

Multiscale Variations in Spatial Equity of Public Parks and Their Influencing Factors

Lihua CHEN¹, Yunfeng JIN², Nan TAO^{3,*}

¹ School of Architecture and Civil Engineering, Jinggangshan University, Ji'an 343009, China

² College of Architecture and Urban Planning, Tongji University, Shanghai 200092, China

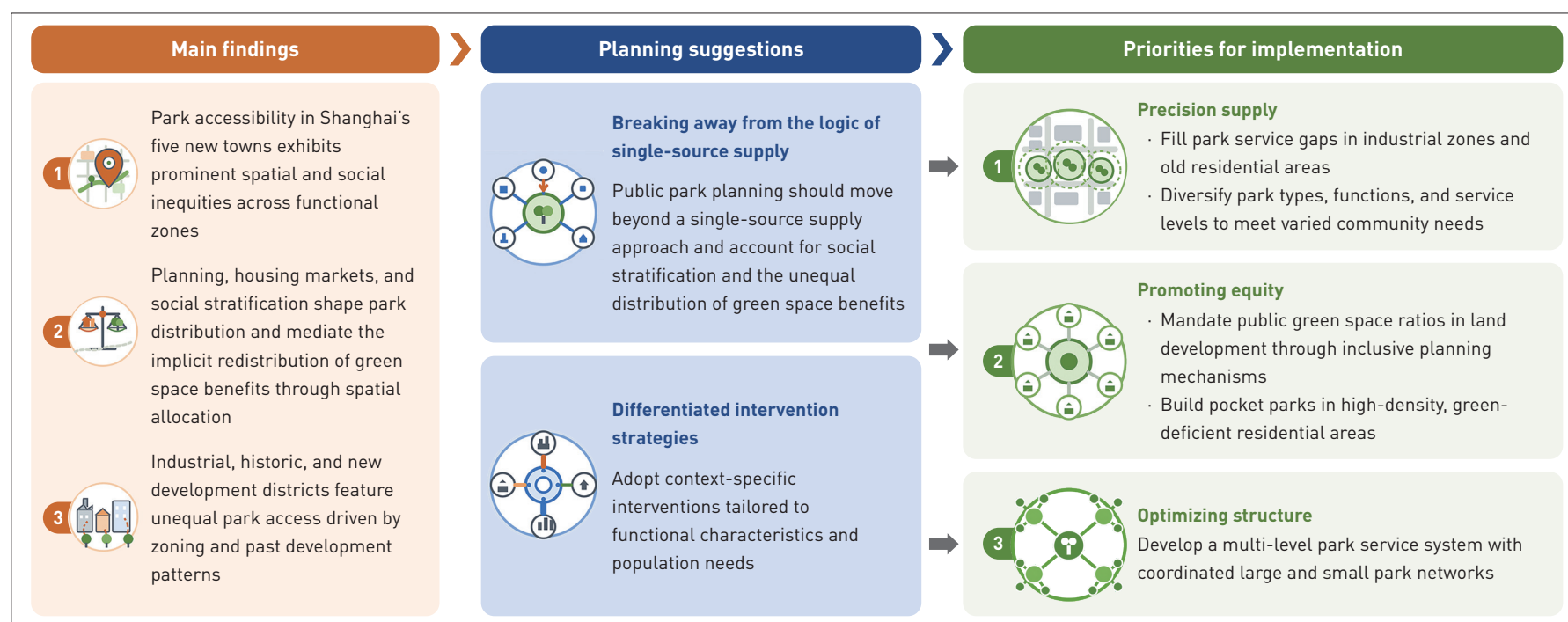
³ School of Architecture and Urban Planning, Kunming University of Science and Technology, Kunming 650500, China

*CORRESPONDING AUTHOR

Address: 727 Jingming South Road, Chenggong District, Kunming 650500, China

Email: taonan5599@qq.com

GRAPHICAL ABSTRACT



ABSTRACT

Against the backdrop of urban development shifting from urban expansion planning to the regeneration of existing urban areas, this study analyzes spatial equity disparities in public parks and their influencing factors from the perspective of urban spatial heterogeneity. Using 86 parks within five new towns in Shanghai, this study constructs an accessibility analysis framework based on an improved Gaussian two-step floating catchment area (G2SFCA) method. This framework evaluates the spatial equity characteristics of public parks at different urban scales and explores associations between residential and subdistrict attributes and spatial equity. The findings reveal that: 1) Spatial equity in

public parks exhibits overall characteristics of “functional unit differentiation,” “scale differentiation,” and “income differentiation.” Accessibility to community parks is most significantly influenced by human activity density, while accessibility to pocket parks is closely correlated with socioeconomic status. 2) The planning logic of “prioritizing production over living” in new town industrial zones, path dependencies in old district regeneration, and the overall forward-looking layout of newly developed areas collectively shape differentiated access opportunities to public parks. Their spatial resources undergo redistribution under the influence of new town planning supply logic and housing market differentiation.

3) Future strategies should enhance targeted park supply across diverse functional zones, balance access to park types for different income groups through planning measures, and optimize layouts by establishing multi-tiered park service systems. This research provides methods and strategies for studying differentiated park equity and planning responses within heterogeneous urban spaces.

KEYWORDS

Public Park; Multiscale Accessibility Measurement; Spatial Equity; Influencing Factors; Shanghai New Towns; Functional Spaces

HIGHLIGHTS

- Construct a multiscale framework for public park spatial equity evaluation
- Use multiscale analysis to identify spatial equity disparities in public parks and associated factors
- Provide strategies for equitable park provision in cities with high functional spatial heterogeneity

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1 Research Background

Equity in public park provision has emerged as a major topic in urban research worldwide. International scholarship has increasingly focused on the growing spatial heterogeneity and social differentiation within cities^[1]. The spatial differentiation of

functional units, such as old urban areas, new development zones, and industrial zones^[2], has shaped diverse patterns of population density, social structure, age composition, and spatiotemporal behavior^[3]. As key public service facilities that support ecological regulation, recreation^[4-5], and social equity^[6-7], public parks are unevenly distributed across urban space, directly affecting the extent to which the recreational needs of different population groups are met^[8-9], thus becoming a major concern in urban research worldwide. International experience has shown that, in the absence of fine-grained and differentiated provision strategies responsive to spatial heterogeneity, inequities in public park services may further exacerbate existing social inequalities and weaken the social foundations of sustainable urban development^[10-11].

Against this global backdrop, Chinese cities are undergoing a complex transition in which urban expansion planning and regeneration of existing urban areas coexist. Under prevailing urban planning paradigms, effectively addressing spatial imbalances in the allocation of public park resources has become an urgent policy challenge. Current approaches to measuring public park accessibility include buffer analysis^[12], network analysis^[13-14], space syntax^[15], gravity models^[16-17], and the two-step floating catchment area (2SFCA) method^[18-19]. However, most existing studies characterize public park accessibility using a single spatial scale, Euclidean distance, or a uniform catchment radius^[20-21], with limited attention to accessibility patterns within clearly differentiated urban areas such as industrial zones and historical zones. As a result, these approaches are poorly suited to complex supply-demand contexts shaped by interacting factors such as pronounced functional zoning and income differentiation. Addressing this gap requires more fine-grained methods to systematically reveal disparities in the spatial equity of public park resource allocation across multiple urban scales and assess the extent of these disparities^[22-23], thereby providing a scientific basis for improving high-quality human settlements in the context of urban regeneration.

The Jiading, Qingpu, Songjiang, Nanhui, and Fengxian New Towns in Shanghai, identified in the Shanghai Master Plan 2017–2035 (the “Shanghai 2035 Master Plan” hereafter) as important strategic nodes in Shanghai’s development^[24-25], are characterized by both high-density built environments and rapid urban regeneration. These characteristics make them ideal settings for testing theories of fine-grained and differentiated public park provision. However, under the influence of established new-town planning paradigms, the spatial distribution of public parks remains uneven. The degree of equity in residents’ access to public parks and the factors

shaping that equity remain poorly understood^[26]. Accordingly, this study focuses on public parks in Shanghai’s five new towns and develops a multiscale accessibility assessment framework encompassing the “residential community–subdistrict–functional unit” levels. The framework is used to examine variations in the spatial equity of public parks systematically. Correlation analysis and a random forest model are then employed to identify the key factors influencing public park spatial equity at different scales and to assess the strength of their associations.

2 Research Methods

2.1 Study Area

Planning for Shanghai’s new towns has generally followed a functionalist paradigm, in which spatial form is organized primarily according to land-use functions. This approach has resulted in common problems such as oversized spatial blocks and relatively homogeneous functions^[27–28]. As typical cases characterized by pronounced functional-unit zoning, Shanghai’s new towns exhibit clear internal functional differentiation. Based on existing studies of functional positioning and relevant planning documents, including the Shanghai 2035 Master Plan, the Guidelines for the Planning and Development of Shanghai’s New Towns, and the urban design plans for Shanghai’s five new towns, the dominant functions within these new towns can be classified into three types of functional units: historic zones (Group A), new development zones (Group B), and industrial zones (Group C)^[29].

