MODELLING SUPPLY–DEMAND RELATIONSHIPS OF PARK GREEN SPACE RECREATION SERVICE FROM THE PERSPECTIVE OF CITY DWELLERS

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Abstract. Modelling the relationship between supply and demand of recreational services for promoting the fair and reasonable layout of urban park green space is very important. Current research studies mainly take the aggregation area as the basic unit, which inevitably leads to the Modifiable Areal Unit Problem (MAUP). Also, more emphasis is placed on the demand side, ignoring the supply pressure of the supply side. To address this issue, we propose a research framework taking the basic supply area and demand area of recreation services as the research units, to measure the supply–demand relationship from the supply side and the demand side, respectively. The application of the framework in Xuchang city of China shows that, it is in line with the characteristics of residents' recreational activities and can avoid the MAUP in the study of the ecosystem service supply–demand relationship. In addition, the framework can effectively identify the park green spaces with excessive supply pressure or low utilization potential and the residential quarters with low accessibility, to provide a practical and effective decision-making basis for coordinating the supply–demand relationship. Our research provides a useful tool for the study of the supply–demand relationship of urban cultural services.
Keywords: *recreation service, ecosystem services, accessibility model, pressure model, congestion risk model*

Introduction

With the acceleration of global population growth and urbanization, the urban population worldwide is growing rapidly, from 751 million in 1950 to 4.2 billion in 2018. By 2050, the global urban population is estimated to increase by another 2.5 billion, representing 68% of the population (UN, 2018). Park green space is an important ecological factor in the urban built environment: it not only provides an ideal place for urban residents to relax, communicate, and socialize (Hunter et al., 2019) but also regulates urban microclimate, controls pollution, and reduces noise, providing a variety of health benefits for urban residents (Su et al., 2011). Therefore, we recognize the considerable importance of evaluating the ecosystem services' supply capacity of urban park green space and residents' demand for them, analyzing the supply–demand relationship, and identifying the areas of imbalance between supply and demand to promote the fair and reasonable layout of urban park green space and improve the overall well-being of urban residents.

Recreation service refers to the recreation pleasure obtained from natural or artificial ecosystems (TEEB, 2010). According to the spatial characteristics of ecosystem services (Costanza, 2008; Haines Young and Potschin, 2010), recreational service belongs to user movement-related service, that is, its service supply area and service benefit area overlap. Then, people need to go to the supply area (urban parks green spaces) for experiential interaction to truly benefit from the service. At present, three main methods are used to

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analyze the spatialization and coordination of the supply and demand of recreation services, as follows. (1) In land cover matrix (Burkhard et al., 2012), according to experts' experience, each land cover type can provide various ecosystem services (0–5) to form an evaluation matrix. The relationship matrix between ecosystem service demand and land cover type is constructed by the same method; then, the difference between supply and demand (−5–5). A negative value means that the service supply exceeds the demand, 0 means that the supply and demand are balanced, and a positive value means that the supply exceeds the demand. This method only needs the land cover data of the study area, and so it is simple and easy to implement. It is widely used in the analysis of supply–demand relationship of recreational services (e.g., Burkhard et al., 2014; Baiyang et al., 2017; Tao et al., 2018; Wu et al., 2019). (2) Taking the park green space area as the potential of service supply, the total service demand is determined according to the per capita green space area guidance standard of the government (e.g., the Shanghai Municipal Government's guidance on green space provision is 13.5×10^{-4} ha/person (Chen et al., 2019)) and the total population of the region. The net recreation service can be obtained by subtracting the supply and demand, and the recreation service coverage can be obtained by dividing the two (e.g., Larondelle and Lauf, 2016; Chen et al., 2019). (3) The supply potential of recreational services is obtained by comprehensive evaluation method based on various regional factors (such as natural degree, natural protection status, and whether a water source is present) (e.g., Baró et al., 2016; Schirpke et al., 2018, 2019), while the demand for services is crosstabulated by population density and distance classification (Baró et al., 2016) or by the number of beneficiaries (number of residents + number of overnight tourists) (Schirpke et al., 2018, 2019). The unit dimensions of the supply and demand indexes are different, so directly comparing service supply and demand is impossible.

Because the supply and demand areas of recreational services are spatially separated, the current method of spatialization and coordination analysis is to first divide the research into several research units (administrative division unit or grid) and then calculate the total supply and demand of each unit, which is the so-called container method. Container method assumes that the residents in the basic unit only choose the park green space in the unit for recreation activities, ignoring the relationship between the research units, inconsistent with the actual situation, and the size and shape of the basic research unit will also affect the final analysis results, resulting in the Modifiable Areal Unit Problem (MAUP) (Openshaw, 1983). In addition, the expert scoring method only semi-quantifies the supply and demand of services according to the types of land use (methods 1 and 3). The corresponding research results are mainly used to explore the spatial distribution characteristics of services and the differences between regions, lacking operability in guiding the practice of landscape and urban planning. There is currently a consensus that ecosystem functions become ecosystem services only when someone benefits from them (Haines-Young and Potschin, 2010; TEEB, 2010; De Groot et al., 2010; Lamarque et al., 2011). For user movement-related recreation service, the ease of accessing park green spaces from people's residential area is one of the most important factors affecting the use of park green spaces (Schetke et al., 2016; Zhang and Tan, 2019; Tardieu and Tuffery, 2019; Mears et al., 2019). Therefore, accessibility analysis provides a powerful tool for illustrating the utilization of such services (Ala-Hulkko et al., 2016). Accessibility is defined as the ease of accessing a location from another location (Rodrigue et al., 2006). In terms of methodology, the methods measuring accessibility mainly include travel cost method (e.g., Ala-Hulkko et al., 2016; Wüstemann

