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Analysis of Agglomeration Characteristics of Public Service Facilities in Mountainous Villages and Towns Based on POI Data

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ABSTRACT

This paper obtains the population data and GDP data of 13 counties in the Aba Tibetan and Qiang Autonomous Prefecture of Sichuan Province, China based on the government statistical data set, obtains the POI data based on the Gaode map, and uses Average Nearest Neigh Index, Kernel Density Analysis, Standard Deviation Ellipse, Pearson Correlation Analysis method to analyze the agglomeration characteristics of public service facilities in each county and its correlation with the level of economic development. The results show that: the public service facilities in the study area as a whole show a spatial pattern of "more in the southeast and less in the northwest"; the spatial agglomeration of various public service facilities is significant, and the degree of agglomeration of tourism-related public service facilities such as catering and shopping is the highest, financial insurance, science, education and other life-related public service facilities have the lowest degree of agglomeration; all kinds of public service facilities are in the direction of "southwest-northeast" as a whole, and public service facilities related to outdoor activities such as sports, leisure and accommodation have the strongest directionality; the spatial agglomeration of public service facilities in the research area is influenced by factors such as natural and economic development.

Keywords: POI, Mountain villages and towns, Public service facilities, Agglomeration characteristics

INTRODUCTION

Public service facilities refer to spaces that provide various public services for urban and rural residents, including basic service facilities such as education, culture, sports, healthcare, commerce, finance, and community services (Kiminami et al., 2006). The spatial layout of public service facilities directly affects the quality of production and life of urban and rural residents. Its distribution and configuration issues have attracted attention from fields such as geography, planning, management, and economics, including the configuration mechanism of public service facilities (Greenhut and Mai, 1980), public satisfaction (Michalos and Zumbo, 1999), location distribution (Langford et al., 2008), and plot characteristics (Liu and Long, 2016).

POI data is widely distributed and easy to obtain (Yang et al., 2019), and has been used for research on the layout of urban and rural public service

facility elements at multiple scales. The research mainly focuses on the characteristics of facility spatial layout (Zhai et al., 2017), equalization and fairness issues (Zhao and Zhang, 2020), and the correlation between other spatial elements and facility distribution (Zhao et al., 2018). The analysis methods include facility clustering analysis based on the average nearest neighbor method (Luo and Zhang, 2021), distribution feature analysis based on kernel density analysis (Ning et al., 2020), spatial development direction prediction based on standard deviation ellipse analysis (Guo and Liu, 2021), and influencing factor analysis based on Pearson correlation analysis (Pei et al., 2018).

This article is based on the national population census data, per capita GDP data, and POI data of Aba Tibetan and Qiang Autonomous Prefecture. Using nearest neighbor index, kernel density analysis, standard deviation ellipse, and Pearson correlation analysis methods to present the spatial agglomeration characteristics of facilities in each county and explore the relationship between economic development level, population migration rate, and the distribution of various service facilities.

METHODOLOGY

Study Area

The location of Aba Tibetan and Qiang Autonomous Prefecture (hereinafter referred to as Aba Prefecture) is 30°5′N-34°9′N, 100°0′E-104°7′E. It is situated on the southeastern edge of the Qinghai-Tibet Plateau and belongs to the northwest mountainous area of Sichuan Province, China. It governs 1 county-level city and 12 counties (Figure 1), with a total area of 84242 square kilometers. Aba Prefecture is located in a remote area, with frequent disasters and underdeveloped economy, making it highly representative and unique among mountainous villages and towns. On the other hand, Aba Prefecture has magnificent natural scenery and profound cultural heritage. Under the leadership of the comprehensive tourism strategy, Aba Prefecture has gradually formed an industrial structure mainly consisting of agriculture, animal husbandry, tourism, and hydropower. The distribution of public service facilities in the region is of great significance for regional development.

Figure 1: County level administrative division map of Aba Prefecture.

Data Collection

The population data is sourced from the sixth national population census data of Aba Prefecture in 2011 and the seventh population census data of Aba Prefecture in 2021; The per capita GDP data used to characterize the level of economic development is sourced from the 2019 government work report of Aba Prefecture. This paper calculates the population migration rate based on population data, and the expression is as follows:

$$R = 1 - M_0/M_1 \tag{1}$$

In the formula: R is the population migration rate, M_0 represents the data of the sixth national population census, M_1 is the data from the seventh national population census.

