Evaluating the accessibility of urban parks and waterfronts through online map service: A case study of Shaoxing, China

Abstract

Regular access to natural environment has many physical and mental health benefits for urban residents. This study was to evaluate the accessibility of urban parks and waterfront in a Chinese canal city at the household level. Shaoxing, a typical canal town in the Yangtze River Delta region of China, was selected as the case study because of its abundant but underused natural resources. The study had measured the shortest travel routes from individual households to parks and waterfronts using data from the online map service and intensive fieldwork. The results show that only 22% of Shaoxing residents live within a 500m walking distance to parks, but scenario analysis shows if the canals were well used, almost all the residents would have access to natural environment within 15 minutes' walk. Thus, the route-based accessibility evaluation method developed in this research offers a fine-grained understanding of household inequality in access to natural environments. It not only provides specific recommendations for planning intervention to improve the accessibility of natural resources in Shaoxing, but also contributes to the advancement of accessibility measures for planning practice. This route-based measure makes it possible to combine other accessibility measures of the travel routes such as sidewalk qualities in future research. The simplicity of this method means that it can be used to evaluate accessibility to other public facilities at the household level to develop walkable neighborhoods in cities.

Keywords:

urban park; waterfront space; walking route; catchment area; online map service; scenario analysis

1. Introduction

Providing inclusive and accessible green spaces is an integral part of 2030 Agenda of the United Nations. Many cities worldwide have put forward policies to promote walking to parks and other natural spaces to improve citizens' physical and mental health. Examples can be seen in Singapore and New York. Both aim to ensure their residents a ten-minute walk to parks by 2030 (Mahaseth, 2021; New York City, 2007). While the European Environment Agency suggested a fifteen minutes' walk to green spaces (Stanners and Bourdeau, 1995; Chen et al., 2020), the Scottish government supported the idea of "twenty-minute neighborhoods" where people could meet their daily needs within twenty minutes' walk (Scottish Government, 2020). In China, the State Council started a national campaign called "*City in the Park*" in 2018 to reinforce the importance of green infrastructure for peoples' wellbeing (Wang et al., 2019). In response to this campaign, for example, Shanghai has launched the "fifteen-minute community life circle" as part of the city's 2040 plan. This has been followed by other Chinese cities of various sizes and configurations.

In many cities which are undergoing rapid urbanization, urban parks usually give way to other land uses (Wolch et al., 2005; Tang and Wang, 2008; Lee and Hong, 2013; Rigolon and Németh, 2021). In some cities, even though green space quota seems to have been achieved, spatial inequity is still significant in residential areas. For a household or community, walking distance to these places depends on its specific location, nearby facilities, and street networks. Therefore, it is fundamental to identify the walking routes at the household level citywide to understand any relevant spatial patterns and inequality of accessibility, particularly for the venerable groups and groups with mobility issues.

Many existing studies and planning practice measured accessibility to natural environment in linear distance between locations, and ignored possible differences among different route choices, particularly with regards to gated communities. Here we used the Baidu Map, a widely-used online map service (OMS) in China, to obtain accurate walking routes from individual households to the parks and waterfront in a medium-sized city. Cities of this size and with abundant canals are under-represented in the literature hitherto. The walking routes recommended by Baidu Map are the shortest distance that residents must travel to access the natural environment, which are more precise than the conventional measure of linear distance. This online map service and relevant big data opens new opportunities for researchers who normally have little access to official land survey maps in China (e.g., the equivalence of the Ordinance Survey map in the UK), to carry out urban analysis as shown in this present study.

Shaoxing is a typical medium-sized water city in the Yangtze Delta region of China. The topography of Shaoxing features plain areas, canals and low hills. Some of the hills in the city are developed into parks since the 1990s, which together with the canals are the main natural resources in the city. These two types of natural environment add complexity for testing out the approach proposed in this research combing the new data from the online map service and field survey. This makes the city an appropriate case study. This research not only takes the locations of parks and canals into consideration, but also zooms in and identifies their exact entrances as parks are often gated and canals having many but specific access points, to inform specific strategies for design and planning intervention.

The following section of the paper reviews the literature on the benefits of urban natural environments, the concept of accessibility, catchment areas, and the emerging studies using online map services. This is followed by a methodology section explaining how we depict the catchment areas of parks and waterfront spaces in this research. The results section reports our analysis of the number of households in Shaoxing within 500m, 1000m, and 1500m walking distances to the parks and waterfronts and their choices of parks within these distances. Compared to the parks, waterfronts of the canals are currently underused due to barriers and years of neglect. To take advantage of these assets, evaluating the accessibility potential of canals is a necessary step to inform planning and retrofit design in the future. Therefore, the analysis about the canals is a scenario study. A discussion of the method, its contribution to knowledge, and recommendations for enhancing accessibility of urban natural spaces in Shaoxing are proposed in the final section.

2. Literature review

2.1 Benefits of walking to urban natural environments

Urban parks and other natural environments in cities have prominent social, ecological, economic, and health benefits for their residents (Bedimo-Rung et al., 2005; Loures et al., 2007). Studies have suggested that urban parks can strengthen social ties, relieve mental stress (Ulrich et al., 1991; Woo et al., 2009), save energy (Zhou and Rana, 2012), reduce surface runoff of rainwater (Sadeghian and Vardanyan, 2013), mitigate urban heat-island effects (Yan et al., 2018; Huang et al., 2021), and improve air quality (Paoletti et al., 2011). In addition, urban parks play a unique and indispensable role in providing opportunities for a wide range of leisure and educational activities, both as walkable destinations and as settings for walking (del Saz Salazar and Menendez, 2007; Sugiyama et al., 2013; Chan et al., 2018). The convenient access to parks has a positive effect on active behaviors like walking, which may alleviate the growing prevalence of obesity, diabetes, and other chronic diseases caused by sedentary lifestyles (Bedimo-Rung et al., 2005; Barton and Pretty, 2010; Miyake et al., 2010).

Exposure to rivers, canals, and coasts also has health benefits for the public (Gascon et al., 2017). Aquatic environments have often been associated with positive perceptions (White et al., 2010). Kaplan (1977, p. 285) remarked that “even unspectacular rivers provide a source of enjoyment and tranquility for many who use only the riverbanks, view the river from afar, or who only know that it is there and available.” Town planners have already recognized the restorative effects of waterfronts and water spaces (Völker and Kistemann, 2011). However, fewer studies have explored issues related to waterfront access compared to those on parks (Gascon et al., 2015). As a linear open space, waterfront potentially offers more access points for the residents. A well-designed and maintained waterfront also provides places for outdoor activities. Waterfronts can be developed in combination with urban parks to enhance the landscape and ecological benefits to the city and its residents.

