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Research on the Spatial Layout of Park Green Space under the Behavioral Patterns of the Elderly—Taking Shijingshan District in Beijing as an Example

Jiayu Wang*, Lingyun Ji

School of Architecture and Art, North China University of Technology, Beijing, 100144, China
*Corresponding author

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Abstract: At this stage, the mismatch problem of urban park green space among the elderly population in my country is becoming increasingly serious, and it is urgent to explore the high-quality demand of the elderly population for park green space. Therefore, this article takes the park green space in Shijingshan District, Beijing as the research object, constructs a supply and demand evaluation index system for park green space from the perspective of the elderly, uses the CRITIC objective weighting method to weight the evaluation indicators, determines the weight of each indicator in the supply and demand subsystems, introduces the coupling coordination degree model to construct a supply and demand evaluation model for park green space spatial layout, evaluates the rationality of the spatial layout of park green space in Shijingshan District, and puts forward corresponding countermeasures and suggestions.

1. Introduction

My country's rapid urbanization process and the improvement of people's living standards have given rise to environmental justice issues hidden behind the allocation of public resources. At the same time, as China's aging rate becomes more and more serious, how to ensure the balance between supply and demand of the elderly group and park green space to improve the quality of life of the elderly has become particularly important. Based on the age-friendly background and from the perspective of supply and demand balance, a park green space layout evaluation model was constructed with Shijingshan District in Beijing as the research object, aiming to improve the research system with urban parks as the research object [1].

2. Review of existing research

2.1. Research on the development process of urban park green space spatial layout

By sorting out relevant domestic and foreign research, the research and development process of park green space spatial layout is summarized into three stages: regional balance, spatial equity, and social equity. In the regional balance stage, the main focus is on the number of parks, which is measured using indicators such as the total urban park area and the per capita park area. In the spatial fairness stage, various accessibility analysis tools based on the GIS platform are used to calculate. In the social equity stage, the abilities and needs of different groups are taken into account in the layout of park green spaces, and factors such as the actual needs of different users, geographical distribution, and economic development levels are taken into consideration [2].

2.2. Current research status of park green space spatial layout evaluation perspective

The rationality of the layout of green space parks is mainly evaluated from three perspectives: supply-demand balance perspective, pattern-process perspective, and opportunity-social equity perspective. From the perspective of balance between supply and demand, the spatial layout of park green spaces should be planned to match population demand. Areas with high demand should be equipped with more green space resources to achieve a balanced and reasonable spatial layout of green space parks [3]. The pattern-process perspective focuses on the ecological service performance of green space parks, quantifying ecological evaluation indicators such as air purification and scenic beauty services in green space parks, and evaluating the spatial layout of green space parks. Equity of opportunity emphasizes the balance of spatial distribution of park green space and is developed from related equity theories intersecting the disciplines of sociology and geography [4].

2.3. Research status of park green space layout evaluation index system

In terms of park green space supply capacity indicators, in addition to considering planning-level indicators such as accessibility, quantity, and area, scholars have also incorporated the ornamental value, cultural value, and indicators representing the use of park green space into the evaluation index system to construct an evaluation index system at the supply level of park green space [5]. In terms of park green space demand capacity indicators, a demand evaluation index system is constructed from three aspects: population size, population structure, and population economic and social status [6].

In summary, this study, on the basis of clarifying the actual use of park green spaces by the elderly in Shijingshan District through field surveys, constructed a supply evaluation index system and a demand evaluation index system adapted to the research unit from the perspective of supply and demand, and introduced a coupling coordination model to construct an evaluation system for the spatial layout of park green spaces from the perspective of the elderly [8-10].

3. Research objects and data

3.1. Research object

Based on the data from the Beijing Municipal Landscaping Bureau and the actual survey, 55 park green spaces in Shijingshan District, Beijing were identified as the research objects, and the 55 park green spaces in Shijingshan District were summarized and analyzed. In terms of park types, there are 23 community parks, 6 special parks, 2 comprehensive parks, 21 amusement parks, and 3 ecological parks is shown in Figure 1.

