Article

Measurement of Urban Park Accessibility from the Quasi-Public Goods Perspective

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Abstract: The rational distribution of parks within an urban park system should ensure reasonable travel distance for citizens, as well as good recreation quality, which seems to be more important than the former in megacities with high population density. However, studies on the accessibility of parks ignored the competitiveness and exclusiveness of urban green space, and the method can be improved to get a more scientific result as the basis for spatial optimization of urban park systems. Therefore, in this study, we consider the park's quasi-public goods attribute when building an accessibility measurement method, and both the park's service supply capacity and demand of citizens were included, as well as the influence of spatial travel cost. This method, based on the empirical research results obtained from a case study of Shaoxing in East China, provides a more suitable accessibility estimate compared with the previous methods, which can reflect the park's spatial distribution characteristics. Recommendations for improving the accessibility of parks include increasing the number of parks, reducing the cost of travel, enhancing park service capacity, and reducing the population density within the park's service area.

Keywords: urban parks; quasi-public goods; competitiveness; exclusiveness; accessibility

1. Introduction

Public parks represent the green land within a city that is open to the public, and their main functions include recreation, protecting the ecological environment, beautifying the landscape, and preventing disasters such as floods [1]. In China, there are four types of park according to the Classification Standard of Urban Green Space: comprehensive, community, theme, and amusement parks [2]. Studies showed that parks can promote the physical and mental health of citizens [3,4], social interaction among citizens, community awareness [5], patient recovery [6], and the construction of a sustainable and harmonious society [7]. For parks to play an active role, they must firstly be accessible; if someone wants to enjoy the services of the park, citizens must be capable of visiting one within a reasonable distance [8]. This is why park accessibility research is valuable [9].

Accessibility is the quantitative expression of the desire and ability of residents to reach a service facility or activity venue [10], and it is often reflected in transportation and land-use planning goals [11]. Park accessibility can be used to indicate its service level based on spatial distribution [12], which is considered an important factor affecting its normal functioning, subsequently influencing its use efficiency [13].

Common methods for measuring the accessibility of urban parks include the minimum distance, travel distance (including simple buffer, cost-weighted distance, and network analysis methods), and the gravity model methods. Researchers generally measured the spatial accessibility of parks from the convenience or distance of citizens to the park [14]. To measure the accessibility of parks

in Shanghai, Yin et al. used the minimum distance method, which was the straight-line distance of residents to the nearest park [15]. Coombes et al. also used the minimum distance to express the green space accessibility in the city of Bristol, United Kingdom (UK) [16]. Nicholas adopted the simple buffer method to measure the accessibility of a park in Bryan, Texas, United States of America (USA) [12], which was able to distinguish between the accessible and inaccessible ranges of parks, but could not reflect the differences in accessibility within the accessible area. Wang found that park accessibility was overestimated when using buffer zone analysis for accessibility measurement in Changzhou [17]. Zhu et al. used the cost-weighted distance method to calculate the accessibility of forests within two kilometers of the city block [18]. Although this method's measurement results are more accurate than those of the simple buffer method, there is no unified standard for the travel resistance setting. Sang et al. used the network analysis method to calculate the accessibility of urban leisure green spaces in Hangzhou [19]. However, this method has some drawbacks; the difficulty in obtaining complete road network data and the impact on accessibility caused by the variation in park attractions due to their varying characteristics cannot be considered. The gravity model method assumes that the accessibility of the park decreases with increasing resistance experienced by citizens, and increases with the increasing service capacity of parks. This analysis method not only considers the influence of distance, but also considers the attraction effect of a park's characteristics such as size, quality, and grade [18]. Hu et al. [20] used this method to measure the accessibility of green space in Shenyang, and Ma et al. [21] used the same method in Guangzhou. Many scholars studied the exogenous factors influencing the accessibility of parks. Li et al. added influence factors of different modes of transport into accessibility evaluation [22], Xu et al. explored how the accessibility varies along socioeconomic gradients [23], and Li et al. explored the degree of matching between the accessibility of parks and residents' access preferences [24].

The above studies proposed various methods to measure the accessibility of parks, and they all simply assumed that the service capacity of each park is unlimited. However, as high-density development is a common feature of urban land use in China, park service shortages are a common problem in many cities. Restricted by factors such as the park size and its supply of facilities, citizens are competitive when enjoying park services. As the number of visitors to parks increases, the parks become crowded and overused. The higher the number of potential users of a park is, the busier and the less accessible the park is. When the spatial distribution of parks matches the population in need, the accessibility is reasonable [25]. In previous studies, the accessibility evaluations lacked consideration of users' competition in sharing the limited supply of parks.

To stabilize their normal function, some parks introduced an exclusive mechanism: charging an entrance fee. Thus, some citizens with low incomes or who are unwilling to pay the fee are excluded from enjoying the park's services. Therefore, these parks should be excluded before the evaluation of accessibility, but this was ignored in previous studies.

