MALAYSIA ARCHITECTURAL JOURNAL

Malaysia Architectural Journal

Journal homepage:
https://majournal.my/index.php/maj
e-ISSN : 2716-6139

A Study on Refining the Supply-Demand Balance of "Parks -- Residents" in Mountain Community Based --an Example of Yuzhong District, Chongqing, China

Cong Gong[1,2], Yu Cao[1*], Changjuan Hu[1*]

[1]School of Architecture and Urban Planning, Chongqing University, Chongqing, 400044, China
[2]Key Laboratory of New Technology for Construction of Cities in Mountain Area, Chongqing University, Chongqing, 400044, China.

ARTICLE INFO

Article history:
Received: 30 April 2024
Received in revised form
Accepted: 15 October 2024
Available online: 23 June 2025

Keywords:

Mountain city community park; supply-demand matching and coupling coordination analysis; pedestrian accessibility; Yuzhong district

ABSTRACT

Parks are important public spaces in mountainous communities, serving not only as places for residents to relax and enjoy leisure activities but also as key factors in enhancing community cohesion and promoting sustainable development. How to thoroughly investigate the supply-demand coupling of “park-residents” based on walkability in mountainous communities is an urgent issue to address. This study proposes a “Three-Section” theoretical framework for evaluating “park-residents” supply-demand. It constructs 18 supply indicators for the “Park-City-Residential Area” pathways and 9 demand indicators for residents. Using the CRITIC and coupling coordination model, and based on ArcGIS, the study conducts a quantitative analysis of the supply-demand balance of park-resident interactions in the mountainous communities of Chongqing’s Yuzhong District. It evaluates the rationality of green space layout and the walkability of routes in this area. The results identify communities, parks, and pathways within different coupling coordination ranges and derive the following conclusions: the overall supply level in the study area is relatively high, but there is a significant deficiency in supply in the central and eastern parts; the spatial distribution of supply and demand is relatively imbalanced, showing a basic characteristic of “higher supply in the west and lower in the east, higher demand in the east and lower in the west”; there is a large disparity in local supply-demand matching, with nearly a fourfold difference between the highest and lowest scoring routes. In conclusion, the study’s outcomes offer valuable insights for optimizing the planning and distribution of parks in mountainous communities. By addressing the identified imbalances and disparities, urban planners can improve the accessibility and equitable distribution of green spaces, ultimately promoting greater walkability and ensuring fair access to park resources for all residents.

* *Corresponding author.*
E-mail address: oranging89@163.com, 31523944@qq.com

1. Introduction

Urban parks, by providing spaces for recreation, exercise, and social interaction, can significantly enhance the physical and mental health of residents[1]. Park accessibility, which refers to the ease of reaching or leaving a park[2], has become a crucial factor in assessing the rationality of urban park layouts[3]. The balance between park supply and demand refers to a state where the services provided by parks meet the needs of the population in a relatively stable manner[4]. In China, mountainous areas account for about one-third of the total land area, with 21 typical mountainous cities, making the balance of park supply and demand in these regions crucial for guiding the planning and resource allocation of green spaces in complex terrains[5-6].

Studies on the balance of park supply and demand have been conducted both domestically and internationally. Fisher et al.[7] discovered spatial differentiation in the supply and demand of ecosystem services. Zheng et al.[8], Zhang & Tan[9], and Liu et al.[10] established evaluation indicators for park supply and demand to assess the balance in urban parks. Wang et al.[11] and Xia et al.[12] analyzed the equity of urban green spaces in high-density cities from the dimensions of green space, social equity, and justice. Zhao et al.[13] used spatial cluster and the Boston Consulting Group Matrix to analyze the aggregation patterns and changes of urban parks from 2010 to 2020, introduced the spatial mismatch model to assess the alignment of supply and demand with GDP and population, and employed Geodetector to analyze influencing factors. Cao et al.[14] developed an assessment framework considering the impact of landscape and greening on the spatial differentiation of residential areas, evaluating the urban green environment and exploring its influencing mechanisms.

On the scale of research units, Baden et al.[7][15] found that the results of environmental justice analysis are influenced by unit scale and study scope. Xu et al.[16] analyzed the spatial changes in the equity of urban green spaces in Munich, Germany, at the county scale. Tan and Samsudin[17] evaluated the efficiency of urban park green space supply at regional, planning area, and sub-district scales, discovering that smaller unit scales such as streets and blocks better reflect spatial differentiation in supply and demand. Tan et al.[18] used land-use models to spatialize population data, assessing the spatial equity of urban green spaces in Wuhan's central area. The study demonstrated that high-resolution population spatial data could more accurately measure green space equity, particularly in 15-min walking distance park coverage and equity differences across different regions. Zhang et al.[19] used high-resolution remote sensing data to reveal significant spatial disparities in green space availability across different community areas.

Some studies considered green space supply within different temporal buffers. Shen et al.[20] used a 1.2 km distance threshold, while Xiao et al.[21] used 1.6 km and 3.2 km distance thresholds to study urban park service supply, evaluating the fairness of green space services. Dai[22] calculated green space coverage within 5-minute intervals between 10 to 30 minutes. These studies mainly focused on macro and meso scales, such as spatial layout and road network structure, with fewer studies on recreational path perception from residents' perspectives. There remains research gap for improvement in the refined study of park supply and demand balance in mountainous cities. The theory of walkability perception can address the measurement of park-resident supply-demand balance in mountainous contexts.

Based on the above analysis, this paper selects the old community of Yuzhong District in Chongqing, a city characterized by its mountainous terrain, as the research object. From the perspective of walkability in mountainous cities, the study proposes a "Three-Section" supply theory for evaluating the supply-demand coupling of "parks and residents" and considers the differentiated needs of residents. The evaluation index system is constructed in two dimensions: the supply of the "Park-City-Residential Area" three-section pathway and the demand of different residents. Using the CRITIC method and the coupling coordination model, the supply-demand balance of "parks and residents" in the mountainous community is analyzed to assess the rationality of green space layout and the walkability of routes, providing a simple yet precise accessibility measurement method for mountainous cities.

Due to the limitations of mountainous terrain, the minimum cost path between points in a mountainous city is far more complex than in flat cities. Urban residents are more reliant on walking and short-distance transportation modes, and the planar distance of park paths does not directly correspond to the actual travel cost [23]. The circuitousness of paths between parks and buildings affects the service range and effectiveness of parks [24]. Unlike traditional methods that only consider straight-line distance, the "walkability perception" theory takes into account the actual distance and perceived experience of residents' walking processes, making it more suitable for cities with complex terrains [25].

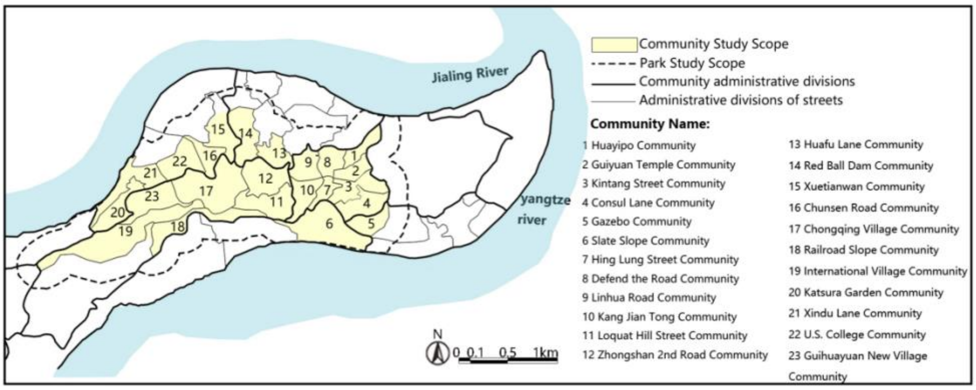
Research on urban green spaces from the perspective of walkability perception includes the evaluation of walkability supply ("Three-Section" supply), analysis of walkability demand (differentiated resident demand), and measurement of walkability supply-demand balance. This provides a refined research framework for the entire walking process of community residents in mountainous cities to reach parks. The "Three-Section" supply theory starts from the perception of the entire process of walking to the park, including the analysis of walking perception in three spatial sections: "building exit-neighborhood exit, neighborhood exit-park entrance, park entrance-park public space node." It comprehensively evaluates the supply capacity of the "park-resident" route from the perspectives of community, pathway, and park node. The walking process of "park-resident" involves the selection of starting points (path planning and service facilities within the neighborhood green space) and endpoints (path planning and service facilities within the park node), as well as the walking environment along the way (walking system, sidewalk facilities, traffic conditions, etc.) [26].

