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Article

Accessibility of Pocket Parks in Xuzhou Old City based on Space Syntax Theory

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Abstract: As an important part of the green space system in high-density cities, pocket parks provide the city with natural ecological functions, including microclimate regulation, stormwater management, and so on, and also play an important role in improving the city image, promoting neighborhood communication and other social benefits. However, at present, there has been little research on the accessibility of pocket parks. Based on the theory of space syntax, pocket parks in Xuzhou old city are selected as the research object. From three dimensions of global integration, local integration, and perceived integration, the accessibility of pocket parks in Xuzhou old city was quantitatively evaluated by Depthmap software. The results showed that (1) the global accessibility and local accessibility of pocket parks in the study area were good, but the distribution of some pocket parks was "misaligned" with the road network layout and (2) the perception accessibility of some pocket parks is low, and the whole road network is perceived through the local road network structure. As a result, many people cannot find the park quickly even if they are close to the green space of the park. Because of the existing problems of pocket parks in Xuzhou old city, we put forward optimization suggestions to increase the accessibility measure of pocket parks in Xuzhou from a humanistic perspective and provide a basis for the distribution of urban pocket parks.

Keywords: pocket parks; Xuzhou old city; space syntax; accessibility

1. Introduction

Green space of parks, as one of the important green infrastructures in the city, provides residents with open green space for leisure and entertainment to improve the urban ecological environment and urban image, as especially it greatly improves the quality of life of residents. With high-density urban construction, citizens' demand for urban green space is increasing day by day. Major cities are faced with problems, including insufficient green space and a lack of civic activity venues. Therefore, pocket parks with small areas and outstanding social features have emerged [1]. As early as 1963, pocket parks were proposed by the Park Association of New York. Pocket parks generally refer to small urban open spaces that are scattered in a large number of high-density urban areas to meet residents' demands for park use [2]. In the current green space classification standard, China has not made a clear definition of the pocket park. Through a comprehensive comparison of 17 parks including small and microgreen spaces in the old city of Xuzhou, the scale of pocket parks is limited to parks under 1 km^2 [3].

From the humanistic perspective, urban space advocates to take walking, and its connotation includes safety, convenience, and accessibility [4]. Scholars believe that the most important demand of urban park green space is accessibility. On the one hand, the park green space with high accessibility generally has more diverse functions, so it meets the needs of different people. On the other hand, accessibility affects the design quality of park green space [5]. Roads with high accessibility and high pedestrian flow potential promote the occurrence of walking activities and have a positive impact on the spatial quality of park green space. The accessibility of the park refers to the accessibility between the starting point and the park [6,7]. As an important criterion for evaluating the rationality of park green space distribution, accessibility has been evaluated by many methods. Based on grid division, Ma calculated the accessibility of the public green space landscape in Guangzhou [8]. Ye studied the refuge accessibility of parks in the central urban area of Shanghai by the 2SFCA model and ArcGIS quantification [9]. In addition, the existing measures of green space accessibility in parks are mostly measured by buffer analysis method and network simulation method with the geographic information system (GIS). At present, there are few studies on green space accessibility combined with the network data for walking, and the accuracy of accessibility measurement needs to be improved.

Spatial syntax theory intuitively reflects the relationship between spatial organization and human behavior [10], and fills the gap of research on the spatial impact and the limitations of topological structure in GIS and other methods. In the early years of accessibility research, GIS and RS platforms were generally used to quantify the spatial accessibility potential, including buffer analysis, network analysis, and minimum distance method. However, these methods have limitations. With the development of science and technology, scholars began to conduct quantitative research on accessibility as combining spatial syntax theory and technology [11]. Sun conducted a quantitative analysis and research on the accessibility of Wuhan comprehensive parks and explored the internal relationship between the social service capacity of urban park green space and its spatial distribution with the software analysis platforms such as Depthmap, GIS, ENVI, and SPSS [12]. Based on relevant theories and technologies of space syntax, Gu made a quantitative evaluation of the accessibility of park green space along the Ming Dynasty Wall in Nanjing and proposed for accessibility optimization [13]. In the context of big data, Fu conducted a quantitative study on the accessibility of Hangzhou comprehensive parks by space syntax to enhance the overall accessibility of comprehensive parks in the future [14]. With space syntax theory, we take the old city of Xuzhou as the research object to explore the accessibility of pocket parks, which enriches the evaluation methods of park green space and makes up for the defects of accessibility evaluation without considering the space itself. The result provides a refined evaluation method for the evaluation of the accessibility of pocket parks in high-density cities. It also provides strong support for the land planning of pocket parks and design based on the perspective of humanity and equity.