Paul Samuelson, the Nobel Prize laureate in Economic Sciences, stated that non-competitiveness and non-exclusivity are unique properties of public goods, differentiating them from private goods [26]. Non-competitive means that when one consumes goods, other people's consumption of the goods is not reduced. In other words, the marginal cost of increased consumers is zero. Non-exclusivity means that, whether an item is consumed by someone or not, one cannot exclude others from consuming it (whether they pay for it or not), or the cost of exclusion is very high. Objects with only one characteristic (either non-competitive or non-exclusive) are considered quasi-public goods, whereas objects without the two characteristics are considered private goods.

Due to the competitive and non-exclusive nature of public parks and the exclusive and non-competitive nature of fee-paying parks, parks should be regarded as quasi-public goods (hereinafter, QPG represents quasi-public goods) rather than pure public goods (hereinafter, PPG represents pure public goods). However, previous researchers only studied parks from the perspective of PPG; thus, from the QPG perspective, we attempted to measure the accessibility of parks using a new method to help planners identify spatial units with low park accessibility, to determine the regions that should

be prioritized for providing park services, to lay a foundation for optimizing the layout, and to help decision-makers to develop equal and effective planning policies and strategies.

2. Materials and Methods

2.1. Study Area and Data

2.1.1. Study Area

The research area was in Shaoxing, a northern city in Zhejiang province in East China. Shaoxing city consists of three administrative districts, including one central urban district (Yuecheng) and two suburb districts (Shangyu and Keqiao). Meanwhile, the urban area is mainly concentrated in the Yuecheng district and had a population over seven hundred thousand at the end of 2017. Thus, in this article, Shaoxing refers to the urban area in Yuecheng district, and it is also the traditional administrative and economic center of Shaoxing city. Furthermore, Shaoxing is one of the first 24 famous historic cultural cities of China, as announced by the Chinese central government. In recognition of its contributions to improving the habitat and urban environment, Shaoxing was rated as the national garden city in 2003, and awarded the United Nations Habitat Award in 2008. Due to the efforts of the Shaoxing Municipal government, Shaoxing is much greener than other similar-sized cities. Therefore, Shaoxing was selected as the study area. The specific research scope (Figure 1) was enclosed by Erhuan Road, covering an area of 45.36 km², which includes the old city and its surrounding areas.

Figure 1. Location of the study area. The inset map shows the location of Shaoxing in Zhejiang province.

2.1.2. Data

Park Data

In addition to the parks which need tickets, there were 41 parks in the study area (Figure 2) in 2012, including one comprehensive park, two regional parks, four community parks, three theme parks, and 16 amusement parks (consisting of 31 small independent green areas or pocket parks).

Figure 2. Spatial distribution map of parks in the study area. Data source: Shaoxing City master plan (2011–2020) and Shaoxing City green space system plan (2012–2020).

In the uncompetitive state, there are three parks (Jishan, Fushan, and Tashan) with exclusive areas where the individuals are not allowed without paying an entrance fee; thus, these areas were excluded from the method.

Spatial Distribution of Population

According to a previous study, the larger the spatial scale of the demographic unit is, the larger the estimated error of individual travel cost and the lower the accessibility accuracy will be [27]. To improve the estimation accuracy, a feasible solution involves using population data with low aggregation [28]. Therefore, taking residential buildings as basic space units, the population of these units was estimated using the following formula:

$$Pop_i = Pop_{avg} \times \frac{S_i}{S_{avg}}, \quad (1)$$

where i is the serial number of residential buildings, Pop_i denotes the population inside building i , Pop_{avg} is the population per household, S_i is the area of residential buildings, and S_{avg} is the story area of residential buildings per household. There are two types of residential buildings: apartment buildings and low-rise traditional buildings. S_{avg} is 116.42 m² for the former and 60.22 m² for the latter according to Chen et al.'s field investigation [7].

Based on residential building data from a 1:500 topographic map provided by Shaoxing Urban Planning Design Institute (Shaoxing, China), the story area of each building was firstly calculated by multiplying the footprint area and the story number; the story area was then multiplied by Pop_{avg} , and then divided by S_{avg} to estimate the population of the building. According to the Shaoxing Population Statistics [29], Pop_{avg} was 2.72 in 2012. The estimated total population in the research area was 424,701, which is quite close to the real population size of 408,840 according to the census data [30]. The overall estimation error of 3.73% is acceptable since it is less than 5%.

