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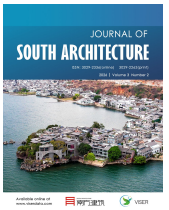

Assessment of Urban Public Green Space Services from the Perspective of the 15-Minute Living Circle

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ABSTRACT: With socioeconomic development and rising living standards, urban public services have gradually shifted from a focus on quantitative provision to a greater emphasis on service quality and refinement. However, pronounced supply-demand mismatches, outdated evaluation approaches, and insufficient quantitative precision undermine the validity of urban public green space assessments and the practicality of improvement strategies. Existing evaluation methods tend to measure service performance at a regional scale, whereas public services are primarily accessed within residents' daily activity spaces. As a result, current assessment frameworks often fail to precisely evaluate the actual service effectiveness of public green spaces. Using Tianhe District, Guangzhou, as a case study, this research develops a demand-oriented framework for evaluating urban public green space services from the perspective of the 15-minute living circle. By integrating multiple datasets and analytical methods, the study conducts a multi-indicator, multi-level assessment of urban public green space services and proposes targeted optimization strategies for different types of urban spaces.

KEY WORDS: 15-minute living circle; urban public services; public green space service assessment; evaluation framework; optimization strategies

Introduction

Urban public green spaces constitute an important form of public service provision and serve as the spatial setting for recreation and leisure activities. They not only perform important urban functions but also exert a significant influence on residents' quality of life and lifestyles. Traditionally, assessments of urban public green space services have focused on the rational allocation of land resources at the regional scale. From the perspective of individual residents, however, whether urban public green spaces are used in daily life depends largely on factors such as the quantity, accessibility, and convenience of green spaces in the vicinity of their homes. When viewed from the perspective of daily service provision, significant problems emerge in the quantity of public green spaces, the equity of their spatial distribution, and the spatial dis-

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parities revealed by different evaluation indicators.

Against the policy backdrop and broader trend of shifting urban public services from an emphasis on absolute quantity to one on service quality and refinement, existing evaluation perspectives and technical approaches are no longer adequate for service-oriented and fine-grained assessment objectives. Adopting a people-oriented perspective, this study takes the 15-minute living circle as the spatial scope of residents' daily activities and seeks to develop a demand-oriented assessment framework for urban green space services. By integrating multiple datasets and analytical methods, the study explores the service effectiveness of urban public green spaces.

1 Literatu rereview

1.1 Assessment of urban public green space services

When emphasis is placed on social performance, urban public green spaces can be regarded as a form of urban public service, and their evaluation has been approached from diverse perspectives.

SUN Defang et al. argued that international studies have primarily focused on accessibility assessment, whereas Chinese studies have emphasized spatial layout and planning standards [1]. SUN Yi et al. suggested that international studies mainly concentrate on three aspects: the impacts of public service provision on residents' health, the equity and accessibility of facility distribution, and the evaluation of service performance and resident satisfaction; in contrast, domestic studies have focused more on standards, site selection and spatial layout, facility provision, and satisfaction assessment [2]. ZHAN Dongsheng further observed that international studies mainly address the location, accessibility, equity, and socioeconomic benefits of public services, while Chinese research places greater emphasis on facility allocation, accessibility, spatial patterns, social differentiation, residents' needs, and satisfaction [3]. Research on urban public services has continued to evolve both domestically and internationally, and differences in analytical perspectives remain evident. Overall, however, facility allocation, accessibility, equity, and satisfaction constitute core concerns shared by scholars in both contexts.

In terms of evaluation methods, relatively mature assessment frameworks were gradually established around the year 2000 [4]. During the subsequent decade, numerous scholars expanded these frameworks by introducing additional indicators from different perspectives, focusing primarily on quantity and efficiency [5,6], accessibility [7-9], equity [10-13], and supply-demand relationships [14,15]. Increasing attention has been paid to the social value of green spaces, while the degree of alignment between services and residents' individual needs has become an important concern. As a result, evaluation frameworks and indicators have shown clear trends toward greater systematization, quantification, refinement, and stronger people-centered orientation.