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et al., 2017), gravity model method (e.g., Lee and Hong, 2013; Xiao et al., 2017) and the cumulative opportunities method (Radke and Mu, 2000). Compared to the first two methods, the cumulative opportunities method, represented by the two-step floating catchment area method, not only considers the travel cost between the residential area and the park green space, the number or scale of the park green space, but also further utilizes the population information of the residence when calculating accessibility (Xu and Wang, 2023). In recent years, the two-step floating catchment area method (Radke and Mu, 2000) have been increasingly widely used in the accessibility analysis of park green space (e.g., Wei et al., 2014; Shen et al., 2017; Wei, 2017; Li et al., 2019; Liu et al., 2022). This method calculates the accessibility of each residence to the park green space and provides a good solution for evaluating the potential satisfaction of demand and the spatial connection between the supply and demand sides. However, the disadvantage is that it does not consider the supply pressure of the supply side and ignores the negative experience caused by possible access congestion.

In this paper, the basic supply area (park green space) and demand area (residential quarter) of recreation services are taken as the research units, and the supply side pressure model corresponding to the demand side accessibility model is constructed consistently in theory and quantity to identify the park green space with potential low utilization rate and excessive pressure. The possible congestion risk of park green space is evaluated by the congestion risk model. The purposes of this paper are to (1) systematically evaluate the supply and demand relationship of park green space recreation services in a way more in line with the characteristics of residents' leisure activities; (2) to eliminate the MAUP in the study of the supply–demand relationship of recreation services; and (3) guide the practice of landscape and urban planning.

Materials and Methods

Experimental area

The city centre of Xuchang is located in the hinterland of the Central Plains (area comprising the middle and lower reaches of the Huanghe River) (*Fig. 1*). It is the political, economic, cultural and transportation center of, and the main component of the built-up area of Xuchang City, Henan Province, China. It belongs to the warm temperate monsoon zone with four distinct seasons. The city centre of Xuchang has 16 subdistricts with a total area of about 97 km^2, the perma-nent population is 599,000, with an urbanization rate of 95.33%, and per capita GDP of CNY 74,886 (Chen and Cui, 2022).

Xuchang has a beautiful ecological environment with lush green trees, gurgling water, and exquisite scenery. In 2017, It was selected as the second batch of national ecological garden cities in China. Up to now, the green coverage rate of Xuchang's built-up area is 41.74%, and the per capita park green area is 16.07 m^2 (Xuchang Municipal People's Government, 2022).

Research framework

We propose a research framework to measure the supply–demand relationship of recreation services from the supply side and the demand side, respectively, as shown in *Figure 2*. Taking the basic service supply area and demand area as the research units, according to the location of the entrance and exit, area, population, and other data of the supply area and demand area, the demand satisfaction and supply pressure of recreation

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service are calculated based on the accessibility model and the pressure model, respectively. On the basis of the supply pressure and demand satisfaction of both sides of recreation service supply and demand, this paper analyzes the spatial coordination and identifies the park green space with excessive supply pressure or low utilization rate and the residential area with low demand satisfaction (accessibility). At the same time, combined with the travel rate of residents and tourist carrying capacity, the congestion risk of park green space is evaluated, providing a decision-making basis for landscape and urban planning practice.