The POI point data used to characterize the richness of facilities is sourced from the Gaode Map API, which screened 23 types of POI. This paper selected 12 types of POI point data that represent regional vitality levels and public services for research, including catering services, shopping services, living services, accommodation services, sports and leisure services, cultural services, transportation services, healthcare services, financial services, scenic spots, administrative agencies, and companies facilities.

The source of administrative division data is the 1:1 million national basic geographic database provided by the National Catalogue Service For Geographic Information (http://www.webmap.cn). The research adopts the CGCS2000 3 Degree GK CM 102E Projected Coordinate System.

Data Analysis

Average Nearest Neigh Index. The average nearest neighbor index is a spatial econometric method that quantitatively describes the proximity of spatial point like elements and judges their spatial pattern characteristics (Huang et al., 2021). The calculation formula is:

$$ANN = \overline{D}_0/\overline{D}_E \tag{2}$$

$$\overline{D}_0 = \sum_{i=1}^{n} d_i/n \tag{3}$$

$$\overline{D}_E = 0.5/\sqrt{n/A} \tag{4}$$

In the formula: ANN represents the average nearest neighbor index; $\overline{D}_0$ represents the average observation distance between each element and the nearest element; $\overline{D}_E$ represents the expected average distance between elements in a random pattern; n is the quantity of elements; A is the area of the study area. The study adopts the average nearest neighbor index analysis method to study the agglomeration of various public service facilities. When ANN<1, the trend of factor distribution is agglomeration, and the smaller the ANN value, the higher the degree of agglomeration; When ANN = 1, the trend of factor distribution follows the model; When ANN>1, the trend of factor distribution is discrete, and the larger the ANN value, the higher the degree of dispersion.

Kernel density analysis. The kernel density analysis method calculates the data aggregation status within the research scope through input, reflecting the spatial relative concentration degree of point element distribution. The calculation formula is:

$$f(x) = \sum_{i=1}^{n} \frac{k}{r^2}\left(\frac{x - x_i}{r}\right) \tag{5}$$

In the formula, $f(x)$ is the kernel density calculation function of spatial position x; n is the number of elements whose distance from the spatial position x is less than or equal to r; k is the spatial weight function; r is the distance attenuation threshold. Its geometric significance in space is that the kernel density value reaches its maximum at each core element x_i, and continuously decreases as it moves away from the core element x_i. Until the distance from x_i reaches the threshold r, the kernel density value drops to 0.

Standard deviation ellipse analysis. The standard deviation ellipse analysis method quantitatively describes the spatial distribution trend and evolution characteristics of the research object by using spatial distribution ellipses with center point, azimuth, major half axis, and minor half axis as basic parameters. The center point of the ellipse represents the center position of the entire data, the long half axis represents the direction of data distribution, and the short half axis represents the range of data distribution (Huang et al., 2021). The calculation formula is:

Average center:

$$\overline{X}_\omega = \frac{\sum_{i=1}^{n} \omega_i x_i}{\sum_{i=1}^{n} \omega_i}, \quad \overline{Y}_\omega = \frac{\sum_{i=1}^{n} \omega_i y_i}{\sum_{i=1}^{n} \omega_i} \tag{6}$$

Elliptical azimuth:

$$\tan\theta = (A + B)/C \tag{7}$$

$$A = \sum_{i=1}^{n} \omega_i \tilde{x}_i^2 - \sum_{i=1}^{n} \omega_i \tilde{y}_i^2 \tag{8}$$

$$B = \sqrt{\left(\sum_{i=1}^{n} \omega_i \tilde{x}_i^2 - \sum_{i=1}^{n} \tilde{y}_i^2\right)^2 + 4\sum_{i=1}^{n} \omega_i{}^2 \tilde{x}_i^2 \tilde{y}_i^2} \tag{9}$$

$$C = 2\sum_{i=1}^{n} \omega_i{}^2 \tilde{x}_i \tilde{y}_i \tag{10}$$

X-axis standard deviation:

$$\rho_x = \sqrt{\frac{\sum_{i=1}^{n} \left(\omega_i \tilde{x}_i \cos\theta - \omega_i \tilde{y}_i \sin\theta\right)^2}{\sum_{i=1}^{n} \omega_i{}^2}} \tag{11}$$