1.2 The living circle concept: Value orientation and delineation methods

Research on living circles is generally grounded in the perspective of residents' daily needs, with particular attention given to issues such as daily life, employment, public service provision, the scale and structure of public spaces, accessibility, spatial organization, and implementation guidelines [16-18]. Some scholars have also examined the feasibility and practical implementation of planning approaches based on the living-circle concept, as well as challenges that may arise during implementation [19, 20]. These studies suggest that, whether viewed from the perspectives of residents' needs, community governance, or planning institutions, a community living circle is fundamentally people-centered and aims to improve residents' quality of life.

With regard to methods for delineating living circles, many studies employ data sources such as GPS trajectories, points of interest (POIs), and mobile phone signaling data to define living circles based on residents' daily activity ranges and spatiotemporal behavioral patterns. In addition, a number of Chinese cities, including Shanghai, Guangzhou, and Ningbo, have incorporated the living-circle concept into planning practice and carried out related planning initiatives [21-25].

2 Assessment of urban public green space services from the perspective of the 15-minute living circle

The 15-minute living circle refers to the spatial area surrounding residents' homes within which daily needs can be met through activities such as work, education, rec-

reation, healthcare, and social interaction [26]. The concept emphasizes the creation of an integrated community environment at the neighborhood scale [27].

The demand-oriented logic inherent in the living-circle perspective—characterized by a people-centered approach and the overarching objective of improving residents' quality of life—together with the application of multi-source data and advanced analytical methods, provides a feasible framework for enhancing the assessment of urban public green space services. Compared with conventional assessment approaches based primarily on land-use perspectives, an evaluation framework grounded in the 15-minute living circle can achieve improvements in three respects: orientation toward residents' everyday behavioral needs, the selection and classification of indicators, and the refinement of indicator calculation methods.

2.1 Indicato rselection

A review of the literature reveals that many scholars have proposed new indicators for assessing urban public green space services or refined the calculation methods of existing indicators. Commonly used indicators include green space area, per capita green space area, and the number of green spaces to reflect the quantity and scale of urban green resources; green coverage ratio, service coverage ratio, and overlap ratio to evaluate service efficiency; travel time along the shortest path, minimum travel cost, path resistance, and average distance to assess accessibility; the Gini coefficient, location entropy, and shareindicator to measure spatial equity and distributional balance; and supply-demand ratio, level of service access, and the coefficient of variation of spatial patterns to evaluate the balance between the supply and demand of green space services.

Although the specific calculation methods of these indicators vary somewhat across studies, their underlying evaluation objectives are broadly consistent. Moreover, while some indicators differ in terminology, their substantive meanings are highly similar. Through comparison, consolidation, and screening of the literature, the most frequently used indicators were identified as green coverage ratio, service coverage ratio, green space area, per capita green space area, equity, shortest path, road-network density, number of green spaces, supply-demand ratio, service overlap ratio, and mix.

Drawing upon the *Planning Guidance of Community-life Circle* (*Draft for Consultation*), an industry standard issued by the People's Republic of China in October 2020 [28] (hereafter referred to as the *Living Circle Guidelines*), the indicators were categorized into four dimensions and evaluated accordingly: Scale, efficiency, accessibility, and quality (Table 1).

Table 1 Evaluation indicator framework for urban public green space services from the perspective of the 15-minute living circle

Dimension	Secondary indicator	Indicator No.	Correlation with service level
Scale	Effective green space area within the 15-minute living circle	A1	Positive
	Effective green space ratio within the 15-minute living circle	A2	Positive
	Effective green space service coverage within the 15-minute living circle	A3	Positive
Efficiency	Per capita effective green space area within the 15-minute living circle	B1	Positive
	Green space shape indicator	B2	Positive
	Green space service overlap ratio	B3	Positive
Spatial accessibility	Road-network density	C1	Positive
	Minimum proximity distance	C2	Negative
	Comprehensive accessibility	C3	Positive
Quality	Green space equity	D1	Positive
	Urban functional mix	D2	Positive

The first four indicators are adapted from the *Evaluation Standard for Urban Landscaping and Greening* GB/T 50563-2010 (hereafter referred to as the 2010 *Evaluation Standard*), with their calculation methods revised and optimized to suit the

analytical perspective adopted in this study. The remaining seven indicators were derived from the literature review and supplement the framework with high-frequency indicators directly associated with residents' daily service needs.

2.2 Data sources

The evaluation indicators are primarily calculated based on datasets including administrative boundaries, residentialcompounds, green spaces, population distribution, transportation networks, and points of interest (POIs) related to urban public services (Table 2).