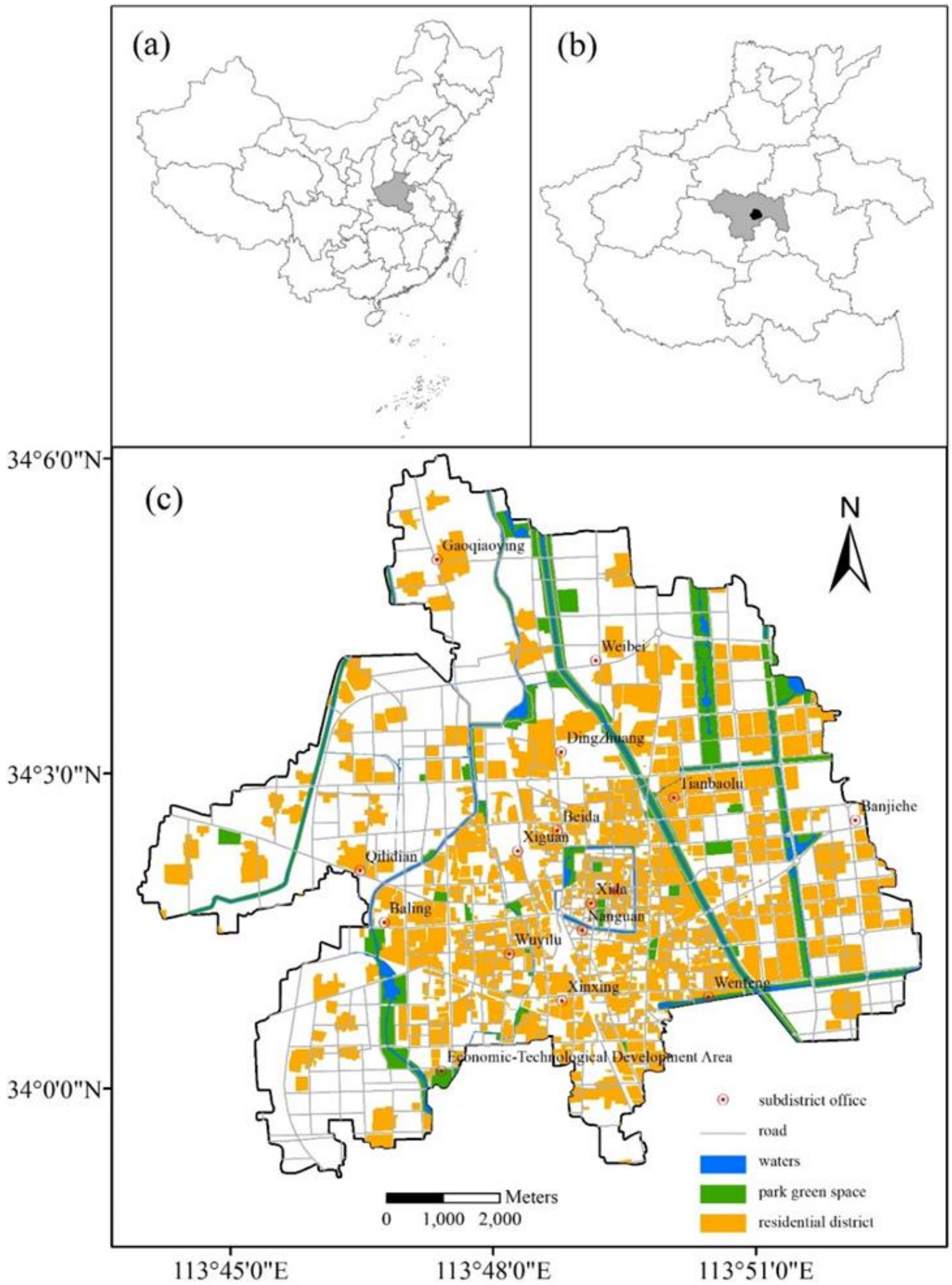

Figure 1. *Location of study area. (a) Location of Henan Province in China; (b) Location of the study area in Henan Province; and (c) The distribution of park green space, residential quarters, and roads in city centre of Xuchang*

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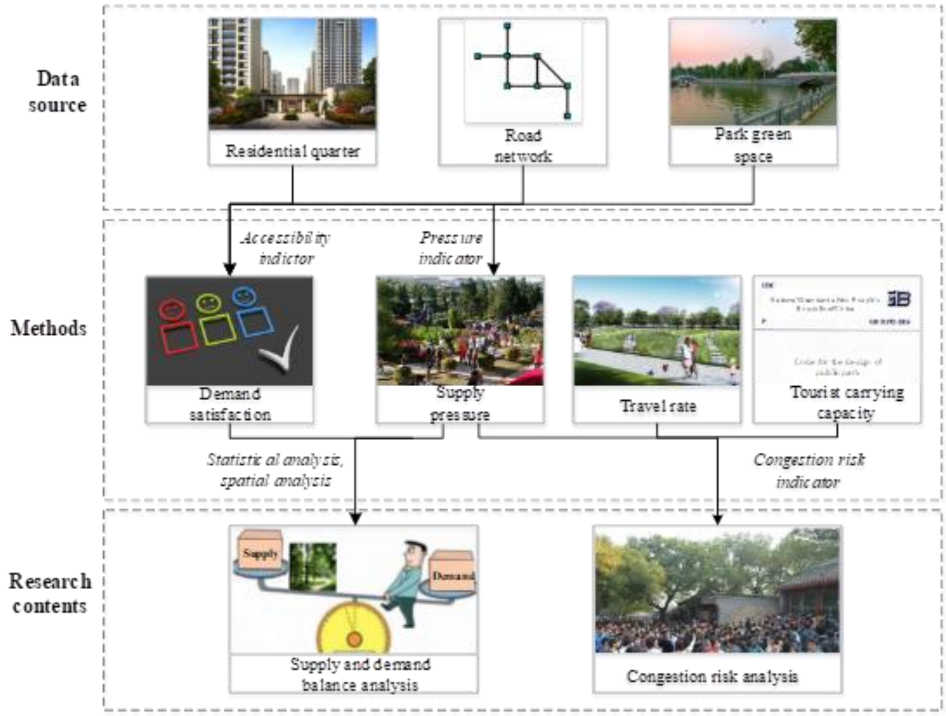