The theory of differentiated residential needs emphasizes the measurement of walking perceptions among different demographic groups. Significant differences exist in park usage and walking preferences among various population groups[27], and vulnerable groups often experience significant inequality in access to green spaces[28]. Kaczynski et al.[29] found that the significant relationships between park proximity and facilities varied widely across gender, age, race, and income groups. Besenyi et al.[30] found that young people with a playground within half a mile or a baseball field within one mile of their homes, females with a park within half a mile, and males with a park within one mile were more likely to achieve higher levels of physical activity. This study divides the demand for park green spaces into two subsystems: material needs and social needs. Material needs focus on quantity and scale, such as POI density and floor area ratio, reflecting the basic needs of residents. Social needs, on the other hand, emphasize quality, equity, and justice, including total population density, population density by age group, unemployment rate, and density of non-local populations, reflecting the deeper and more differentiated needs of residents[31].

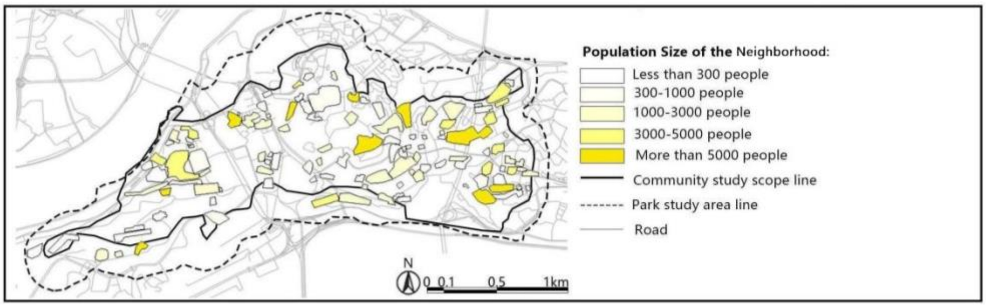
2. Methodology

2.1 Research Area Overview

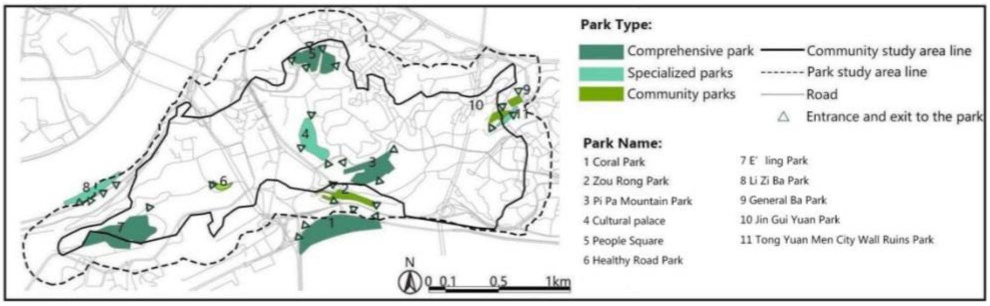
The study focuses on the mountainous community of Yuzhong District in Chongqing, encompassing 23 street communities, covering an area of 343 hectares, and including 117 residential complexes with 243 buildings. The primary scope of the study is extended to include all urban and community-level parks within a 15-min walking distance from any residential area, resulting in a total of 12 parks considered for the actual study area (Fig. 1). According to the slope classification standards in the Chinese "Mountain Building Design" [32], steep and very steep slopes are primarily located in the western and central-southern parts of the area, while the northern and central-eastern parts are relatively flat. The total area of parks within the study area is 46.04 hectares, with 2 parks in the west, 6 parks in the central area, and 4 parks in the east. The mountainous residential environment of Yuzhong District features a well-developed community service infrastructure, with gradually improving community facilities and convenient living services. Basic amenities such as convenience stores, restaurants, and medical points are available within the community, meeting the daily needs of residents.



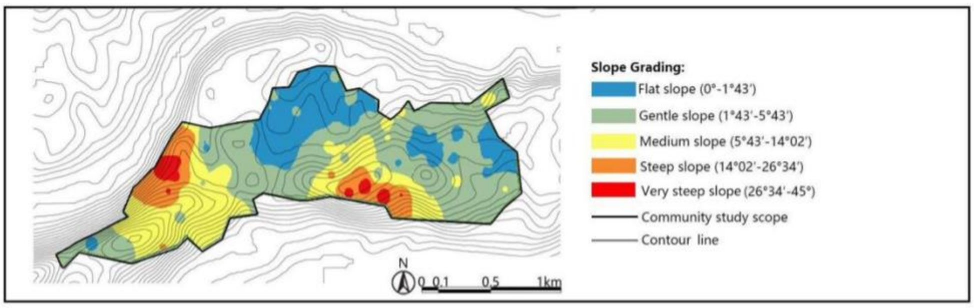
(a)Administrative divisions of streets and neighborhoods in the study area



(b) Population size distribution of neighborhood in the study area



(c) Distribution of parks and types in the study area



(d)Slope distribution of settlements in the study area

Fig. 1. Diagrammatic representation of the study area

2.2 Supply Indicators Selection and Calculation

Considering the environmental factors of mountain cities, the study focuses on the supply situation in three aspects: community, path, and park. Community supply refers to the accessibility data of walking distances, times, and slopes within the community, as well as the completeness of infrastructure and service facilities[33]. Quantitative indicators include the average time from each building to the residential area's entrance, average slope, types, numbers, and quality of community facilities, green space area, and their match with residents' needs[34]. Path supply focuses on the accessibility and convenience of transportation paths in mountain cities. Quantitative indicators include walking time, slope, number of pedestrian bridges and underpasses, and POI density[35]. Park supply reflects the distribution of green and recreational spaces in mountain cities. Quantitative indicators include the travel cost from park entrances to park nodes, including walking time, slope conditions, green space area, and the number and types of facilities[35].

When calculating accessibility in mountain cities, the impact of slope must be considered. The influence of slope on accessibility is reflected in two aspects: first, it increases the actual distance and time residents need to reach parks due to the need to overcome terrain obstacles; second, it limits the service range of parks, making it difficult for residents in high-slope areas to enjoy park services[36]. The study categorizes the calculation methods for supply indicator factors and proposes the following four refined calculation methods (Table 1).

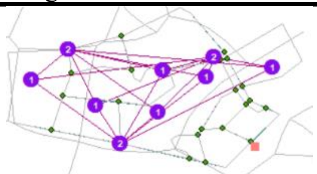
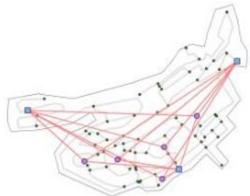
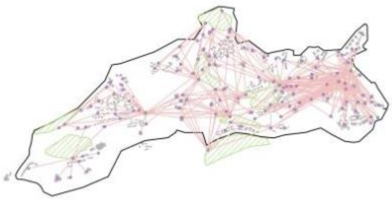
i. Baidu Map API to Calculate Distance Thresholds: Using the Baidu Map API interface, "start-to-end" path matching is performed for each residential area and park entrance, screening 559 routes. The screening criteria include: first, the travel time should be within 15 minutes; second, excluding cases where one residential area corresponds to multiple entrances of the same park, retaining the route to the nearest park entrance; third, excluding cases where one park entrance corresponds to multiple residential areas, retaining the route to the nearest residential area entrance. After screening, 338 routes were obtained. All routes within a 15-minute travel time are selected, and their average walking speed is analyzed to be 1.17 m/s. Therefore, 1050 meters is used as the 15-minute walking accessibility distance. The inverse distance weighting method is used to generate visual graphs for each indicator, classified using natural breaks.

