Accessibility Analysis of Parks in Xigong District of Luoyang City Based on GIS Technology

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Abstract. This paper takes Puyang City, Henan Province as an example to study its current transformation effect. It sets up five dimensions of economic benefit, resource benefit, people's livelihood development, ecological efficiency and scientific and technological construction level, and analyzes the impact of Puyang City through the entropy weight-TOPSIS model. Key indicators of transformation, and use the super-efficiency DEA model to measure the efficiency value of five dimensions year by year. After the evaluation of the transformation performance measurement system, it is found that the current urban transformation of Puyang is progressing well; from the research results, the transformation effect of Puyang city mainly depends on the high-quality development of resource efficiency and scientific construction, which will continue to promote more efficient and sustainable development in the future. Sustained development provides ideas, and also serves as a reference for other resource-based cities like Puyang to implement transformation.

Keywords: Improved two-step floating catchment area method; Urban park accessibility; Service radius; Xigong District, Luoyang City.

1. Introduction

Parkland in cities is an important part of the urban green space system, which is both a spatial carrier for greening aggregation and a recreational place for residents to relax. Well-developed park nodes in cities directly promote residents' participation in physical fitness activities and significantly improve the mental health of nearby people [1].

With the reform and opening up and the rapid development of China's economy, the urban population has been increasing and the city has been expanding. Until now, Luoyang has developed into a regional center with an area of 218.2 square kilometers and a population of 2.25 million. By 2020, the central city of Luoyang will have 45% green coverage, 38% green space, and 12m2 of parkland per capita [2]. The products of urban economic development, such as residential and commercial areas, are occupying the original green space, resulting in a decrease in the amount of green space in the city. With the increase of per capita income, the national demand for green space in parks is gradually expanding. Balancing the construction of parkland and economic development in densely populated areas has become a critical issue in urban planning and development.

In recent years, China has issued a series of policies on park construction and green space planning, such as the "Guidance on Regulating the Development of Theme Park Construction" in 2018 and the "Guidance on Scientific Greening" in 2021, which point out the need to scientifically carry out large-scale national greening actions and optimize resource allocation. These policies also stressed the reason why the government attaches importance to park construction for the park green space in cities as an important urban green space system: It is both a spatial carrier for greening gathering and a recreational place for residents to relax.

Well-developed park nodes in cities directly promote the participation of residents in physical fitness activities and significantly improve the mental health of nearby populations. Additionally, urban parks play an indispensable role in reducing the urban heat island effect, controlling carbon emissions, and improving air quality. Therefore, the use of scientific analysis to assess the accessibility of parks in cities has become a hot topic in the field of urban research.

2. Literature Review

The concept of accessibility was first introduced in 1959 by Walter Hansen, who used accessibility models to predict the distribution of population in different areas of the city [3] . At that time, accessibility models were not integrated with parks. In 1997, Erkip used accessibility models to assess the equitable distribution of parks and recreation facilities in Ankara, but the small number of people surveyed in the chapter is only 144, not forming a large-scale reference opinion [4]. In 2011, Dai used the Gaussian based 2-step floating catchment area (2SFCA) method for the first time to assess green-space accessibility in Atlanta, Georgia [5]. Dony's innovative comparison of four modes of transportation to study public park accessibility in Mecklenburg County, North Carolina, USA through an improvement of the 2SFCA method [6].

China research on park and green space accessibility has only started to develop in the past two decades. In 1999, Yu Kongjian et al. first used landscape accessibility as a factor to evaluate urban green space systems, laying a solid foundation for subsequent park accessibility research in China [7]. In 2011, Cheng Yan et al. first used the 2SFCA method to calculate the park accessibility index in the suburban Yuhuatai district of Nanjing, and reference points in that article mainly choose the quality points of the park and ignore the problem of path selection between the park green space and the residential area, and the obtained results deviate from the actual situation [8]. Ren Jiaduo et al. quantified the relationship between park accessibility and population density in Huangpu District by using an improved 2SFCA method, with an innovative use of multi-threshold search method [9]. Han Shuyao et al. Used the 2SFCA method to quantitatively study the green space accessibility in Haikou by walking mode. The number of households in the district was used as the population reference, and the effect of vacancy rate was not considered [10].