Walking as an active and environmentally sustainable travel mode has been promoted in many countries to access urban parks and other facilities (Nicholls, 2001). Many researchers have found evidence that green spaces within walkable distance are correlated with physical and mental health, livability, commercial vibrancy and community cohesion (Sullivan et al., 2004; Ekkel and de Vries, 2017). These benefits can be maximized by built environments that facilitate walking (Zhai and Baran, 2017). McCormack and Shiell (2011) identified that connectivity, land use mix and population density were important factors affecting residents' level of physical activities. Neighborhoods with good street connectivity, few cul-de-sacs and small block sizes, tend to encourage social interaction and physical activities. These characteristics make the travel routes more diverse and generally shorter. Higher population density and diverse land uses are also likely to facilitate walking (Turrell et al., 2013).

2.2 Accessibility of the urban natural environment

The usage of urban natural environment by residents is largely determined by how accessible these places are (Nicholls, 2001). Measuring accessibility covers a wide range of aspects and can be categorized as either place-base or people-based (Siddiq and Taylor, 2021). The former considers spatial characteristics such as distance, road connectivity, traffic speed, population density, site legibility and physical barriers (e.g., busy roads, rivers), etc. (Wolch et al., 2014; Mecredy et al., 2011; Echeverria et al., 2014; Chan et al., 2018). The latter takes personal experiences and perceptions such as safety, comfort and aesthetics etc into consideration. In the last three decades, an increasing amount of available urban data has induced various place-based approaches of accessibility analysis. Such methods ranged from the gravity model, KD2SFCA (kernel density two-step floating catchment area), space syntax tools, ESRI walk-time, to Google walkshed, etc. (Hansen,1959; Era, 2012; Zheng et al.,2020). However, the complexity of these models often prevents them from being applied in practice and policy-making (Siddiq and Taylor, 2021). Some researchers call for simple accessibility measures for ease of interpretation (Bertolini et al., 2005) and participation of multiple stakeholders.

In this research, we focus on distance mainly, because it is arguably the most important factor among accessibility metrics of the natural environment (Giles-Corti et al., 2005; McCormack et al., 2010; Sugiyama et al., 2014). Distance beyond certain threshold affects residents' decisions of whether and how to travel to natural spaces (Giles-Corti et al., 2005). The threshold for walking is often around 400m or 500m for adult, which is about five minutes' walk. Some studies promote a ten-minute or fifteen-minute walk, about 800m to 1000m as acceptable walking distances to access facilities (Boone et al., 2009; Ekkel and de Vries, 2017; Rigolon, 2017). Park visiting frequency declines with increasing distances, the so-called "distance decay" effect, has been found in empirical studies across many countries (Coombes et al., 2010; Martínez and Viegas, 2013). Such thresholds and decay effect, are more sensitive in making walking decisions than with other travel modes, particularly among the disabled, the elderly and children who are frequent users of parks (Rossi et al., 2015; Guo et al., 2019). Therefore, it is necessary to include multi-thresholds of distance in accessibility evaluation in order to offer inclusive planning strategies for those social groups. The present research thus adopted 500m, 1000m and 1500m in the analysis.

The routine tool of “walkable sheds”, also called “ped-sheds”, is defined as circular buffers with the facility (e.g., park) in the center of the radius (Thadani et al., 2010; Sandalack et al., 2013; Scoppa et al., 2018). In China, this tool currently has been widely used in urban planning, and has serious pitfalls: the actual routes that residents need to travel to access facilities may be much longer than the straight-line radial distance; and the spatial qualities along the routes is not considered. These pitfalls are amplified by the very limited access points of gated communities which has been the most common model of residential development in China since the 1990s (Pow 2009; Xu and Yang, 2009). The gates, walls and fences of residential areas effectively prolong the travel distance for residents and create a very unfavorable environment for walking. This situation was exacerbated by additional restrictions during the COVID-19 pandemic. Moreover, many urban parks in China are also enclosed by fences or walls with limited entrances. The detour of travel distances can be represented by the pedestrian-directness ratio (PDR), which is the ratio of the actual walking length to the straight-line distance (Hess et al., 1999; Stangl, 2012). This ratio is used in this research to indicate the level of permeability of the urban environment.

2.3 Online map services for route estimation

Over the past decade, a large number of new data sources have been tested in urban research and planning including smart card data, GPS data from taxis, mobile phone data and volunteered geographic information etc. (Engin et al., 2020). Online Map Services (OMS) from Google, Waze, Baidu, Gaode and so on can provide reliable route estimation on cost, distance, duration, etc. of multiple travel modes. The recommended route and relevant estimation are generally precise and reliable, although common users may not necessarily follow the route recommendations due to personal preferences. Using the open-source OMS data, researchers with coding skills can generate multi-routes estimation without building the whole street network model which otherwise is time-consuming yet a compulsory step of data preparation for GIS analysis (Guan et al., 2020). The OMS data has facilitated accessibility study of various facilities at large scales, such as commercial centers and medical facilities (Hao et al., 2017; Rong et al., 2020). Those study is useful for planning practice to determine the optimal distribution of these facilities (Gu et al.,2010). In other research, for instance, Zhu et al. (2017) quantified fuel-saving opportunities by comparing the API-recommended routes to the actual routes used by travelers based on a large-scale real-world travel dataset; Liu et al. (2020) developed scenario analysis of school catchments to estimate possible reductions in vehicular travel distances in school commutes. Nevertheless, very few research focused on the spatial inequity of accessibility evaluation of natural environment, particularly in median and small sized cities and towns. The approach and knowledge derived from the studies of big cities (Zheng et al., 2020; Niu et al.,

2018) may not be transferable to other cities due to local differences in natural resources and contexts. For example, canals can both be an asset and barriers to access other facilities. Thus, this present research focused on Shaoxing, a medium city with a distinctive canal system. Yet the water towns are common in the Yangtze Delta Region.

3. Methodology

3.1 The study area

Shaoxing is located in the southeast of China, with a history of more than 2,500 years and a population of five million. There are 6,759 canals in Shaoxing, accounting for about 10% of the urban area. Most of them run north-south or east-west in a chessboard pattern (Peng 2019). The configuration of canals has made Shaoxing a well-known water town for hundreds of years (Figure 1). In 2019, the Shaoxing government issued regulations and policies to promote cycling and to prioritize walking within the historical Old City.

Figure 1. Waterfront spaces in Shaoxing (source: the authors).

The study area, covering 455.6 hectares, includes the Old City and the surrounding areas within the Second Ring Road (Figure 2). The First Ring Road is around the moat of the Old City which constitutes Fushan and Tashan sub-districts (*jie-dao*). There were originally nine hills in the Old City. Three of them have been preserved and developed into Jishan Park, Tashan Park, and Fushan Park in the 1990s. Outside the Old City, the urban area is divided by several canals and bounded by the Second Ring Road, consisting of freeways and elevated highways. We included all the public parks (free of charge) and waterfronts of canals in the study area to evaluate accessibility of the natural environment (Figure 2 and 3, Table 1).