ii. Baidu Map API to Calculate Time Distance: Through the Baidu Map Route Planning API interface, the average travel time under internet big data is obtained, considering factors such as road grade, terrain elevation difference, and traffic congestion, thereby improving data accuracy. Specifically, the Baidu Map coordinates of park entrances (32) and residential centroids (117) are used as reference points to crawl the time and distance corresponding to 3744 routes. Data collection occurred on December 19 and 20, 2022, from 8:30 AM to 6:30 PM on working days. The time cost is included in the accessibility calculation model via the Baidu Map API, replacing the road network's maximum distance with the extreme travel time to parks as the search domain.

iii. OD Cost Matrix from Network Analysis to Calculate Travel Information for Each Building in the Community: The study selects the UTM zone 48N WGS 84 coordinate projection, representing Chongqing's geographical location. The geographic location data of each building and the community entrance are collected, along with the community road network data. Using ArcGIS network analysis, a network dataset is established to construct an OD (Origin-Destination) cost matrix. In the model, each building is set as the origin, and the community entrance as the destination. The matrix records all possible routes from each building to each entrance and calculates the time and distance from each building to the community entrance.

iv. Selecting Park and Community Entrances Rather than Centroids: Traditional accessibility calculations often use the centroids of parks and communities as representative points for calculations. However, this method has limited precision and ignores the actual locations and layouts of entrances. When choosing park and community entrances as key points for accessibility analysis, attention must be paid to the actual spatial interfaces and entrance characteristics, as they directly affect residents' actual travel experience and perception, accurately reflecting the walking accessibility of residents from different locations. Treating each building as an independent departure and arrival point, rather than relying solely on the centroids of residential areas or districts, can more accurately simulate the movement of pedestrians between different buildings and interact with the road network in practice. This analysis method considers both the transportation network and the distribution of buildings' impact on walking accessibility, providing more accurate and comprehensive walking accessibility evaluation results.

Table 1
Calculation of spatial network model

Space network elements	Element information	Diagrams
Starting point: residential building unit (demand side)	Population, structure, socio-economic level, educational attainment	
Destination point: park (supply side)	Community supply Park supply	
Network edges: paths	Path supply Average time, slope	

2.3 Demand Indicators Selection and Calculation

The socio-economic status of residents comprehensively reflects their employment, income, and social standing, representing individual socio-economic characteristics. Some studies use relatively simple indicators to evaluate residents' demand capabilities, such as population size, floor area ratio, and building density, without including socio-economic attributes like educational attainment, monthly household income, and housing prices. Based on a review of demand indicators literature, and considering comprehensiveness and data availability, this study selects four aspects of residents' demand capability indicators: population size[37-38], age structure[10,18], economic level[39], and educational attainment[4].

i. Population Size and Structure: To calculate population size and structure proportions, data on the number of households and the floor area ratio of residential areas are obtained from the Anjuke website, which provides representative market information. The number of households in each residential area is collected and converted to population numbers using the average household size from the Seventh National Population Census (2.62 persons per household). From the 2023 Chongqing government gazette, specific data on the proportions of children (under 14 years) and elderly (over 60 years) in Yuzhong District are obtained: children (under 14 years) constitute 10.86% and the elderly (over 60 years) constitute 19.76%. These proportions are used to assess the park demand from different age groups.

ii. Economic Level: Economic level is indirectly represented by data from the Anjuke website on housing listing prices, property fees, and the year of construction (building age) in the mountainous communities of Yuzhong District, Chongqing, in October 2023. Housing listing prices can indirectly reflect the economic development level of an area; property fees indicate residents' living costs; and the year of construction reflects the area's urbanization process.

iii. Educational Attainment: The educational attainment of the population is assessed using data from the 2023 Chongqing government gazette on the numbers of people with education levels of junior high school and below, and university and above. The disadvantaged groups in Chinese cities include laid-off workers lacking educational resources and skills, while residents with higher educational attainment have an advantage in park accessibility[40]. Ultimately, it is found that the population with junior high school education and below constitutes 38.257% of the total population of Yuzhong District, while the population with university education and above constitutes 31.172% of the total population

2.4 Indicator Weighting

The CRITIC (Criteria Importance Through Intercriteria Correlation) method is an objective weighting method suitable for multi-indicator evaluation. It determines weights based on contrast intensity (measured by standard deviation) and conflict (reflected by indicator correlation). Given the large number of study indicators and the correlation between data, the CRITIC method, combined with a questionnaire survey, is chosen for weighting (Table 2).

The specific steps are as follows:

$$S_j = \sqrt{\frac{\sum_{i=1}^{n}(y_{ij} - \bar{y}_j)^2}{n-1}} \tag{1}$$

$$R_j = \sum_{i=1}^{p}(1 - r_{ij}) \tag{2}$$

$$C_j = S_j \sum_{i=1}^{p}(1 - r_{ij}) = S_j \times R_j \tag{3}$$

$$W_j = \frac{C_j}{\sum_{j=1}^{p} C_j} \tag{4}$$

In equations (1), (2), (3) and (4), S_j is the intensity of comparison, R_j is the standard deviation of the j ndicator. C_j is the correlation coefficient between the i indicator and the j indicator, the larger C_j is, the more information is available and the higher the weight is. W_j is the weight of the j indicator.

From Nov 27 to Dec 10, 2023 (covering weekdays and weekends), during the time periods of 9:00-11:30 and 13:00-17:00, a questionnaire survey was conducted with elderly people active in Pi Pa Shan Park and its surrounding streets. The survey aimed to understand the preferences of residents in the mountainous community of Yuzhong District, Chongqing, regarding park visits, covering aspects such as "gender, age, and frequency of park visits." A total of 170 questionnaires were distributed and collected, with 163 valid questionnaires obtained after screening. The questionnaire analysis revealed that the frequency of park visits is significantly correlated with walking time ($r=0.49$, $p<0.01$). Among the age groups of 45-59 and 60-74 years, the proportion of people visiting the park daily is relatively high, indicating that these age groups are more inclined to visit the park regularly. Analysis of the reasons for residents in Yuzhong District, Chongqing, to go to the park showed that the weights of the community, path, and park were 1.96:2.93:5.11, respectively. This results in the weighting ratio among the three supply systems, which are uncorrelated with each other.

Table 2
Evaluation index system and weighting values of "Park-Resident" pathway

Systems	Factor Layer	Indicator Layer	Indicator Properties	Initial Weight (%)	Initial Weight Sum (%)	Ndicator weight(%)	Factor weight (%)
Supply system	Community supply	Average time from each building to the community entrance/exit (s)	Negative	29.8	100	5.8	19.6
		Average slope from each building to the community entrance/exit (°)	Negative	24.5		4.8	
		Area of community green space (m^2)	Positive	10.8		2.2	
		Facility type (pcs)	Positive	19.1		3.7	
		Facility number (pcs)	Positive	15.8		3.1	
	Path supply	Path time (s)	Negative	22.4	100	6.6	29.3
		Average slope (°)	Negative	24.6		7.2	
		Traffic light number (pcs)	Negative	7.6		2.2	
		Footbridge, step and underpass number (pcs)	Negative	8.7		2.5	
		Within the 50m buffer zone on both sides of the road centerline Number of large POI (pcs/100m)	Positive	7.3		2.2	
		Within the 50m buffer zone on both sides of the road centerline Large POI type (pcs/100m)	Positive	10.3		3.0	
		Within the 50m buffer zone on both sides of the road centerline Small-scale POI number (pcs/100m)	Positive	9.0		2.6	
		Within the 50m buffer zone on both sides of the road centerline Types of small POI (pcs/100m)	Positive	10.1		3.0	
	Park supply	Average time from park node to park entrance/exit (s)	Negative	28.4	100	14.5	51.1
		Average slope from park node to entrance/exit (°)	Negative	30.9		15.8	
		Park node area (m^2)	Positive	9.0		4.6	
		Facility type (pcs)	Positive	17.4		8.9	
		Facility number (pcs)	Positive	14.3		7.3	
Demand system	Population size	Population per settlement (persons)	Positive	7.3	20.6	-	-
		Plot ratio	Positive	13.3			
	Population structure	Child population (14-) (persons)	Positive	7.3	14.6		
		Elderly population (60+) (persons)	Positive	7.3			