In conclude, the main methods to evaluate the accessibility of park green space for the surrounding areas in China focused on theoretical research, and did not take into account the actual travel status of regional residents and the number of resident populations. Therefore, this paper takes the large parks in the planned scope and the permanent resident population in the census as the research object, considers the two travel modes of walking and electric vehicles, takes the park door as the center point of the radiation radius, and takes 500m, 1000m, 2000m, and 5000m as the radiation radii. This paper uses the improved Gaussian 2SFCA method to evaluate the accessibility of the urban park space, in order to provide a reference for the space selection and later planning of the urban parks.

3. Overview of the Research Area and Data Sources

3.1 Research Subjects

With 9 streets (Fig. 1), 66 communities, and 9 city parks of various types. The uneven distribution of green space resources within the urban areas of Luoyang City has resulted in some residents not being able to enjoy the services provided by public recreational green space, which has a significant impact on their daily lives. At the same time, Luoyang Municipal Government also put forward the guideline of increasing the green space coverage of the city in the fourth session of the 14th National People's Congress. The uneven distribution of parks and green space coverage needs to be supplemented by systematic research, and the current situation in Xigong District is in urgent requirement of planning and renovation.

3.2 Data Sources

This paper refers to the classification of parks into three categories: comprehensive parks, community parks and garden parks based on the service radius in the Study on Green Space Accessibility of Urban Parks Based on Service Radius by Yan Ye et al. [11] . Combined with the POI data, 10 parks with an area larger than 1000m^2 in Xigong District were selected as the research objects (Table 1), and the outline of Xigong District, the location and range of park green space, the location of neighborhoods, and the street division range POI data were downloaded through OpenStreetMap and Gaode electronic map. This paper attempts to study the accessibility of green spaces in parks in the Xigong District from the perspective of the living circle of street residents.