On this basis, the study area was defined as the 26 subdistricts within Shanghai’s five new towns. Two main considerations guided the delineation of urban functional units. First, the planning and development of Shanghai’s New Towns have been strongly shaped by a spatial organization model based on planned zoning, resulting in relatively distinct differences among functional areas in terms of spatial structure and development orientation. Second, most of Shanghai’s new towns have evolved from existing urban settlements, with subsequent expansion into newly developed areas and the allocation of industrial spaces. Their internal areas can therefore be further grouped into 3 types of functional units: historic zones, new development zones, and industrial zones. Given the marked differences in their primary functions—including residential, commercial, administrative, and production activities—subdistricts differ in their functional orientation, as do residents’ preferences for recreational use of public parks. Based on the Shanghai Street Design Guidelines^[30] and relevant studies on the identification of subdistrict functional types^[31], the subdistricts

were classified into 3 categories: 1) community-oriented subdistricts, primarily located in historic zones that developed from existing urban settlements and dominated by residential functions; 2) comprehensive service-oriented subdistricts, primarily located in new development zones formed through the planned expansion of the New Towns and characterized by a mix of residential, commercial, and administrative functions; and 3) industrial support service subdistricts, primarily located in industrial zones dominated by industrial production functions (Table 1, Fig. 1).

2.2 Research Data Processing

2.2.1 Public Park Data

The Shanghai Special Plan for Ecological Space (2021–2035) establishes, with the aim of enhancing service capacity, a multilevel urban–rural park system comprising national parks, country parks (regional-level parks, $\geq 400 \text{ hm}^2$), urban parks ($\geq 10 \text{ hm}^2$), regional parks ($\geq 4 \text{ hm}^2$), community parks ($\geq 0.3 \text{ hm}^2$), and micro (pocket) parks ($\geq 400 \text{ m}^2$)^[32]. The plan also seeks to make full use of the ecological resources of the new towns, to ensure that residents can reach a park within a 5-minute walk^[25].

On this basis, the types and hierarchy of the sampled public parks were determined. The samples were drawn from the list of parks specifically rated by the Shanghai Municipal Park Management Affairs Center. Specifically, the study used the list of star-rated urban parks, which provides information on park area, location, and type. High-quality environments, well-developed facilities, and standardized service and management generally characterize these parks. They also tend to exhibit relatively high

Table 1: Subdistricts included in the three subdistrict types

Subdistrict type	Subdistricts included
Community-oriented subdistrict	Juyuan New Area; Jiading Town Subdistrict; Xincheng Road Subdistrict; Nanqiao Town; Jinhai Subdistrict; Yueyang Subdistrict; Yongfeng Subdistrict; Yingpu Subdistrict; Xiayang Subdistrict
Comprehensive service-oriented subdistrict	Malu Town; Nanhui New Town; Jinhui Town; Fangsong Subdistrict; Zhaoxiang Town
Industrial support service subdistrict	Xuhang Town; Waigang Town; Anting Town; Shuyuan Town; Nicheng Town; Wanxiang Town; Situan Town; Fengpu Subdistrict; Zhongshan Subdistrict; Guangfulin Subdistrict; Chedun Town; Xianghuaqiao Subdistrict

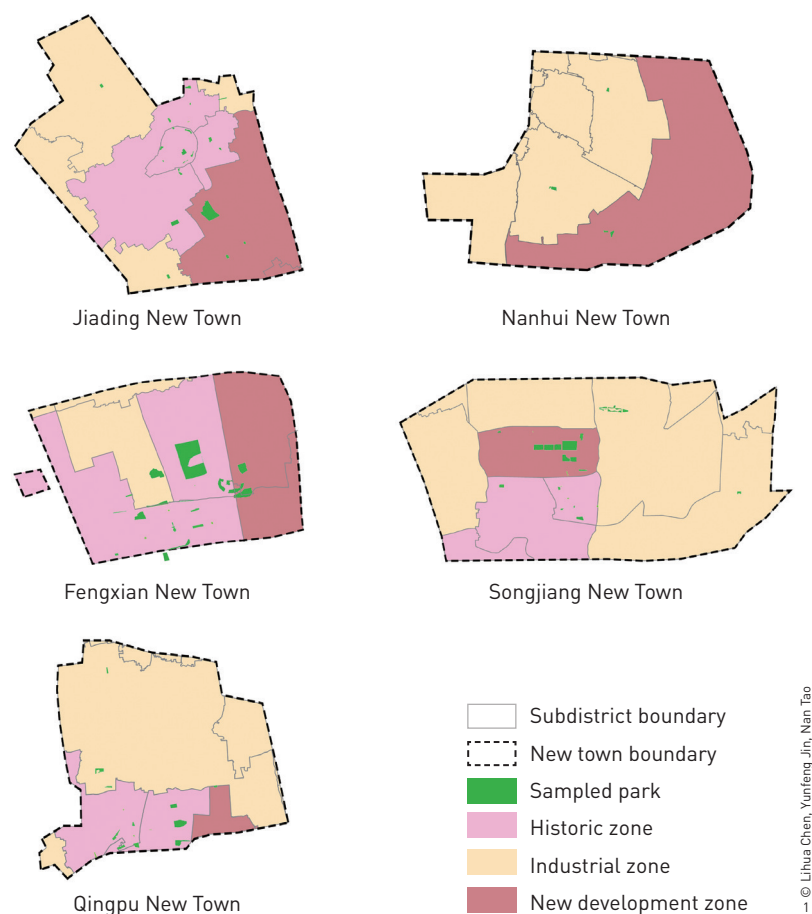


Fig. 1 Study area, sampled parks, and functional units of Shanghai's new towns.

spatial attractiveness and a strong capacity to meet residents' recreational needs, making them representative of the level of park service provision. Ultimately, 86 public parks within Shanghai's five new towns were included in the study, comprising 28 regional parks, 44 community parks, and 14 pocket parks (Fig. 1).

2.2.2 Residential Community Data

Residential community data included resident population and residential attributes. Resident population served as the demand-side data for evaluating public park accessibility, while residential attributes were used as explanatory factors in the analysis of public park spatial equity. The data were obtained from the Anjuke platform and collected in 2022, covering key information for residential communities within Shanghai's five new towns, including community name, total number of households, built-environment characteristics (i.e., green space ratio, floor area ratio), average housing price, and property management fee. In 2022, following the full implementation of the Shanghai 2035 Master Plan, the five new towns were transitioning from planning blueprints to

large-scale development. Data from this period therefore provide a representative snapshot of actual residential conditions during this transition. After data cleaning, 1,667 residential communities were identified within the study area, comprising 1,003,646 households. Based on the average household size of 2.32 persons reported in Shanghai's Seventh National Population Census, the total permanent resident population within the study area was estimated at approximately 2,328,459.

Housing prices in residential communities are commonly used as a proxy for residents' socioeconomic status^[33–34]. In this study, ordinary kriging interpolation was applied to characterize the spatial distribution of housing prices across residential areas^[35]. The resulting housing-price surface was then classified using the Jenks natural breaks method into three categories—low-income, middle-income, and high-income residential communities—to represent socioeconomic differentiation among residents across the new towns (Fig. 2).

2.3 Research Methods

2.3.1 Multiscale Accessibility Measurement for Public Park Spatial Equity Assessment

This study develops an analytical framework for examining differences in public park spatial equity through accessibility assessment across multiple urban spatial units—"residential community-subdistrict-functional unit." Moving progressively from micro- to meso- and macro-scale perspectives, the framework reveals how public park spatial equity varies across urban scales. Specifically, it evaluates daily-use equity at the residential-community level, basic-provision equity at the subdistrict level, and regional structural equity at the urban functional-unit level. This multiscale approach enables a comprehensive understanding of the supply-demand relationship between public park resources and population distribution within the city, while also enriching the multilevel analytical framework for environmental justice in public park provision (Fig. 3).

At present, the spatial equity of public parks is commonly assessed through accessibility analysis^[36–37], typically using Euclidean distance^[38] or network distance^[39]. However, these approaches have several limitations. First, they often fail to adequately account for residents' actual travel routes to parks across different modes of transportation, limiting their ability to reflect residents' access to public parks accurately. Second, applying a uniform catchment radius to all supply locations overlooks differences in service capacity among different types of public parks and cannot adequately capture heterogeneity in the intensity