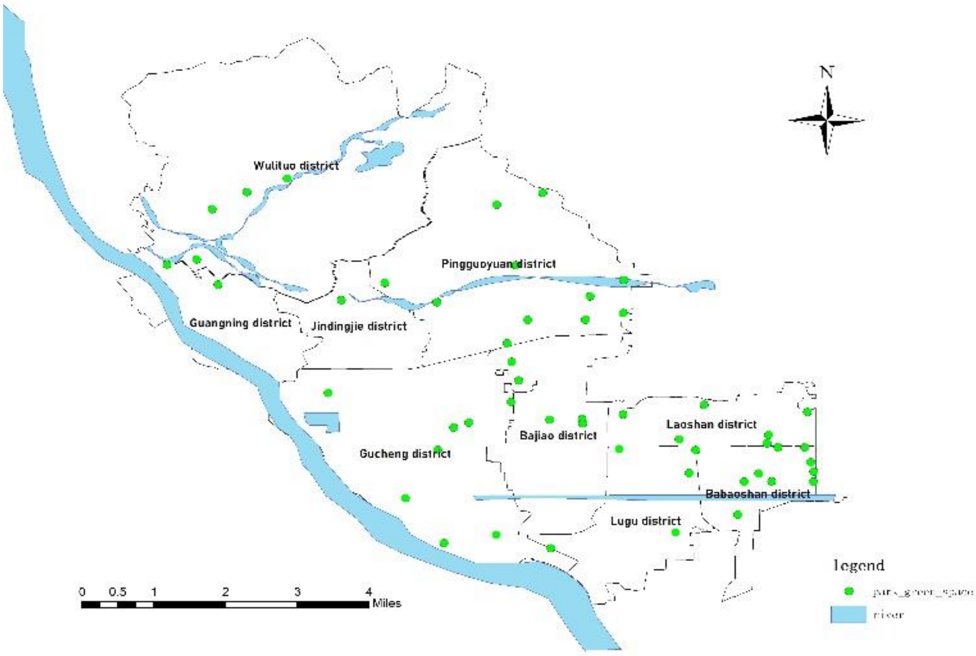


Figure 1. Distribution map of park green space in Shijingshan District, Beijing

3.2. Research scope

Determined based on the boundaries of Shijingshan City, the total area is 85.75 square kilometers. Shijingshan District has jurisdiction over nine streets: Babaoshan Street, Laoshan Street, Bajiao Street, Gucheng Street, Pingguoyuan Street, Jinding Street, Guangning Street, Wulituo Street and Lugu Street [7].

3.3. Data sources and preprocessing

The selection of park green spaces is based on the park list issued by the Beijing Municipal Landscaping and Greening Bureau, and also refers to the Beijing Shijingshan District Green Space System Planning Map in the "Beijing Shijingshan District Landscaping Special Plan (2016-2035)", supplemented by Baidu satellite images and Amap POI. The elderly population is based on the street population by age group in the Qi Census Data Center to obtain the population of each age group in each residential land. By defining the population over 60 years old as the elderly, the number of elderly people in each plot can be obtained. The data is input into the GIS spatial data set, then the data of the study area is imported into the ArcGIS platform, and then a unified projected coordinate system is used to calibrate the data. Finally, the evaluation method in this article is used for calculation and analysis.

4. Research framework and methods

4.1. Research framework

Starting from the two independent goal layers of green space park supply capacity and residents' demand capacity, we will construct a green space park supply capacity index system and a residents' demand capacity index system respectively to form an overall green space park spatial layout evaluation index system. The supply system emphasizes the quantity, area, and accessibility level of park green space. The overlap degree of flat and park green space services and the quality of park green space based on the perspective of the elderly; the demand system mainly considers the number of the elderly population, the elderly population demand index and the elderly service satisfaction, and then assigns weights to the indicators using the critic weight analysis method, and finally substitutes them into the coupling coordination model for evaluation.

4.2. CRITIC weighting method

The CRITIC weighting method refers to presenting the effective data information carried by different indicators by calculating the variability and conflict between indicators on the premise of mastering the sample data, and using this as the basis for dividing indicator weights.