2. Research Object and Scope

When studying urban form by space syntax theory, the following methods are generally adopted to define the research scope: (1) The ring highway, railway, and moat in the city often play a role of separation, they can be used as the boundary of the scope, and (2) For urban areas that lack clear boundaries, the effect of edge utility can be reduced by setting up buffer zones.[12]

The research object of this study is mainly distributed in the old city of Xuzhou. Referring to the division of the old city in the Master Urban Planning of Xuzhou (2007−2020), the first method is adopted to take the area of about 1544.94 ha as the scope of the research area, which is 500 m away from the old Yellow River road in the north, Yunlong Lake in the south, the old Yellow River road in the east, and the West Third Ring Road in the west [15]. By 2021, 17 pocket parks have been built in the old city. Due to the small size of the pocket parks, some of the parks have not been named. Therefore, for a unified sample, 17 pocket parks in the old city are named with their names, as shown in Fig. 1.

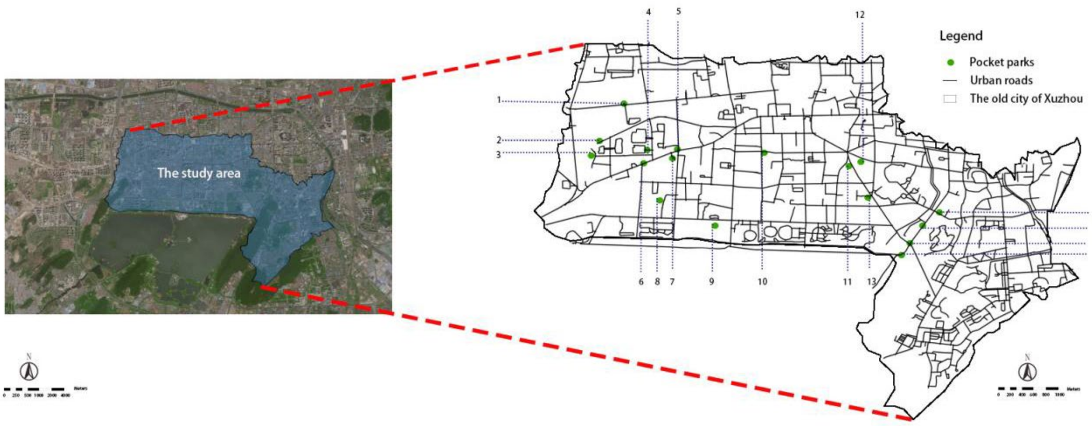

Fig. 1. Map of study area.

3. Data Sources and Research Method

3.1. Data Sources

The road network and boundary data required in this study are obtained from the network data of OSM (Open Street Map) and Tianditu in 2020. OSM is a website for fast access to free, data-rich, and detailed vector map data. The data from OSM and Tianditu are used as the basis for many scholars and institutions. The data of pocket parks are obtained from the official website of Xuzhou, and Xuzhou Municipal Parks Bureau, Baidu Map, and other network data. The location of pocket parks on the map is determined by field investigation.

3.2. Data Processing

Axis model is the most basic analysis method in space syntax theory. Hillier published a related article in New Architecture in 1985. Since 2003, the axis model has gradually been widely used in quantitative analysis of urban spatial form in China. We studied the accessibility of pocket parks in the old urban area of Xuzhou by axis analysis method. The road data was imported into AutoCAD, then unnecessary ground traffic and layers were left out. At the same time, the differences were corrected by referring to the Google Earth satellite image in 2021. According to the modeling principle of "the number of axis segments and turns should be the least" and "the intersection of the axis should come out", 4587 line segments were drawn. Unlink processing was performed on the roads that were projected to intersect (but not actually intersect). Node Count indicator is used to screen unconnected line segments, and then it was imported into Depthmap space syntax software developed by University College London for calculation and analysis.