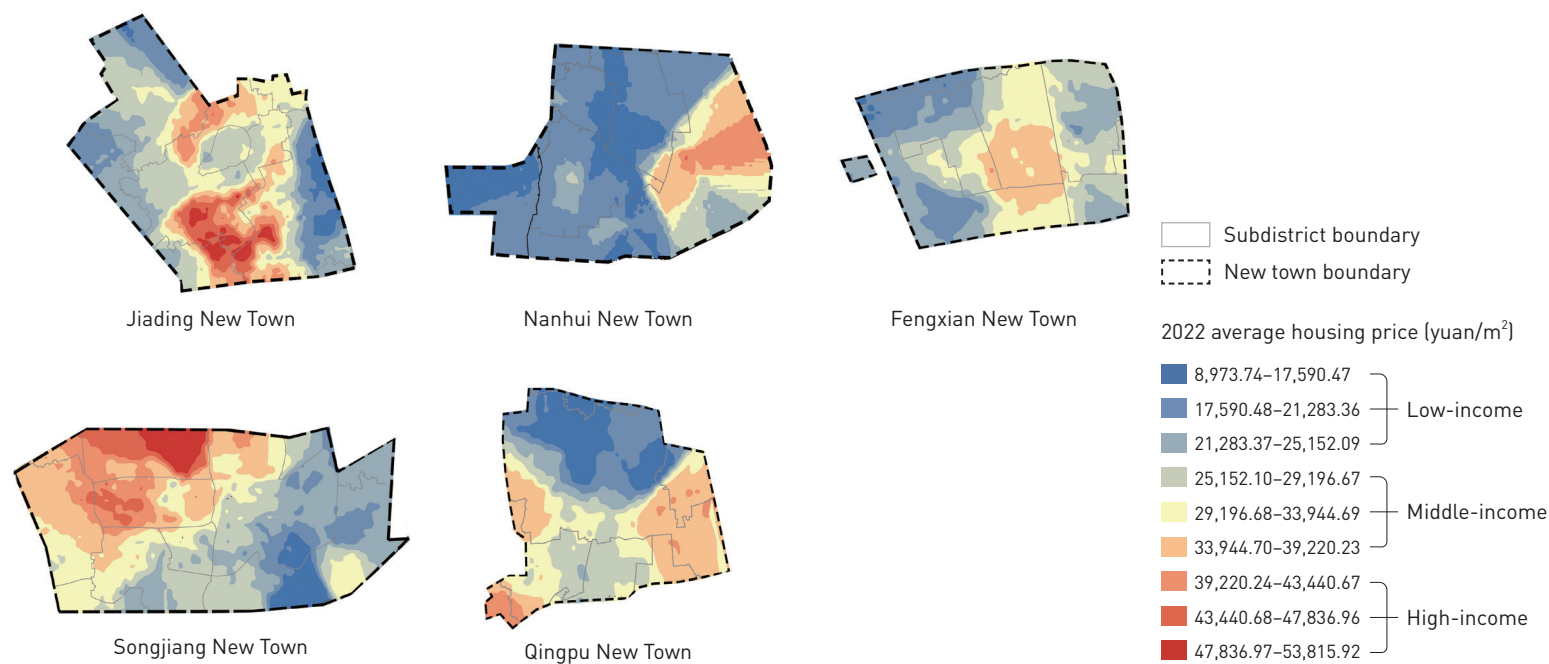
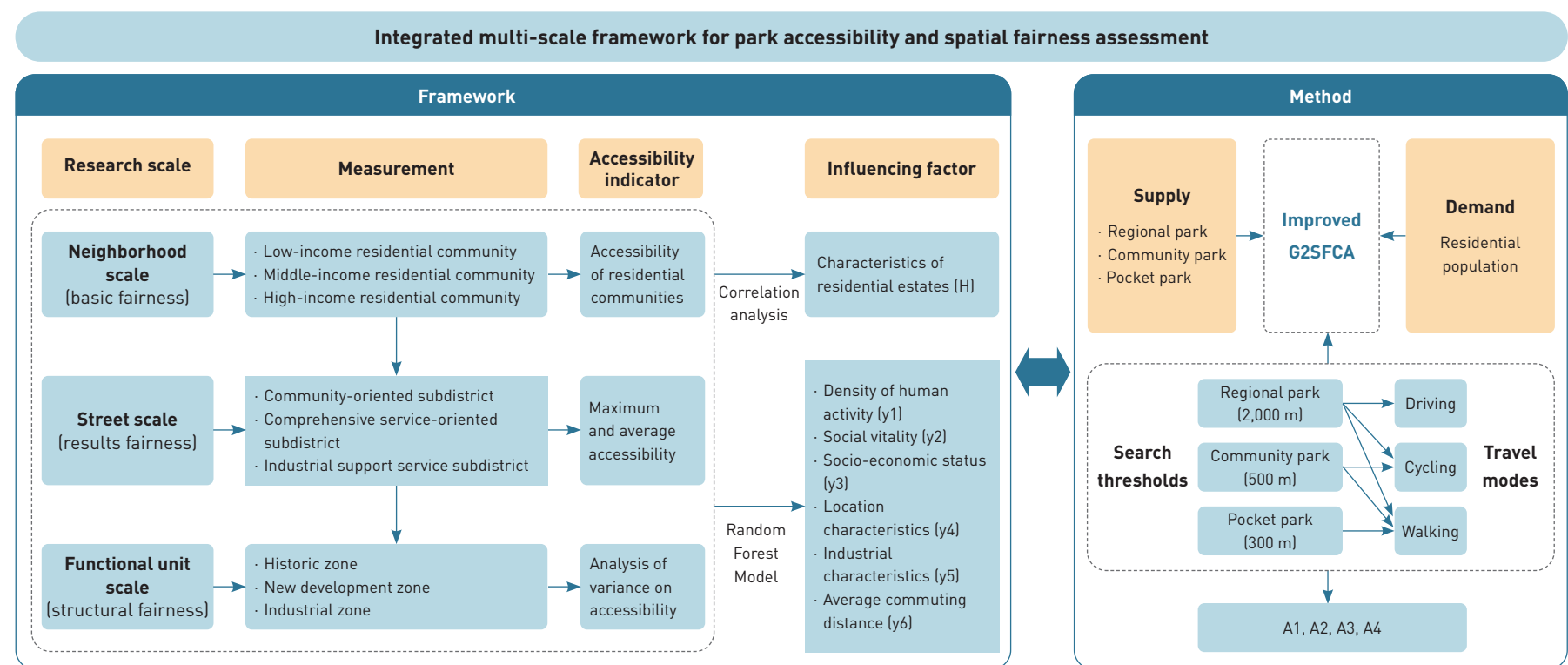


Fig. 2 Spatial distribution of housing prices across residential communities in Shanghai's new towns.

Fig. 3 Analytical framework for public park spatial equity based on multiscale accessibility measurement across residential communities, subdistricts, and urban functional units.

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of residents' demand^[40]. To address these limitations, this study employs an improved G2SFCA method to measure accessibility. By introducing differentiated service catchment radii and refining the representation of travel-mode choices, the method improves the spatial precision of public park accessibility measurement.

This study applies the G2SFCA method that incorporates both public park supply locations and residential demand locations^[41], with public park accessibility calculated in two steps^[17]. Compared

with the conventional approach, two major improvements were introduced. 1) Residents' actual travel behavior was more realistically represented by simulating travel routes. Using the route-planning application programming interface (API) provided by an online mapping service, batch queries were performed to determine travel routes from residential-community demand locations to public parks within the corresponding service catchments. The catchment delineation was further refined by

incorporating actual travel routes under three transport modes: walking, cycling, and driving. 2) Following the service-radius standards for public green spaces specified in the *Technical Guidelines for Shanghai Regulatory Detailed Planning (2016)*^[42], the service radii were set at 2,000 m for regional parks (by walking, cycling, and driving), 500 m for community parks (by walking and cycling), and 300 m for pocket parks (by walking).

Step 1: The centroid of each public park j was identified, and a spatial catchment area is established based on a specified distance threshold d_0 . All residential demand points k located within this catchment area were identified, and their resident populations were aggregated. Following the Gaussian function, weights were assigned according to distance decay effects. The weighted population within the catchment area was then summed to calculate the supply-demand ratio R_j :

$$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \leq d_0\}} G(d_{kj}, d_0) D_k}, \quad (1)$$

where D_k denotes the population at demand point k , estimated in this study using residential population data derived from Anjuke; d_{kj} is the road-network distance between locations k and j , with demand point k included in the catchment area when $d_{kj} \leq d_0$; S_j denotes the area of public park j ; and $G(d_{kj})$ is the Gaussian distance-decay function used to account for spatial impedance. The function is defined as follows:

$$G(d_{kj}, d_0) = \begin{cases} \frac{e^{-\frac{1}{2}\left(\frac{d_{kj}}{d_0}\right)^2} - e^{-\frac{1}{2}}}{1 - e^{-\frac{1}{2}}}, & d_{kj} \leq d_0. \\ 0, & d_{kj} > d_0 \end{cases} \quad (2)$$

Step 2: For each residential demand point k , a spatial catchment area was defined using the distance threshold d_0 . All public parks j located within this catchment were identified, and their supply-demand ratios R_j were weighted using the Gaussian distance-decay function and then summed. The resulting value represents the distance-cost-based public park accessibility A_i^F at demand point (k):

$$A_i^F = \sum_{j: d_{ij} \leq d_0} G(d_{ij}, d_0) R_j. \quad (3)$$

In the equation, a larger value of A_i^F indicates higher public park accessibility. The final accessibility measures include overall public park accessibility by walking (A1), accessibility to regional parks (A2), accessibility to community parks (A3), and accessibility to pocket parks (A4).

Public park accessibility was visualized in ArcGIS using inverse

distance weighted (IDW) interpolation, with a variable search radius based on 12 points and a power parameter of 2. In the environment settings, both the processing extent and mask were set to match the base map. The interpolated accessibility values were then classified into seven levels using the Jenks natural breaks method.