Figure 2. *Research framework*

Accessibility model

The accessibility model calculated by the Gaussian-based two-step floating catchment area method (Dai, 2011) is used to analyze the demand satisfaction of residents enjoying recreation service. Compared with the two-step floating catchment area defining the accessibility using a dichotomous measure, Gaussian-based two-step floating catchment area continuously accounts for the distance decay of accessibility within a catchment (Dai, 2010). The detailed calculation process has been explained in the research of Xu and Wang (2023). The diagram of the Gaussian-based two-step floating catchment area method is shown in *Figure 3*. We use the gate (or entrance) position of residential quarter and park green space as the origination (O) and destination (D) points. If there is more than one gate (or entrance) for them, the minimum value of all OD distance is taken.

Pressure model

The pressure model is proposed to analyze the access pressure from residents in surrounding residential quarters on the service supply side. It is also based on the spatial location, scale, and road network of park green space and residential quarters. The model adopts the process opposite to the accessibility model.

Firstly, for each residential quarter i of the demand side of recreational service, the path distance threshold d_0 is given to form the space reach range. For the area of each park green space k falling within the space reach range (i.e., $d_{ki} \leq d_0$), the Gaussian equation is used to assign corresponding weight according to the distance from the residential quarter, then the weighted sum is carried out to obtain the potential usable park green space of residential quarter i. The total population of residential quarters is divided by the area of potentially available park green space to obtain the demand–supply ratio D_i (person / m^2).

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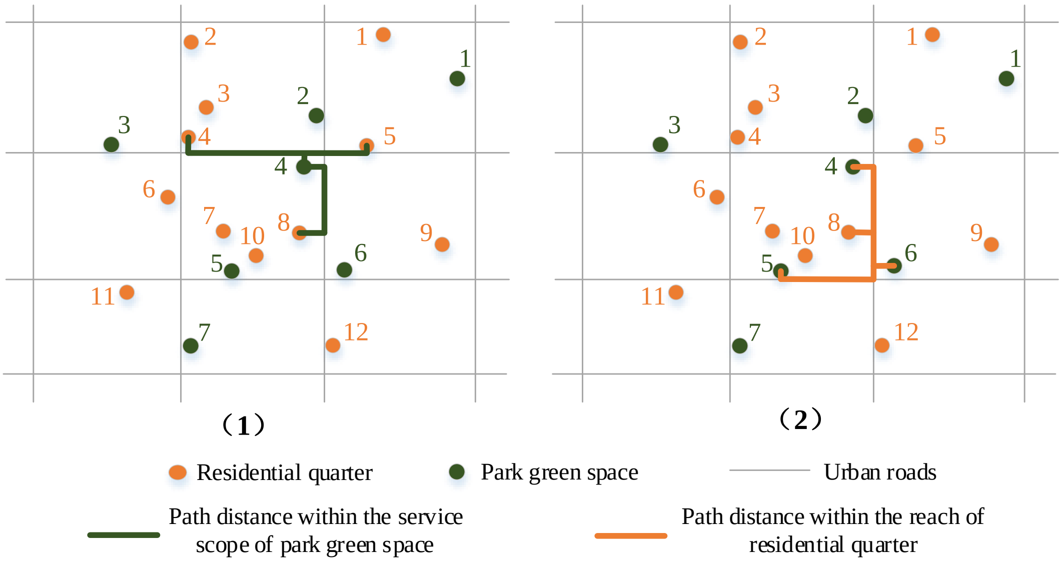

Figure 3. *Schematic diagram of Gaussian-based two-step floating catchment area method. (1) Three residential quarters 4, 5, and 8 are within the service scope of park green space 4; (2) three parks 4, 5, and 6 are within the reach of residential quarter 8*

$$D_i = \frac{P_i}{\sum_{k \in \{d_{ki} \le d_0\}} G(d_{ki}, d_0) S_k} \quad \text{(Eq.1)}$$

where S_k is the area of park green space *K* within the spatial accessibility of residential quarter *i* ($d_{ki} \le d_0$), d_{ki} is the path distance from the entrance of park green space *k* to the gate of residential quarter *i*, P_i is the total population of residential quarter *i*, and $G(d_{ki}, d_0)$ is a Gaussian equation considering the problem of space friction. The calculation method is shown in *Equation 2*.

$$G(d_{ki}, d_0) = \begin{cases} \dfrac{e^{-\left(\frac{1}{2}\right)\times\left(\frac{d_{kj}}{d_0}\right)^2} - e^{\left(-\frac{1}{2}\right)}}{1 - e^{-\left(\frac{1}{2}\right)}}, & if \quad d_{ki} \le d_0 \\ 0, & if \quad d_{ki} > d_0 \end{cases} \quad \text{(Eq.2)}$$

Secondly, for each park green space *j* at the service supply end, the path distance threshold d_0 is given to form its spatial service range. Similarly, demand–supply ratio (D_l) of each residential quarter *l* within the spatial service range is weighted by a Gaussian equation. Then, the weighted sum of these demand–supply ratios is used to obtain the service supply pressure T_i of each park green space *i*. The size of T_i indicates the population per unit area served by each park green space within its space service scope, that is, the potential utilization, and the unit is person / m^2.

$$T_i = \sum_{l \in \{d_{jl} \le d_0\}} G(d_{jl}, d_0) D_l \quad \text{(Eq.3)}$$

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where l refers to all residential quarters within the service scope of park green space j ($d_{jl} \leq d_0$).