2.2. Accessibility Measurement from the Perspective of QPG

Based on the quasi-public goods characteristic of parks, the supply of service ability and citizens' demands to parks should be considered during the accessibility measurement. The ratio of supply to demand ($ratio_{s/d}$) can reflect the accessibility to a large extent. The higher the $ratio_{s/d}$ is, the more accessible the parks are. The level of accessibility is also related to the spatial resistance between travel source and destination. Considering the above two aspects, the accessibility A_j of a specific space unit j to parks can be measured according to

$$A_j = \sum_{i=1}^n \frac{Svc_i}{d_{ij}^\beta}, \quad (2)$$

where i is the serial number of the park, n is the total number of parks, Svc_i is the service capacity of park i , d_{ij} is the space resistance from building j (hereinafter referred to as the space unit) to park i , and β is the gravitational attenuation coefficient.

2.2.1. Park's Service Capacity

Considering the quasi-public goods characteristics of parks, their service capacity is determined by the corresponding service supply and demand levels. The following measure was adopted:

$$Svc_i = \frac{S_i}{D_i}, \quad (3)$$

where S_i is the service supply level of the park i , and D_i is the demand level of the park i .

Supply Level S_i

The supply level of a park is represented by the total population S that can be served within the service scope of parks in a non-competitive and non-exclusive state. It is determined by two factors: the visitor capacity C and the turnover coefficient e . The formula is as follows:

$$S_i = C_i \times e. \quad (4)$$

Large parks (comprehensive parks and theme parks) have a low turnover coefficient, which represents the tourist flow speed in one day, compared with small parks due to their complete or large-scale facilities. According to relevant studies, for large parks, e is <1.5 ; for small parks, e is <3 [31]. In this study, the maximum serving population of a park in a non-competitive and non-exclusive state was used to measure the accessibility of parks. Therefore, e was set to 1.5 for comprehensive parks and theme parks, and 3 for others.

Park Capacity C_i

The visitor capacity of a certain park provides the basis for management to control the number of visitors and arrange the number and scale of park facilities to avoid accidents such as visitor casualties or damage to the inside facilities caused by park overcapacity [32]. When the number of visitors is within the park capacity, the utility of a park decreases due to competition between the increasing

visitors in the park. When the number of visitors exceeds the capacity, the park is in an unreasonably competitive state, which means that the public cannot normally enjoy the park service.

According to the relevant regulation [31], comprehensive parks own relatively complete facilities. The recreation space that visitors can use is about one-third of the total area, and the remaining two-thirds encompasses water bodies, forests, and flower beds that cannot be entered. The regulation also stipulates that the per capita occupied area of each visitor in comprehensive parks is 60 m², whereas that of the other kinds of parks is 30 m².

The number of visitors that a park can accommodate (C_i) was estimated according to the following formula:

$$C_i = \frac{Area_i}{Area_m}, \quad (5)$$

where $Area_i$ is the total area of park i in a non-exclusive state and $Area_m$ is per capital occupied area of the park for each visitor.

Service Radius of Park

The European Environment Agency recommends that people should be able to access parks within a 15-min walk [33]. Based on a Europe-wide evaluation report on the accessibility of parks, residents of several major European cities and many small cities live within the 15-min walking circle of urban parks [34]. More strictly, English Nature, a government agency, and the Swedish government recommend that people should be able to visit parks within 300 m of their homes [33,35]. The evaluation standard of urban landscape greening (GB/T 50563–2010) in China states that a 500-m service radius of parks should fully cover all residential land [36]. The national garden city evaluation standard requires the service radius of urban public parks (larger than 1000 m²) to be 500 m [37].

With reference to the worldwide planning guidelines, the relevant standard [2], and Chinese park system planning, e.g., Hangzhou urban green space system planning (2002–2020) or Harbin city ecological garden city green space system planning (2002–2020) [38], the park service radii were set according to their type and scale (Table 1).

Table 1. Service radii of parks.

Type of Park	Area (hm ²)	Service Radius (km)
Comprehensive park	$S \geq 25$	3
	$20 \leq S < 25$	2.5
	$10 \leq S < 20$	2
	$S \geq 10$	1.5
	$5 \leq S < 10$	1.2
	$2 \leq S < 5$	1
Community park	$S \geq 5$	1
	$1 \leq S < 5$	0.8
	$0.4 \leq S < 1$	0.5
	$S \geq 0.4$	0.5
Theme park	$S \geq 40$	2.5
	$20 \leq S < 40$	2
	$10 \leq S < 20$	1.5
	$5 \leq S < 10$	1.2
	$1 \leq S < 5$	1
	$0.1 \leq S < 1$	0.3
Amusement park	$S \geq 5$	1
	$1 \leq S < 5$	0.8
	$0.1 \leq S < 1$	0.5

Note: S represents the area of parks.

Level of Demand for a Certain Park D_i

The demand level for a certain park is represented by the demand population within its service radius, and the formula is as follows:

$$D_i = P_i \times \rho, \quad (6)$$

where P_i is the number of residents in the service range of park i , and ρ is the residents' trip rate.