One-way analysis of variance (ANOVA) was used to examine whether an independent variable has a significant effect on a dependent variable. The total sum of squares (SST) can be decomposed into the between-group sum of squares (SSR) and the within-group sum of squares (SSE). The between-group variation reflects differences in the dependent variable associated with different levels of the independent variable, whereas the within-group variation represents variation attributable to random factors. When a significant overall difference was detected, Fisher's least significant difference (LSD) post hoc multiple-comparison test was typically conducted to identify specific differences among groups^[43]. In this study, one-way ANOVA was used to test whether the number of residential communities served by public parks differed significantly among different functional spaces.

2.3.2 Multiscale Analysis of Factors Associated With Public Park Spatial Accessibility

At the residential-community scale, Pearson correlation analysis was used to identify relationships between residential-community attributes and accessibility to different types of public parks. Correlation analysis assesses the association between quantitative variables in terms of both the presence and strength of a relationship. Using SPSS, correlation coefficients can be interpreted by their magnitude and direction: the strength of association may range from no correlation to weak, moderate, or perfect correlation, while the direction may be positive or negative^[43]. In this study, residential-community attributes were grouped into two categories: housing price factors and built-environment factors. Housing price factors included the average housing price (H1) and the property management fee (H5). Built-environment factors were derived from the 2022 residential community dataset for Shanghai's five new towns, obtained from the Anjuke platform. They included residential population (H2), floor area ratio (H3), green space ratio (H4), year of completion (H6), and property-right duration (H7). These factors were used as explanatory variables to test their correlations with public park accessibility across residential communities.

Building on the Pearson correlation analysis, a random forest regression model was employed to further compare the relative contributions of residential-community attributes to public park accessibility through feature-importance analysis. Random forest

is an ensemble learning method based on bagging and consists of multiple decision trees^[44]. For regression tasks, multiple independent decision trees are constructed using bootstrap samples of the same dataset, with random subsets of predictor variables considered at each split. Their predictions are then aggregated to obtain the final model output^[44]. In this study, the random forest regression model was used to rank the feature importance of built-environment and housing-price attributes of residential communities in relation to public park accessibility, thereby identifying the relative importance of residential-community attributes associated with disparities in public park spatial equity.

At the subdistrict scale, drawing on previous studies of subdistrict characteristics such as urban population density, urban vitality, and urban form^[2-3], and considering factors including the development history, industrial functions, and locational characteristics of Shanghai’s new towns, this study selected 6 explanatory variables (y1–y6) representing key urban characteristics of the subdistricts. Bivariate correlation analyses were then conducted between these variables and public park accessibility within community-oriented, comprehensive service-oriented, and industrial support service subdistricts, respectively, to identify the subdistrict characteristics most strongly associated with variations in public park accessibility (Table 2).

Building on the subdistrict-scale analysis, linear regression was performed for the three functional units of Shanghai’s new towns—historic zones (Group A), new development zones (Group B), and industrial zones (Group C)—to examine the relationships between the key factors identified for different types of public park accessibility and the corresponding accessibility measures. The resulting coefficients of determination (R^2) were used to further assess the explanatory power of these key characteristics for explaining variations in public park accessibility at the functional-unit scale.

3 Results

3.1 Spatial Equity of Public Parks at the Residential-Community Scale

3.1.1 Overall Spatial Equity of Public Parks at the Residential-Community Scale

As shown in Table 3, regional parks had the highest level of walking accessibility, with 47.6% of residential communities located within the 2,000 m walking service range. Cycling ranked second, with 40.8% of residential communities having access to regional

Table 2: Factors associated with public park accessibility at the subdistrict scale and their definitions

Subdistrict-scale explanatory Factors	Definition of factors
Density of human activity (y1)	Represented by population density within the subdistrict
Social vitality (y2)	Number of points of interest (POIs) for major daily-life service facilities within the subdistrict
Socioeconomic status (y3)	Measured using the standardized average commodity housing price and the number of residents with a bachelor’s degree or above, with weights of 0.48 and 0.52, respectively
Locational characteristics (y4)	Travel distance from the subdistrict administrative center to Shanghai’s city center (i.e., People’s Square)
Industrial characteristics (y5)	Number of industrial enterprises per unit area of the subdistrict
Average commuting distance (y6)	Average home–work commuting origin–destination (OD) distance of public park visitors

Table 3: Statistics on residential community coverage by accessible public parks

Travel mode	Public park type	Number of residential communities meeting the accessibility standard (N)	Percentage of total residential communities (%)
Walking	Regional park	794	47.6
Driving	Regional park	653	39.2
Cycling	Regional park	680	40.8
Walking	Community park	150	9.0
Cycling	Community park	124	7.4
Walking	Pocket park	24	1.4

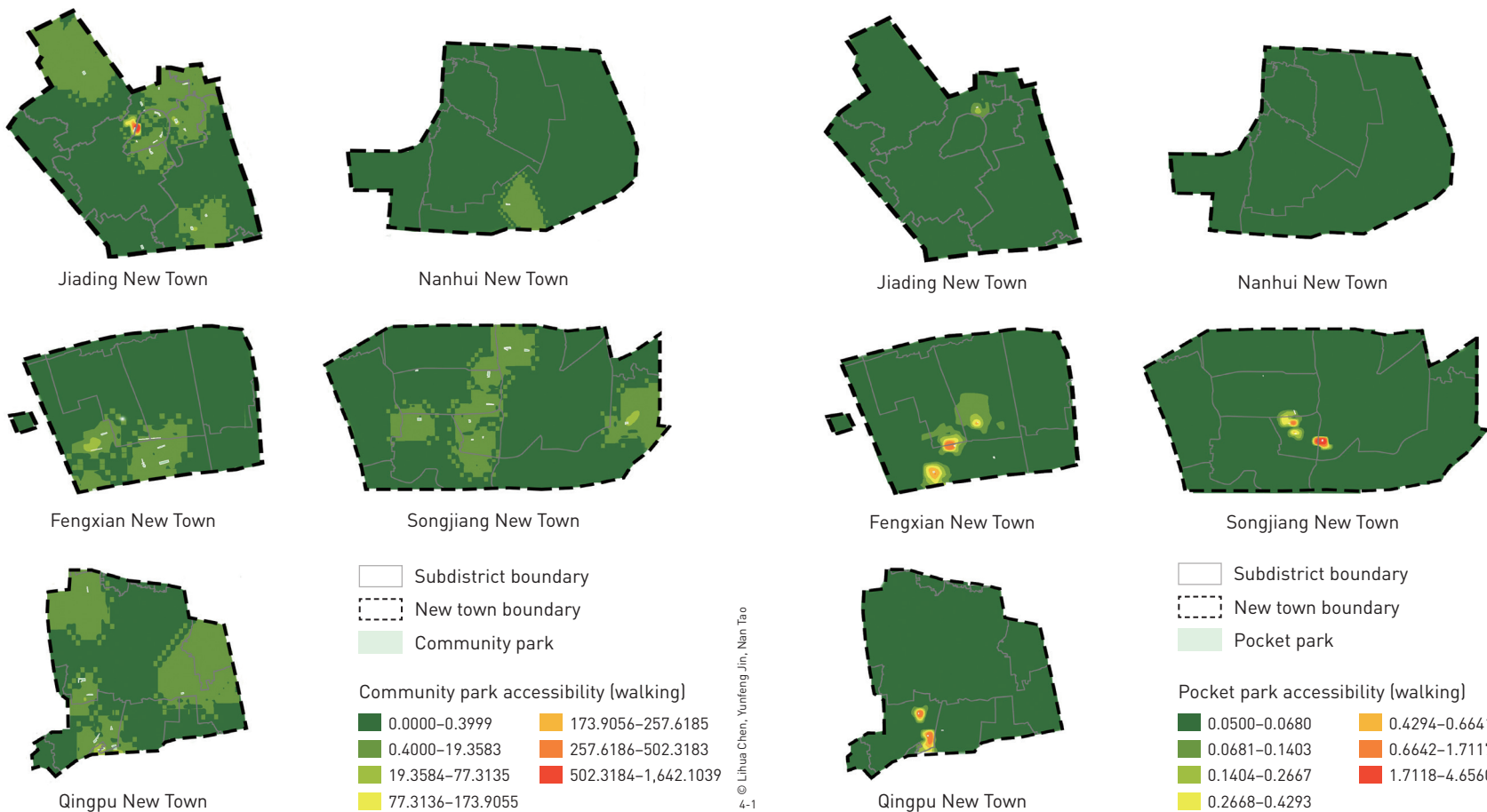
parks. In comparison, community parks and pocket parks showed lower rates of meeting the accessibility standard. For community parks, the number of residential communities meeting the accessibility standard by walking exceeded that by cycling.

3.1.2 Spatial Equity Disparities in Public Parks at the Residential-Community Scale

1) Low-income residential communities showed a strong spatial overlap with areas of high accessibility to pocket parks. As shown in Fig. 4, accessibility to pocket parks exhibited a highly localized spatial pattern, with only a few isolated high-accessibility peaks occurring at specific locations. Accessibility declined sharply around these peaks, resulting in extremely narrow service areas centered on individual high-accessibility points. This pattern indicates that pocket parks can serve nearby low-income residents. However, across the study area, the overall provision of pocket parks remains insufficient, and high-accessibility areas do not provide broad coverage of all concentrations of low-income residential communities. Consequently, the spatial equity of pocket park provision remains limited.