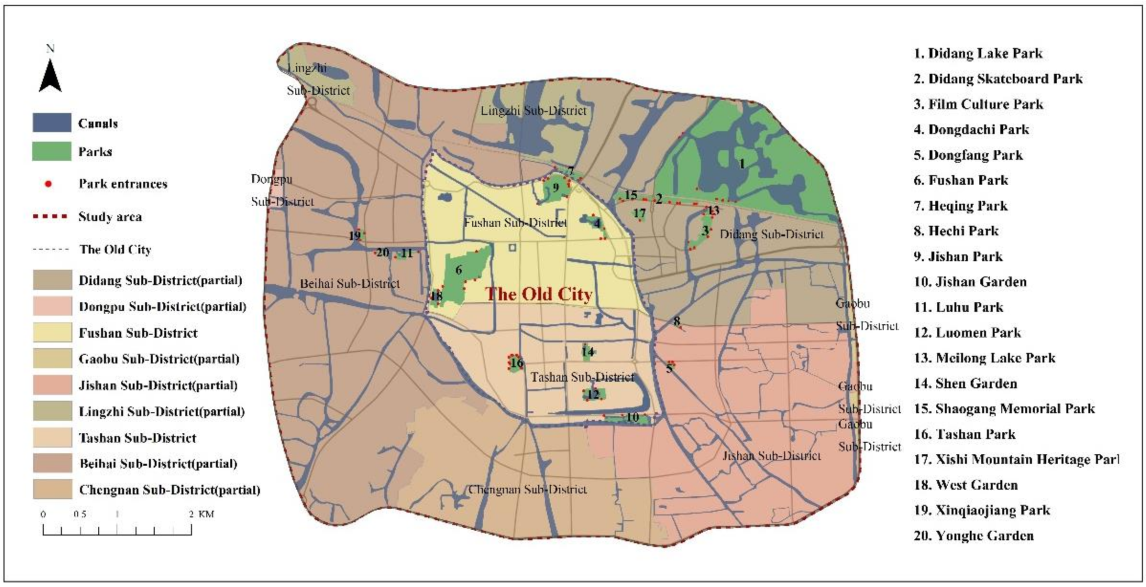

Figure 2. Study area and the locations of the twenty parks.

Table 1. Basic information about the parks.

	Park name	Numbers of entrances	Area (ha)	Perimeter (km)	Water within park	Connected with canals	Walled or Fenced
1	Didang Lake Park	10	252.44	6.96	Y	Y	N
2	Didang Skateboard Park	6	3.14	1.31	N	N	N
3	Film Calture Park	7	1.56	1.46	N	Y	N
4	Dongdachi Park	4	4.52	1.25	Y	N	Y
5	Dongfang Park	3	0.80	0.38	N	Y	N
6	Fushan Park	5	30.46	3.09	N	Y	N
7	Heqing Park	2	2.59	0.91	Y	Y	Y
8	Hechi Park	1	0.4	0.35	N	Y	N
9	Jishan Park	8	11.56	1.59	Y	Y	N
10	Jishan Garden	3	6.11	1.37	Y	Y	N
11	Luhu Park	2	2.00	0.84	Y	Y	Y
12	Luomen Park	4	4.89	0.92	Y	Y	Y
13	Meilong Lark Park	5	1.21	0.43	N	Y	N
14	Shen Garden	1	2.99	0.89	Y	Y	Y
15	Shaogang Memorial Park	5	3.74	1.23	N	Y	N
16	Tashan Park	9	3.65	0.77	N	N	Y
17	Xishi Mountain Heritage Park	1	2.09	0.61	N	N	Y
18	West Garden	3	2.62	0.71	Y	N	Y
19	Xinqiaojiang Park	3	1.03	0.43	N	Y	N
20	Yonghe Garden	1	0.60	0.44	N	Y	Y

3.2 Methods and metrics

Through Python3.7 coding, we scraped POIs (points of interest), AOIs (areas of interest) and the shortest routes via Baidu Map API, then cleaned the data for spatial analysis and visualization in ArcGIS 10.6. Baidu Map was the most widely used OMS in China compared to Google Map and Open Street Map, thus provided the most accurate data. The data processing and metrics are explained below (Table 2):

Table 2. Metrics relevant to service capacity.

Metric	Definition and Comment
Service POIs	Number of residential buildings that can be served by the park or its entrance within a walking distance.
Service AOIs	Number of communities that the park or its entrances can serve at a certain distance.
Service area	Total area of the communities in an urban park's pedestrian catchment area.
Service population	Number of people within the walking distance of the natural environment.
PDR	Ratio of the actual walking-route distance and the straight-line distance between two points, indicating the detour degree of the route (Stangl, 2012).

(1) Based on cross-validation of field investigation and satellite imagery, we input the coordination of the twenty urban parks' entrances (84 in total) in ArcGIS 10.6, and identified 1,612 waterfront access points. These access points were defined according to the intersections between canals and roads where the distance was less than 20m from the water (Figure 3).

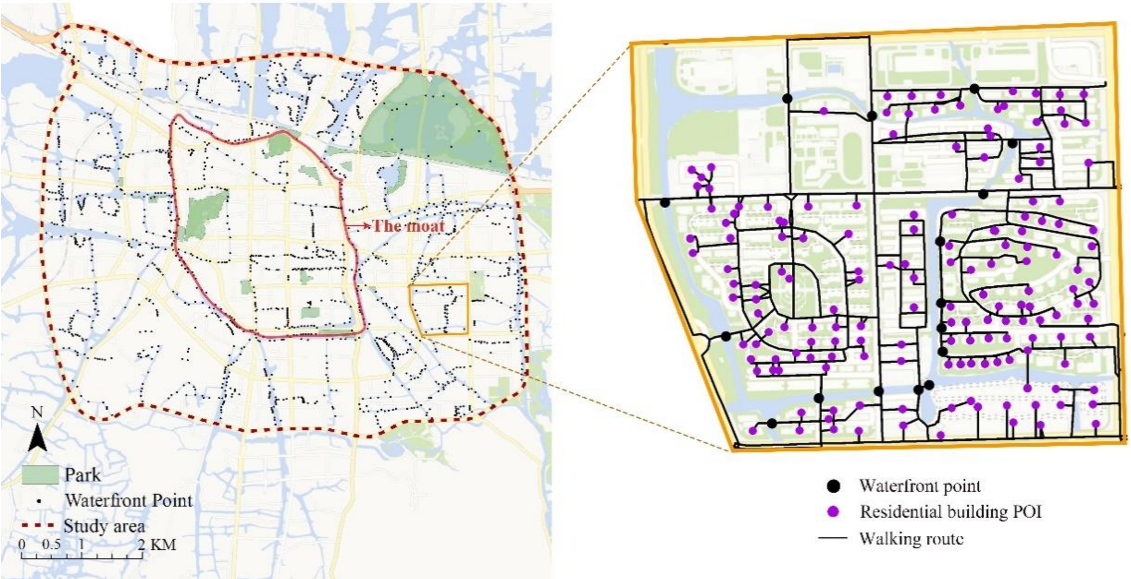

Figure 3. Water system and waterfront point distribution.