The calculation process of CRITIC weighting is as follows:

1) Data preparation

Collect and organize the indicator data to be analyzed, and construct a data matrix$X$, in which each row represents a research object and the columns represent each indicator.

$$X_{ij} = \begin{bmatrix} x11 & x12 & \cdots & x1n \\ x21 & x22 & \cdots & x2n \\ \vdots & \vdots & \cdots & \vdots \\ xm1 & xm2 & \cdots & xmn \end{bmatrix} \tag{1}$$

2) normalized data matrix

The data matrix is normalized to eliminate the influence of dimensions. Commonly used standardized processing methods are:

The processing of positive indicators is:

$$\mathrm{x_{ij}} = \frac{\mathrm{x_{ij}} - \min(\mathrm{x_j})}{\max(\mathrm{x_j}) - \min(\mathrm{x_j})} \tag{2}$$

The processing of negative indicators is:

$$\mathrm{x_{ij}} = \frac{\max(\mathrm{x_j}) - \mathrm{x_{ij}}}{\max(\mathrm{x_j}) - \min(\mathrm{x_j})} \tag{3}$$

Moderate indicator processing formula:

$$\mathrm{x_{ij}} = \frac{|\mathrm{x_j} - \frac{\max(\mathrm{x_j}) - \min(\mathrm{x_j})}{2}|}{\max(\mathrm{x_j}) - \min(\mathrm{x_j})} \tag{4}$$

3) Calculate variability metrics

Calculate the standard deviation (volatility) of each indicator

$$S_j = \sqrt{\frac{\sum_{i=1}^{m}(x_{ij} - \bar{x}_j)^2}{m-1}} \tag{5}$$

Among them,$m$is the number of research objects,$\bar{x_j}'$is the mean value of the$j$index. This indicator is the variability indicator, and the greater the indicator value, the greater the weight.

4) Calculate conflict index

Calculate the correlation matrix between each indicator R. Correlation uses the Pearson correlation coefficient:

$$r_{jk} = \frac{\sum_{j,k=1}^{m}(x_{ij} - \bar{x}_j)^2(x_{ik} - \bar{x}_k)}{\sqrt{\sum_{j=1}^{n}(x_{ij} - \bar{x}_j)^2 \sum_{k=1}^{n}(x_{ik} - \bar{x}_k)^2}} \tag{6}$$

Then calculate the conflict index, the formula is as follows:

$$A_j = \sum_{i=1}^{n}(1 - r_{ij}) \tag{7}$$

The conflict index represents the strength of the relationship between indicators. The greater the correlation coefficient value, the smaller the conflict. Then the smaller the conflict index value, the lower the final weight.

5) Calculate the amount of information

Calculate weights based on standard deviation and correlation. The formula is as follows:

$$C_j = S_j * A_j \tag{8}$$

Among them,$w_j$is the weight of the$j$th indicator.

6) Calculate weight

Normalize the calculated weights so that the sum of all weights is 1:

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \tag{9}$$

In the formula, $W_j$is the weight of j indicator.

4.3. Coupling coordination model

The coupling coordination degree model integrates the coupling status between systems or elements and the development levels of the two. It is an effective evaluation tool for studying the overall balanced development degree of a region.

1) Calculate composite index

Based on the standardized values and comprehensive weights of various indicators, the supply capacity of park green space and the demand capacity of residents are treated as independent subsystems. Calculate the comprehensive evaluation index of the park's supply capacity and residents' demand capacity respectively. The specific calculation formula is as follows:

$$f(x) = \sum_{i=1}^{n} \lambda_i \cdot x_i \tag{10}$$

$$g(y) = \sum_{i=1}^{n} \lambda_i \cdot y_i \tag{11}$$

In the formula:f(x)- Comprehensive index of community park supply; g(x) - Comprehensive index of residents' demand; n - Total number of secondary indicator values; xi - Standardized value of the i-th indicator in the supply system; Yi - Standardized value of the i-th indicator in the demand system; λi - Weight of the i-th indicator in the supply and demand system indicators, and the sum of the weights is equal to 1.

2) Calculate coupling

The coupling degree can reflect the balance between supply and demand. Based on the comprehensive index of the supply and demand subsystem, the coupling degree value of each living circle can be further calculated. The specific calculation formula is:

$$C = \left\{ f(x) \cdot g(x) \left[\frac{f(x)+g(y)}{2}\right]^{-2} \right\}^{\frac{1}{2}} \tag{12}$$

In the formula, f(x) and g(x) respectively represent the comprehensive index of the park green space supply capacity subsystem and the residents' demand capacity subsystem. C is the coupling degree value, which is between [0,1]. The larger the value, the better the match between the park green space supply capacity and the residents' demand capacity, and the higher the rationality. On the contrary, the worse the match, the worse the rationality.