Table 2 Data categories and sources

Data category	Primary data source	Data content
Administrative divisions	Tianditu Cloud Platform of Spatiotemporal Information	Boundaries of subdistricts and communities
Residential compounds	Baidu Map Open Platform	Boundaries of residential compounds[1)]
Urban public green spaces	Baidu Map Open Platform	Boundaries of urban public green spaces
Population	"Number of households" data from real-estate websites	Population of each community[2)]
Road network	OpenStreetMap	Road network
Urban public service POIs	Baidu Map Open Platform	Eight categories: Fresh produce markets, dining services, supermarkets and department stores, shopping malls, healthcare services, bank branches, postal services, and government institutions

2.3 Evaluation objectives

Following the "Living Circle Guidelines", the evaluation indicators are classified into four dimensions: scale, efficiency, accessibility, and quality. Scale reflects the level of green space provision; efficiency reflects the service capacity of green spaces; accessibility measures the time and distance costs incurred by residents in accessing green spaces; and quality reflects the equity of green space distribution and the convenience of accessing green space services (Table 3).

Table 3 Assessment framework for urban public green space services from the perspective of the 15-minute living circle

Dimension	Indicator	Objective
Scale	Effective green space area within the 15-minute living circle	Evaluate the area of green spaces effectively serving residents' daily activities
	Effective green space ratio within the 15-minute living circle	Evaluate the proportion of area covered by effective green spaces
	Effective green space service coverage ratio within the 15-minute living circle	Evaluate the proportion of residential compounds covered by effective green space services within the 15-minute living circle
Efficiency	Per capita effective green space area within the 15-minute living circle	Evaluate the amount of effective green space available per resident for daily use
	Green space shape indicator	Evaluate the complexity of green-space boundaries
	Green space service overlap ratio	Evaluate the diversity of green-space choices available to residents within their daily activity range
Spatial accessibility	Road-network density	Evaluate the likelihood of residents reaching green spaces
	Minimum proximity distance	Evaluate the minimum travel cost required to reacha green spaces
	Comprehensive accessibility	Evaluate the overall accessibility
Quality	Green space equity	Evaluate the equity between population distribution and green-space provision
	Urban functional mix	Evaluate the degree of mix of green spaces and other public service facilities

3 Empirical assessment of urban public green space services in Tianhe District, Guangzhou

The evaluation indicators were calculated at three spatial levels—region, subdistrict, and community. Results at the regional level can be used to compare performance against planning standards and findings from comparable studies, thereby revealing the relative strengths and weaknesses of individual indicators. Given that evaluation out-

comes should ultimately inform the optimization of the built environment within specific administrative units, further analysis of spatial differentiation was conducted at both the subdistrict and community levels.

3.1 Region-level assessment

Residentialcompounds were used as the basic analysis units. Based on the existing road network, a walking distance of 1,000 m (approximately a 15-minute walk), was defined as the service area for daily life. Urban public green spaces located within this range were regarded as effective green spaces within the 15-minute living circle (Figure 1).