(2) Through Python coding, we extracted from Baidu Map API 4,938 residential buildings POIs and 580 communities AOIs in the study area, then scraped the shortest walking routes from each park entrance and waterfront access point to the residential buildings. Each route from the points of origination (residential POIs) to destinations (park entrance POIs) was generated with the Python codes and ArcGIS. We obtained data of straight-line distance, walking-route distance, coordination, turns, PDR (pedestrian-directness ratio) etc. for the analysis (Figure 4).

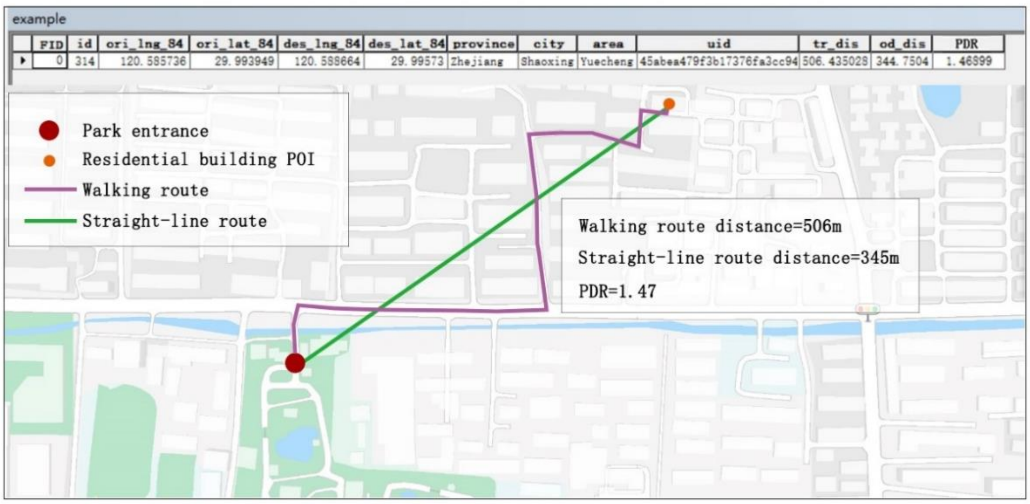

Figure 4. Example of a walking route and its PDR.

(3) To estimate the access capacity of parks and waterfronts, we measured the amount of residential buildings POIs and area of residential AOIs within the shortest route distance of 500m, 1000m and 1500m respectively. The total areas of residential AOIs, also at three thresholds, were taken as the catchments and capacity indication. Besides, we calculated the service population by multiplying population density with AOI area of communities within the catchments for calculating the number of potential users of the natural spaces.

4. Results

4.1 Catchment areas of the parks

Household access to parks

The results show that there are 843 (19.91% of the total), 2,195 (44.45%) and 3,227 (65.35%) residential building POIs within 500m, 1000m and 1500m walking distance of nearby urban parks respectively (Table 3). The underserved POIs are mostly located in the Jishan, Chengnan, Beihai sub-districts and the periphery areas of the Second Ring Road (Figure 5). These areas need financial and administrative support for park development and the detailed suggestion is explained in Section 5.

Table 3. Park service capacity, according to the route-based method.

Distance or Time	Service POIs	Service AOIs	Service area (ha)	Service population (× 10,000 people)
500 m	843	157	348.55	8.9
1000 m	2,195	327	776.47	19.07
1500 m	3,227	431	1050.99	26.48
15 min	2,369	344	806.86	20.05

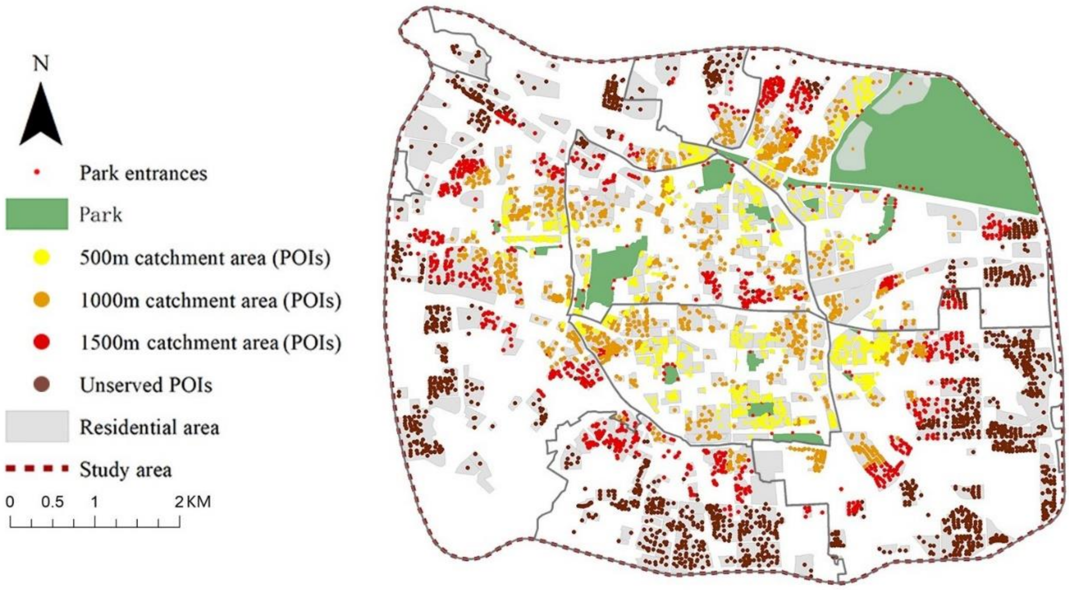

Figure 5. 500-m, 1000-m, and 1500-m park pedestrian catchment areas.

There is a clear disparity in access to parks between households within the Old City and those within the Second Ring Road, despite the fact that 8 parks are located in the Old City while 12 are located outside. Specifically, 38%, 88% and more than 99% of residential building POIs in the Old City are within 500m, 1000m and 1500m walking distances from parks respectively, compared to only 10%, 31% and 45% of those outside the Old City (Figure 5). Similarly, the residents of the Old City enjoy more options of parks than those residing outside (Figure 6). On average, each residential building POI within the Second Ring Road has access to 1.96 parks within the 1500m walking distance, whereas those in the Old City have access to 3.66 parks within the same distance. This favorable condition of the Old City is attributed to the comparatively even distribution of urban parks and their entrances.