3) Calculate synergy

The coupling degree only reflects the supply and demand balance between the two subsystems of park green space supply capacity and residents' demand capacity, but it cannot judge the overall utility. Therefore, a synergy model was introduced to reflect the overall effectiveness of community park supply capabilities and elderly residents' demand capabilities. The specific calculation formula is:

$$T = \frac{1}{2} f(x) + \frac{1}{2} g(y) \tag{13}$$

$$D = \sqrt{C \cdot T} \tag{14}$$

In the formula: T is the degree of development; L is the degree of coupling; D is the degree of synergy;

5. Results and analysis

5.1. Weight calculation results

CRITIC weight calculation results of park green space supply and demand capacity is shown in Table 1.

Table 1. CRITIC weight calculation results of park green space supply and demand capacity

target layer	indicator layer	Metric variability	Indicator conflict	amount of information	weight
Park green space supply capacity	Number of unit parks	0.3220	6.1926	1.9939	0.1037
	Park area per capita	0.3477	5.7817	2.0105	0.1045
	Park green space quality score	0.3439	5.5172	1.8971	0.0986
	Effective service area ratio	0.4159	5.8870	2.4485	0.1273
	Service scope overlap	0.4055	10.0800	4.0871	0.2125
Park green space demand capacity	Number of elderly people	0.3651	7.5946	2.7729	0.1442
	Elderly Population Demand Index	0.3886	6.2150	2.4150	0.1256
	Service satisfaction of the elderly	0.2989	5.3877	1.6104	0.0837

5.2. Park green space spatial layout evaluation results

The normalized index values and index weights are substituted into the coupling coordination model for calculation. The calculation results of the coupling coordination model between the supply capacity of park green space and the demand capacity of the elderly in various streets in the park green space of Shijingshan District, Beijing are as follows is shown in Table 2.

Table 2. Calculation results of coupling coordination degree of park green spaces in various streets in Shijingshan District

street name	supply comprehensive index	demand composite index	Coupling degree C	Development degree T	Synergy D
Wulituo Street	0.2957644	0.4137163	0.9860834	0.3547404	0.5914419
Guangning Street	0.2792563	0.5321892	0.9501784	0.4057227	0.6208937
Jinding Street	0.1974743	0.1651000	0.9960057	0.1812872	0.4249271
Pingguoyuan Street	0.4199199	0.6428729	0.9777486	0.5313964	0.7208135
ancient city streets	0.6103919	0.6050666	0.9999904	0.6077293	0.7795662
Bajiao Street	0.2201515	0.4918655	0.9243227	0.3560085	0.5736434
Laoshan Street	0.3485655	0.6343441	0.9567997	0.4914548	0.6857287
Lugu Street	0.3503255	0.5029631	0.9838706	0.4266443	0.647891
Babaoshan Street	0.4906397	0.6642858	0.9886324	0.5774627	0.7555782

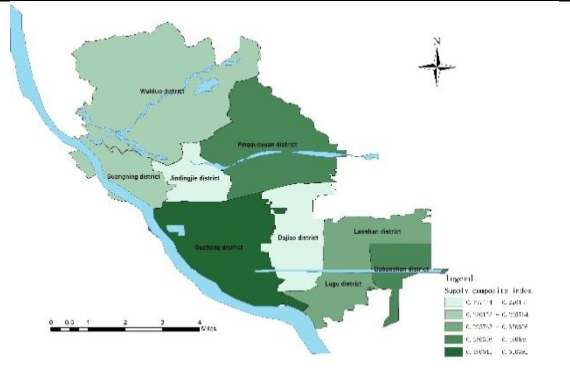
5.3. Analysis and discussion on the spatial layout of park green space

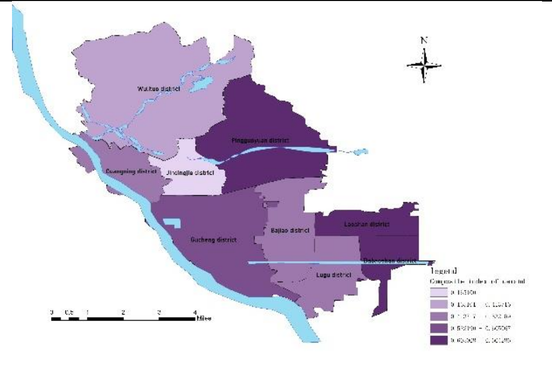
1) Evaluation of spatial pattern of supply and demand comprehensive index