3.3. Research Methods

In 1971, the space syntax theory was proposed by Hillier et al. Since then, it has been widely used in analysis including road topology analysis, traffic flow prediction, historical district reconstruction planning, and actual urban planning and design [16]. Based on analyzing the relationship between rail transit accessibility and actual performance, evaluation models have been established. Its core idea is to regard space as a part of engineering social and economic activities and explore the relationship between human activities and urban spatial structure from the quantitative description of urban space. The space syntax theory includes several different models to interpret and understand urban space. The model analysis is based on the theory to generalize space with straight lines and translate space into a system of straight lines [17]. Based on the theory, we comprehensively evaluated the accessibility of pocket parks in Xuzhou old city from three dimensions of global accessibility, local accessibility, and perceived accessibility.

3.3.1. Global accessibility

Global accessibility refers to the degree of difficulty for residents to reach the pocket park at any location in the spatial system, which is expressed by the global integration degree in space syntax. The degree of connection between the nearest road in the pocket park and all roads in the study area is reflected by the global integration degree. The higher the global integration, the closer the traffic connection between the pocket park and the surrounding area, the more convenient the residents can reach the destination, so the accessibility is also higher. The calculation of global integration is performed by Eq. (1).

$$GI_i = \frac{n\{log_2[(n+2)/3-1]\}+1}{(n-1)(MD_i-1)} \quad (1)$$

where the GI_i denotes the global integration, MD_i denotes the average depth value, and n denotes the number of axes in the research area.

3.3.2. Degree of local integration

Local accessibility refers to the degree of difficulty for residents to reach the pocket park near the location, which is expressed by the local integration degree in space syntax. Local integration measures the space within a certain distance around the pocket park. The calculation of local integration is carried out by Eq. (2).

$$LI_i = \frac{n\{log_2[(n+2)/3-1]\}+1}{(n-1)(MD_i-1)} \quad (2)$$

where the LI_i denotes local integration, MD_i denotes average depth value, and n denotes the number of road axes within several steps around the park green space.

3.3.3. Intelligibility

Perceived accessibility refers to residents' perception of the road network around the pocket park, which is expressed by comprehensibility in space syntax. The higher the intelligibility is, the easier it is for residents to obtain global spatial information through their spatial structure. The comprehensibility level is represented by the linear correlation coefficient of the axis connectivity and global integration within the research area, as shown in Eq. (3). Intelligibility is to import the connection values and global integration values of all roads in the research area into SPSS. Then, the correlation between them is calculated and analyzed.

$$Int_i = \frac{\left[\sum(c_i-\overline{c})(I_i-\overline{I})\right]^2}{\sum(c_i-\overline{c})^2\sum(I_i-\overline{I})^2} \quad (3)$$

where the Int_i denotes intelligibility value, $\overline{c}$ denotes mean value of spatial connectivity within the research scope, C_i denotes connection value of each axis, $\overline{I}$ denotes the average value of global integration within the research scope, and I_i denotes the global integration value of each axis.

4. Research Results and Analysis

4.1 Analysis of Global Accessibility of Pocket Parks in the Old City of Xuzhou

The global integration degree of roads in Xuzhou old urban area with radius $R=n$ was extracted from Depthmap and superimposed with pocket park layout. The line color is different with different values. The warmer the line color is, the higher the global integration is, and the colder the line color is, the lower the integration is.

Figure 2 shows that the integration degree of Xuzhou old city is higher in the east and lower in the west. Several scenic spots are located in the most integrated central areas of the old city, including Stagestage, Yunlong Park, and Yunlong Mountain. The global integration degree of all road axes in the study area was taken as the weight, and the kernel density analysis was carried out in ArcGIS. According to the natural fracture method, the mapping results were divided into 9 categories. The first 3 categories with large coefficients were defined as "core areas". As shown in Fig. 3, the nuclear density analysis map was superimposed with the distribution of pocket parks in the old urban area to find out that most pocket parks are not distributed in the core area with the highest degree of integration. However, being distributed in its edge, several pocket parks and the spatial distribution of the overall road integration degree of the study area has a certain degree of dislocation.