Due to the easy access to amusement parks, they have a relatively higher trip rate compared with other parks. According to relevant studies, the trip rate of large parks (comprehensive parks and theme parks) should be $\rho \geq 12\%$ while that of small parks (community parks and amusement parks) should be $\rho \geq 20\%$ [31]. In this study, the minimum demand population was considered for measuring accessibility, i.e., the trip rates of large and small parks were assigned to 12% and 20%, respectively.

2.2.2. Travel Cost and Gravity Attenuation Coefficient

Cost of Travel d

Considering the spatial resistance, the network analysis method is always used to calculate the travel cost in an urban road network to evaluate park accessibility. However, the travel cost from the urban road network to residential buildings is often neglected.

As residential neighborhoods in China are always surrounded by walls, for large-scale residential areas, the travel cost inside the residential area cannot be ignored. Therefore, travel cost d can be calculated as follows:

$$d = d_x + d_y, \quad (7)$$

where d_x is the distance cost within the residential quarter, and d_y is the distance cost of the road network. Since there is always more than one entrance and exit for a residential neighborhood, as well as a park, the minimum d was used for accessibility estimation.

For most citizens, the perceived park's accessibility seldom varies if the travel distance is within a certain threshold. Simultaneously, to avoid the overestimation of accessibility in the case of shorter travel distances, a 300-m travel distance threshold was set, which means that travel distances shorter than 300 m were regarded as 300 m when measuring park accessibility. If the travel distance was between 300 m and the service radius of the park, the real travel distance was used for measurement.

In conclusion, Equation (3) can be simplified as

$$A_j = \sum_{i=1}^n \frac{Area_i \times e}{Area_m \times P_i \times \rho \times (d_x + d_y)^\beta}. \quad (8)$$

Gravity Attenuation Coefficient β

The gravity attenuation coefficient represents the degree to which accessibility decreases with the increase in space resistance. The attraction and the accessibility of a park decrease with increasing travel distance to the park. However, no agreement was reached among scholars about a reasonable value for the gravity attenuation coefficient. Since many researchers chose 1 as the coefficient [39,40], we also set β to 1.

2.3. A Comparative Method from the Perspective of PPG

To verify the difference between the proposed method from the QPG perspective and the conventional method from the PPG perspective, we used a comparison method to evaluate the accessibility. When the parks are considered as pure public goods, their service supply should fully meet the demand of individuals in their service area. Thus, S_{vic} is 1 because the demand is equal to

the supply. Based on the gravity method, the comparative formula from the perspective of PPG is as follows:

$$A_j = \sum_{i=1}^n \frac{1}{d_{ij}^\beta} \quad (9)$$

2.4. Data Source

All the statistical data in this article, including the population data, were from the Shaoxing local government. Those data are all openly accessible online [29,30]. The spatial data, including the parks, road network, and buildings (both footprints and story number) were extracted from 1:500 topographic maps, which were provided by the Shaoxing Urban Planning Design Institute (Shaoxing, China).

3. Results

From the perspective of QPG, the actual carrying capacity of some parks cannot meet the needs of the population within the service range, and many parks have insufficient service capacity. Only seven parks, including Tashan (10; hereinafter, the number in the parentheses following the name of a park indicates its identifier (ID) in Appendix A) and Fushan (33), can fully meet the needs of all residents within the service range (Appendix A).

Thirty four parks with insufficient green space supply included amusement parks, community parks, and theme parks. Among them, the amusement parks were mainly located in the peripheral area of the old city of Shaoxing, whereas the remaining parks were mainly distributed along the boundary area near the old city.

Based on Equations (3) and (9), the accessibility values of parks within the urban area of Shaoxing, from the perspectives of PPG and QPG, were calculated, taking the residential units within the scope of the empirical research area as basic units. Assuming that parks as public goods have unlimited service supply capacity, the average accessibility of the parks of each basic unit was 2.31, of which the highest value was 17.19. However, from the perspective of QPG, the average accessibility of parks decreased significantly, weakening to 1.27, and the highest value was 8.52.

To facilitate the spatial analysis and diagrams, park accessibility data from the perspective of PPG and QPG were classified and counted using the mean method, and the accessibility was divided into six categories. Among them, the basic units with 0 accessibility were regarded as a single type, and the accessibility measure values were divided into five equal ranges. From high to low, the accessibility level was classified into five categories (Table 2): level 5 (80–100%), level 4 (60–80%), level 3 (40–60%), level 2 (20–40%), and level 1 (0–20%).

Table 2. Accessibility data. PPG—pure public goods; QPG—quasi-public goods.