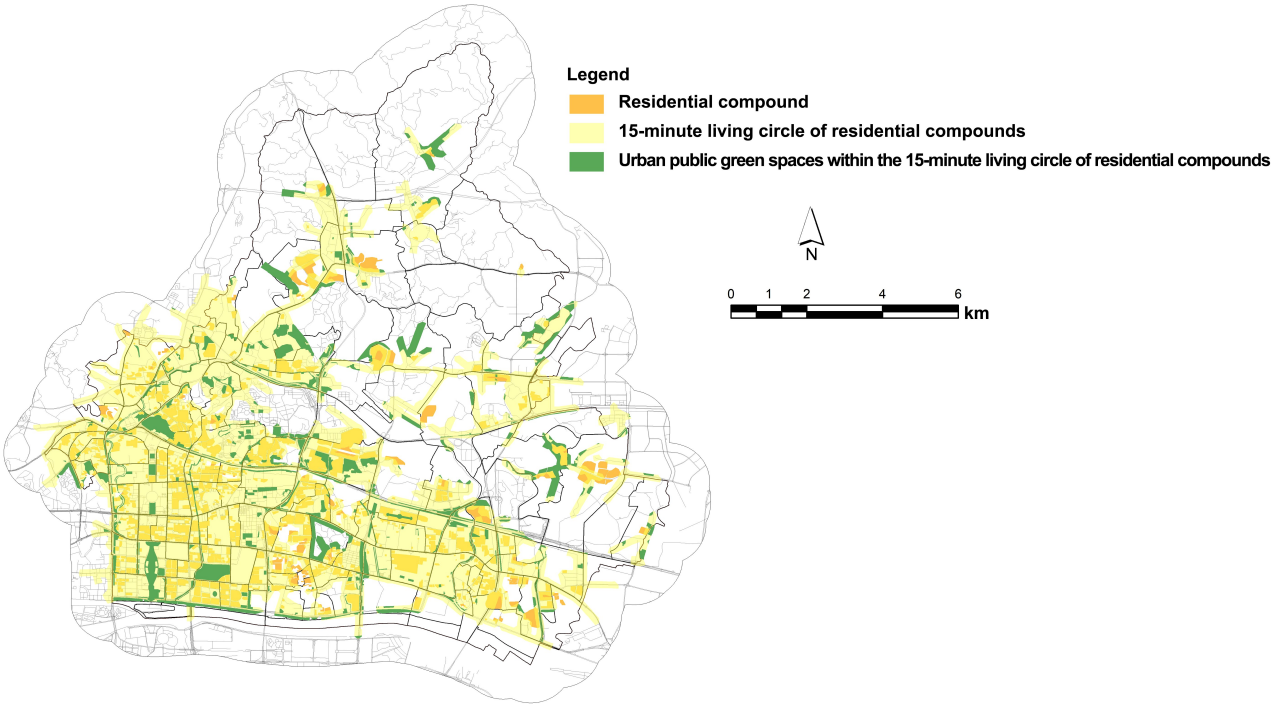

Figure 1 Urban public green spaces within the 15-minute living circles of residential compounds

3.1.1 Assessment results for scale indicators

(1) Effective green space area within the 15-minute living circle

A total of 47.5 km^2 of urban public green space is located within Tianhe District and its surrounding 1,000 m buffer zone. However, only 10.0 km^2 of this green space is capable of providing daily services to residential compounds within the district. Although the remaining green spaces make substantial contributions in ecological and economic terms, their effectiveness in serving residents' daily activities is limited because of their long distance from residential areas.

(2) Effective green space ratio within the 15-minute living circle

The effective green space ratio within the 15-minute living circle of Tianhe District is only 11.94%, substantially lower than the green space ratio of 25.9% calculated according to the "2010 Evaluation Standard".

(3) Effective green space service coverage ratio within the 15-minute living circle

Residential compounds located within a 15-minute walking distance from urban public green spaces along the existing road network were considered to be covered by green space services at this travel threshold (Figure 2). The effective service coverage ratio reaches 90.6%, which essentially meets the target of 90% coverage within a 15-minute walking distance proposed in the "Guangzhou Master Plan (2017 – 2035)". This result indicates that, in terms of scale, the current provision of urban public green space services in Tianhe District adequately covers residents' daily needs.

3.1.2 Assessment results for efficiency indicators

(1) Per capita green space area within the 15-minute living circle

The per capita green space area within the 15-minute

living circle of Tianhe District is 5.8 m^2, considerably lower than the 25.28 m^2 calculated according to the "2010 Evaluation Standard". This suggests that the provision of urban public green space for residents' daily needs remains insufficient.

(2) Shape indicator

Within Tianhe District and its 1,000 m buffer zone, the total perimeter length of green spaces capable of providing services within the 15-minute living circle is 33.6 km, yielding a shape indicator of 26.6.