Since pocket parks are generally small in area, a buffer zone with a radius of 300 m is established in consideration of service radius and travel purpose of residents, and the average global integration degree of all axes within the buffer zone is the global integration degree of the park. According to the value of global integration, 17 parks were rearranged from low to high, as listed in Table 1. According to the calculation and analysis, the average global integration degree of pocket parks is 0.5952, which is 0.4344 higher than the average global integration degree of roads. Therefore, the overall global accessibility of pocket parks in Xuzhou old urban area is good. Most of the pocket parks are located in high accessibility areas with superior geographical positions, but there is still room for improvement. Pocket parks located on both sides or at intersections of main roads in the study area are at a high level of global accessibility, such as No. 9 pocket park located at Hubei Road and No. 16 pocket Park located at the intersection of Sudi Road and Zhongshan North Road. On the contrary, the global accessibility of the surrounding pocket park with lower road grades is poor, such as the No. 3 pocket park with only one lower road. The comparison between No. 9 park and No. 3 park shows a difference of 0.281 in their global integration degree. As the accessibility of pocket parks is uneven, and some of them serve too limited people, so accessibility needs to be improved.

Fig. 2. Superposition analysis of global integration degree and pocket parks.

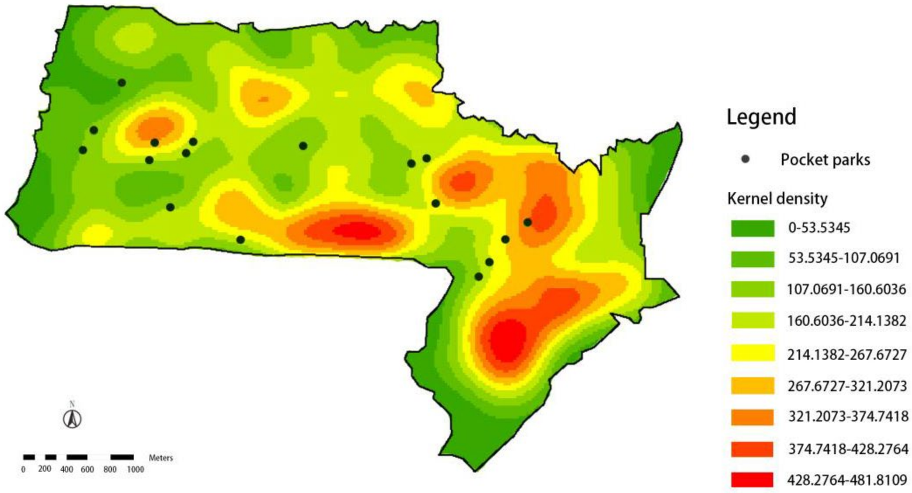

Fig. 3. Relationship between kernel density of roads global integration degree and pocket parks layout

Table 1. Global integration degree and ranking of pocket parks in old urban area of Xuzhou City

Rank	The pocket park samples	Global integration
1	*No.3 Park*	0.4383
2	*No.1 Park*	0.4697
3	*No.2 Park*	0.4944
4	*No.4 Park*	0.5364
5	*No.17 Park*	0.5484
6	*No.8 Park*	0.5873
7	*No.7 Park*	0.5899
8	*No.10 Park*	0.6039
9	*No.11 Park*	0.6068
10	*No.6 Park*	0.6191
11	*No.12 Park*	0.6267
12	*No.5 Park*	0.6323
13	*No.13 Park*	0.6467
14	*No.14 Park*	0.6565
15	*No.15 Park*	0.6641
16	*No.16 Park*	0.6780
17	*No.9 Park*	0.7193
	Average	0.5952

4.2 Analysis of Local Accessibility of Pocket Parks in Old City of Xuzhou

Pocket parks, as an important component of green infrastructure in cities, mainly serve the surrounding residents on foot, so the analysis of local accessibility is of great significance. The local accessibility of pocket parks is quantified by the local integration degree of space syntax, and the measurement of local integration degree refers to the agglomeration or dispersion degree of roads within a few steps (usually 3 steps) from the nearest road to a pocket park and the surrounding area. Therefore, in combination with the convenient travel distance of surrounding residents, the local integration degree with a topological distance of 3 (radius R=3) was selected for analysis in the calculation process. Figure 4 shows the result that is expressed in the same way as global integration. Road of local integration is weighted in the ArcGIS for nuclear density analysis, and the kernel density analysis map was superimposed with the distribution of pocket parks in the old city. As shown in Fig. 5, the distribution of local integration degree is similar to that of global integration degree, and the kernel density is higher in the east than in the west. Compared with the global integration, the area with high value decreased, and the spatial distribution of high and low-value areas became more fragmented. Pocket parks were mostly distributed in the edge area with high integration degrees.