Congestion risk model

When the number of visitors in the park green space exceeds its designed capacity, congestion occurs. According to the service pressure of park green space, the per capita occupied area index of park visitors, the travel rate of residents, and the congestion risk of different park green spaces can be evaluated. The calculation method of the congestion risk coefficient of park green space is as follows:

$$R_i = \frac{S_i}{T_i \times TR} \quad \text{(Eq.4)}$$

where R_i is the congestion risk coefficient of park green space i, S_i is the tourist capacity of visitors per unit area (person / m^2), T_i refers to the service supply pressure of park green space i (person / m^2), and TR is the travel rate of residents, which is the proportion of people visiting park green spaces to the total number of people.

Given that the park green spaces in the experimental area are built mostly according to the water system, the unit area tourist capacity of the park green space is calculated according to the composition of its land area and water area. As regards the tourist capacity of different types of parks, according to the national standard < Code for the design of public park> (GB51192-2016) issued by the Ministry of Housing and Urban–Rural Construction of the People's Republic of China, the park's land area per capita is 30 m^2, approximately 96 m^2/household (the average household population in the study area is 3.2), and the water area per capita is 200 m^2, approximately 640 m^2/household in the research area. Then, the population capacity per unit area of each park green space is calculated (Si=(L_i/96+W_i/640)/(L_i+W_i), where L_i is the land area of the park and W_i is the water area of the park). The travel rate (TR) of residents is based on the statistics of Fang et al. (2017) with the help of mobile phone signaling data on the travel rate of parks and green spaces in Shanghai (the average is 4.87%), taking 5%.

Data sources

The spatial distribution of residential quarters, park green spaces, and urban road networks were obtained from QuickBird images of the study area in 2014, and an unmanned aerial vehicle was used to update the data of the urban fringe to the end of 2020. The number of residential buildings is obtained from the real estate service platform HomeLink (https://xc.lianjia. com/), the planning permission document of the Xuchang Natural Resources and Planning Bureau (http://zrzyhghj.xuchang.gov.cn/), and field surveys. For more detailed data acquisition information, see Xu and Wang's (2023) research. Choosing an appropriate path distance threshold (d_0) is important because it determines whether a park green space is accessible (Dai, 2011). As summarized by Xu and Wang (2023), the selection of distance thresholds is diversified. Given that as a small city, most citizens in the research area visit park green spaces on foot, with a distance of 1000 m (approximately 10 minutes of walking) being acceptable (You, 2016; Tu et al., 2020). The 500 m (approximately 5 minutes of walking) was also chosen to examine the variation in accessibility and pressure resulted from different thresholds. Accessibility

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analysis and pressure analysis are based on 5- and 10-minute walking distances (i.e., 500 and 1000 m, respectively), and are implemented by ArcGIS10.7 and MATLAB R2015a software.

Results

Supply and demand relationship of urban park green space recreation service

The relationship between supply and demand of urban park green space recreation services within 5-and 10-minute walking ranges is shown in *Figure 4*. Overall, the accessibility of park green space for residential quarters in the south-central and southwest parts of the study area is relatively low, whereas the accessibility for the residential quarters distributed along both sides of the park in the east, north, and west is relatively high. As regards the 5-minute service range, 460 residential quarters have 0 accessibility, and the total number of households accounts for 34.99% of the entire study area. These residents have no park green space to visit within a 5-minute walk, and their demand for recreation services cannot be met. The residential quarters with low accessibility (≤ 5 m^2 / household) are mainly distributed in the streets of Xinxing, Nanguan, and Wuyi in the central and southern parts of the study area. The residential quarters with better accessibility are mainly distributed in the streets of Tianbao, Banjiehe, Wenfeng, and Dingzhuang in the east and north of the research area. Compared with the 5-minute service range, the accessibility within the 10-minute service range has been significantly improved: the number of residential quarters with 0 accessibility has decreased to 110, and the total number of households accounts for 9.65% of the entire study area. The number of low accessibility (≤ 5 m^2 / household) residential quarters has also greatly decreased.