Y-axis standard deviation:

$$\rho_y = \sqrt{\frac{\sum_{i=1}^{n} \left(\omega_i \tilde{x}_i \sin\theta - \omega_i \tilde{y}_i \cos\theta\right)^2}{\sum_{i=1}^{n} \omega_i^2}} \tag{12}$$

In the equation: $(\overline{\overline{X}}_\omega, \overline{Y}_\omega)$ is the central coordinate of the ellipse; (x_i, y_i) is the coordinate of i; ω_i is the weight; θ is the azimuth angle; $\tilde{x}_i$, $\tilde{y}_i$ is the deviation between the coordinates of i and the center of the ellipse; ρ_x, ρ_y represents the standard deviation along the major and minor axes, respectively, and represents the values of the major and minor axes of the ellipse.

Pearson correlation analysis. Use Pearson correlation analysis to examine the correlation between population migration rate, GDP, and service facility distribution.

RESULTS

Distribution Results of Various Service Facilities

The overall spatial agglomeration of various service facilities is significant, with different spatial agglomerations. According to the calculation results of the nearest neighbor index (Table 1), it can be seen that: (1) The nearest neighbor index ANN of various service facilities is less than 1, showing a clear spatial clustering feature. The spatial agglomeration of various service facilities varies. Firstly, the nearest neighbor index of tourism related public service facilities such as catering services, shopping services, and accommodation services is the smallest (0.09-0.10), exhibiting extremely strong clustering characteristics. (2) The nearest neighbor index of public service facilities related to daily life, such as life services, financial services, sports and leisure services, transportation services, administrative agencies, cultural services, and healthcare services, is relatively high (0.19-0.27), showing a strong clustering feature. (3) The nearest neighbor index of companies and scenic spots is the highest (0.29-0.41), showing a strong clustering feature.

The distribution trend of various public service facilities is generally similar, with similar distribution among different types. From the standard deviation ellipse analysis results (Figure 2), it can be seen that: (1) From the shape of the standard deviation ellipse, the distribution direction of various service facilities is generally southwest northeast, which basically conforms to the three-point growth pole layout in the prefecture, namely, Maerkang City, Jiuzhaigou County, Wenchuan County and Mao County. (2) From the long axis of the standard deviation ellipse of various facilities, the long axis of scenic spots and transportation service facilities is in the direction of Jiuzhaigou County. (3) From the elliptical shape of the standard deviation of various facilities, accommodation services and sports and leisure services have the strongest directionality.

The spatial distribution of various public service facilities varies. According to the results of kernel density analysis (Figure 3), it can be seen that: (1) The high-density areas of various service facilities are generally concentrated in the centers of each county, and the overall density presents a pattern of

"high in the southeast and low in the northwest". (2) The aggregation of four types of facilities, namely catering, shopping, living services, and healthcare services, that serve basic daily needs, is relatively balanced in the centers of each county. (3) The balance of accommodation services, sports and leisure services, cultural services that serve spiritual and cultural needs is poor, showing a trend of high in the east and low in the west. (4) The scenic spots and transportation service facilities that support tourism development are densely distributed in the east and middle. The high-density belt is concentrated in Wenchuan County, Mao County and Jiuzhaigou County on the east edge of Aba Prefecture, and the high-density belt connects Markang City and Ruoergai County. (5) Companies, financial services that support economic development have shown two growth poles: Maerkang City, Wenchuan County, and Mao County.

Table 1. POI facility nearest neighbor index calculation results.