Socio-economic level	House price (yuan/m^2)	Negative	13.4	42.0
	Property management fee (yuan/month-m^2)	Negative	13.2	
	Construction year (years)	Negative	15.4	
Education attainment	Population with high school education or below (persons)	Positive	7.3	22.8
	Population with a university degree or above (persons)	Negative	15.5	

2.5 Coupling Coordination Model

The coupling coordination model can reflect whether the spatial layout of park green space supply is reasonable and whether the spatial distribution is fair and just. It also measures the strength of interaction between supply and demand systems, helping to reveal the dynamic mechanisms between these systems. This model is widely used in the fields of urban ecosystem services and demand[41-42]. This study introduces the coupling coordination model, treating supply capacity and demand capacity as two independent subsystems, each constructed with multi-level indicators. The calculation method is as follows:

$$f(x) = \sum_{i=1}^{n} \lambda_i \times x_i \tag{5}$$

$$g(y) = \sum_{i=1}^{n} \lambda_i \times y_i \tag{6}$$

$$C = \left\{ f(x) \bullet g(x) \bullet \left[\frac{f(x)+g(x)}{2}\right]^{-2} \right\}^{1/2} \tag{7}$$

In the formula (5), (6) and (7), f(x) and g(y) represent the composite indices of supply and demand subsystems, and n represents the total number of indicator values. x_i and y_i are the normalized values of the first i factor, and w_i represents the weight of the factor in the sub-indicators. C represents the value of the coupling degree, which takes a value between 0 and 1. The larger the C value, the better the matching between the supply system and the demand system.

$$T = \alpha f(x) + \beta g(y) \tag{8}$$

$$D = \sqrt{C \times T} \tag{9}$$

In the formula (8) and (9), D represents the degree of coupling coordination, reflecting the degree of coordination and matching and comprehensive development of supply capacity and demand capacity, with a value range between 0-1, the larger the value, the higher the level of coordinated development of supply capacity and demand capacity. T represents the degree of coordinated development. $\alpha$and$\beta$are the weights to be determined, and the study considers that the importance of supply capacity and demand capacity is comparable, so they both take the value of 0.5.

2.6 Technical Process and Data Analysis

First, through field exploration, representative communities in the mountainous areas of Yuzhong District are surveyed and analyzed. This includes investigating the locations of entrances and exits, slopes, facilities, and green spaces. A total of 163 questionnaires are distributed to gather information on users' needs regarding the supply in "within the community," "along the path," and "within the park." These needs are combined with the survey to screen demand indicators, representing the demand differences of different groups and providing data support for factor weighting. Second, the study leverages big data technology to obtain travel times from residential areas to parks via the Baidu Map API interface. The Baidu Map route planning function is used to collect elements such as the number of pedestrian bridges, traffic lights, and POI information for each travel route. To estimate population and other data, relevant information is scraped from the Anjuke website. Third, based on the collected basic environmental data, statistical methods are used to explore and analyze the correlations between variables. Combining the questionnaire data, tools such as EXCEL and SPSS are used for systematic data organization and analysis. Fourth, based on the ArcGIS spatial mapping platform, regional analysis is conducted at a macro level, while individual parks or communities are analyzed at a micro level. Spatial visualization mapping of each supply and demand indicator is completed. Through weighted overlay of supply and demand indicators, spatial mapping of supply-demand matching types is drawn, hierarchically dividing the supply system, demand system, and supply-demand coupling system, and visually presenting the matching situation between them(Fig. 2).

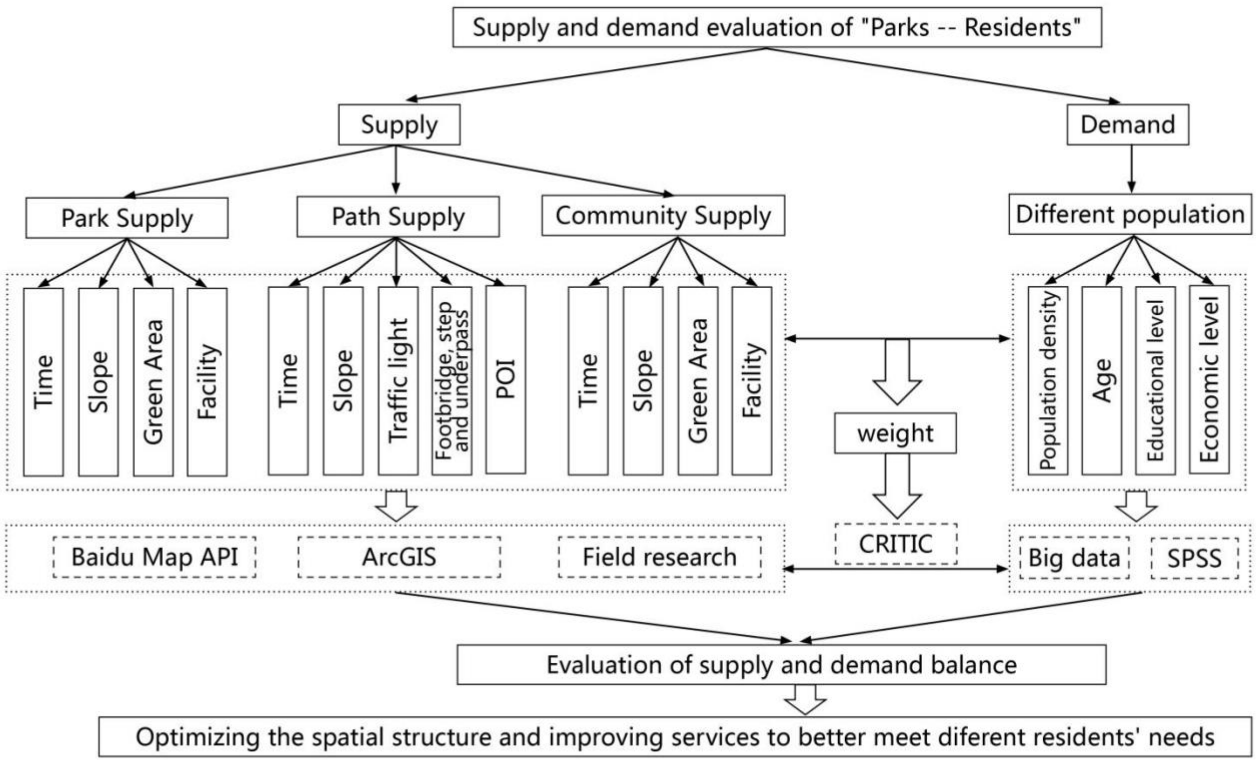


Fig. 2. Research framework

3. Results

3.1 "Three-Section" Supply Evaluation

In terms of community supply, an analysis of 12 residential areas under the same indicators (Table 3) reveals that each area exhibits unique characteristics in road layout, building distribution, entrance and exit settings, and terrain conditions, all of which affect accessibility and overall supply levels. Caixin Yuzhong City Neighborhood, E'ling Peak Neighborhood, and Jufeng Jinxiu Shengshi Neighborhood scored relatively high overall (Figure 4). In contrast, Jialing Neighborhood, Renmin Road Residential Neighborhood, Huayi Village Neighborhood, and Kunyu Mingshi City Neighborhood scored relatively low (Fig. 3).

In terms of path supply, a detailed visualization of a total of 1,593 paths was conducted (Figure 5), comprehensively analyzing indicators such as path distance, path time, cumulative elevation gain, elevation difference, average slope, number of traffic lights, number of pedestrian bridge steps and underpasses, and the number and types of large and small POIs on both sides of the road centerline. In the path supply score statistics, the median was 0.559, and the mean was 0.552. Specifically, the path "Pi Pa Mountain Zheng Street Second Alley Neighborhood- Coral Park" had the lowest path supply score at only 0.344, while the path "Shanghai Oriental Garden - People Square" had the highest path supply score, reaching 0.746 (Fig. 4).