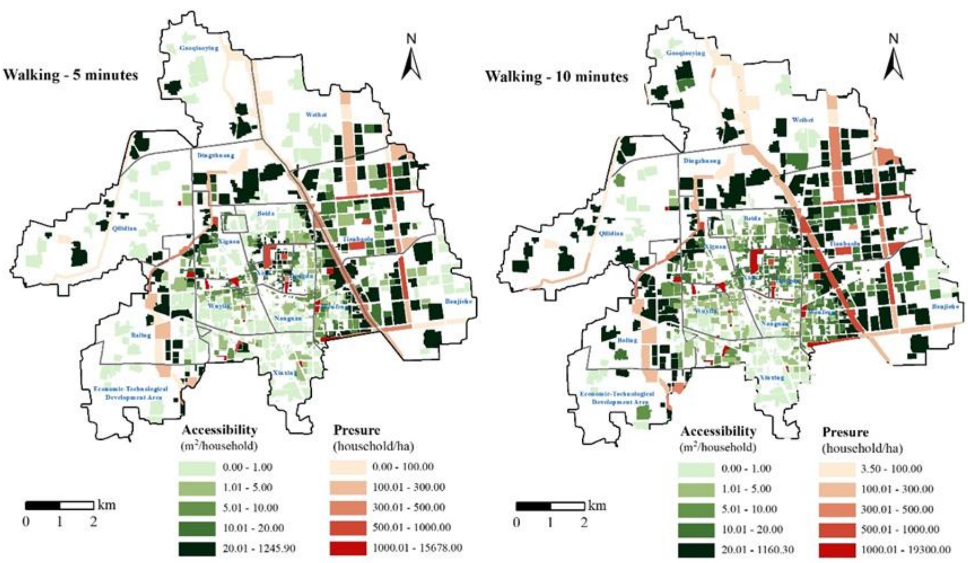

Figure 4. *Relationship between supply and demand of recreation service in park green space*

Overall, the visiting pressure of the park green space is opposite to the accessibility of the residential quarter, that is, the pressure of park green space around the residential quarters with higher accessibility is low, whereas the pressure of park green space around

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the residential quarters with lower accessibility is high. In terms of spatial distribution, the parks with a visiting pressure of more than 1000 households/ha within the 5-minute service range are mainly distributed in the central and southern parts of the study area, where it is dominated by small parks with a concentrated population distribution. The recreational services provided by these parks are in short supply. The parks with low visiting pressure are mainly distributed in the northeast, west, and southwest of the study area, where the parks are large in area and number, and the population is relatively small. The recreational services provided by the park green space in these areas are in the state of oversupply, and the potential utilization rate is low. With the increase in service range, more residential quarters have corresponding parks to serve them, and the accessibility of park green space in residential quarters increases, so the visiting pressure of park green space increases correspondingly. Therefore, the visiting pressure of park green space within the 10-minute service range increases significantly, and the spatial distribution trend is similar to that of the 5-minute service range.

Analysis of supply–demand relationship of urban park green space recreation service under different service ranges

The accessibility and pressure changes of park green space under different service ranges is shown in *Figure 5*. Overall, with the increase in service range, some residents who had no access to park green space under the original short service range could have access to park green space, so the accessibility of residents' park green space increased (changes in accessibility > 0), and the pressure of park green space increased accordingly (changes in pressure > 0). At the same time, it is accompanied by the decrease of accessibility (changes in accessibility < 0) and the decrease of pressure (changes in pressure < 0). The main reason for the decrease of the accessibility of park green space in this part of residential quarters with the increase of service range is that more residents participate in sharing the same park green space, but no new park green space is available to visit, or the new park green space is small. The main reason that the visiting pressure of park green space decreases with the expansion of service range is that with the expansion of service range, the residents they serve have new park green space to visit, and few or no new residents are included in their service range. In addition, the accessibility of some residential quarters remains unchanged because they have no park green space to visit under the two service ranges, and their accessibility is always 0.

Congestion risk assessment of urban park green space under different service ranges

The congestion risk coefficient of park green space in different service ranges is shown in *Figure 6*. Overall, with the increase of service range, the congestion risk of park green space also increases. The park green spaces with high congestion risk in the study area are concentrated in the south-central regions: the park green spaces with congestion coefficients greater than 1 often have congestion in the case of daily travel rate, and even more serious in the case of high travel rate during holidays. The park green space with congestion coefficients between 0.76 and 1 will not be congested under the condition of normal travel rate, but it is easy to be congested under the condition of a sudden increase of holiday travel rate. In other areas, the congestion coefficients of park green spaces are less than 0.75, and the risk of congestion is small. However, the potential utilization rate of park green spaces with congestion coefficients less than 0.25 is l.

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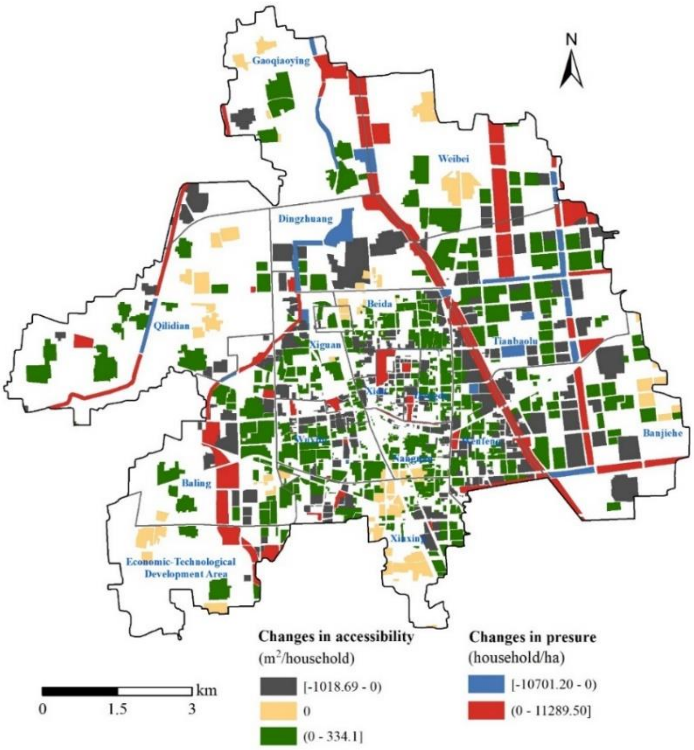