2) Middle-income residential communities showed a strong spatial overlap with areas of high accessibility to community parks. As shown in Fig. 5, accessibility to community parks exhibited a dispersed spatial pattern, with multiple independent high-accessibility patches scattered across the urban area. Each

Fig. 4 Accessibility to community parks by walking and cycling.
Fig. 5 Accessibility to pocket parks by walking.



patch had a limited spatial extent, with accessibility declining rapidly from its local peak toward the surrounding areas. This pattern can be attributed to the relatively small size and limited service radius of individual community parks, whose high-accessibility areas therefore cover only compact surrounding neighborhoods. Middle-income residential communities were concentrated within these localized service areas, resulting in a pronounced spatial correspondence between the two.

3) High-income residential communities showed a strong spatial overlap with areas of high accessibility to regional parks. As shown in Fig. 6, accessibility to regional parks exhibited a distinct spatial pattern: a single high-value core patch centered on each regional park, with accessibility gradually declining toward the periphery. This pattern can be attributed to the well-developed active-mobility networks surrounding regional parks and the high accessibility of park entrances, which result in substantially higher park accessibility by walking and cycling than by driving. Consequently, areas of high accessibility were largely confined to nearby residential areas, where high-income residential communities were

Fig. 6 Accessibility to regional parks via different travel modes.



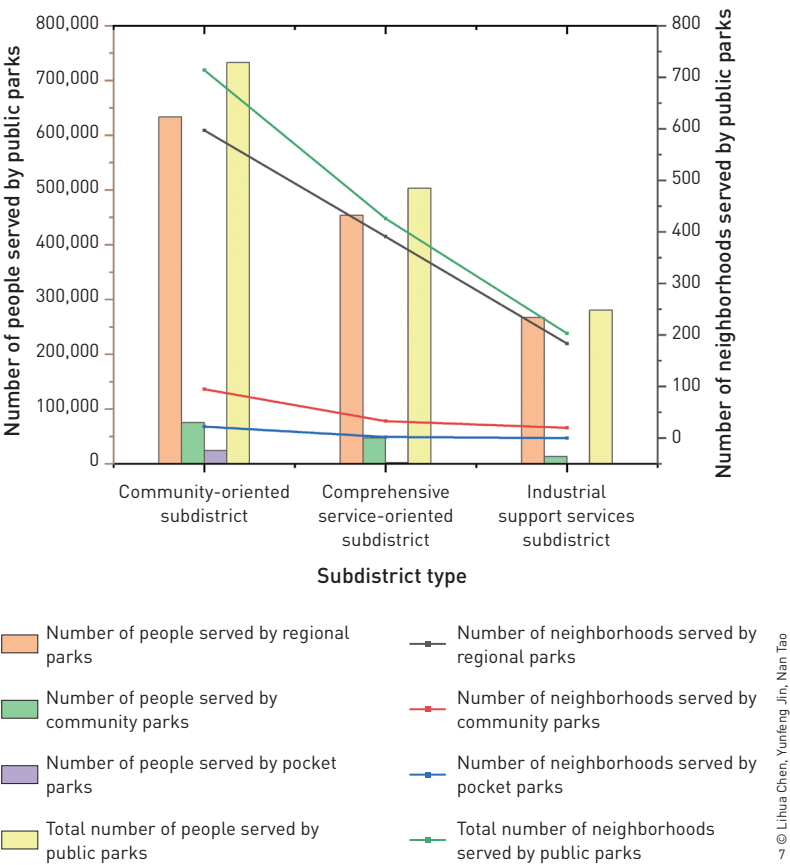
also concentrated, resulting in a pronounced spatial correspondence between the two.

3.2 Spatial Equity of Public Parks at the Subdistrict Scale

3.2.1 Overall Public Park Accessibility and Service Coverage at the Subdistrict Scale

Figure 7 shows a clear association between subdistrict function and the population and number of residential communities covered by public park services. Community-oriented subdistricts served 732,839 residents across 714 residential communities. Among the different park types, regional parks constituted the primary service providers, covering 633,509 residents and 597 residential communities. Comprehensive service-oriented subdistricts showed intermediate levels of service coverage, with public parks serving a total population of 503,247 across 426 residential communities. By contrast, industrial support service subdistricts recorded the lowest service coverage, serving only 280,425 residents across 203 residential communities. This pattern indicates that, as subdistrict functions shift from community-oriented services toward industrial support, both demand for public park services and the degree of

Fig. 7 Number of residential communities and population served by public parks across different subdistrict types.



population concentration decline correspondingly.

As shown in Table 4, four subdistricts fell into the “extremely high” or “very high” categories of overall walking accessibility to public parks, including one comprehensive service-oriented subdistrict and three community-oriented subdistricts. This distribution indicates relatively high levels of public park spatial equity in these two types of subdistricts. By contrast, industrial support service subdistricts were concentrated mainly in the “moderate,” “moderately low,” and “extremely low” accessibility categories, and most subdistricts classified as having “extremely low” accessibility were industrial support service subdistricts (Fig. 8).

3.2.2 Spatial Equity Disparities in Public Parks at the Subdistrict Scale

This subsection uses the maximum and mean values of public park accessibility to characterize differences in the distribution of accessibility across subdistricts (Fig. 9), thereby revealing variations

Table 4: Overall walking accessibility of public parks at the subdistrict scale

Accessibility Level	Subdistrict	Number of subdistricts (N)	Percentage of the total number of subdistricts (%)
Extremely high	Fangsong Subdistrict, Jiading Town Subdistrict	2	7.7
Very high	Nanqiao Town, Jinhai Subdistrict	2	7.7
High	Xiayang Subdistrict, Chedun Town, Fengpu Subdistrict, Xincheng Road Subdistrict	4	15.4
Moderately high	Yingpu Subdistrict, Yueyang Subdistrict, Shuyuan Town, Malu Town	4	15.4
Medium	Xianghuaqiao Subdistrict, Nicheng Town, Nanhui New Town	3	11.5
Moderately low	Zhongshan Subdistrict, Yongfeng Subdistrict, Guangfulin Subdistrict, Zhaoxiang Town, Anting Town, Juyuan New Area, Xuhang Town	7	26.9
Extremely low	Wanxiang Town, Situan Town, Jinhui Town, Waigang Town	4	15.4

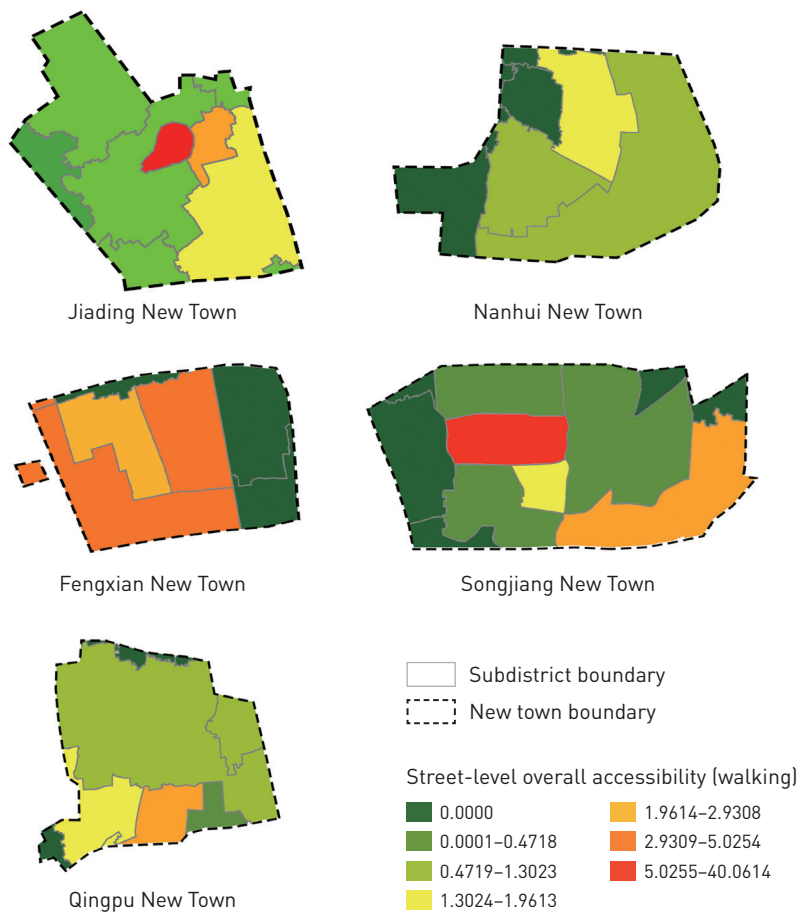


Fig. 8 Overall walking accessibility to public parks at the subdistrict scale.

Fig. 9 Mean and maximum accessibility of different types of public parks.