Two Perspective	Break Points of Five Accessibility Categories					Min.	Max.	Mean	SD
	Level 1 (0–20%)	Level 2 (20–40%)	Level 3 (40–60%)	Level 4 (60–80%)	Level 5 (80–100%)				
PPG	3.44	6.88	10.31	13.76	17.19	0	17.19	2.31	2.74
QPG	1.71	3.41	5.11	6.82	8.52	0	8.52	1.27	1.51

3.1. Evaluation Results Based on Comparison Method

Figure 3 shows the evaluation results based on the comparison method. Tables 3 and 4 show the statistical results of the number of residential units and the population, respectively.

Figure 3. Accessibility evaluation results from the perspective of pure public goods (PPG). From high to low, the accessibility level was classified into five categories (Table 2).

Table 3. Statistical results of the number of units in each level from the perspective of pure public goods. The results were classified into six levels and three scopes.

Accessibility Level	Inside the Old City		Outside the Old City		Whole Study Area	
	Number of Units	Percentage	Number of Units	Percentage	Number of Units	Percentage
0	0	0.00%	5205	60.02%	5205	38.94%
1	2495	53.14%	2085	24.04%	4580	34.26%
2	1713	36.49%	858	9.89%	2571	19.23%
3	385	8.20%	472	5.44%	857	6.41%
4	69	1.47%	52	0.60%	121	0.91%
5	33	0.70%	0	0.00%	33	0.25%
Total	4695	100.00%	8672	100.00%	13367	100.00%

Table 4. Statistical results of the population in each level from the perspective of pure public goods. The results were classified into six levels and three scopes.

Accessibility Level	Inside the Old City		Outside the Old City		Whole Study Area	
	Population (n)	Percentage	Population (n)	Percentage	Population (n)	Percentage
0	0	0.00%	153,513	51.69%	153,513	36.15%
1	61,032	47.78%	75,977	25.58%	137,009	32.26%
2	48,884	38.27%	40,754	13.72%	89,638	21.11%
3	12,959	10.15%	24,122	8.12%	37,081	8.73%
4	3416	2.67%	2598	0.87%	6014	1.42%
5	1446	1.13%	0	0.00%	1446	0.34%
Total	127,737	100.00%	296,964	100.00%	424,701	100.00%

Even when considering the unlimited service capacity of parks, 38.94% of residential units in Shaoxing were not within the service scope of the urban park system. In particular, urban parks in the north and south of the study area were relatively few and small, preventing a large number of basic residential units in the above area to enjoy park services. Due to the growth of the urban population and the expansion demand of urban land in the Shaoxing urban area, many suburbanized residential areas, with gated communities as the main type, appeared in the market-led suburbanization development process. Simultaneously, the government-led public service facilities, including park and green space

facilities, were relatively behind in terms of construction, which means that this type of residential area is a suburban “sleeping city” that lacks parks and green space services. Newly built residential areas in the periphery of the city tended to be spatially scattered, with many independent development plots. The parks were far from the surrounding original residential groups, with poor spatial agglomeration; thus, the existing park system in the Shaoxing urban area was unable to cover the peripheral areas.

In addition to many basic units outside the service scope of parks in suburbs, the accessibility of parks in more than half of the basic units was relatively low, among which level 1 accounted for 34.26% and level 2 accounted for 19.23% of the total. In terms of spatial distribution, the proportion of basic units with low accessibility was much higher within than outside Shaoxing old city. The total number of basic units in levels 1 and 2 accounted for nearly 90%, which accommodated nearly 110,000 urban residents. The number of basic units with high accessibility, levels 4 and 5, was relatively low, accounting for only 1.16% of the total. The units with high accessibility were in the northeast of Jishan park (40) and Dongdachi park (36). The buildings along Yan’andong Road, Renmin East Road, and around Hechi park (16, 17), Dongdachi park (36), and Nanyunhe park (6, 11, 12, 19, 21) also showed a relatively high park accessibility.

From the perspective of PPG, the park accessibility of basic units within the research scope reflected significant spatial heterogeneity. Even if the existing park system could provide an unlimited supply in a non-exclusive and non-competitive state, nearly 40% of the building units still would not enjoy the effective services of parks. Among the building units enjoying park services, many with low accessibility were concentrated in the urban center and suburban areas. Especially from the center to the northwest of the old city, due to the relatively few green parks, there was a large continuous distribution of poorly accessible areas. However, in the southeast side of the old city, the accessibility level of basic units was relatively high due to the number and dense spatial distribution of parks.

3.2. Evaluation Results Based on Proposed Method

Figure 4 shows the evaluation results based on the proposed method. Tables 5 and 6 show the statistical results of the number of units and the population, respectively.

Table 5. Statistical results of the number of units in each level from the perspective of quasi-public goods. The results were classified into six levels and three scopes.