The calculation method of local accessibility of pocket parks is similar to that of global accessibility, and the statistical ordering is shown in Table 2. According to the calculation, the average local integration degree of pocket parks is 1.6884, which is 1.0968 higher than the average global integration degree of roads. This indicates that the local accessibility of pocket parks in Xuzhou old city is also good as a whole. In terms of distribution, pocket parks located on both sides of main roads or at intersections still have high local accessibility, among which No. 7, 6, and 9 pocket parks have the highest local accessibility. The traffic facilities around these parks are relatively perfect, making it convenient for residents to reach the park. However, the local accessibility of No. 3 and No. 8 pocket parks is significantly lower than the average. The local accessibility of these parks is poor, and it is not convenient for residents to enter the park even if they are close to the park. The local accessibility of pocket parks in the old city is also uneven, and several pocket parks need to be improved in the subsequent construction.

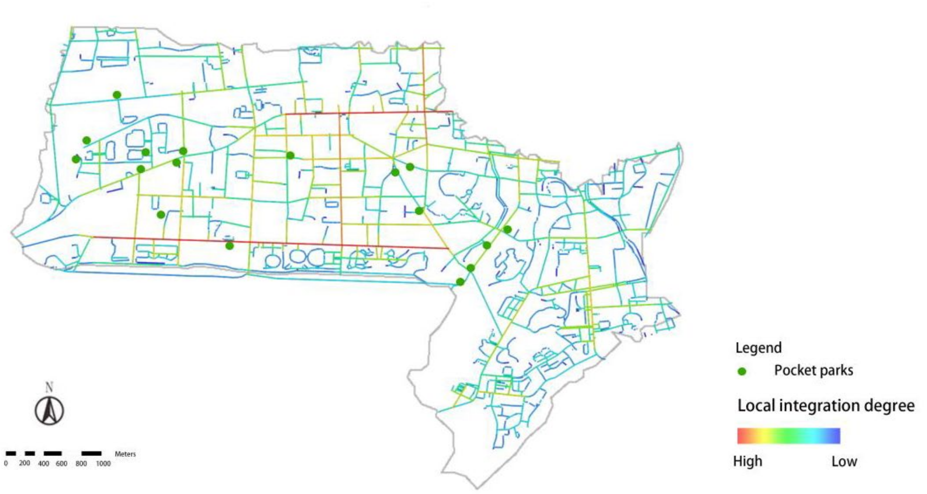

Fig. 4. Superposition analysis of local integration degree and pocket parks.

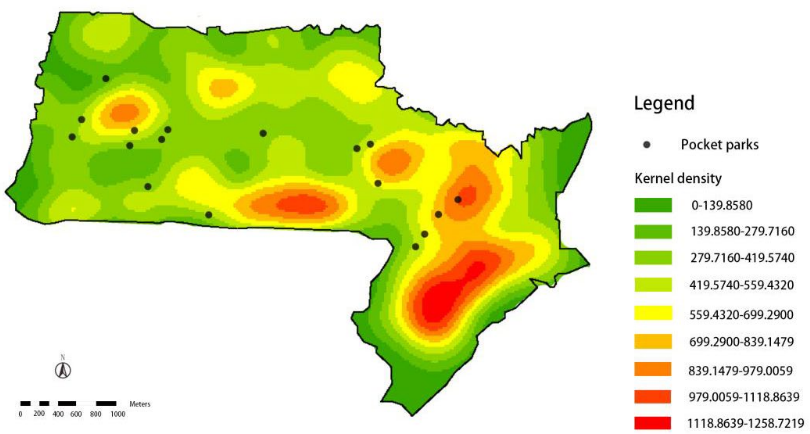

Fig. 5. Relationship between kernel density of roads local integration degree and pocket parks layout.