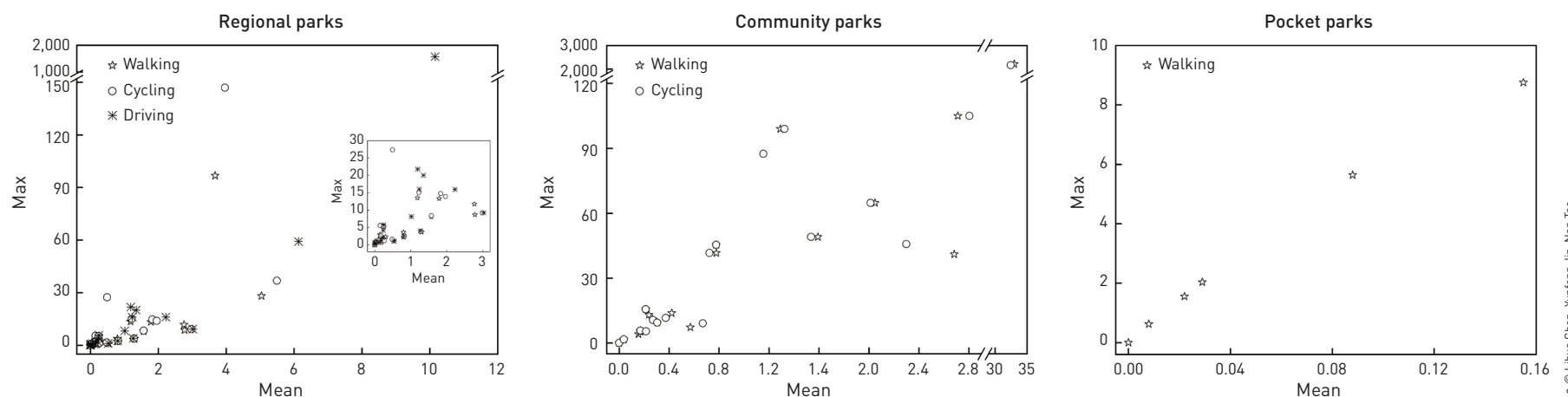
in public park spatial equity among subdistrict types. As shown in Fig. 9, for regional parks, both the mean and maximum values of walking accessibility were generally concentrated below 6. However, the maximum walking-accessibility values differed markedly from those for cycling and driving, indicating substantial variation in regional park accessibility across travel modes. For community parks, the mean accessibility values for walking and cycling

were generally similar, although the maximum values for cycling (or walking) were notably high in some subdistricts. For pocket parks, both the mean and maximum values of walking accessibility exhibited relatively concentrated distributions.

1) Regional park equity was relatively high in comprehensive service-oriented subdistricts. Overall, accessibility to regional parks differed markedly among the 3 types of subdistricts. Among the subdistricts ranking relatively high in walking accessibility, 5 were comprehensive service-oriented subdistricts, 2 were community-oriented subdistricts, and 3 were industrial support service subdistricts, indicating that regional park equity was generally higher in comprehensive service-oriented subdistricts than in the other two types. More specifically, Fangsong Subdistrict in Songjiang New Town recorded the highest walking accessibility to regional parks, with a maximum value of 28 and a mean value of 5. For cycling, the maximum and mean accessibility values were 36.8 and 5.5, respectively, while for driving they were 59.1 and 6.1, respectively.

2) Community park equity was markedly higher in community-oriented subdistricts than in the other subdistrict types. Among the subdistricts ranking relatively high in walking accessibility to community parks, 6 were community-oriented subdistricts, indicating that community park resources were relatively concentrated in this type of subdistrict and that their spatial equity was higher than in the other subdistrict types. However, the substantial gap between the maximum and mean accessibility values for community parks indicates persistent internal disparities. For pocket parks, the maximum and mean accessibility values also differed markedly, reaching 8.756 and 0.155, respectively.

3) Public park equity in industrial support service subdistricts was associated with the degree of industry-city integration. Overall, public park accessibility was relatively low in industrial support service subdistricts, although substantial variation was observed within this category. Chedun Town and Fengpu Subdistrict, both classified within



this functional type, exhibited “high” levels of public park accessibility, reflecting relatively high levels of industry–city integration.

3.3 Spatial Equity of Public Parks at the Functional-Unit Scale

3.3.1 Overall Spatial Equity of Public Parks Across Different Functional Units

Because walking-accessibility data were available for all three types of public parks, walking was selected as the common metric for overall accessibility. Overall accessibility was then calculated by summing public park accessibility values across different functional types of subdistricts. As shown in Fig. 10, the highest values of overall walking accessibility to public parks across Shanghai’s five new towns were concentrated mainly in new development zones and historic zones. By contrast, overall walking accessibility to public parks was generally lower in industrial zones. Nanhui New Town, which has developed on an industrial foundation and has undergone urban transformation for a relatively short period, exhibited generally low public park accessibility. Nevertheless, its public park services covered a relatively extensive area, extending to surrounding areas such as Nicheng Town and Shuyuan Town.

3.3.2 Variance Analysis of Public Park Equity at the Functional-Unit Scale

Analysis of variance (ANOVA) was used to compare differences in the number of residential communities and residents served by public parks among subdistricts in the Group A, Group B, and Group C of Shanghai’s New Towns (Table 5). The results showed that service coverage by community parks and pocket parks differed significantly among the functional units ($p < 0.05$), with the main differences



Fig. 10 Overall walking accessibility to public parks across different functional units.

occurring between Group A and Group C. Specifically, the number of residential communities served by community parks differed significantly between Groups A and C, with a mean difference of 9.653, indicating that community parks in historic-zone subdistricts

Table 5: Post hoc multiple comparisons

Dependent variable	Group (I)	Group (J)	Mean difference (I–J)	Standard error	Significance	95% Confidence interval	
						Lower bound	Upper bound
Number of residential communities served by community parks	A	B	5.275	4.068	0.210	–3.240	13.790
		C	9.653*	3.468	0.012	2.395	16.911
	B	A	–5.275	4.068	0.210	–13.790	3.240
		C	4.378	3.980	0.285	–3.953	12.709
	C	A	–9.653*	3.468	0.012	–16.911	–2.395
		B	–4.378	3.980	0.285	–12.709	3.954

(Continued)

Table 5: Post hoc multiple comparisons (Continued)

Dependent variable	Group (I)	Group (J)	Mean difference (I-J)	Standard error	Significance	95% Confidence interval	
						Lower bound	Upper bound
Number of residential communities served by pocket parks	A	B	2.350	1.189	0.063	-0.139	4.839
		C	2.750*	1.014	0.014	0.628	4.872
	B	A	-2.350	1.189	0.063	-4.839	0.139
		C	0.400	1.164	0.734	-2.036	2.836
	C	A	-2.750*	1.014	0.014	-4.872	-0.628
		B	-0.400	1.164	0.734	-2.836	2.036
Population served by pocket parks (persons)	A	B	2,575.400	1,446.656	0.091	-452.494	5,603.294
		C	2,992.000*	1,233.056	0.025	411.183	5,572.817
	B	A	-2,575.400	1,446.656	0.091	-5,603.294	452.494
		C	416.600	1,415.411	0.772	-2,545.889	3,379.089
	C	A	-2,992.000*	1,233.056	0.025	-5,572.817	-411.183
		B	-416.600	1,415.411	0.772	-3,379.089	2,545.889

NOTE

* indicates the mean difference is significant at the 0.05 level. Because the ANOVA showed no significant difference in the population served by community parks, this variable was not included in the post hoc analysis.

served significantly more residential communities than those in industrial-zone subdistricts. For pocket parks, both the number of residential communities and the number of residents served also differed significantly between Groups A and C, with mean differences of 2.750 and 2,992.000, respectively. Overall, the everyday service coverage of community parks and pocket parks in Shanghai’s new towns was clearly uneven between historic zones and industrial zones. In particular, industrial-zone subdistricts had relatively low numbers of residential communities and residents served by pocket parks, indicating scope for improving the provision of parks for everyday use.

4 Multiscale Analysis of Factors Associated With Public Park Equity

4.1 Residential Community-Scale Correlation and Feature Importance Analysis of Public Park Accessibility

Correlation analysis between public park accessibility and

residential attributes showed that accessibility to regional parks was positively correlated with average housing price, floor area ratio, and property management fee (Fig. 11). This suggests that higher-quality residential communities may have better access to regional park resources. In contrast, accessibility to pocket parks was not significantly correlated with the green space ratio of residential communities, indicating that the provision of pocket parks in Shanghai’s new towns tends to be greater in residential communities with relatively limited internal green space.

Feature-importance analysis based on the random forest models showed that the model for regional park accessibility achieved an R^2 of 0.29. In contrast, the models for pocket park, community park, and overall public park accessibility yielded R^2 values of -0.05, -0.01, and -0.01, respectively, all indicating poor model performance. These results suggest that variations in regional park accessibility may be more readily captured by the random forest model. Nevertheless, with an R^2 of approximately 0.3, the

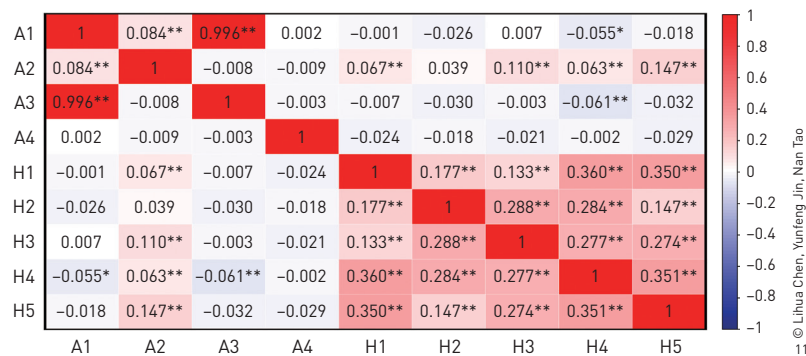


Fig. 11 Correlation analysis between public park accessibility and residential-community attributes (** indicates correlation is significant at the 0.01 level, * indicates correlation is significant at the 0.05 level).

model's explanatory power remains limited and requires further improvement. As shown in Table 6, property management fee, average housing price, and residential population emerged as relatively important features associated with variation in regional park accessibility.