It is worth noting that the households which have access to the most parks are mainlly near the First Ring Road rather than in the central area of the Old City, and they have access to at least four parks within 1500m. Households located in the northwest and west within proximity of the First Ring Road have access to up to 8 public parks, while households in the west and south parts of the city near the Second Ring Road have almost no access. This comparasion shows the most inequality among households in Shaoxing. The First Ring Road/moat area was developed about 20 years ago, when a series of riverside parks were built in the planning process at the time.

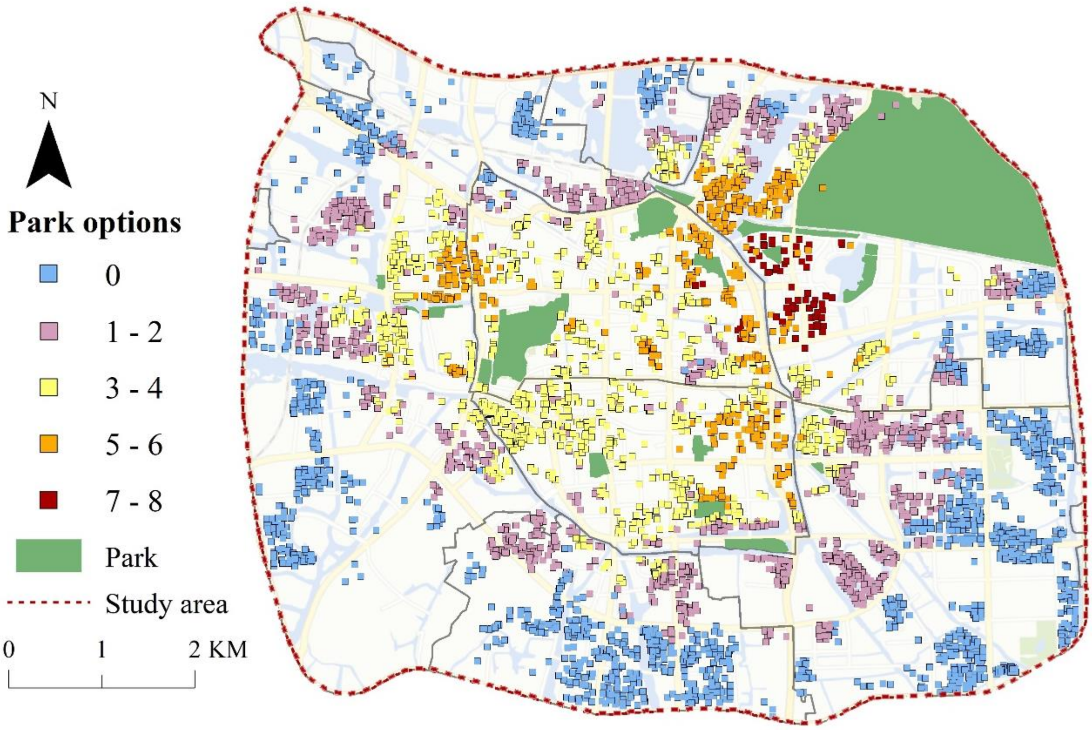

Figure 6. Park options for residents within 1500 m walking distance.

Park access capacity

Regarding access capacity of parks, the average service area is 169,210 m^2. There are 50, 200, and 468 average service POIs within 500m, 1000m and 1500m walking distance of parks, respectively. There were disparities in service POIs across the twenty parks (Figure 7), particularly for the routes within 1500m. The three parks with the most service POIs in this category were Fushan Park, Jishan Park and Tashan Park, which served 729, 778 and 717 POIs respectively. The reason is that more entrances and denser residential buildings are around the three parks in the Old City. In comparison, Film Culture Park, Didang Lake Park, and Meilong Lake Park had the fewest service POIs (232, 214 and 121, respectively). Didang Lake Park, although the largest, served fewer POIs, which can be attributed to the low population density nearby (1% of the total population).

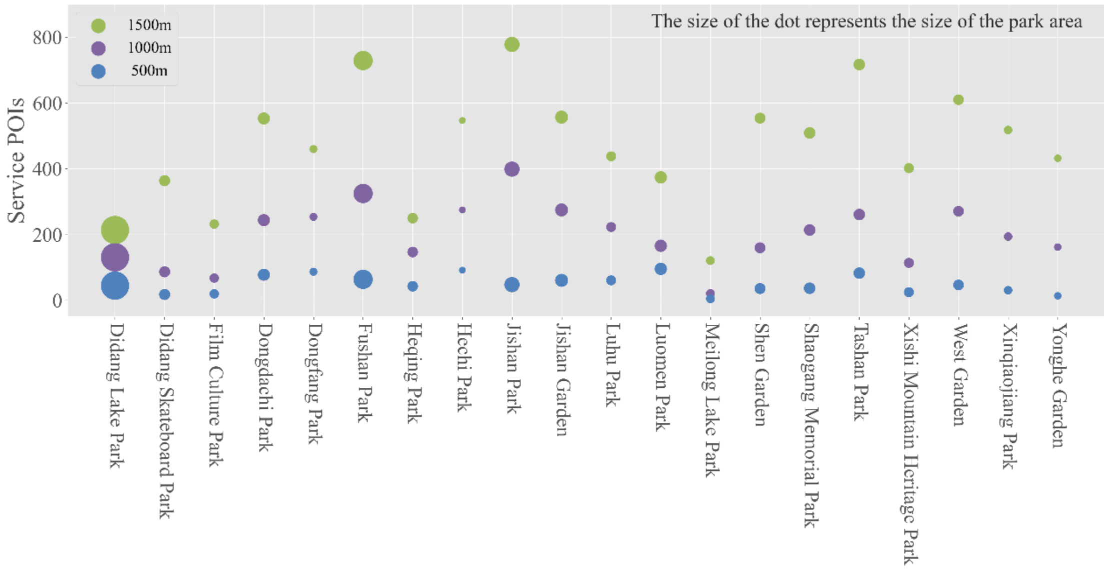

Figure 7. POIs served by 500-, 1000-, and 1500-m pedestrian catchment areas.

Route's PDR and park entrances

The average and median PDRs of walking routes from residential buildings to park entrances are 1.51 and 1.38, respectively. These are higher than the PDRs of the well-connected grid network in historical neighborhoods in European cities (about 1.3) and lower than those of typical suburban neighborhoods in the USA (about 1.6) (Hess et al., 1999; Scoppa et al., 2018). There were sixteen parks with the average and median PDRs below 1.6, which indicated comparatively permeable street networks nearby. The PDRs of Xinqiaojiang Park, Shaogang Memorial Park, and Yonghe Garden were above 1.8, and the highest PDR was Yonghe Garden, with an average PDR of 2.20 (Figure 8).