Table 2. Local integration degree and ranking of pocket parks in old urban area of Xuzhou City

Rank	The pocket park samples	Local integration
1	*No.3 Park*	0.4223
2	*No.8 Park*	0.8491
3	*No.17 Park*	1.0457
4	*No.1 Park*	1.1561

5	*No.2 Park*	1.2410
6	*No.4 Park*	1.4674
7	*No.12 Park*	1.6101
8	*No.10 Park*	1.7597
9	*No.15 Park*	1.8381
10	*No.14 Park*	1.8426
11	*No.5 Park*	1.8594
12	*No.16 Park*	1.9245
13	*No.11 Park*	1.9606
14	*No.13 Park*	1.9626
15	*No.7 Park*	2.0075
16	*No.6 Park*	2.2132
17	*No.9 Park*	3.5436
	Average	1.6884

Based on the global integration and local integration degree of superposition of the pocket park, the park is divided into three types: regions with high global and local integration, regions with high global integration but low local integration, and regions with low global integration but high local integration and superposition them with pocket park locations for analysis. The results are shown in Table 3.

Table 3. Comprehensive analysis on the overall and local integration of some pocket parks in the old urban area of Xuzhou City.

Integration		Park number	Number of parks
Global integration	Local integration		
High	High	5、9、10、13、16	5
High	Low	12、14、15	3
Low	High	6、7、11	3

Pocket parks with high global integration and local integration have relatively perfect transportation in all aspects around them, enabling residents within the research area to efficiently use the pocket park, including No. 5, 9, 10, 13, and 16 parks. Pocket parks with high global integration but low local integration have insufficient transportation around them, including No. 12, 14, and 15 parks. However, from the overall scope of the study area, the access is still relatively convenient, and there is a good development potential in the old city area. However, pocket parks mainly are for the fitness activities and communication activities of surrounding residents, which are relatively less affected by the overall traffic. Therefore, more attention needs to be paid to the construction of roads around the park. Pocket parks with low global integration but high local integration are not easy to pass in terms of overall traffic such as No.6, 7, and 11 parks. However, in terms of their local scope, they are still areas with a relatively dense human flow and better serve the surrounding residents. In addition, there are many pocket parks in the old city with low global and local integration. As their traffic availability is not perfect, attention needs to be paid to the subsequent construction of pocket parks.

4.3 Analysis of Perceived Accessibility of Pocket Parks in the Old City of Xuzhou

With Depthmap calculation, the values of connectivity and global integration of each pocket park were counted and imported into SPSS to calculate the Pearson correlation coefficient between them and obtain the comprehensibility of green spaces of each park and arrange green spaces in order of comprehensibility from high to low.

The comprehensibility of all road axes in the research area is 0.306, indicating that the perceived accessibility of the whole research area is not high. It is difficult to obtain the spatial information of the whole city through the understanding of local space. The average comprehensibility of pocket parks in the old city of Xuzhou is 0.614, which is higher than the comprehensibility of the overall road axis in the research area, as listed in Table 4. As shown in Table 5, the values of No. 3, 5, 15, 17, 9, 11, 13, 1, and 14 parks exceed the average value. These parks have relatively high perceptual accessibility, and residents can accurately find parks and perceive the overall road network through the structure of the local road network around them. However, the perceived accessibility of several parks is below the average, which results in the difficulty that residents cannot quickly find the park even if they are close to the pocket park. The perceived accessibility of green space in such parks needs to be improved.

Table 4. Calculation results of SPSS.

		Connectivity	Integration[HH]
Connectivity	Pearson correlation	1	0.306**
	Significance (bilateral)		0.000
	N	4587	4587
Integration[HH]	Pearson correlation	0.306**	1
	Significance (bilateral)	0.000	
	N	4587	4587

**Significant correlation was found at p=0.01 level (bilateral).

Table 5. Comprehensibility and ranking of some pocket parks in old urban area of Xuzhou City.