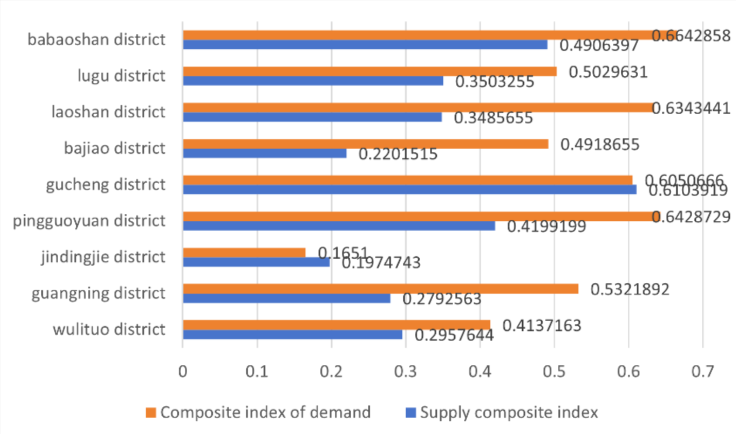
From the perspective of the spatial pattern of the comprehensive index of supply and demand, the average comprehensive index of park green space supply in Shijingshan District, Beijing is 0.3569, and the average average comprehensive index of resident demand is 0.4431. The supply capacity of park green space is smaller than the demand capacity of residents. The park green space supply comprehensive index of various streets in Shijingshan District is mostly in the numerical level of 0.10~0.60. Only the park supply index of Gucheng Street is greater than 0.60. The high supply capacity is due to the services of urban parks in the streets. The supply comprehensive index of 6 streets is lower than the average level of Shijingshan District. Generally speaking, the supply capacity of park green space in various streets in Shijingshan District is weak and the supply capacity varies greatly is shown in Table 3.

Table 3. Spatial pattern of comprehensive index of park green space supply

Service satisfaction index of public and elderly population in various subdistricts in Shijingshan District







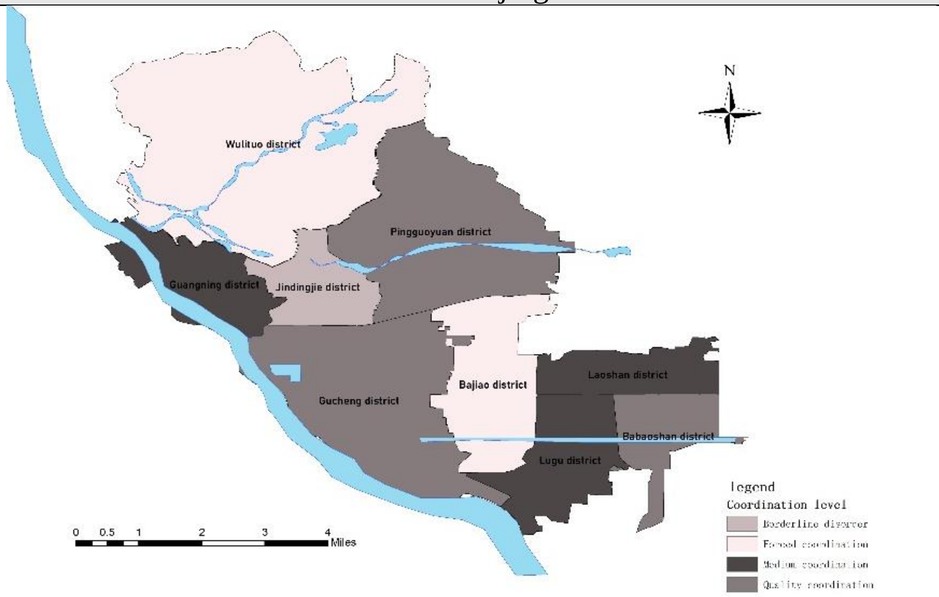
2) Evaluation of collaborative hierarchical spatial pattern