Accessibility Level	Inside the Old City		Outside the Old City		Whole Study Area	
	No. Units	Percentage	No. Units	Percentage	No. Units	Percentage
0	0	0.00%	5205	60.02%	5205	38.94%
1	1874	39.91%	2109	24.32%	3983	29.80%
2	2007	42.75%	740	24.32%	2747	20.55%
3	800	17.04%	372	4.29%	1172	8.77%
4	14	0.30%	168	1.94%	182	1.36%
5	0	0.00%	78	0.90%	78	0.58%
Total	4695	100.00%	8672	100.00%	13367	100.00%

Table 6. Statistical results of population in each level from the perspective of quasi-public goods. The results were classified into six levels and three scopes.

Accessibility Level	Inside the Old City		Outside the Old City		Whole Study Area	
	Population (n)	Percentage	Population (n)	Percentage	Population (n)	Percentage
0	0	0.00%	153,513	51.69%	153,513	36.15%
1	43,578	34.12%	81,320	27.38%	124,898	29.41%
2	56,883	44.53%	32,852	11.06%	89,735	21.13%
3	26,526	20.77%	17,852	6.01%	44,378	10.45%
4	750	0.59%	7322	2.47%	8072	1.90%
5	0	0.00%	4105	1.38%	4105	0.97%
Total	127,737	100.00%	296,964	100.00%	424,701	100.00%

Figure 4. Accessibility result map based on the proposed method from the perspective of quasi-public goods (QPG).

When parks were considered quasi-public goods, the standard deviation of the data sample of accessibility level changed from 2.74 to 1.51, which means that the discrete degree of the accessibility measurement value of parks decreased. The proportion of basic units for levels 2–4 increased, reaching 20.55%, 8.77%, and 1.36%, respectively, covering about 142,000 people. The accessibility level of the basic units in the old city was mainly level 2, reaching 42.75%, mainly concentrated in the center of the old city, as well as the residential area on the east side of Fushan park (33), the southeast side of Jishan park (40), and around Luomen park (7). However, few basic units in old city had high accessibility levels (levels 4 and level 5) including the new-century apartment on the east of the old city and the Beihai community on the west side of Fushan park (33). In contrast, the basic units with high accessibility were mainly concentrated outside of the old city, including the north and south sides of Yonghe park (32), Luhui park (30), and around Hechi park (16,17).

3.3. Results Comparison

The present spatial configuration of the park system is unequal, whether from the PPG perspective or QPG perspective. The formation of the above phenomenon was closely related to the Shaoxing space development process. Before the 1990s, Shaoxing's urbanization rate was low, and the city construction mainly centered in the old city. Since the 1990s, the old city was rated as a famous historical and cultural city in China, which means that land use and housing construction were restricted by the protection plan. Thus, urban construction started to break through the original boundary of the old city, with the eastern part chosen for public facilities and the south side chosen as a residential area for the new citizens and the old city population. After 2013, with the adjustment of the Shaoxing administrative division, the northern part gradually became the urban development hotspot. The different urban spatial expansion directions during each period and the regional function differences led to the spatial distribution differences between the inside and outside the old city, and also between the east and west parts of the study area.

Compared with the measurement results of park accessibility from the perspective of PPG (Figure 5), more than 42% of the basic units showed different degrees of decline (Table 7) and spatial distribution characteristics, such as lower accessibility in the east of the study area. Among them, the most severe decreases in basic units were found around Jishan park (40), Dongdachi park (36), Luomen park (7), Nanyunhe park, and along Shunjiang Road (6, 11, 12, 19, 21). In contrast, the basic units whose accessibility decreased less were distributed along the outer areas of the city, as well as the basic units in the inner areas of the old city, such as the Huanchengxi Road area and the residential cluster around Tashan park (10). No decline was observed in the area with relatively low accessibility from the center to the southwest of the old city, mainly because the basic units in the area are near Fushan park (33), which could fully meet the needs of the population within its service area. No difference was found in the supply capacity from the perspective of PPG or QPG, guaranteeing the accessibility of the basic units.

Figure 5. The change in accessibility based on the proposed and comparison methods. The park accessibility decreased or remained steady compared to that from the perspective of pure public goods.

Table 7. Statistical results of the number of units within each level from the change in accessibility based on the proposed and comparison methods. The results were classified into six levels and three scopes.

Change in Accessibility	Inside the Old City		Outside the Old City		Whole Study Area	
	No. Units	Percentage	No. Units	Percentage	No. Units	Percentage
No Change	2008	42.77%	5693	65.65%	7701	57.61%
Decrease	2687	57.23%	2979	34.35%	5666	42.39%
Total	4695	100.00%	8672	100.00%	13,367	100%

4. Discussion

From the perspective of QPG, the method of measuring park accessibility reflected a more suitable evaluation of the service capacity of the urban park system and the ability of residential units to obtain park services, compared with the accessibility analysis method from the perspective of PPG. The most

significant difference was in the assessment of the real service capacity of parks. Considering the nature of quasi-public goods, taking only the spatial proximity as the influencing factor in the research about accessibility would lead to the overestimation of the accessibility and hide the problems with the park system's spatial layout, as evidenced by the Shaoxing old city. Although there are three comprehensive parks in Shaoxing old city, the increase in population in this area promoted the demand for parks, resulting in the actual park accessibility of the living space in the old city being relatively low.