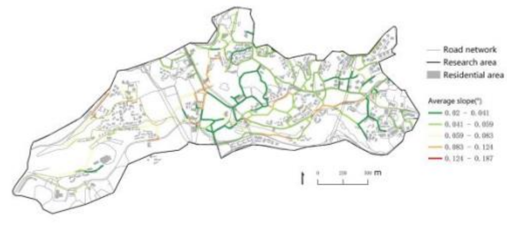
In terms of park public space node supply, there are significant differences among various nodes in terms of average time, distance, slope, elevation difference, green space area, types and number of facilities, and supply scores . The Bonsai Garden node in Pi Pa Mountain Park had the lowest supply score, below 0.2. In contrast, the New Century Plaza and Century Light Column in Coral Park, the Camphor Forest Ecological Plaza in Li Zi Ba Park, and General Ba Park nodes had higher supply scores, exceeding 0.7(Fig. 5). In terms of the "three-section" total supply(Fig. 6) , Pi Pa Mountain Park has the lowest supply at 0.41, while General Ba Park has the highest three-stage total supply at 0.73.

Table 3
"Three-Section" supply indicator statistics

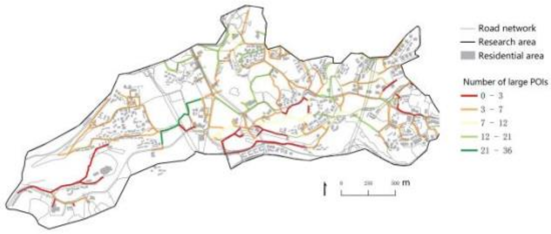
Indicators		Mean	Median
Time	Average time from each building to entrance/exit (s)	124	121
Elevation	Average slope from each building to the entrance/exit (°)	0.05	0.05
Green spaces and facilities	Green area (m^2)	900	460
	Facility type (pcs)	3	2
	Facility number (pcs)	4	3
Total community supply		0.50	0.46
Average timing	Average time (s)	543	557
Elevation	Average slope (°)	0.056	0.052
Road connectivity, safety	Traffic light number (pcs)	1	1
	Footbridge, step and underpass number (pcs)	1	1
POI along the street	Large POI number (pcs/100m)	7	6
	Large POI type (pcs/100m)	3	3
	Small POI number (pcs/100m)	134	116
	Small POI type (pcs/100m)	8	8
Total supply of pathways		0.552	0.559
Timing	Average time (s)	220	180
Elevation	Average slope (°)	0.063	0.047
Green spaces and facilities	Green area (m^2)	980	446
	Facility type(species)	4	4
	Facility number (pcs)	7	7
Total park supply		0.53	0.54

Fig. 3. Community supply

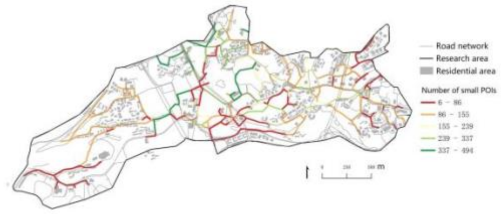
(a) Average time for "neighborhood-park" paths



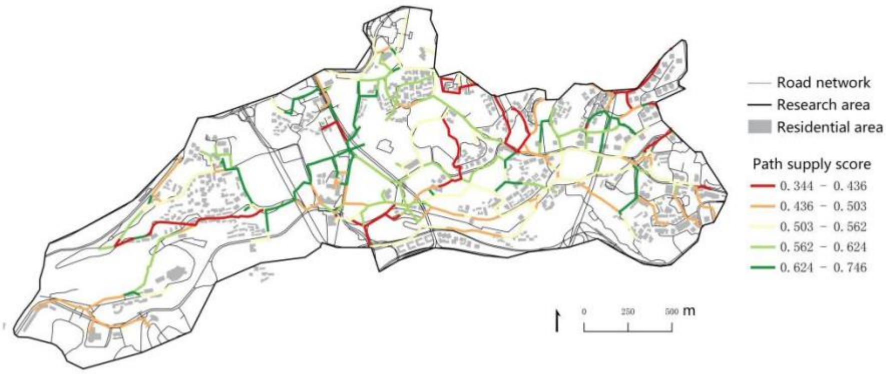
(b) Average slope for "neighborhood-park" paths



(c) Number of large POIs supplied by "neighborhood-park" paths



(d) Number of small POIs supplied by "neighborhood-park" paths



(e) "Neighborhood-park" path supply distribution based on all indicators

Fig. 4. Path supply

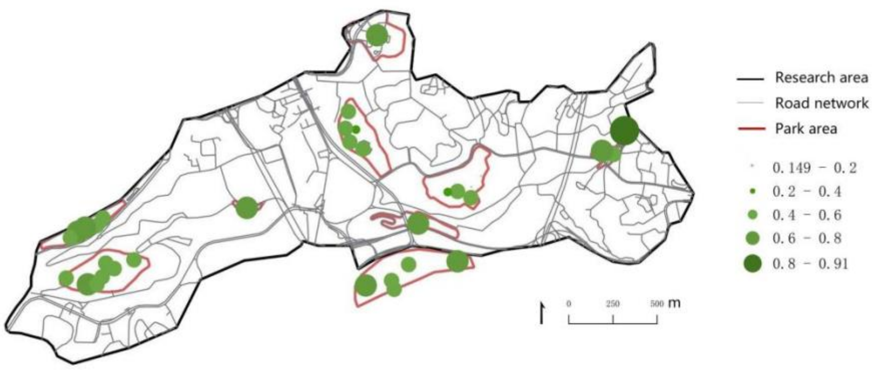


Fig. 5. Park supply

Fig. 6. "Three-section" supply

3.2 Community Demand Evaluation

Based on ten criteria—population of each residential area, number of children, number of elderly, housing prices, property fees, floor area ratio, year of construction (building age), number of people with education levels of junior high school and below, number of people with university education and above, and total demand score—the demand of residents was evaluated (Fig. 7). In terms of total demand scores (Table 4), the average score was 0.503, with a median score of 0.525. E'ling Peak Neighborhood had the lowest total demand score at 0.156, while Jiankang Road Neighborhood led with the highest score of 0.653, a difference of approximately 4.19 times between the two. Each Neighborhood exhibited different characteristics in terms of population structure, housing prices, property fees, floor area ratio, year of construction, and educational levels. Additionally, correlation analysis using SPSS (Table 5) revealed that housing prices were significantly correlated with the population of each residential area ($r=-0.120$, $P=0.000$, $P<0.01$); property fees were significantly correlated with the population of each residential area ($r=-0.078$, $P=0.002$, $P<0.01$); floor area ratio was significantly correlated with the population of each residential area ($r=0.087$, $P=0.000$, $P<0.01$); and the year of construction was significantly correlated with housing prices ($r=0.637$, $P=0.000$, $P<0.01$).

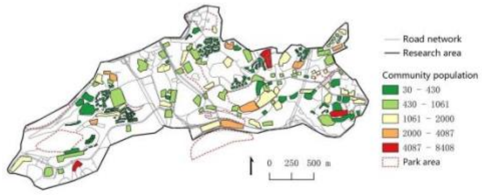
Table 4
Demand indicator statistics

Indicators	Mean	Median
Population per community(persons)	606	262
Plot ratio	2.93	2.60
Childre population (persons)	66	28
Elderly population (persons)	120	52
House price (yuan/m^2)	12443	10395
Property management fee (yuan/month-m^2)	1.28	1.00
Construction year (years)	2003	2000
Population with high school education or below (persons)	232	100
Population with a university degree or above (persons)	189	82
Total demand	0.503	0.525

Table 5
Correlation analysis of demand indicators

Settlement properties	Count	Correlation coefficient	P-value
House price vs Population per community	1593	-0.12	0.000*
Property management fee vs Population per community	1593	-0.078	0.002*
Plot ratio vs Population per community	1593	0.087	0.000*
Construction year vs Population per community	1593	0.006	0.797
Construction year vs House prices	1593	0.637	0.000*

*Denotes significant correlation at $P < 0.01$

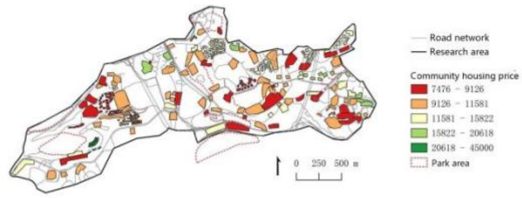


(a) Community demand based on population size

(b) Community demand based on plot ratio

(c) Community demand based on property management fee

(d) Community demand based on construction year



(e) Community demand based on house price

(f) Community demand distribution based on all indicators

Fig. 7. Community demand

3.3 Supply-Demand Balance Evaluation

Through coupling coordination analysis, the total supply, total demand, coupling degree (C value), coordination degree (T value), coupling coordination degree (D value), and coupling coordination level were obtained (Fig. 8). The final results identified the routes and parks within the seven levels of coupling coordination intervals (Table 6). A larger coupling degree (C value) indicates greater interaction between the systems. The coupling coordination degree (D value) ranges between 0 and 1, with a higher value indicating a higher degree of system coordination.