Figure 5. *Accessibility and pressure changes of park green space under different service ranges*

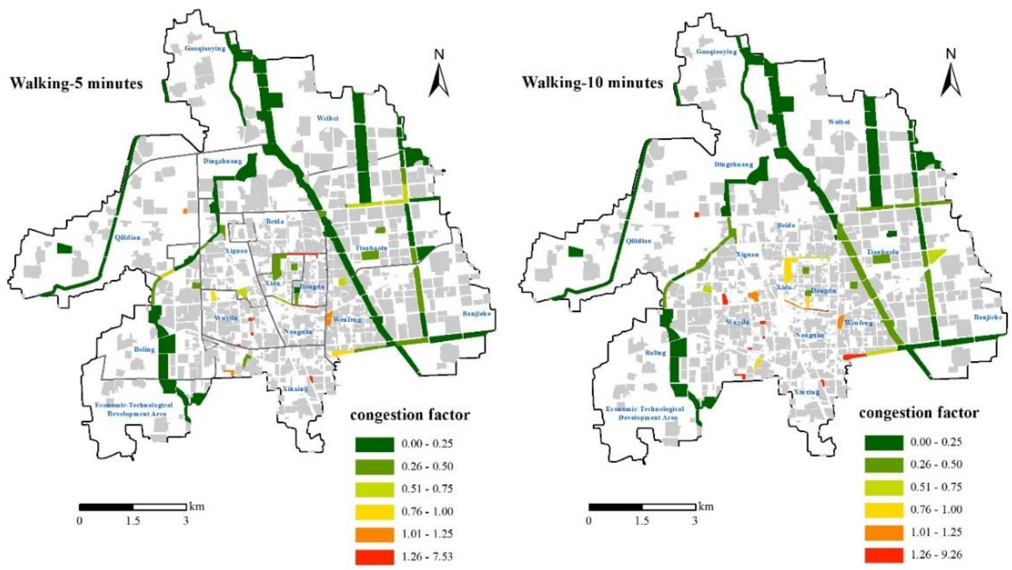

Figure 6. *Congestion risk coefficients of urban park green space*

Discussion

Necessity of taking service supply area and demand area as research units

At present, the research on the relationship between supply and demand of recreational services is mostly based on aggregated units (e.g., Larondelle and Lauf, 2016; Chen et al., 2019). This method assumes that the residents in the basic unit only choose the park

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green space in the unit for recreation activities, ignoring the relationship between the research units, inconsistent with the actual situation. The various living behaviors of urban residents are carried out around the residence. Therefore, taking the residential quarter as the basic unit to study the demand satisfaction of park green space recreation service can avoid the MAUP when using the summarized area (administrative division or grid) as the research unit. When the summarized area is used as the basic research unit, the peak cutting and valley filling effect (Xu et al., 2017) will conceal some residential quarters whose needs cannot be met and park green spaces with low potential utilization rate and excessive pressure, indicating a lack of operability in landscape and urban planning. The analysis directly from the most basic service supply and demand areas is more in line with the actual situation of residents' leisure activities and can provide practical and operable solutions for coordinating the supply and demand of leisure services (Xu and Wang, 2023). Tan and Samsudin (2017) also pointed out that the research for guiding park planning should be carried out on a smaller scale by studying the scale effect of urban park spatial equity evaluation.

The accessibility analysis takes into account the spatial relationship between residence area and park green space, but it is also mainly based on the aggregation unit (e.g., Wei et al., 2014; Shen et al., 2017; Wei, 2017; Li et al., 2019; Liu et al., 2022). In addition, it only analyzes the demand satisfaction of the demand side and does not consider the supply pressure of the supply side and ignores the negative experience caused by possible access congestion. The research framework proposed in this paper measures the balance of supply and demand of recreational services from the perspective of the demand and supply sides, respectively. The accessibility index reflects the satisfaction degree of residents' demand for recreational services, the higher the accessibility, the higher the degree of demand being satisfied; by contrast, the lower the accessibility, the lower the degree of demand being satisfied. The pressure index reflects the pressure of the park green space to provide recreational services. When the pressure is high, the supply side is in a state of short supply. By contrast, when the pressure is low, the supply side is in a state of oversupply. Therefore, taking the basic service supply area and demand area as the research unit, the separation of the research area is avoided, and the MAUP in the research of service supply–demand relationship can be effectively solved.