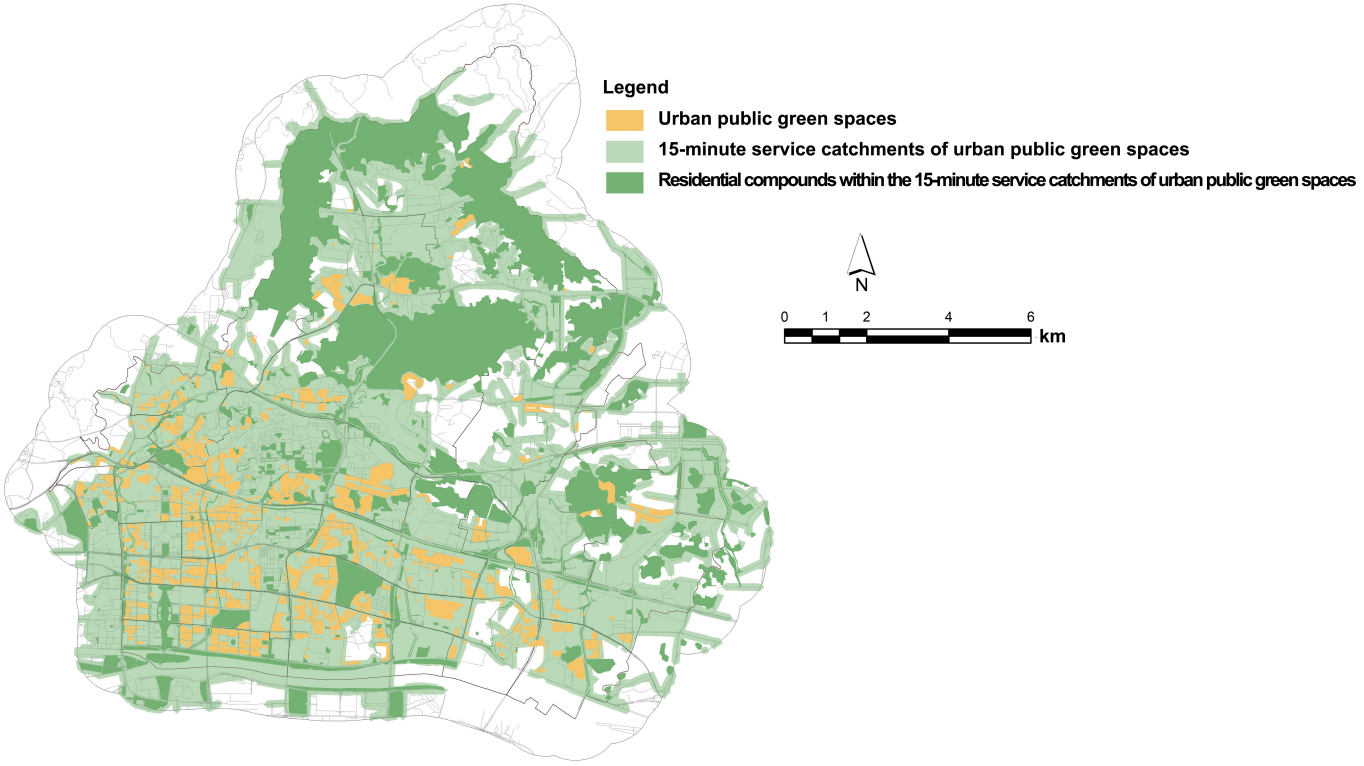

Figure 2 Residential compounds within the 15-minute service catchments of urban public green spaces

(3) Service overlap ratio

The service overlap ratio of urban public green spaces across Tianhe District is approximately 51.11%. In other words, about half of the residential land area is covered by the service areas of two or more green spaces. Residential land served by at least two green spaces is covered an average of 3.5 times.

3.1.3 Assessment results for accessibility indicators

(1) Road network density

According to the 2020 *Monitoring Report on Road Network Density in Major Chinese Cities*, the road network density of Tianhe District is 7.0 km/km^2[29].

(2) Minimum proximity distance

The average minimum distance betweena residential compound and the nearest urban public green space (Minimum Proximity Distance) is 695.7 m, approximately equivalent to a 10-minute walk. A total of 805 residential compounds are located within 1,000 m of their nearest urban public green space, accounting for 78.2% of all residential compounds.

(3) Comprehensive accessibility

At the regional level, comprehensive accessibility between urban public green spaces and residentialcompounds was measured using origin-destination (OD) cost matrix analysis. Taking urban public green spaces as origins and residential compounds as destinations, a cost matrix was generated using an impedance threshold of 1,000 m. The results indicate that the southwestern part of Tianhe District offers residents a greater range of choice opportunities for green spaces.

3.1.4 Assessment results for quality indicators

(1) Green space equity

Significant disparities exist in residents' access to urban public green space services across Tianhe District. Among residents with relatively low levels of access, 20% of the population receives only 1.5% of total Public green

space services, whereas the same proportion of the population with relatively high levels of access receives 60.7% of such resources (Table 4).