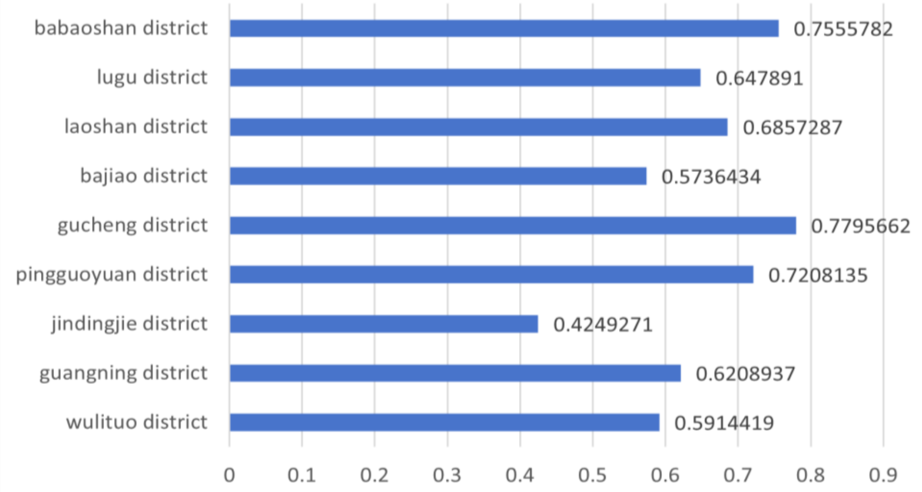
From the perspective of the spatial pattern of coordination level, the average value of the overall supply and demand coordination degree in Shijingshan District, Beijing is 0.6445, which is at the medium level of coordination. There are 4 types of coordination levels within the scope of the study. Among them, Jinding Street is on the verge of disorder; 2 are at the barely coordinated level, and 3 streets are at the medium coordination level. This type of street has a large number of green spaces and a large area. The effective service area ratio of the park green space is relatively low and the services are heavy. The overlap rate is high, and due to the small number of elderly people, the demand ability of the elderly is average; there are three streets with high-quality coordination level.

These areas have a high proportion of elderly people and have a high demand for green parks. Therefore, these areas show a high level of coupling coordination is shown in Table 4 and Table 5.

Table 4. List of spatial patterns of supply and demand coordination levels of park green space in various streets in Shijingshan District, Beijing

Spatial pattern of supply and demand coordination of park green space in various streets in Shijingshan District





MAX= 0.78	MIN= 0.42

Table 5. Classification of supply and demand coordination of park green space in various streets in Shijingshan District, Beijing

collaborative interval	Synergy	synergy level	Number of streets	street name
Disorders	0≤D≤0.3	severe disorder	0	
Transitional class	0.3<D≤0.4	Moderate imbalance	0	
Coordination	0.4<D≤0.5	On the verge of disorder	1	Jinding Street

class	0.5<D≤0.6	Barely coordinated	2	Wulituo Street, Bajiao Street
	0.6<D≤0.7	medium coordination	3	Guangning Street, Laoshan Street, Lugu Street
	0.7<D≤1.0	High quality coordination	3	Pingguoyuan Street, Gucheng Street, Babaoshan Street

6. Conclusion and outlook

1) The supply and demand system of park green space in Shijingshan District is generally in a state of "supply exceeds demand"

Judging from the spatial pattern of the comprehensive index of supply and demand, the supply capacity of park green space in Shijingshan District, Beijing is smaller than the demand capacity of residents. From the perspective of the spatial pattern of synergy levels, there are 6 streets whose comprehensive supply index is lower than the average level in Shijingshan District. Generally speaking, the supply capacity of park green space in various streets in Shijingshan District is weak and the supply capacity varies greatly. There are 7 streets supplying Chichi, 1 low supply-low demand street, and only 1 high supply-high demand street. In addition, some streets have high overlapping rates of park services, which to a certain extent leads to a waste of resources.

2) The coordination of green spaces in streets and parks passing by rivers is relatively good.

Shijingshan District of Beijing is generally at a medium coordination level. From the perspective of spatial distribution, there is a certain correlation between the supply and demand synergy of park green space in Shijingshan District and the number and area of park green space in the street. Generally speaking, the greater the area and quantity of park green space in a street, the higher the synergy value of its park green space. The streets in the ancient city have the highest degree of synergy. The main reason is that the streets in the ancient city are located next to the Yongding River and have large-scale park green space resources. For other streets, the study found that areas with rivers passing through them have more park green space resources than areas without rivers passing through them.

3) Parks with high accessibility and low overlap in service scope have higher green space quality and higher satisfaction among the elderly.

According to the survey results, streets with a high service area ratio and overlapping park green space service ranges have relatively high coupling coordination results, both above the average level. At the same time, a survey of park green spaces in such streets found that their service facilities are relatively complete, the environment is tidy, and the park green space is of high quality. By investigating parks with low park accessibility, it was found that the spatial quality of parks is the worst, mainly due to single facilities and lack of management and maintenance, which to a certain extent affects the supply capacity and service level of park green space.

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