Implications for urban planning

The accessibility of park green space for residential quarters at the service demand side is mainly affected by the entrance and exit position, road network, nearby resident density, and park green space area. Therefore, by identifying residential quarters with limited access to park green space and analyzing the reasons, decision support can be provided for improving the accessibility of the demand side, including adding residential quarter entrances and exits, improving road network, and adding new park green space. Similarly, according to the pressure of the service supply side, we identify the park green space with excessive visiting pressure and formulate corresponding measures, such as expanding the area of the original park green space and building new park green space nearby, to alleviate the visiting pressure. At the same time, we can also identify the park green space with low potential utilization and improve the potential utilization rate by adding the entrance and exit of the park green space and changing the closed type into the open type. For example, for the residential quarters with low accessibility in the south-central part of the study area, due to the great pressure of the park green space around them, we can only expand the area of the existing parks or build new parks to meet the

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residents' demand for recreational services. For most of the residential quarters with low accessibility in other streets, the accessibility of park green space can be improved by improving the road network and increasing the entrance and exit of the residential quarters because the park green space serving them is open and the service pressure is relatively low.

The accessibility of the demand side and the pressure of the supply side changes with the change in service range, which is related to the area and spatial distribution of the park green space as well as the population and spatial distribution characteristics, potentially providing a basis for the reasonable planning of urban park green space and the layout of residents. Under normal circumstances, when the service pressure of a park green space is small, with the expansion of the service range, it can serve more residents, so the service pressure increases correspondingly, while the accessibility of the residential quarters near it decreases due to the increase of the population sharing the park and the accessibility of the residential quarters far away from it increases. However, in the areas where the distribution of green space is relatively concentrated and the population is relatively sparse, the changes are complex. The visiting pressure of some parks will decrease with the expansion of service range. The main reason for this finding is that with the expansion of the service range, the residents they serve have new park green space to visit, and few or no new residents are included in the service scope.

In addition, according to the park green space congestion index, we can evaluate the risk of park green space congestion during working days and holidays within the specific service range. According to the accessibility and travel rate of the park green space in each residential quarter, we can also predict the possible congestion risk when visiting the park green space nearby, providing the basis for formulating effective measures to alleviate congestion.

Limitations and prospects

The accessibility model of the service demand side and the pressure model of the supply side both change with the change of service range. Therefore, no unified standard exists to strictly determine the critical value when the service reaches the balance of supply and demand in order to further clarify the residential quarters where the demand for recreational services is met, and where the demand is not met; the park green space where the service demand exceeds the supply, and where the supply exceeds the demand.

In addition, this study uses the number of building households instead of permanent population data of each residential quarter (Xu and Wang, 2023). Due to the influence of occupancy rate of residential quarter, in addition to the residential quarters with 0 accessibility (no park green space to visit within the specific service range), the accessibility of park green space in other residential quarters is better, and correspondingly, the pressure of park green space will be smaller. Furthermore, in the risk assessment of park green space congestion in the experimental area, on the one hand, the travel rate refers to the statistical data of other regions, which might not be completely consistent with the actual situation of the study area. On the other hand, the residents are assumed to go to the nearest park for recreation activities. The choice of park green space depends on a variety of factors, including not only the distance but also the visitors' own preferences and the characteristics of park green space.

Therefore, analyzing the pressure on the supply side and the accessibility on the demand side of recreational services according to the detailed census data of residential quarters is more in line with the actual situation. Further research can be combined with

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factors of residents in residential quarters such as the age structure, income status, and education level to analyze whether significant differences occur in the accessibility of park green space among them and identify vulnerable groups in visiting park green space. In addition, through big data such as mobile phone signaling, we can identify the residents who visit the park green space, track their residential quarters, analyze the number of visitors and service range of each park green space, as well as the number of people and travel distance of each residential quarter, to establish the spatial connection between the service demand areas and supply areas, explore the main factors that affect the choice of residents' recreation sites and the number of visitors to park green space and provide operational guidance and suggestions for landscape and urban planning.

Conclusions

This paper constructs a new research framework of the supply–demand relationship of recreational services. On the basis of the accessibility model and the pressure model, the supply–demand relationship of recreational services is measured from the demand and supply sides, respectively. The application of the framework in the experimental area shows that the following. (1) The framework takes the basic service supply area (park green space) and demand area (residential quarter) as the research unit rather than the summary area, which is more in line with the characteristics of residents' recreational activities and can avoid the MAUP in the study of ecosystem service supply–demand relationship. (2) The framework can effectively identify the park green space with excessive supply pressure or low utilization potential, as well as the residential quarter with low accessibility and provide practical and effective decision-making basis for coordinating the supply–demand relationship of recreation service. (3) According to the congestion risk model, the possible congestion risk of park green space is predicted, providing the basis for the formulation of effective measures to alleviate the congestion situation. Further research can be combined with the detailed census data of residential quarters and mobile phone signaling big data to explore the leading factors affecting the choice of residents' recreation places and provide operational guidance and suggestions for landscape urban planning.

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