Regarding the analysis of total supply and total demand data, the average total supply was 0.508, with a median of 0.514. The highest total supply was "Caixin Yuzhong City Building 2 - General Ba Park," at 0.825, while the lowest total supply was "Kunyu Mingshi City Building 5 - Pi Pa Mountain Park Bonsai Garden," at 0.249. The average total demand was 0.496, with a median of 0.510. The statistical data of the coupling degree (C value) indicated an average of 0.901 and a median of 0.969. Among all samples, the lowest C value was "E'ling Peak Building 6 - E'ling Park Yihui Garden," at only 0.236. Additionally, the average coordination index (T value) was 0.568, with a median of 0.58. The highest T value was "Xinde Village Neighborhood - General Ba Park," at 0.898, while the lowest T value was "E'ling Peak Building 1 - E'ling Park Kansheng Building," at only 0.216. For the coupling coordination degree (D value), the average was 0.713, with a median of 0.749. The highest D value was "Xinde Village Neighborhood - General Ba Park," at 0.948, while the lowest D value was "E'ling Peak Building 1 - E'ling Park Kansheng Building," at only 0.255. The statistical data of coordination levels showed an average of 7.62 and a median of 8. In the sample, the highest coordination level was "Yinzhong Building - General Ba Park," while the lowest coordination level was "Kunyu Mingshi City Building 5 - Pi Pa Mountain Park Bonsai Garden"(Table 7, Table 8).

Table 6
All route coupling coordination levels number statistics

Coupling coordination interval	Coupling coordination degree (D)	Number (percentage)
Level 1	0≤D<0.4	81 (5.1%)
Level 2	0.4≤D<0.5	34 (2.1%)
Level 3	0.5≤D<0.6	115 (7.2%)
Level 4	0.6≤D<0.7	265 (16.6%)
Level 5	0.7≤D<0.8	721 (45.2%)
Level 6	0.8≤D<0.9	364 (22.8%)
Level 7	0.9≤D<1.0	13 (0.8%)

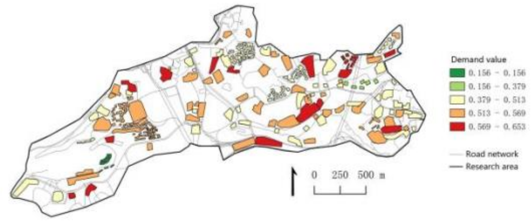
Table 7
Park coupling coordination value statistics

Park	Mean	Median	Standard Deviation
Total	0.713	0.749	0.137
General Ba Park	0.875	0.876	0.031
Jin Gui Yuan Park	0.806	0.805	0.028
Tong Yuan Men City Wall Ruins Park	0.769	0.769	0.028
People Square	0.794	0.789	0.023
Zou Rong Park	0.810	0.803	0.020
Healthy Road Park	0.849	0.850	0.020
E'ling Park	0.518	0.471	0.247
Li Zi Ba Park	0.778	0.772	0.038
Pi Pa Mountain Park	0.652	0.669	0.090
Coral Park	0.775	0.781	0.043
Culture Palace	0.756	0.759	0.037

Table 8
Park coupled coordination intervals statistics

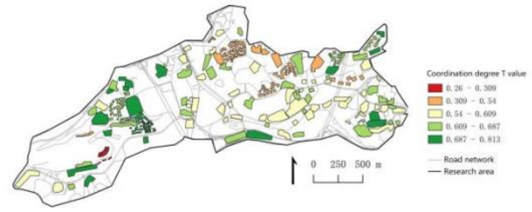
Coupling coordination interval	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Total
D value	0≤D<0.4	0.4≤D<0.5	0.5≤D<0.6	0.6≤D<0.7	0.7≤D<0.8	0.8≤D<0.9	0.9≤D<1.0	-
General Ba Park	0	0	0	0	1	59	12	72
Jin Gui Yuan Park	0	0	0	0	33	41	0	74
Tong Yuan Men City Wall Ruins Park	0	0	0	0	56	10	0	66
People Square	0	0	0	0	43	18	0	61
Zou Rong Park	0	0	0	0	8	14	0	22
Healthy Road Park	0	0	0	0	4	79	1	84
E'ling Park	77	0	0	13	37	27	0	154
Li Zi Ba Park	0	0	0	4	105	61	0	170
Pi Pa Mountain Park	4	34	115	223	197	7	0	580
Coral Park	0	0	0	4	34	17	0	55
Culture Palace	0	0	0	21	203	31	0	255
Total	81	34	115	265	721	364	13	1593

(a) "Parks -- Residents" coupling: supply value map

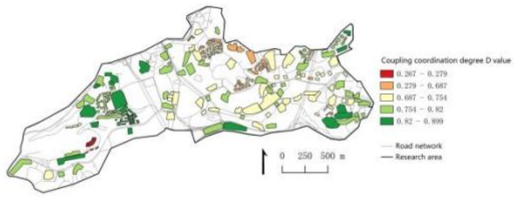


(b) "Parks -- Residents" coupling: demand value map

(c) "Parks -- Residents" coupling: C-value map



(d) "Parks -- Residents" coordination: T-value map



(e) "Parks -- Residents" coupling coordination: D-value map

(f) "Parks -- Residents" coupling coordination level map

Fig. 8. "Park-Settlement" supply-demand coupling Evaluation

4. Discussion

4.1 Coupling Analysis of Supply and Demand in Mountainous Cities

Within the study area, the overall supply and demand exhibit a relatively matched and coordinated state; however, significant disparities exist between specific regions. These differences are evident in three main aspects: first, although the overall supply level is relatively balanced, the central and eastern parts of the site show a noticeable supply deficit, indicating a significant supply-demand gap. Second, the spatial distribution of supply and demand is relatively imbalanced, with distinct spatial differentiation, characterized by "abundant supply in the west and insufficient supply in the east; strong demand in the east and relatively weak demand in the west." Lastly, the localized differences are particularly prominent. For instance, the route with the highest value, "Xinde Village Neighborhood - General Ba Park" (0.948), contrasts sharply with the route with the lowest value, "E'ling Peak Building 1 - E'ling Park Kansheng Building" (0.255), showing a disparity as high as 3.7 times, indicating substantial differences in localized supply-demand relationships.

4.2 Urban Design Recommendations

Base on the results of the "park-residential area" coupling coordination study, optimization strategies are proposed at macro, meso, and micro levels. At the macro level, the plots are classified into imbalance, primary coordination, and good coordination categories, with optimization and regulation strategies proposed for the total supply, supply-demand structure, and development strategies. At the meso level, refined urban design strategies are developed for community, pedestrian systems, and green space structures. At the micro level, the focus is on the detailed design of community, road, and park landscape nodes[10,43]. These three-level strategy designs provide a comprehensive and systematic “park-resident” path optimization for mountainous communities. The research results aim to offer valuable information and references for relevant government departments in the construction and planning of park green spaces, urban slow public spaces, and community green spaces in mountainous cities, thereby promoting the improvement of fairness in the supply and demand levels of public service facilities in the mountainous communities of Yuzhong District, Chongqing.