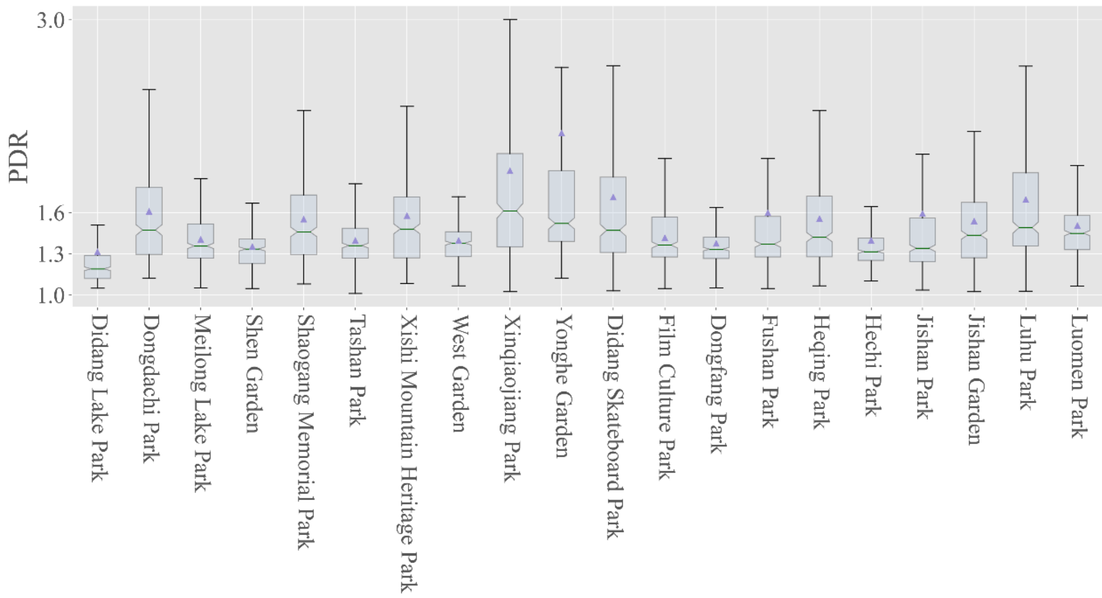

Figure 8. PDRs of the routes from home to park (within1500 m).

The number of park entrances and PDR showed a moderate correlation (Figure 9). The Pearson correlation coefficient of the number of entrances and the average PDR of each park was –0.339, and that of the median PDR was –0.436. This suggests that deploying more park entrances would improve residents' access to parks by making the travel routes more direct than it currently is, although the number of residential buildings and the length of the walking routes around the parks may vary considerably.

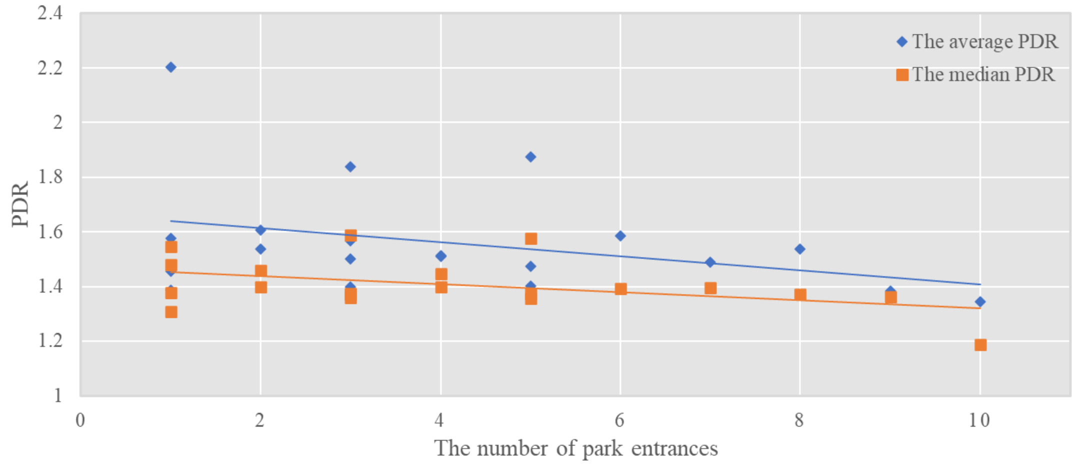

Figure 9. Relationship between number of park entrances and PDR.

4.2 Park case studies

In terms of route distances within 500m, the lowest access capacity was found in five parks, Yonghe Garden, Didang Skate Park, Xishi Mountain Park, Meilong Lake Park and Film Culture Park. A comparison between these five parks and Luomen Park, which has the highest access capacity, shows the importance of the configurations of parks' surrounding areas (Figure 10). This configuration can be measured by the service-POI ratio which refers to the percentage of service POIs measured by route-based distance to that of those measured by circular buffer (ped-shed). This index represents to what extent the ped-shed method, a routine measure in planning, underestimates the walking distances. Therefore, it can indicate service efficiency to a certain extent (Table 4). The service-POI ratio of Yonghe Garden was 8%, which can be attributed mainly to nearby superblocks consisting of gated communities with very limited number of entrances. The residents have to walk out from the community gates, which prolongs the travel distance, then walk toward the park along the urban streets. The service-POI ratios of Didang Skate Park and Xishi Mountain Park are around 20%. For the former, long routes are due to the superblocks and gated communities, similar to Yonghe Garden. For the latter, it is mainly because of the rivers which acted as a physical barrier to park access. Regarding Meilong Lake Park and Film Culture Park, the numbers of residential building POIs (xx) measured within the 500m route distance are limited. Luomen Park served the nearby residential units efficiently due to the even distribution of its entrances in relation to the surrounding residential areas.