Category	Catering serives facilities	Shopping services facilities	Living services facilities	Sports and leisure services facilities	Accomm-odation services facilities	Cultural services facilities
ANN	0.09	0.09	0.19	0.21	0.10	0.26
Average observation distance/km	0.22	0.19	0.74	1.04	0.25	1.57
Expected average distance/km	2.29	2.11	3.70	4.87	2.38	6.00
Score	-112.63	-128.54	-69.70	-46.95	-109.08	-37.08
Category	**Healthcare Services facilities**	**Transportat -ion services facilities**	**Financial services facilities**	**Scenic Spots services facilities**	**Adminstrative services facilities**	**Company facilities**
ANN	0.27	0.21	0.20	0.41	0.24	1.46
Average observation distance/km	1.54	1.32	1.43	2.74	0.62	0.29
Expected average distance/km	5.77	6.17	7.14	6.60	2.59	4.99
Score	-38.52	-38.17	-31.51	-28.41	-94.00	-43.30

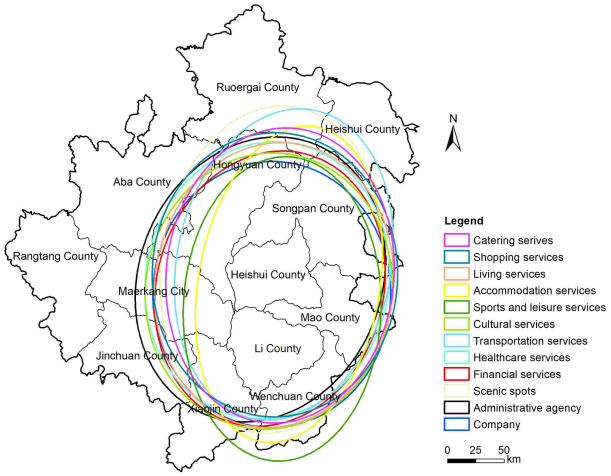

Figure 2: Ellipse of standard deviation for various service facilities in Aba Prefecture.

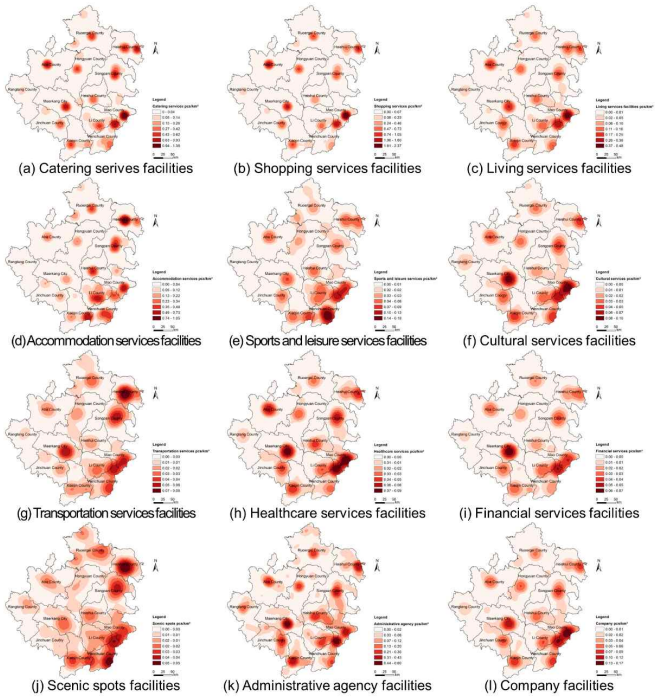

Figure 3: Analysis of kernel density of various service facilities in Aba Prefecture.

Correlation Analysis Results of the Distribution of Various Service Facilities

Pearson correlation analysis was conducted on the population migration rate, GDP, and density of various facilities in each county. The results (Figure 4) show that the population migration rate is significantly positively correlated with the density of accommodation services, administrative agencies, transportation services, and scenic spots facilities; GDP is significantly positively correlated with culture, sports, health, transportation, finance, scenic spots, administrative agencies, company facilities.