4.3 Research Limitations

During the research process, it was found that although this study has a certain level of control over the significance and innovation of the topic, there are still some limitations. First, the theoretical analysis of the supply-demand balance for green spaces in mountainous city communities is mainly based on the coupling coordination degree model’s coefficient weights and classification, using the questionnaire survey method and CRITIC. Questionnaire surveys can be influenced by the respondents’ mindset and willingness, while the CRITIC relies on the authenticity and accuracy of the data, which can somewhat affect the path evaluation results and cause indicator bias. Second, the study uses many evaluation indicators, with data collected from different fields. Thus, multiple channels and software are required for data organization and analysis. Although data was integrated into the ArcGIS platform after organization and analysis, it is still affected by multiple uncertainties, such as inconsistent data formats and missing data. Third, the study divides the supply balance of green spaces in mountainous park cities into regions. Specifically, it is divided into three sections: from buildings to community entrances, from community entrances to park entrances, and from park entrances to park nodes. However, the data on residents’ demand for park green spaces is limited, making it difficult to obtain. The actual demand for park green spaces by residents is influenced by complex factors, making it impossible to achieve complete quantification and indicatorization. Fourth, the study conducted field research and analysis on 12 large communities and communities with significant elevation differences in Yuzhong District, Chongqing. Although the empirical analysis is typical and representative, it does not cover all buildings and residents in the entire Yuzhong District. The selection of park nodes was influenced by both subjective and objective factors.

4.4 Future Research and Prospects

First, research data needs to be more refined. It was found during the research process that there is room for improvement in the refinement of data collection, organization, and analysis. Due to the unavailability of some data resources, similar indicators and methods were used to advance the research. Obtaining income data for residents in the mountainous communities of Yuzhong District, Chongqing, was challenging; hence, the average housing price and property fees in the study area were used as equivalent indicators. These two indicators can partially reflect residents’ basic income levels but cannot fully equate to actual income data, affecting the precision of the evaluation indicators.

Second, the indicator system still needs improvement. Although the study has constructed a relatively comprehensive evaluation indicator system for green park space layout from a supply-demand perspective, covering the supply capacity of green parks and residents’ demand capacity, it has not fully considered the differences in the supply capacity of the parks themselves and the impact of the floating population on residents’ demand due to data limitations. Future research will strive to obtain more comprehensive data to further improve the evaluation indicator system and more accurately assess the layout effectiveness of green parks[31].

Third, the data formats from various databases can be integrated. Integrating data from various sources, such as websites, APIs, and mobile applications, poses a challenge in ensuring data completeness and accuracy, avoiding deviations during data import and export. Particularly, data obtained from multiple channels, such as Baidu Map Path API and ArcGIS network mobile analysis, may have significant differences in format, unit, and parsing methods. To ensure the effectiveness of the research, continuous experimentation and optimization of data conversion and integration processes are needed, exploring more precise, scalable, and scientific data integration methods[45].

Fourth, communities and parks can be further categorized. For the classification of communities and parks[46], the study adopts classifications of large and small communities and large and small parks. Although this classification facilitates preliminary analysis, further refinement is needed. Future research can consider classifying communities based on more dimensions such as population density, age structure, income level, and cultural background to more accurately assess the demand for park green spaces in different types of communities. For parks, a more detailed classification can be considered based on their functions, area, vegetation types, and landscape features to gain a more comprehensive understanding of the impact of different types of parks on residents' lives[10].

5. Conclusions

This study focuses on the mountainous communities of Yuzhong District, employing empirical research methods to analyze the supply-demand situation between residents and parks. Utilizing various methods, including questionnaire surveys, ArcGIS spatial analysis, statistic analysis, and big data research, comprehensive data on the "Three-Section" supply and differentiated resident demand was collected. The study found that the overall supply-demand match between "parks-residents" in the mountainous communities of Yuzhong District is relatively coordinated, but certain areas exhibit significant supply-demand conflicts. Specifically, the findings can be summarized into three main points:

i. Most routes and parks fall into the coordinated category of coupling coordination, but some routes and parks are in the imbalanced category.

ii. The spatial distribution of supply and demand is relatively unbalanced, with distinct spatial differentiation characterized by "higher supply in the west and lower supply in the east, and higher demand in the east and lower demand in the west," resulting in a significant supply deficit in the central and eastern parts of the area.

iii. There are substantial differences in localized supply-demand match: the highest value route "Xinde Village Neighborhood to General Ba Park" (0.948) and the lowest value route "E'ling Peak Building 1 to E'ling Park Kansheng Building Park" (0.255) differ by a factor of 3.7.

The research findings can provide scientific evidence for government decision-making, promoting more precise and efficient planning and construction of park facilities. Additionally, the findings contribute to enhancing the fairness of community public service facilities, enabling residents to enjoy high-quality public services and reducing development disparities between communities.

Acknowledgement

This research was funded by the National Natural Science Foundation of China (No. 51908078, 52308008) and China Postdoctoral Science Foundation (No. 2023M730408)

References

[1] Kabisch, N., van den Bosch, M., & Lafortezza, R. (2017). The health benefits of nature-based solutions to urbanization challenges for children and the elderly–A systematic review. *Environmental Research*, vol. 159, pp. 362-373.

[2] Li, Z., Fan, Z., Song, Y., & Chai, Y. (2021). Assessing equity in park accessibility using a travel behavior-based G2SFCA method in Nanjing, China. *Journal of Transport Geography*, vol. 96, 103179.

[3] Long, Y., Qin, J., Wu, Y., & Wang, K. (2023). Analysis of urban park accessibility based on space syntax: Take the urban area of Changsha City as an example. *Land,* vol. 12(5), 1061.

[4] Wang, X., Meng, Q., Liu, X., Allam, M., Zhang, L., Hu, X., Bi, Y., & Jancsó, T. (2023). Evaluation of fairness of urban park green space based on an improved supply model of green space: A case study of Beijing central city. *Remote Sensing*, vol. 15(1), 244.

[5] Wang, Y., Shen, J., & Xiang, W. (2018). Ecosystem service of green infrastructure for adaptation to urban growth: Function and configuration. *Ecosystem Health and Sustainability*, vol. 4(5), pp. 132-143.

[6] Ji, Y., Zhang, L., Liu, J., Zhong, Q., & Zhang, X. (2020). Optimizing spatial distribution of urban green spaces by balancing supply and demand for ecosystem services. *Journal of Chemistry*, pp. 1-8.

[7] Fisher, B., Turner, K. R., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, vol. 68(3), pp. 643-653.

[8] Zheng, Y., Wang, S., Zhu, J., Huang, S., Cheng, L., Dong, J., & Sun, Y. A. (2023). Comprehensive evaluation of supply and demand in urban parks along "Luck Greenway" in Fuzhou. *Sustainability*, vol. 15(3), 2250.

[9] Zhang, J., & Tan, P. Y. (2023). Assessment of spatial equity of urban park distribution from the perspective of supply-demand interactions. *Urban Forestry & Urban Greening*, vol. 80, 127827.

[10] Liu, B., Tian, Y., Guo, M., Tran, D., Alwah, A. A. Q., & Xu, D. (2022). Evaluating the disparity between supply and demand of park green space using a multi-dimensional spatial equity evaluation framework. *Cities*, vol. 121, 103484.

[11] Wang, C., Wang, S., Cao, Y., Yan, H., & Li, Y. (2023). The social equity of urban parks in high-density urban areas: A case study in the core area of Beijing. *Sustainability*, vol. 15(18), 13849.

[12] Xia, G., He, G., & Zhang, X. (2024). Assessing the spatial equity of urban park green space layout from the perspective of resident heterogeneity. *Sustainability*, vol. 16(13), 5631.

[13] Zhao, K., Chen, C., Wang, J., Liu, K., Wu, F., & Cao, X. (2024). Examining the spatial mode, supply–demand relationship, and driving mechanism of urban park green space: A case study from China. *Forests*, vol. 15(1), 131.