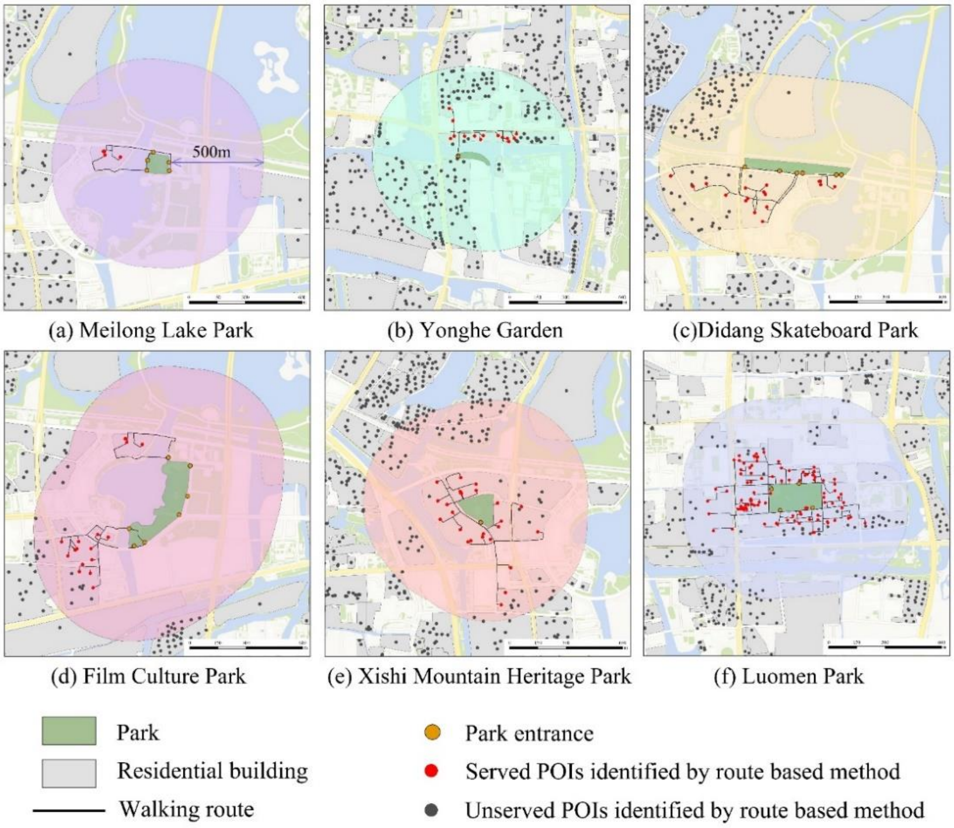

Figure 10. Pedestrian catchment area of the six parks within 500m.

Table 4. Service efficiency of six parks.

Name	Service POI (calculated by route-based method)	Service POI (calculated by circular buffer method)	Service POI ratio	Number of entrances	Average PDR
Meilong Lake Park	4	4	100%	5	1.59
Yonghe Park	14	172	8%	1	1.55
Didang Skateboard Park	18	90	20%	6	1.58
Film Culture Park	20	47	43%	7	1.49
Xishi Mountain Park	25	108	23%	1	1.72
Luomen Park	96	164	59%	4	1.56

4.3 Scenario analysis of the service potential of waterfront

Waterfront space near the canals is additional natural environment to the parks, particularly outside the Old City where parks are fewer. The 500m walking distance to waterfront covers 91% of residential building POIs, much more than those to the parks (17%). Furthermore, the research identified a disparity of waterfronts access capacity within and outside the Old city, being 95 % and 89 % respectively if measured within the 500m route distance. All the residential building POIs were within the 1000m walking distance from the waterfront. Comparing to the limited service catchment area of urban parks, the waterfront space showed considerable service potential. Such potential needs to be realized through appropriate design, planning and management of these spaces. Relevant recommendations are included in the next section.

Figure 11 shows the combined result of the 500m waterfront catchment area with the 500m, 1000m and 1500m park catchment areas. These two natural spaces together are able to serve 96% of the residential building POIs. Nevertheless, there are still areas far from either parks or waterfronts. In Chengnan and Jishan sub-districts, some residents don't have any access to either parks or canals, so priority should be given to new park provision in these areas.

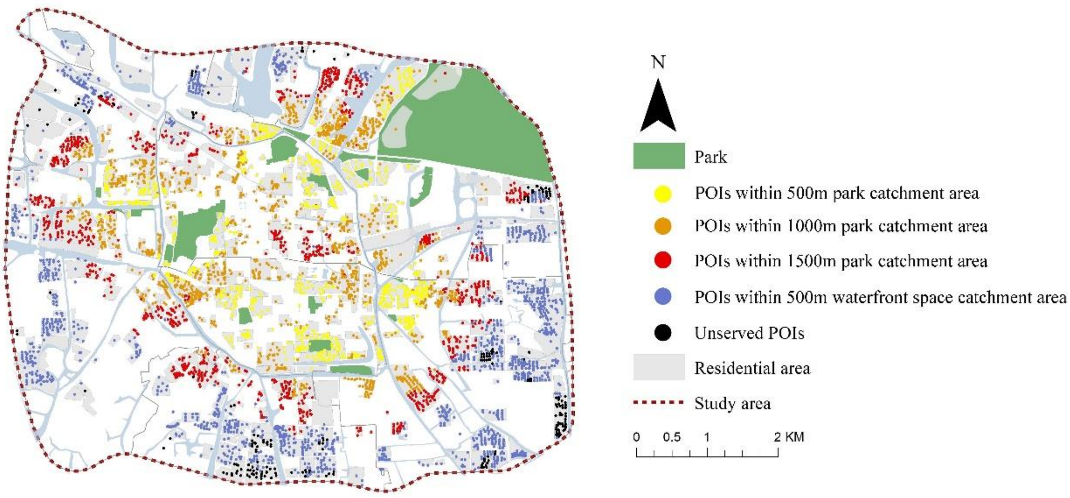

Figure 11. Potential of waterfront space: The overlap of the 500m waterfront space.

5.Discussion

This study uses data from the online map services to simulate as closely as possible the shortest walking routes that people take from their home to the nearby natural environment. The analysis reveals great inequality among households in urban park access, which can be attributed to the combined consequence of urban development patterns (e.g., gated community) and natural topography. It also unfolds the potential of remedying the inequity with appropriate planning, particularly with regard to waterfront development. This study suggests three ways to improve the accessibility of natural environment in Shaoxing:

The first strategy is to add new entrances to existing parks as indicated by the analysis. Many communities and parks are fenced or walled in Shaoxing (Figure 12), which creates a very unfavorable environment for walking and results in a lack of park access from the surrounding communities. Building new parks is effective but not always feasible due to the scarcity of land (Karmanov and Hamel, 2008; Rigolon, 2016), especially in compact urban areas (Rigolon and Flohr, 2014; Wolch et al., 2014; Chan et al., 2018). Nevertheless, new parks should be considered in the Chengnan and Jishan sub-districts as shown in the research. For other areas, a pragmatic measure is to add more park entrances along urban streets near residential areas and this will reduce walking distance and improve access capacity of the parks. For instance, if an entrance is added to the east side of Xishi Mountain Heritage Park (Figure 13), the number of service POIs can be increased from 402 to 453 (13%) at the 1500m level, 114 to 137 (20%) at the 1000m level, and 25 to 35 (40%) at the 500m level.

(a) Park fence and gate

(b) Community fence and gate

Figure 12. The fences of parks and communities in Shaoxing (source: author).