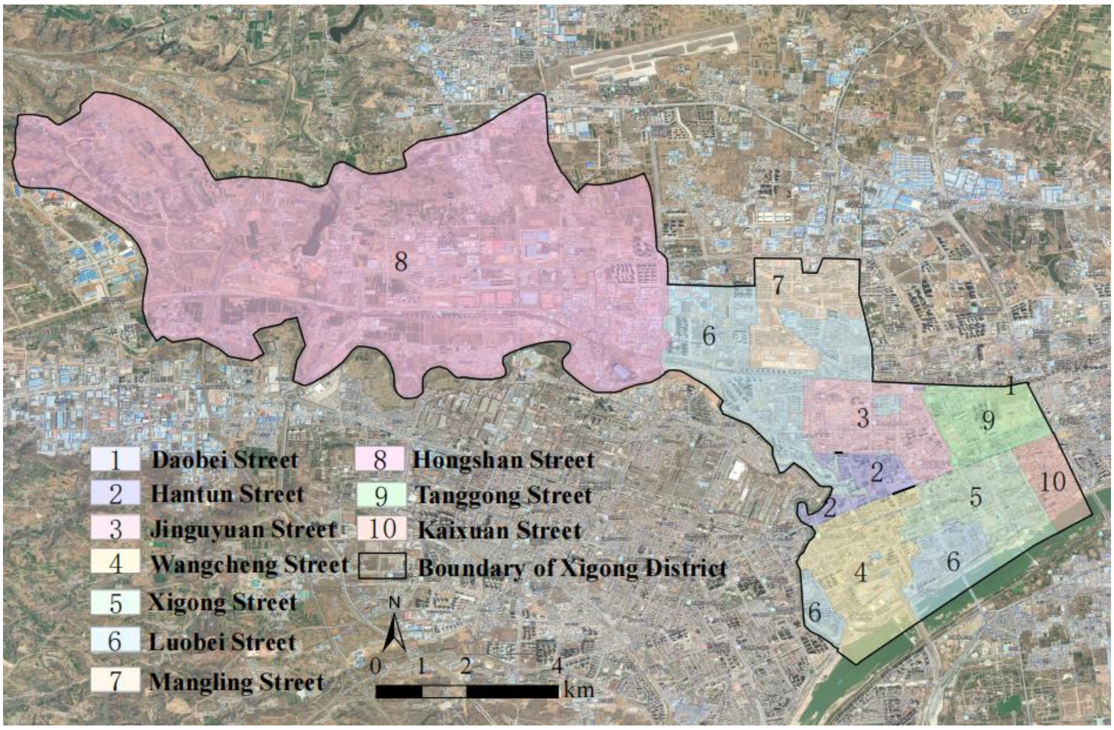

Fig. 1 Location of Xigong District and the distribution of each street

Table 1. Parkland statistics for areas larger than 1000m^2 in Xigong District, Luoyang

Numble	Park Name	Street	Floor space (m^2)
1	Guohua Road Park	Luobei Street	10600
2	National Peony Park	Hongshan Street	300000
3	Luopu Park	Xigong Street	12000000
4	Jiuzhouchi Scenic Area	Tanggong Street	139250
5	Luoyang Martyrs' Cemetery	Luobei Street	77500
6	Sanyanggong Park	Wangcheng Street	50,000
7	Wangcheng Park	Hantun Street	720000
8	Yingtaogou Scenic Area	Hongshan Street	533333
9	Zhouwangcheng Plaza	Xigong Street	1700

4. Research Methodology

4.1 Improved Gaussian Based 2-step Floating Catchment Area Method

Park accessibility can be calculated using Gaussian 2SFCA method. In the past studies, the center of the park was used as the reference point in the park accessibility study using the two-step search method. Different park areas and shapes may affect the results [12], so this study uses the park entrance and exit as the reference point, and residents are considered to have access to the park service's when they reach the park entrance and exit [13].

4.2 Entropy Weight Method

The entropy weight method allows measuring the quantity of park green space supply in different administrative districts, and the improved Gaussian two-step moving search method is used to assess the accessibility of parks of different classes within the Xigong District.

The specific calculation is as follows.

4.2.1 Data standardization

Suppose k indicators X1, X2, ..., Xk are given, and suppose that the data of each indicator is normalized to Y1, Y2, ..., Yk

$$Y_{ij} = \frac{X_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)}$$

4.2.2 Calculate the entropy and weight of the index

Calculate the information entropy of the j indicator

$$E_j = -\frac{1}{\ln m} \Sigma_{i=1}^{m} p_{ij} \ln p_{ij}$$

$$p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{m} Yij}$$

Calculate the weight of the j indicator

$$w_j = \frac{1 - E_j}{\sum_j 1 - E_j}$$

4.2.3 Weighted calculation of index scores

Using the weighted summation formula to calculate the composite score of the sample

$$S = \sum_j 100 * y_{ij} w_j$$

5. Results and Analysis

5.1 Number of Parks Supplied

In this paper, the Entropy Weighting Method is used to calculate the per capita green space area and green space ratio for each street area, park area and population in Xigong District, and then calculate the information entropy value and weight of the number of parks, park green space area, per capita green space area and green space ratio (Table 2).

Table 2. Weighting factors obtained by the Entropy Weighting Method

Term	Information entropy value e	Information utility value d	Weighting factor W	Weighting percentage
Number of parks	0.87	0.13	12.35%	0.12
Park green area	0.73	0.27	25.25%	0.25
Green space per capita	0.63	0.37	34.85%	0.35
Percentage of green space	0.71	0.29	27.55%	0.28

At the same time, this paper uses the weighted sum formula to calculate the comprehensive score of each street park quantity, and with reference to the comprehensive index grading method proposed by previous scholars, the comprehensive score is divided into optimal (comprehensive index ≥ 0.05), good (0.05 > comprehensive index ≥ 0.02), and poor (0.02 > comprehensive index ≥ 0) levels to obtain the quantity of park supply for each street in Xigong District, Luoyang City (Table 3).