Rank	The pocket park samples	Comprehensibility
1	*No.10 Park*	0.413
2	*No.6 Park*	0.422
3	*No.12 Park*	0.462
4	*No.2 Park*	0.490
5	*No.16 Park*	0.514
6	*No.4 Park*	0.578
7	*No.8 Park*	0.587
8	*No.7 Park*	0.598
9	*No.3 Park*	0.629
10	*No.5 Park*	0.643
11	*No.15 Park*	0.650
12	*No.17 Park*	0.656
13	*No.9 Park*	0.706
14	*No.11 Park*	0.743
15	*No.13 Park*	0.744
16	*No.1 Park*	0.774
17	*No.14 Park*	0.833
	Average	0.614

5. Conclusions

We quantitatively analyze the accessibility of pocket parks in Xuzhou old city from three dimensions of global accessibility, local accessibility, and perceived accessibility. The overall global accessibility, local accessibility, and perceived accessibility of pocket parks in the old city are good. The average value of global integration (0.5952), local integration (1.6884), and perceived accessibility (0.614) were all higher than the average value of road characteristics. Pocket parks located beside main roads or at intersections (No. 9, 13, and 16 parks) ranked relatively high in global and local accessibility. However, both global and local accessibility of several parks is low for No. 3 pocket park that is surrounded by buildings with only one low-grade road. The accessibility of such pocket parks needs to be improved.

The distribution of pocket parks in the old city has a certain dislocation with the global and local accessibility of road networks. In the study area, the global accessibility of several parks is poor while local accessibility is good. Although such pocket parks are located in areas with insufficient traffic structures in the study area, such parks are convenient and serve the surrounding residents well. However, for the parks with good global accessibility but poor local accessibility, the served population by pocket parks is relatively small. Due to the small service radius of pocket parks, the park generally serves the people who reach the park in less than 10 min. Therefore, the construction of pocket parks needs more attention to local accessibility.

The perceived accessibility of pocket parks in Xuzhou old city is uneven, and several pocket parks with low comprehensibility are not conducive for residents to reach their destinations through local road networks as they are easy to get lost. In the later construction, we need to pay attention to the quality construction of pocket parks, considering the geographical location and its characteristics, shaping memorable landscape nodes with signs to be set up and improved for the perception of the pocket park.

We comprehensively analyze the accessibility of pocket parks in Xuzhou old city from the perspective of the spatial syntax theory and practice, which is a summary and supplement of previous studies, but there are still the following limitations: (1) we only discussed the accessibility of pocket parks in 2021 and did not analyze the continuous and dynamic changes of the accessibility of pocket parks in time-series, and (2) the consideration of residents' travel mode is not comprehensive. The limitations are the direction of future research to discuss the impact of residents' single travel mode on accessibility measurement.

6. Suggestion on Accessibility Optimization

Low accessibility gives the park less popularity and function and affects its efficiency of use as an urban public space. Therefore, based on the above research results, the following suggestions are made.

6.1 Improving Surrounding Transportation System

Taking "Xuzhou City master Plan (2007-2020)" as a reference, the road needs to be planned and built. Combing the road network of the old urban area, connecting the roads with low accessibility around pocket parks to the roads with high accessibility outside, and opening up the connection between branch roads and secondary roads improve the road network accessibility and enhance the global and local accessibility. Secondly, for pocket parks with poor accessibility, it is necessary to construct surrounding roads with the improvement of slow traffic system and walking path and to improve the local accessibility of pocket parks in the old city of Xuzhou. Third, the entrance and exit of the pocket parks in the old city of Xuzhou and the seamless connection between the inner road and the city road need to be enhanced to improve the perceived accessibility of the park.

6.2 Optimizing the Landscape Construction of Pocket Parks

The landscape of the pocket park also affects the attraction of the park to the citizens, thus affecting the accessibility [18]. In particular, the perceived accessibility of the pocket parks is deficient to a certain extent. Therefore, in the follow-up construction, the green space of pocket parks in the old city needs to be shaped with consideration according to its geographical location and current situation. The overall accessibility of pocket parks in the old city needs to be improved by strengthening the attraction of parks with appropriate infrastructure, signage systems, and guiding functions.

6.3 Coordinate the distribution of pocket parks in the city

For solving the problems of perceived accessibility deviation and unequal distribution of pocket parks in old urban areas, the existing pocket parks need to be well protected, and the internal construction needs to be reasonably increased at the same time. Because of its small service radius, the pocket park serves the people around the park. Therefore, the park is required to be near densely populated areas such as commercial and residential areas to provide resting and social space and meet the needs of residents and regional development.

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