[14] Cao, Y., Li, Y., Shen, S., Wang, W., Peng, X., Chen, J., Liao, J., Lv, X., Liu, Y., Ma, L., Hu, G., Jiang, J., Sun, D., Jiang, Q., & Liao, Q. (2024). Mapping urban green equity and analysing its impacted mechanisms: A novel approach. *Sustainable Cities and Society*, vol. 101, 105071.

[15] Baden, M. B., Noonan, S. D., & Turaga, R. M. R. (2007). Scales of justice: Is there a geographic bias in environmental equity analysis? *Journal of Environmental Planning and Management*, vol. 50(2), pp. 163-185.

[16] Xu, C., Haase, D., Pribadi, D. O., & Pauleit, S. (2018). Spatial variation of green space equity and its relation with urban dynamics: A case study in the region of Munich. *Ecological Indicators*, vol. 93, pp. 512-523.

[17] Tan, P. Y., & Samsudin, R. (2017). Effects of spatial scale on assessment of spatial equity of urban park provision. *Landscape and Urban Planning*, vol. 158, pp. 139-154.

[18] Tan, C., Tang, Y., & Wu, X. (2019). Evaluation of the equity of urban park green space based on population data spatialization: A case study of a central area of Wuhan, China. *Sensors (Basel, Switzerland)*, vol. 19(13), 2929.

[19] Zhang, Y., Wu, Q., Wu, L., & Li, Y. (2021). Measuring community green inequity: A fine-scale assessment of Beijing urban area. *Land (Basel)*, vol. 10(11), 1197.

[20] Shen, Y., Sun, F., & Che, Y. (2017). Public green spaces and human wellbeing: Mapping the spatial inequity and mismatching status of public green space in the central city of Shanghai. *Urban Forestry & Urban Greening*, vol. 27, pp. 59-68.

[21] Xiao, Y., Wang, Z., Li, Z., & Tang, Z. (2017). An assessment of urban park access in Shanghai – Implications for the social equity in urban China. *Landscape and Urban Planning*, vol. 157, pp. 383-393.

[22] Dai, D. (2011). Racial/ethnic and socioeconomic disparities in urban green space accessibility: Where to intervene? *Landscape and Urban Planning*, vol. 102(4), pp. 234-244.

[23] Liu, Y., Fan, P., Yue, W., Huang, J., Li, D., & Tian, Z. (2019). Assessing polycentric urban development in mountainous cities: The case of Chongqing Metropolitan Area, China. *Sustainability*, vol. 11(10), 2790.

[24] Xie, C., Zhao, M., Li, Y., Tang, T., Meng, Z., & Ding, Y. (2023). Evaluating the effectiveness of environmental interpretation in national parks based on visitors' spatiotemporal behavior and emotional experience: A case study of Pudacuo National Park, China. *Sustainability*, vol. 15(10), 8027.

[25] Vichiensan, V., & Nakamura, K. (2021). Walkability perception in Asian cities: A comparative study in Bangkok and Nagoya. *Sustainability*, vol. 13(12), 6825.

[26] Al-Hagla, K. (2009). Evaluating new urbanism's walkability performance: A comprehensive approach to assessment in Saifi Village, Beirut, Lebanon. *Urban Design International*, vol. 14(3), pp. 139-151.

[27] Ma, Y., Brindley, P., & Lange, E. (2022). The influence of socio-demographic factors on preference and park usage in Guangzhou, China. *Land*, vol. 11(8), 1219.

[28] Bao, Z., Bai, Y., & Geng, T. (2023). Examining spatial inequalities in public green space accessibility: A focus on disadvantaged groups in England. *Sustainability*, vol. 15(18), 13507.

[29] Kaczynski, A. T., Besenyi, G. M., Stanis, S. A. W., Koohsari, M. J., Oestman, K. B., Bergstrom, R., Potwarka, L. R., & Reis, R. S. (2014). Are park proximity and park features related to park use and park-based physical activity among adults? Variations by multiple socio-demographic characteristics. *The International Journal of Behavioral Nutrition and Physical Activity*, vol. 11(1), 146.

[30] Besenyi, G. M., Kaczynski, A. T., Wilhelm Stanis, S. A., Bergstrom, R., Oestman, K. B., & Colabianchi, N. (2016). Sex differences in the relationship between park proximity and features and child and youth physical activity. *Children, Youth and Environments*, vol. 26(1), pp. 56-84.

[31] Zheng, Z., Zhang, Z., & Wang, S. (2023). Measurement and development of park green space supply and demand based on community units: The example of Beijing's Daxing New Town. *Land*, vol. 12(5), 943.

[32] Lu, J. W., & Wang, H. S. (2007). *Mountain architectural design*. Beijing: China Construction Industry Press.

[33] Schröter, M., Barton, D. N., Remme, R. P., & Hein, L. (2014). Accounting for capacity and flow of ecosystem services: A conceptual model and a case study for Telemark, Norway. *Ecological Indicators*, vol. 36, pp. 539-551.

[34] Wang, J., & Zhou, J. (2022). Spatial evaluation of the accessibility of public service facilities in Shanghai: A community differentiation perspective. *PloS One*, vol. 17(5), e0268862.

[35] Song, G., He, X., Kong, Y., Li, K., Song, H., Zhai, S., & Luo, J. (2022). Improving the spatial accessibility of community-level healthcare service toward the '15-minute city' goal in China. *ISPRS International Journal of Geo-Information*, vol. 11(8), 436.

[36] Jin, Y., He, R., Hong, J., Luo, D., & Xiong, G. (2023). Assessing the accessibility and equity of urban green spaces from supply and demand perspectives: A case study of a mountainous city in China. *Land*, vol. 12(9), 1793.

[37] Huang, S., Wang, C., Deng, M., & Chen, Y. (2023). Coupling coordination between park green space (PGS) and socioeconomic deprivation (SED) in high-density city based on multi-scale: From environmental justice perspective. *Land*, vol. 12(1), 82.

[38] Tang, H., Yan, J., & Zheng, C. (2023). Supply-demand matching and coupling coordination characteristics of urban park green space from a health perspective. *Intelligent Buildings International (London), ahead-of-print*, pp. 1-15.

[39] Wang, Z. H., Yan, G. G., & Wang, S. Y. (2023). Fairness evaluation of landscape justice in urban park green space: A case study of the Daxing part of Yizhuang New Town, Beijing. *Sustainability,* vol. 15(1), 370.

[40] Nesbitt, L., Meitner, M. J., Girling, C., et al. (2019). Who has access to urban vegetation? A spatial analysis of distributional green equity in 10 US cities. *Landscape and Urban Planning*, vol. 181, pp. 51-79.

[41] Xiaomin, G., Chuanglin, F., Xufang, M., & Dan, C. (2022). Coupling and coordination analysis of urbanization and ecosystem service value in Beijing-Tianjin-Hebei urban agglomeration. *Ecological Indicators*, vol. 137, 108782.

[42] Yang, M., Zhao, X., Wu, P., Hu, P., & Gao, X. (2022). Quantification and spatially explicit driving forces of the incoordination between ecosystem service supply and social demand at a regional scale. *Ecological Indicators*, vol. 137, 108764.

[43] Tong, A., Qian, X., Xu, L., Wu, Y., Ma, Q., Shi, Y., Feng, M., & Lu, Z. (2023). Demand-led optimization of urban park services. *Forests, vol. 14*(12), 2371.

[44] Li, Z., Bai, X., Xu, Z., Ma, H., Xu, Y., Wang, N., & Yue, X. (2023). The optimal spatial delineation method for the service level of urban park green space from the perspective of opportunity equity. *Environmental Science and Pollution Research International*, vol. 30(36), pp. 85520-85533.

[45] Samuelsen, J., Chen, W., & Wasson, B. (2019). Integrating multiple data sources for learning analytics—review of literature. *Research and Practice in Technology Enhanced Learning*, vol. 14(1), pp. 1-20.

[46] Cao, S., Du, S., Yang, S., & Du, S. (2021). Functional classification of urban parks based on urban functional zone and crowd-sourced geographical data. *ISPRS International Journal of Geo-Information*, vol. 10(12), 824.