4.2 Subdistrict-Scale Correlation Analysis of Public Park Accessibility

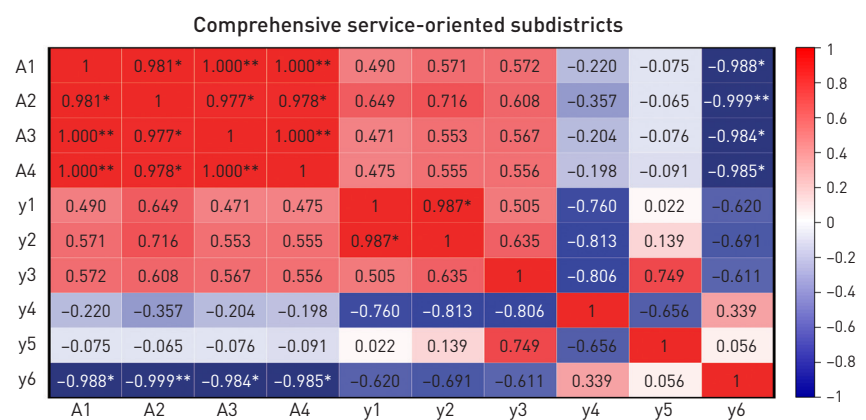
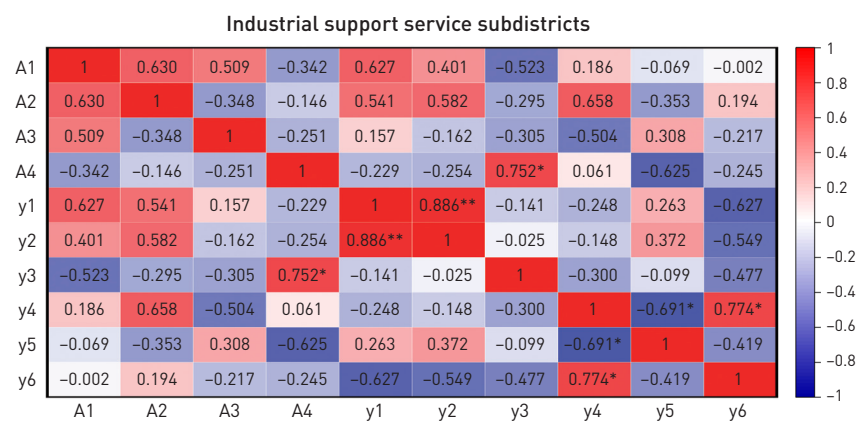
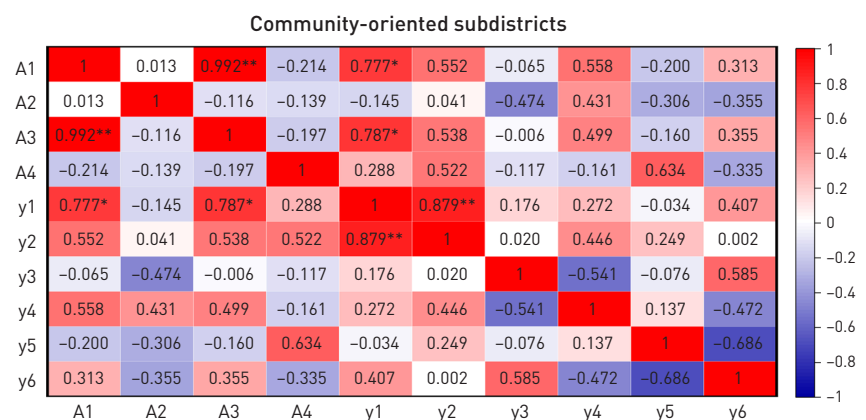
At the subdistrict scale, correlation analysis of factors associated with public park accessibility identified human activity density as a key correlate. In community-oriented subdistricts, human activity density showed strong positive correlations with both overall public park accessibility ($r = 0.777, p = 0.023$)

Table 6: Feature importance analysis of residential factors associated with regional park accessibility

Residential factor	Feature importance score
Property management fee (H5)	0.254093
Average housing price of residential communities (H1)	0.208913
Residential community population (H2)	0.196907
Floor area ratio (H3)	0.116901
Completion year (H6)	0.114404
Green space ratio (H4)	0.071163
Property rights duration (H7)	0.037619

and community park accessibility ($r = 0.787, p = 0.020$). The correlations with human activity density were stronger in community-oriented subdistricts than in industrial support service subdistricts. Within industrial support service subdistricts, pocket park accessibility was significantly correlated with socioeconomic status characteristics ($r = 0.752, p = 0.019$), whereas no statistically significant correlation was observed in community-oriented subdistricts (Fig. 12).

Fig. 12 Correlation heatmap of factors associated with public park spatial accessibility across different subdistrict types (** indicates correlation is significant at the 0.01 level, * indicates correlation is significant at the 0.05 level).

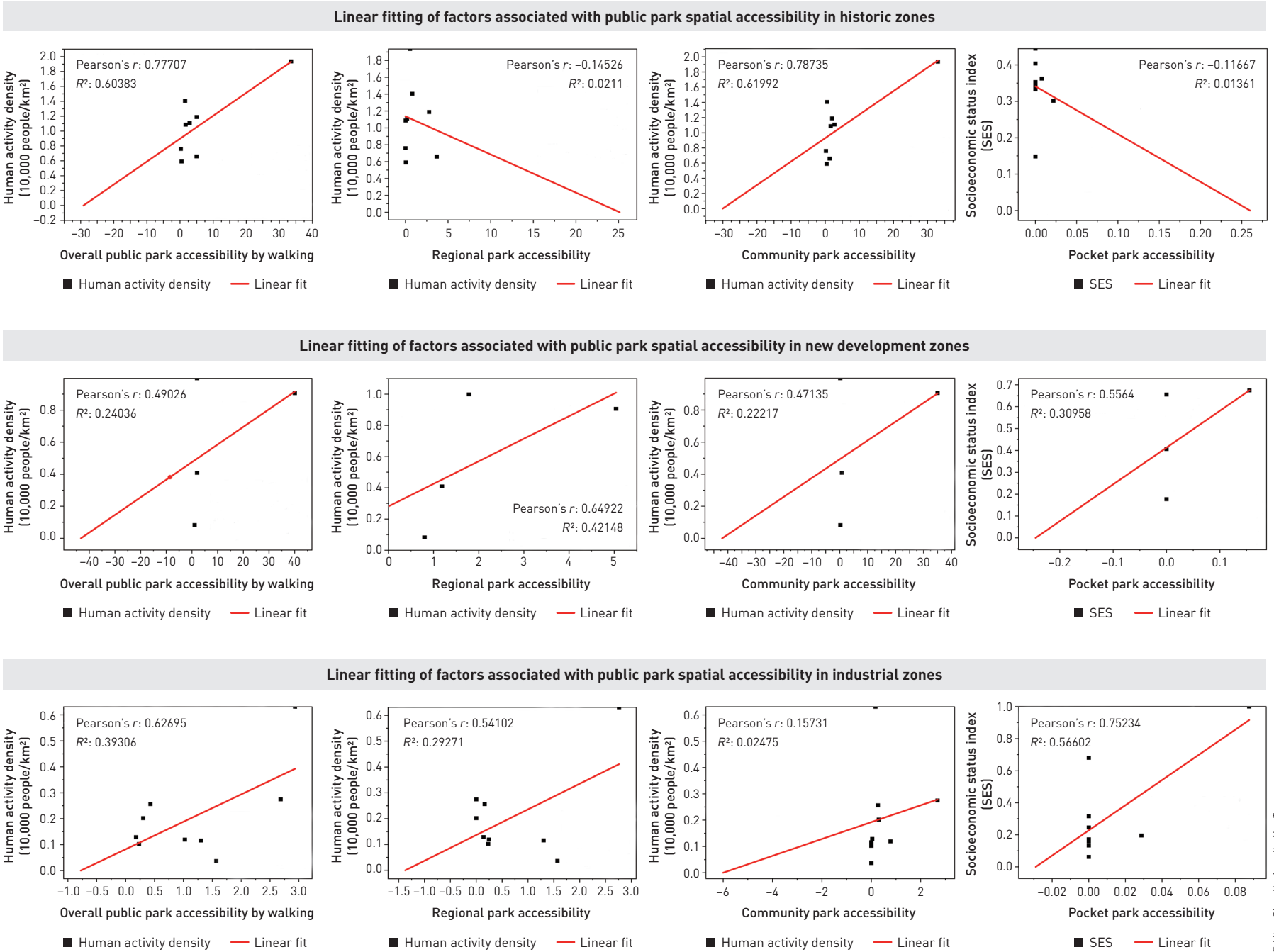


4.3 Functional Unit-Scale Linear Fitting Analysis of Public Park Accessibility

To further examine how human activity density and socioeconomic status relate to public park accessibility, linear fitting was conducted at the functional-unit scale to assess the explanatory power of these two indicators. The results showed that, within the historic zones, human activity density had a relatively pronounced relationship with both overall accessibility and community park accessibility ($R^2 = 0.604$ and 0.620 , respectively). In contrast, its

relationship with regional park accessibility was weak ($R^2 = 0.020$). In the industrial zones, human activity density showed a relatively strong relationship with overall accessibility ($R^2 = 0.393$). Also, it explained some variation in regional park accessibility ($R^2 = 0.292$), but its relationship with community park accessibility was limited ($R^2 = 0.025$). Socioeconomic status showed the greatest explanatory power for pocket park accessibility in the industrial zones ($R^2 = 0.566$), whereas its explanatory power was negligible in the historic zones ($R^2 = 0.013$) (Fig. 13).