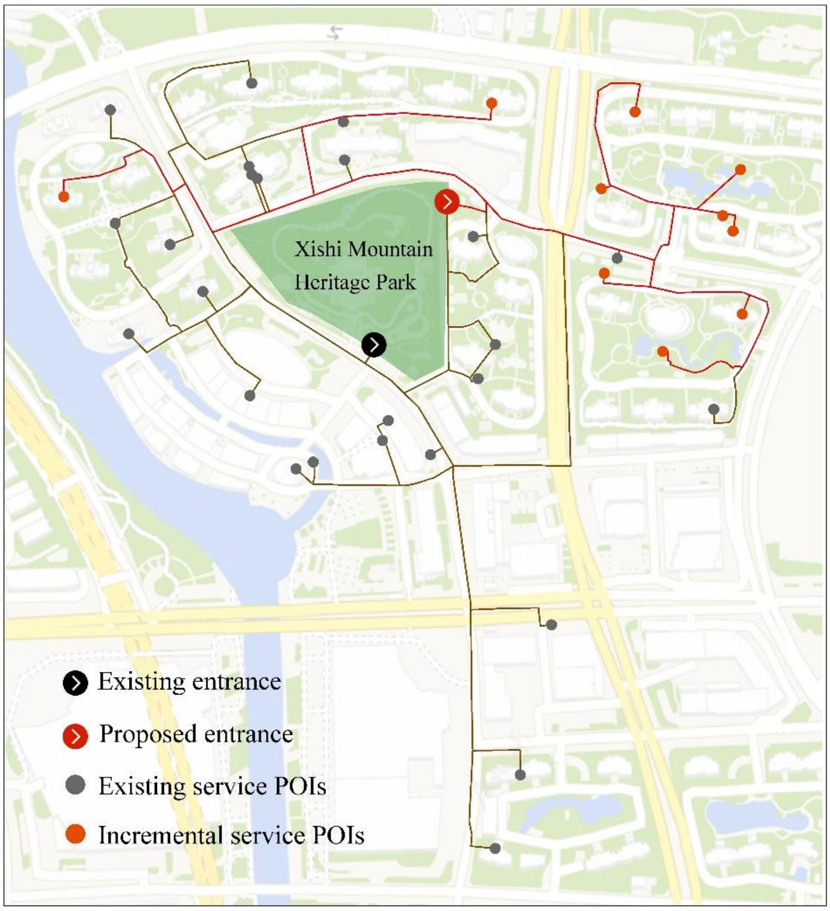

Figure 13. Scenario analysis of Xishi Mountain Park.

Second, opening up or increasing the number of entrances in gated communities could be another strategy. In February 2016, the State Council of China promoted the gradual open-up of residential communities (Central Committee of CCP, 2016). On the one hand, this policy promotes sustainability (e.g., cut off traffic carbon omission) and inclusiveness (e.g., more amenities enjoyed by wider public). On the other hand, it may against the residents' interests to completely open up the communities due to security concerns (Jiang and Qiu, 2020). Therefore, responsive design to achieve safe public spaces should focus on 'eyes on the streets' and 'neighborhood surveillance' (Jacobs, 1961; Han et al., 2021), which would provide conditions for opening up the communities. This urban form transformation can only be achieved through incremental and participatory approaches. Specific site analysis at the neighborhood level is essential which has been partially demonstrated in Section 4.2.

Finally, offering more waterfront access for the public is an effective way to reduce the inequality of natural space access. The canals need to be integrated into the city's ecological system in planning. Although not all waterfront spaces can be used as public spaces due to complex land ownership issues, a considerable percentage of them can be made available—for instance, segments adjacent to urban streets, or where the nearby land is owned by the state or the collective. Street furniture or facilities for walking may be provided to connect parks with canals to form a network of green-blue spaces.

Furthermore, it is also beneficial for residents' mental health to enhance the visibility of canals as suggested by Kaplan (1977) (Figure 14). In the Old City, most of the canals were separated from the urban streets by walls, fences, dense vegetation, and parked cars. These obstacles prevented the water from being seen or access from nearby streets and should be removed or managed where possible. Where barriers are removed, appropriate safety measures should be in place to prevent falls of visitors which can be achieved through vegetation or other bank treatments. Outside the Old City, many waterfront spaces are inaccessible for the pubic because they are occupied by gated factories, enterprises and residential communities. It may be possible to establish public-private partnership with these stakeholders to gradually open up the waterfront in urban regeneration, as increased accessibility to these locations can also bring economic benefits to the stakeholders.

Figure 14. The low quality of waterfront space in Shaoxing (Source: Baidu street view image, Nov 2019).

Apart from planning recommendations, the approach developed in this research makes contribution to the concept of accessibility measures on four aspects. First, it provides a fine-grained understanding of access inequality at the household level citywide which identifies intervention priorities among residential locations in the city, for example, some neighborhoods in Chengnan and Jishan districts in Shaoxing. Possible strategies for intervention can also be revealed as discussed above. Second, the walking route-based method using open source data is simple and straightforward which encourages wide adoptions by researchers and practitioners. Indeed, as mentioned before, literature argues for such operational accessibility measures as opposite to complex ones (Siddiq and Taylor, 2021). Third, this simple method can be easily multiplied with accessibility assessments on other public facilities such as healthcare facilities, schools and community centers etc. for a comprehensive accessibility evaluation within neighborhoods. This in turn helps to achieve the aforementioned policy goals of building walkable neighborhoods overall in China and beyond. This research already demonstrates a combination of accessibility evaluations on parks and waterfront spaces. Finally, the route-based method opens opportunities to attach other routes related spatial qualities in the evaluation, such as street walkability, and people-based accessibility measures with specific social groups which demands for further qualitative analysis. Those most disadvantaged neighborhoods as identified in this research could be studied combing some qualitative methods such as residents' travel diaries, interviews and site survey.

6. Conclusion

The walking distance along specific routes from households to nearby parks and waterfront is a basic measure to evaluate the service of natural environment in cities. Acquiring the routes from home to parks and waterfront at the household level citywide would be impossible for researchers if this OMS data was not available. In this paper, we presented a pragmatic approach to delineate walking catchment based on the shortest routes to evaluate the accessibility of natural spaces. It also identified possible locations for intervention with suggested planning strategies to tackle the inequality of natural environment access, such as adding park entrances, opening gated communities to shorten walking routes, and appropriating waterfronts for the public. The service potential of a combination of waterfront and park spaces is promising and deserving planning attentions.

There are several limitations to this study. First, we did not consider pocket green spaces and greenspaces within the gated communities which are exclusive for the residents who live there. Examining their role and potential would provide a full picture of natural space accessibility. Nevertheless, we reckon that the large public parks should serve all residents equally as they provide significant physical and metal benefits for residents. Moreover, a detailed survey of available waterfront space would be useful to understand their land ownership, scenery quality and regeneration plans, etc., to inform design and planning decisions for specific sites. Third, we assumed that the residents preferred the shortest route to access natural environment, but the actual visiting routes may be different depending on other factors such as the spatial quality of the routes and personal preference. Fourth, socio-demographic characteristics of the communities were not considered as we have no access to these data. This limited our understanding on spatial inequity and injustice in relation to specific social groups. These limitations can be addressed in future research.

Nevertheless, we demonstrated in this case study how the OMS urban data combing with fieldwork can evaluate the accessibility of urban natural environment efficiently for diagnosis and prescription of urban problems. The research method is relevant for planning research and practice beyond Shaoxing in other water towns and cities.

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