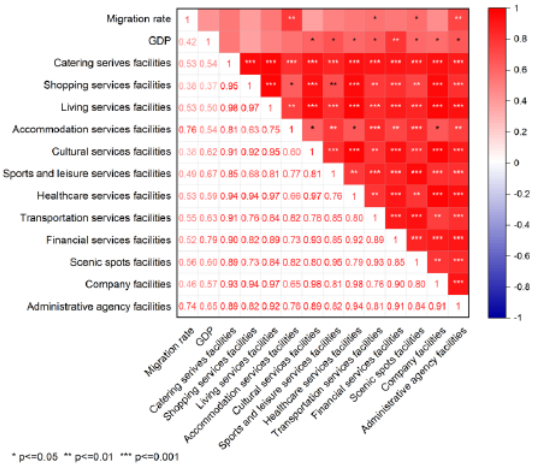

Figure 4: Correlation analysis results of density of various service facilities with population migration rate and GDP.

DISCUSSION

Differences in Facility Density Due to Geographical Advantages

In mountainous villages and towns in Aba Prefecture, various public service facilities tilt towards the areas near Chengdu Plain, administrative centers, and popular tourist attractions. Firstly, the convenient transportation in Wenchuan County, Mao County, and other areas near the Chengdu Plain is the foothold of the concept of "high mountains towards dams, small cities towards big cities" in the northwest counties. Adjacent to the Chengdu Plain, it has a rich range of business formats, corresponding to a variety of public service facilities with high density. Secondly, as the administrative center of Aba Prefecture, Maerkang City has a significant resource agglomeration effect brought about by regional level, and various public service facilities gather here; Correspondingly, the administrative centers of each county gather over half of the public service facilities at the community level. Finally, as one of the oldest and most important natural resources in Aba Prefecture, Jiuzhaigou Valley Scenic and Historic Interest Area Scenic Area has rich public service facilities around it.

Differences in Facility Distribution Caused by Different Industrial Structures

Under the guidance of the government's comprehensive tourism development strategy, the agglomeration of tourism related public service facilities such as accommodation and catering is the strongest. In order to attract tourists, tourism facilities are distributed around important cultural scenic spots, resulting in a strong agglomeration of tourism service facilities. Public service facilities for cultural, healthcare and other daily needs are distributed in various mountainous villages and towns. Secondly, the long axis of scenic spots and traffic service facilities is towards Jiuzhaigou County, which is in line with the objective reality that Jiuzhaigou Valley Scenic and Historic Interest Area County is a strong tourist hotspot. Finally, tourism related accommodation service facilities have the strongest directionality, with obvious clusters in the southeastern part of Aba Prefecture, Maerkang City, and east of Hongyuan County. This is because tourism is the main industry in the southeast of Aba Prefecture, while agriculture and animal husbandry are the main industries in the northwest.

Differences in the Number of Facilities Caused by the Level of Economic Development

With the process of urbanization development, the indicators for measuring the economic development level of mountainous villages and towns include not only the commonly used GDP, but also the population migration rate. Mountain villages and towns with high levels of economic development have higher levels of personnel mobility and population migration. Based on the correlation analysis results, it can be concluded that mountainous villages and towns with higher levels of economic development have a higher density of public service facilities. At the same time, regions with high levels of economic

development have high levels of development in cultural, sports, financial, corporate and other service facilities, thus forming a spatial pattern of "more in the southeast and less in the northwest" for public service facilities.

CONCLUSION

The results indicate that the overall public service facilities in the study area exhibit a spatial pattern of "more in the southeast and less in the northwest"; Various types of public service facilities are highly concentrated around administrative centers, with tourism related public service facilities such as catering and shopping having the highest concentration, while life related public service facilities such as finance, culture have the low concentration; All kinds of public service facilities are in the direction of "southwest northeast", covering the administrative center of Aba Prefecture, Maerkang City, the famous natural resources Jiuzhaigou County, Wenchuan County and Mao County near the Chengdu Plain. Among them, public service facilities related to tourism activities such as sports and accommodation are the most directional. The spatial agglomeration of public service facilities in the research area is jointly influenced by factors such as nature, industrial structure, and economic development.

Based on this, research recommendations: Firstly, strengthen the allocation of various public service facilities in the northwest of the region and increase the number of various public service facilities in the region. Secondly, promote the balanced distribution of public service facilities in mountainous villages and towns, with a focus on developing the allocation of facilities in township centers to promote fair resource allocation; Finally, pay attention to the living needs of residents and further improve the configuration of public service facilities for daily life such as culture, healthcare, and finance.

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