From Table 3, it can be seen that the supply quantity of each street is uneven, only four streets have the optimum park supply quantity, 50.00% of the streets are in the poor grade, and the number of parks is unevenly distributed from the overall view of Xigong District. The two streets with the highest overall park ratings are Wangcheng Road and Luobei Street, with standardized ratings of 1.00 and 0.83 respectively. The overall number of parks in Wangcheng Road is large and densely populated, while Luobei Street is sparsely populated with a large per capita green area. Hongshan Street, as the largest street in Xigong District, has a per capita green space area of 26.79, and the overall rating of 0.22 for the number of parks is in good grade. Among the streets with an overall rating of less than 0.20, Daobei Street, Jinguyuan Street and Kaixuan Street have a rating of 0. The reason is that these three streets are located in the early construction area of Xigong District, and the number of parks is 0. Among them, Kaixuan Street is mostly set up with famous monuments, ignoring the construction of parks and green spaces. The population of the five streets with poor park numbers accounts for 48.00% of the population of Luoyang City, and nearly half of the residents in Xigong District have a mismatch between the demand for green space and the actual supply. In the later planning, it is urgent to excavate the "sporadic plots" in these street areas to carry out the pragmatic demand of park construction and green space supplement.

Table 3. Number of parks supplied by streets in Xigong District, Luoyang

Street	Overall number of parks rating	Standardization of quantity scores	Grading
Wangcheng Road Street	941182.24	1.00	Optimum
Luobei Street	781312.70	0.83	
Xigong Street	759238.47	0.81	
Mangling Street	759096.33	0.81	
Hongshan Street	210842.83	0.22	Good
Hantun Street	182168.70	0.19	
Tanggong Street	35232.41	0.04	Poor
Daobei Street	0	0	
Jinguyuan Street	0	0	
Kaixuan Street	0	0	

5.2 Spatial Distribution Characteristics of the Park

In this study, 9 parks within the Xigong District were selected, including 5 comprehensive parks, 3 community parks and 1 recreational park for analysis. The following conclusions can be drawn from the community and park distribution map (Fig. 2).

The spatial distribution of parks is more uneven, showing the characteristics of dense in the southeast and sparse in the northwest. There are fewer parks in the central community-dense area of Xigong District and fewer communities in the park-dense area in the east, which is closely related to the gradual shift of the urban center from the old city near the center to the Xigong Street and Wangcheng Street near the southeast. The supply of parks varies widely by street, with Daobei Road, Jinguyuan Street, and Kaixuan Street having scant urban green space, all close to 0. Jinguyuan Street, the second largest street in terms of number of communities, has ten communities without any urban parks. Wangcheng Street, Luobei Street, Xigong Street, and Mangling Street have higher park areas of 3720000m^2 , 3088100m^2 , 3000850m^2, and 3000000m^2 respectively. Xigong Street has the highest percentage of accessible park area at 53.00%. The highest urban green space area per capita is in Luobei street, and the per capita area is 65.90m^2, which is a late developed area with only two communities, relatively low population density, and large green space area.