Fig. 13 Linear fitting trends of factors associated with public park spatial accessibility across different functional units.



Overall, regional park accessibility may be jointly associated with multiple factors, and the dominant correlates warrant further investigation. Community park accessibility showed a relatively strong association with human activity density, whereas pocket park accessibility was closely associated with socioeconomic status.

5 Conclusions

As shown above, owing to the differentiated functional development and historical path dependence within Shanghai's new towns, substantial disparities persist in access to public parks among different types of subdistricts and residents across income groups. Equity in public park access is characterized by differentiation across functional units, park-size scales, and income levels. These patterns provide a representative case for understanding issues of environmental justice in public park provision amid the transformation of existing urban areas through regeneration and the continued development of new towns.

5.1 Nested Patterns of Public Park Equity

This study developed an analytical framework for evaluating public park accessibility across 3 spatial scales in new towns—residential community, subdistrict, and functional unit—and systematically identified the characteristics and influencing factors of disparities in public park equity at different spatial scales. The results indicate that subdistrict type, the development orientation of functional units, the degree of industry-city integration, and human activity density are closely associated with public park equity in Shanghai's new towns. Analysis at the residential community scale further revealed the relationships between resident population size, residents' economic status, and public park provision. Compared with previous studies that have largely focused on a single administrative or community scale, this multiscale perspective enables a more comprehensive understanding of the structural mismatch between the spatial distributions of public park resources and population within new towns, while extending the theoretical framework for multilevel analyses of environmental justice in public park provision.

5.2 Public Park Provision and Socioeconomic Differentiation

Correlation analysis showed that regional park accessibility was positively associated with socioeconomic and income-related indicators, such as average housing prices and property management fees, suggesting that higher-income groups have greater access to high-quality park resources. In contrast, pocket

park accessibility was more strongly associated with residents' socioeconomic status. It tended to favor residential communities with low green space ratios, thereby creating a localized compensatory effect. Public park equity was also closely associated with the intensity of population demand. These findings suggest that the spatial provision of public parks in Shanghai's new towns is shaped not only by the logic of planning-led supply but is also deeply embedded in housing-market dynamics and socioeconomic stratification, revealing a less visible mechanism through which green welfare is redistributed via spatial resources. This finding provides a new theoretical perspective for understanding the distributional justice of public service facilities among different social groups in the development of China's new towns.

5.3 Equity of Opportunity and Dynamic Spatial Justice in Public Park Accessibility

This study shows that opportunities to use public parks are unevenly distributed across different functional units and resident groups. The planning logic of the industrial zones, which prioritizes production over everyday living needs, the early path dependence embedded in the regeneration of the historic zones, and the more integrated and forward-looking spatial planning of the new development zones have jointly shaped differentiated opportunities for access to public parks across Shanghai's new towns. These findings indicate that conventional static evaluation systems based primarily on per capita green space area or green space ratio cannot fully capture equity in opportunities for park use. Accordingly, the analysis shifts toward a dynamic spatial justice framework centered on accessibility, everyday availability, and differences among social groups. This perspective offers useful implications for extending theoretical discussions on the equity-efficiency trade-off in the supply of and demand for urban public park services within the discipline of Landscape Architecture.

6 Discussion and Limitations

6.1 Discussion

Through a multiscale analysis of public park accessibility in Shanghai's new towns, this study further reveals that public park equity is shaped not only by the direct effects of planning-led provision but also by socioeconomic processes such as the housing market and community differentiation. The main findings can be summarized as follows:

1) The subdistrict types and functional development orientations of Shanghai's new towns, as well as the degree of

industry–city integration, were significantly associated with the overall distribution of public parks. This finding is consistent with previous studies showing that residents in different types of subdistricts have unequal access to public parks^[45–46]. However, given the small sample size of comprehensive service-oriented subdistricts, the corresponding correlation results should be interpreted with caution. From the perspective of functional units, this study further demonstrates structural differences in public park provision among different functional spatial units, such as industrial zones and historic zones, reflecting the logic of planning-driven resource allocation at the regional scale.

2) At the residential community scale, this study found that regional park accessibility was positively correlated with indicators such as average housing prices and property management fees, indicating that higher-income groups have greater access to high-quality park resources. This finding is consistent with a substantial body of research on park and green-space gentrification^[47], suggesting that public parks, as a form of public service infrastructure, may likewise be capitalized through the housing market in new towns and thereby become part of an implicit mechanism of welfare distribution.

Based on the findings of this study, the following optimization strategies are proposed. 1) Targeted provision: Differentiated public park layout strategies should be adopted for different functional units, with priority given to addressing service gaps in industrial zones and historic zones. In response to variations in the needs of different population groups across subdistricts, public park provision should place differentiated emphasis on the hierarchy of provision, service functions, and service levels. 2) Promoting equity: Institutional safeguards and targeted resource allocation should be strengthened, alongside more inclusive planning mechanisms. In land transfer and development processes, clear requirements should be established for the proportion of green space that must be provided and made publicly accessible. Targeted compensation should also be directed toward disadvantaged areas: in residential areas with low green space ratios and high population densities, the development of pocket parks should be prioritized. 3) Structural optimization: A multilevel service system should be established to reshape a coordinated network of large and small public parks.

6.2 Study Limitations

Although the random forest model used in this study revealed nonlinear relationships between residential attributes and public park accessibility, its explanatory capacity remains limited. Future research could incorporate more advanced explainable machine

learning methods or combine them with approaches such as structural equation modeling to further investigate the mechanisms and interaction effects of individual factors, thereby advancing a more rigorous understanding of the determinants of public park equity.

In addition, the public park sample was derived primarily from the official park list released by the local park management authority in 2022. Because pocket park development was still at an early stage at that time, the number of pocket parks included in the sample was relatively limited. This also to some extent reflects the predominance of large-scale planned park development in new towns. Against the current backdrop of urban regeneration in existing built-up areas, future research could focus more closely on mechanisms for the fine-grained provision of small and micro green spaces in historic zones and industrial zones, as well as on the temporal dynamics of multiscale equity, thereby further advancing the understanding of how spatial justice is produced.

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多尺度视角下公园绿地空间公平性分异与影响因素

陈丽花¹, 金云峰², 陶楠^{3,*}

1 井冈山大学建筑工程学院, 吉安 343009

2 同济大学建筑与城市规划学院, 上海 200092

3 昆明理工大学建筑与城市规划学院, 昆明 650500

*通信作者

地址: 昆明市呈贡区景明南路727号

邮编: 650500

邮箱: taonan5599@qq.com

摘要

在城市由增量规划转向存量更新的发展背景下, 本研究探究了城市空间异质性视角下公园绿地的空间公平差异及其影响因素。本文以上海5个新城内的86个公园绿地为研究对象, 构建基于多尺度视角下改进高斯两步移动搜索法的公园绿地可达性分析框架, 评估不同城市空间尺度下公园绿地的空间公平性特征, 并探讨居住属性、街道特征属性对公园绿地空间公平的影响作用。研究发现: 1) 公园绿地空间公平性总体呈现出“功能单元分化”“规模尺度分化”“经济收入分化”的特征, 社区公园可达性受到人类活动密度影响最大, 口袋公园可达性与社会经济地位密切相关; 2) 产业区“重生产、轻生活”的规划逻辑、历史片区更新中的路径依赖、新开区的整体前瞻性布局共同塑造了差异化的公园绿地获取机会, 其空间资源在新城规划供给逻辑主导与住房市场分化影响下进行再分配; 3) 建议未来应加强城市不同功能单元的公园绿地精准供给, 通过规划手段平衡不同收入人群享有公园绿地类型, 构建多层次的公园绿地服务体系等布局优化策略。本研究为城市异质空间背景下公园绿地公平性的差异性特征识别与精细化规划响应提供了方法与策略。

关键词

公园绿地; 多尺度可达测度; 空间公平性; 影响因素; 上海新城; 功能空间

文章亮点

- 构建多尺度城市公园空间公平性评估框架
- 识别解析公园空间公平性差异及其影响因素
- 为功能空间异质性较大城市内的公园布局规划提出公平性策略

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