Based on Equation (9), from the perspective of PPG, for a specific urban space, the factors affecting its accessibility are the number of surrounding parks and travel costs. Therefore, by optimizing the park system, increasing the number of parks could increase the spatial density of parks and reduce the citizens' travel costs, which is important to rapidly enhance the accessibility. However, considering parks as quasi-public goods in this accessibility measurement method, the factors influencing accessibility are expanded to the park scale, park turnover rate, per capita area of parks, the number of surrounding residents, and trip rate of park services. Those influencing factors can be divided into three categories: the correlation influencing factors, which mainly refer to the spatial relationship between the basic unit and surrounding parks, including the number of surrounding parks and travel costs; environmental factors, which mainly refer to the number of residents within the park service area; and type factors, which are directly related to the types of parks, including the park turnover rate, the rate of residents around the park, and the per capita occupied area of parks.

According to the proposed method, the number of surrounding parks, the turnover rate of parks, and the park area positively influenced accessibility, whereas travel cost, the number of residents within the park's service range, the travel rate of residents, and the per capita area of parks were all negatively correlated. Therefore, for the park system, the accessibility can be improved by changing the type factors, such as increasing the non-exclusive service area of parks. In addition, the service capacity of parks can be enhanced by increasing the turnover rate and reducing the per capita occupancy of the park area to improve the overall service capacity of the park system. For residential units, the spatial difference of accessibility is also affected by environmental and correlation influencing factors, such as the location and the population density of nearby residential areas.

Therefore, the accessibility level is related to the correlation factors including spatial proximity of a park to the citizens and the number of surrounding parks. Environmental factors also exert an important influence on park accessibility. However, the type factors, which include the park's own characteristics, are not determined by the nearby residential units. So, the environmental factors and correlation factors play more critical role in accessibility change. In this article, we take the change in accessibility of residential units as the dependent variable, and the park service supply capacity (measured by the number of nearby parks), spatial proximity (the average road network distance to nearby parks), nearby population density (the storey height of building units) as the independent variables. We used the least squares method to analyze the influence of various factors on the change in accessibility. All units with zero accessibility were removed in this analysis to improve the effectiveness of regression analysis which was performed by IBM SPSS Statistics V22.0. Based on the data analysis results, the regression equation can generally describe the relationship between the dependent variable and independent variables (coefficient of determination (R^2) > 0.6). The significance test showed that the number of surrounding parks, the average network distance, and the story condition of residential units had a significant impact on the change in accessibility level. In the regression formula, we found a significant positive correlation between the number of parks and the decline in accessibility, indicating that the more concentrated the park area is, the higher the degree of accessibility decline from the perspective of QPG will be. The number of building unit stories is also positively correlated with the decrease in accessibility level. Because Shaoxing is an ancient Chinese city with a long history, differently aged architectural forms had distinct story characteristics. Inside the old city, the traditional Chinese residential houses are mostly courtyard buildings with fewer stories, usually no more than three stories. From 1949 to the 1990s, the main type of newly built houses were four- to six-story apartment buildings. In the 21st century, due to the increase in land prices and the agglomeration of

the population, new residential communities are dominated by high-rise apartments with more than seven stories. The patchy development and cluster layout of urban construction resulted in the spatial concentration of building units in different urban development stages, and the building height of basic units is often consistent with that of surrounding areas. Therefore, the stories of the residential unit not only indicate the land-use intensity, but also the regional development intensity of the surrounding area. Thus, the increase in the number of stories means the rapid promotion of population, which leads to an increase in the total demand for parks and a further decline in accessibility. Different from the above two influencing factors, the average network distance was negatively correlated with decreasing accessibility level; the farther the average distance from the surrounding green space is, the smaller the change range of the accessibility level of residential units will be. This kind of residential units with large network distances are always in the service area of fewer parks, and they are not affected by the combined effect of the park service capacity decrease, considering that large parts of parks in Shaoxing have a lower service capacity than expected.