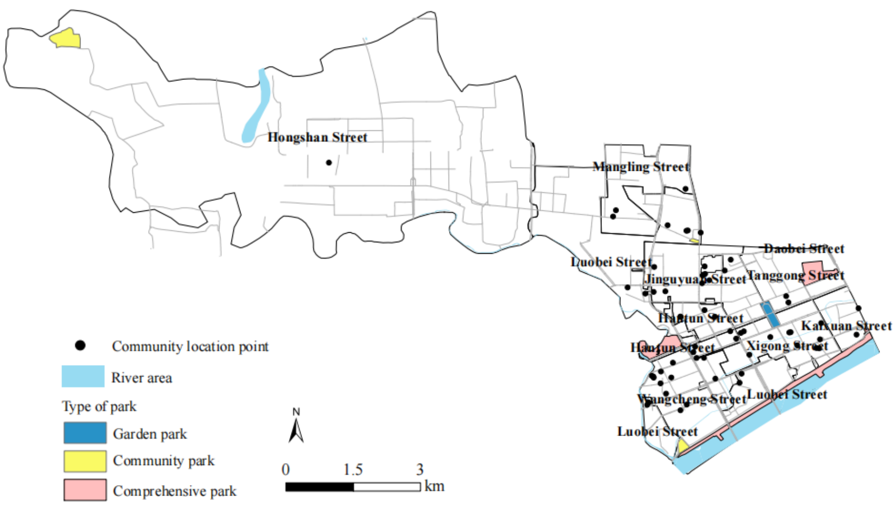

Fig. 2 Distribution of parks and community points in Xigong District

5.3 Park Accessibility Analysis

The treated accessibility of the city park 500m, 1000m, 2000m and 5000m is shown in Figure 3. The accessibility is higher in the southeast within the whole Xigong District, and the overall accessibility range spreads from the south to the north, and only within the 5000m road network can completely cover the southeast location. Under non-motorized conditions, it takes 20 minutes to reach the city park for all residents except those on Mangling Street, Hongshan Street and Luobei Street. Whether using walking or non-motorized travel, parks in Xigong District have a blind spot in coverage in the northwest.

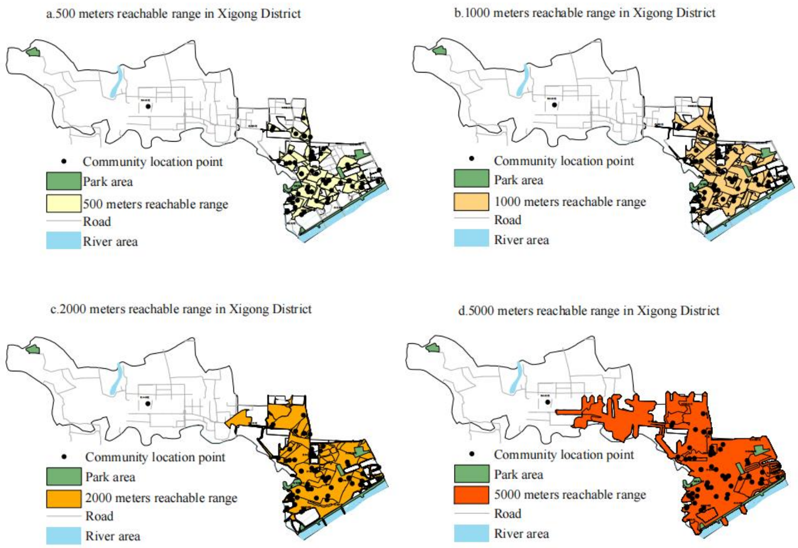

Fig. 3 500, 1000, 1500, and 2000 meters reachable range of the park in Xigong District

The higher the accessibility of the parks, the easier it is for the residents of the area to reach the park entrance from the community point, and Table 4 reflects the results of the accessibility grading of the parks in Xigong District. The area with better park accessibility remains the southeastern part of the study area, including the Kaixuan Street, Xigong Street, Wangcheng Street and Tanggong Street. These streets are adjacent to each other, located in the center of Xigong District and have a prosperous economy, and the road network and urban facilities are relatively well developed in these areas. Additionally, these streets are close to the larger parks in Xigong District, such as Wangcheng Park, Luopu Park and Jiuzhouchi Scenic Area. The highest accessibility value of 65.83 is for Wangcheng Road, while Xigong, which has the highest accessibility by walking mode, has a slightly lower accessibility value of 59.11 by non-motorized means than Wangcheng Road, because different modes of transportation affect the service area of parks and the number of neighborhoods and streets within the search area. Since fewer streets are accessible by foot, residents of these streets near the park have access to more park services. The remaining 2 streets with 0 accessibility and 4 neighborhoods fall within the blind area of accessibility. Because of the distance from the main parks, the residents of these communities are basically unable to reach the city parks and enjoy the corresponding services and leisure functions brought by the parks under the condition of 30min walking and 20min non-motorized driving. In general, park accessibility in Xigong District shows an uneven and polarized distribution, and the equity of city park resources is poor.

