute accessibility	0.81	0.40
Population coverage	74.95	93.31

As can be seen from Table 4, the accessibility of cultural and sports facilities in Daoli District is 0.40, and that in Nangang District is 74.95, twice that in Daoli District. The accessibility of Daoli District is lower than that of Nangang District. However, due to the large internal differences in Nangang District, the value of most areas is 0, so the accessibility of recreational and sports facilities is spatially high in the middle and low on the two sides.

Table 5: Accessibility of park facilities and population coverage.

index	Nangang District	Daoli District
15-minute accessibility	2.09	2.84
Population coverage	93.78	97.94

As can be seen from Table 5, the accessibility of park facilities in Daoli District is 2.84, and that in Nangang District is 2.09. The accessibility of Daoli District is about 1.3 times that of Nangang District. In terms of population coverage rate, Daoli District is 97.94, and Nangang District is 93.78. The population coverage rate of Daoli District is about 4% higher than that of Nangang District.

4.3 Comparative Analysis

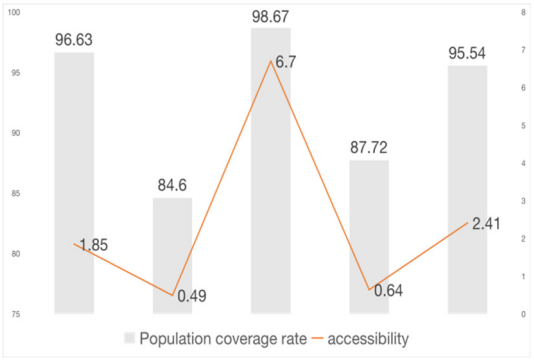

Figure 1: Comparison of accessibility and population coverage of various facilities.

According to Figure 1, the 15-minute accessibility and population coverage of commercial, park, and educational facilities are relatively high. The 15-minute accessibility of cultural, sports, and medical facilities is less than 85% of the population, and the accessibility is less than 0.8, indicating that there is room for optimization of the spatial layout of cultural, sports, and medical facilities.

5 CONCLUSION

Five types of representative public service facilities in the study area were selected in the text, and their grid analysis was carried out by using tools. The data showed that if the accessibility was greater than 0, it meant that the residents represented by the grid units were within 15 minutes of the public service facilities. Further analysis shows that there are 14632 (62.49%) grid data that can use five types of public facilities within 15 minutes in the study area, and 2181930 (73.58%) people can reach five types of public service facilities within a 15-minute life circle through the conversion of grid units and population data.

Based on the above analysis, the following three conclusions are drawn: 1) The accessibility and population coverage of education facilities, commercial facilities, and park facilities are reasonable, and the population distribution is relatively matched. However, the layout of medical facilities and cultural and sports facilities is contradictory to the population distribution, and there is still a large space for improvement in the spatial layout. 2) The special spatial distribution of different public facilities can be seen through the grid data. On the whole, the accessibility presents a

spatial layout of "high in the middle and low on both sides". 3) The overall data of 15-minute accessibility of public facilities are good, with nearly 80% of residents within its range, and the overall spatial distribution is reasonable. But there are still some people who cannot fully enjoy high-quality public service facilities.

REFERENCES

Chen Fan. (2020), Spatial pattern and accessibility of medical and health institutions in the main urban area of Hefei. Jiangsu Urban Planning, 2020, (07): 28-32.

Fryer G E, Drisko J, Krugman R D, et al. (2010), Multi-method assessment of access to primary medical care in rural Colorado[J]. Journal of Rural Health, 2010,15(1):113-121

Luo, Jun. (2014). Integrating the Huff Model and Floating Catchment Area Methods to Analyze Spatial Access to Healthcare Services[J]. Transactions in Gis, 2014, 18(3):436-448

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

Tao Zhoulin, Cheng Yang. (2016). Progress in two-step mobile search and its extended form [J]. Progress in Geography, 2016,35(05):589-589

Xiao huabin, Yuan Qifeng, Xu Huijin. (2009). Research on the spatial distribution of park green space based on accessibility and service area [J]. Planners, 2009,25(02):83-88