Due to the spatial heterogeneity of the park accessibility in Shaoxing and the differences in their formation mechanism, the strategies for optimizing the park system in Shaoxing need to match the spatial distribution characteristics in different regions. The old city has a mature park system and has almost all the comprehensive parks and theme parks. Therefore, the accessibility of parks can be improved through the following optimization strategies: firstly, increasing the non-exclusive service area in the existing parks to improve the service capacity; secondly, moving some urban residents in old city to the suburbs through the urban renewal and the historical and cultural protection processes of the old city. As part of urban renewal, the land use should be changed to promote the living quality and enhance the vitality of the city center. Thus, it is necessary to transform some residential and commercial space into small amusement parks to increase the spatial density of parks in the old city and reduce the service demand of the original parks. For the area outside the old city, the accessibility of green space can be improved mainly by optimizing the layout and type of the parks. To meet the needs of residents and to address the lack of parks in the north and south suburban areas, comprehensive parks should be included in the further city master plan and the facilities should be built as soon as possible. Large-scale amusement parks with good location condition should be upgraded to comprehensive parks to improve their service quality and expand their service capacity, such as Nanyunhe park (6, 11, 12, 19, 21) and the river-side park on Renmin East Road (25, 26, 28, 29). Through the adjustment of factors, such as the service scale of parks and nearby service population, the optimization plan can promote the overall accessibility level of the peripheral area of Shaoxing.

Basically, we used the proposed accessibility measurement to calculate the potential park accessibility, which is a consequence of theoretical method research. Meanwhile, with attention paid to ecological protection and human living experience in the urban master plan, the proposed method could help policy-makers to plan a rational land-use layout which has a more balanced residential, working, and leisure space. However, the proposed method has at least two drawbacks: firstly, the measurement lacks citizen investigation to understand the practical willingness to obtain park services, leading to the turnover rate potentially being overestimated or underestimated; secondly, the measurement ignores the individuality of each park. Uniform standards of trip rate and per capita occupied area were used in the measurement of the same kind of parks. The above deficiencies would somehow affect the accuracy of the estimated park accessibility. Therefore, in further research, it is necessary to have field investigations for enriching the data source and to use the multi-fractal model for improving the accuracy of the evaluation method [41]. Furthermore, based on big data such as mobile phone signals, the theoretical method also needs comparative empirical research to verify its reliability.

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Appendix A

Table A1. The basic information of parks.

No.	Name of Park	Type	Supply–Demand Ratio	Location *
1	Lujiazhuang Park	Amusement park	0.20	Outside
2	Pingshuixijiang river-side green land	Amusement park	0.10	Outside
3	Jiangnan amusement park	Theme park	0.33	Outside
4	Jishui park	Amusement park	0.31	Inside
5	Jianshui park	Amusement park	0.31	Inside
6	3rd Nanyunhe park	Amusement park	0.15	Outside
7	Luomen park	Community park	0.27	Inside
8	Zhishui square	Amusement park	0.50	Inside
9	Dongfang garden	Community park	0.48	Outside
10	Tashan park	Regional park	1	Inside
11	4th Nanyunhe park	Amusement park	0.41	Outside
12	5th Nanyunhe park	Amusement park	1	Outside
13	Shen park	Theme park	0.49	Inside
14	Changxi crossing park	Amusement park	1	Outside
15	Xiban park	Community park	0.95	Outside
16	1st Hechi park	Amusement park	1	Outside
17	2nd Hechi park	Amusement park	0.74	Outside
18	Ertong park	Theme park	1	Inside
19	1st Nanyunhe park	Amusement park	0.07	Outside
20	1st Shunjiang Road park greenbelt	Amusement park	0.10	Outside
21	2nd Nanyunhe park	Amusement park	0.14	Outside
22	Xi park	Amusement park	0.14	Inside
23	1st river-side green land on Huancheng East Road	Amusement park	0.37	Inside
24	2nd Shunjiang Road park greenbelt	Amusement park	0.35	Outside
25	1st river-side park on Renmin East Road	Amusement park	0.52	Outside
26	2nd river-side park on Renmin East Road	Amusement park	0.38	Outside
27	2nd river-side green land at Huancheng East Road	Amusement park	0.49	Inside
28	3rd river-side park at Renmin East Road	Amusement park	0.09	Outside
29	4th river-side park at Renmin East Road	Amusement park	0.18	Outside
30	Luhu park	Amusement park	0.53	Outside
31	Henghe greenbelt	Amusement park	1	Outside
32	Yonghe park	Amusement park	0.11	Outside
33	Fushan park	Citywide park	1	Inside
34	1st Shenglixi Road green space	Amusement park	0.95	Outside
35	2nd Shenglixi Road green space	Amusement park	0.89	Outside
36	Dongdachi park	Community park	0.07	Inside
37	3rd river-side green land on Huancheng East Road	Amusement park	0.43	Inside
38	4th river-side green land on Huancheng East Road	Amusement park	0.20	Inside
39	5th river-side green land on Huancheng East Road	Amusement park	0.19	Inside
40	Jishan park	Regional park	0.09	Inside
41	Heqing park	Amusement park	0.36	Outside

* The location column describes whether the park is inside the old city: outside: the park is located outside the old city; inside: located inside the old city.

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