Table 4. Xigong District Urban Park Accessibility Classification

Natural break point grading	Park accessibility values	The number of communities included in the street	Percentage
1	0.00	4	6.56%
2	0.001-7.29	7	11.48%
3	7.29-21.31	19	31.15%
4	21.31-53.57	19	31.15%

6. Conclusions and Recommendations

6.1 Recommendations

6.1.1 Balance the distribution of parks

The "General Office of the State Council on the guidance of scientific greening" proposed that each city should build district parks, pocket parks, small micro-green spaces to improve the city's green space system, to achieve the goal of "300m to see the green, 500m to see the park" for residents to travel.

The distribution of parks in Xigong District is mostly concentrated in the area near the water system and the southeast area. In the subsequent urban planning and construction process, the government should first improve the areas with low or no park accessibility to build community parks or pocket parks below the community level, and build small parks for the needs of nearby residents to help improve the quality and vitality of the whole street.

6.1.2 Increasing the number of entrances and exits to improve park accessibility

The entrances and exits of the parks have an important influence on the accessibility and service radius of the parks. At present, except for the larger parks of Wangcheng Park and Luopu Park, which have multiple entrances and exits, the entrances and exits of other parks are relatively few. Under the current operation of the park, the reasonable increase of entrances and exits can help to reduce the travel time of residents and solve the road detour problem.

6.1.3 Improve the construction and quality of park infrastructure

The carrying capacity and service capacity of parks can improve the ability of parks to meet the needs of residents. At present, Xigong District can optimize and improve the existing parks when it is impossible to add more parks in the dense construction area. By enhancing the green area of parks, as well as strengthening infrastructure construction, attempts are made to improve the overall service level of parks by improving the current status of park governance.

6.1.4 Establish a system of rewards and penalties

The construction of parks and green spaces is guaranteed to be in line with the pace of urban planning and development and the creation of economic zones by means of sound laws and specific incentives and penalties. The construction of urban parks will be based on an assessment of the needs of the population in residential areas, so that the development of the environment and the needs of the inhabitants will not be neglected while the city is being built.

6.2 Conclusion

Based on the research on the accessibility of urban parks at home and abroad, this paper conducts an example study on the accessibility of parks within Xigong District of Luoyang City by using three analysis methods: literature research method, entropy weight method and improved Gaussian based 2-step floating catchment area. This paper takes 9 existing urban parks in Xigong District as samples, and tries to solve the problem of the current situation of weak pedestrian accessibility within the site by using ArcGIS and other software to analyze the entropy power method and 2-step floating catchment area method for urban parks, and compare and analyze the accessibility differences of different streets.

Based on the entropy power method, this paper analyzes the parks in Xigong District through ArcGIS platform to know that the spatial distribution of parks in Xigong District shows an uneven distribution. From the spatial distribution, it is concluded that urban parks are mainly distributed in the south and east of Xigong District, and a large part of them are located near the water system of Luo River. Based on Gaussian 2SFCA method, it can be seen that the accessibility of parks among streets shows uneven characteristics, with the highest accessibility value of Wangcheng Road street in the case of 20 minutes of non-motorized driving, and the highest accessibility in the walking mode is Xigong Street. The reasons for this are the large number of communities in Wangcheng Street and

Xigong Street, the high population density and the characteristics of park distribution that match the population concentration trend. Hongshan Street and Daobei Street were built earlier and lacked urban planning updates to keep up with the times, resulting in significant deficiencies in park configurations. It is urgent to build pocket parks or increase the construction of comprehensive parks near the communities to achieve the goal of improving the accessibility of residents to parks.

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