Based on the cumulative proportion of urban public green space services enjoyed by different proportions of the resident population, the Gini coefficient (G) was calculated. For comparison, reported Gini coefficients are 0.292 for Gongshu District in Hangzhou [30], 0.431 for the area within Wuhan's Third Ring Road [31], 0.246 for Nanshan District in Shenzhen [32], and 0.392 for Ba'nan District in Chongqing [15]. The calculated Gini coefficient for urban public green space services in Tianhe District is 0.5549, indicating a relatively high degree of inequity in service provision.

(2) Urban functional mix

To evaluate the degree of urban functional mix at the district level, Tianhe District was divided into a 500 m × 500 m grid, and a functional-mix indicator was calculated for each grid cell (Figure 3). The results reveal a pronounced concentration of functional diversity toward the southwestern part of the district.

3.2 Subdistrict- and community-level assessment

The regional level results provide an overview of the overall condition of urban public green space services in Tianhe District. To further examine spatial differentiation among the indicators, all indicators were calculated separately at the subdistrict and community levels. The results were classified into five categories: High, relatively high, moderate, relatively low, and low.

Table 4 Cumulative proportions of urban public green space services by population group

Cumulative proportion of permanent residents/%	Cumulative proportion of urban public green space/%
0	0
10	0.3
20	1.5
30	4.6
40	9.3
50	14.4
60	21.2
70	29.1
80	39.3
90	52.8
100	100

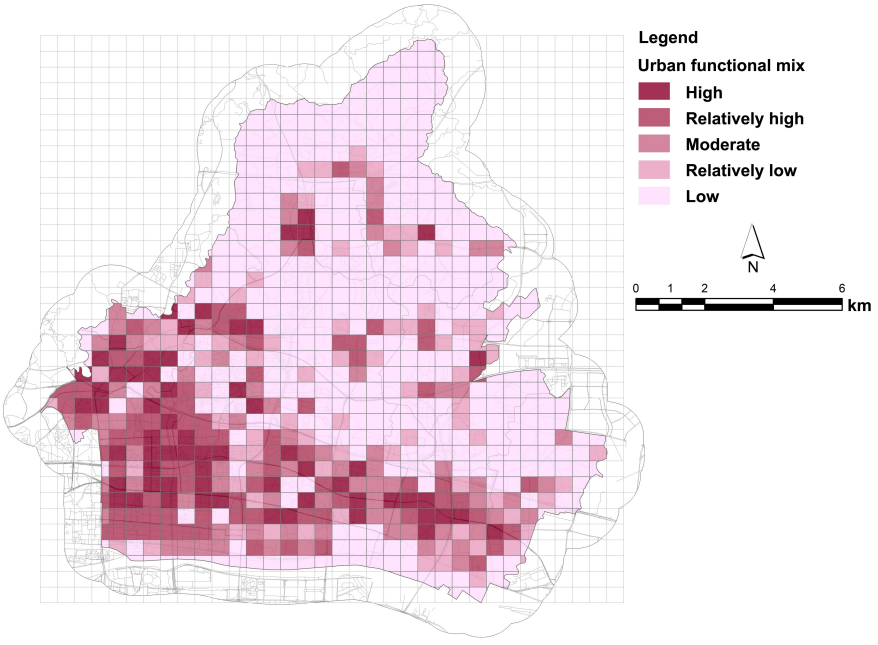

Figure 3 Distribution of functional mix across the area

In quantitative studies, the definition of "community" varies considerably. Some studies examining community living circles at the subdistrict level have effectively treated residential compounds as communities [33], whereas studies conducted at the regional level have often regarded subdistricts themselves as communities [34,35]. Field in-

vestigations further revealed that many residential compounds in Guangzhou have already displayed maps of 15-minute living circles, in which the term "community" corresponds to cadastral communities. This definition offers a higher level of spatial precision than the subdistrict and more closely approximates the spatial extent of a living circle than individual residential compounds.

3.2.1 Single-indicator assessment

(1)Assessment results for scale indicators

The scale dimension comprises three indicators: Effective green space area, effective green space ratio, and effective green space service coverage ratio within the 15-minute living circle. Effective green space area refers to the area of green spaces capable of serving residents' daily activities; effective green space ratio denotes the proportion of urban public green space within the area covered by the living circle; and green space service coverage ratio represents the proportion of residential compounds that can access green space services. These indicators focus primarily on the effectiveness of green spaces in meeting residents' daily needs and reflect the level of green space provision and service within the 15-minute living circle (Figure 4).

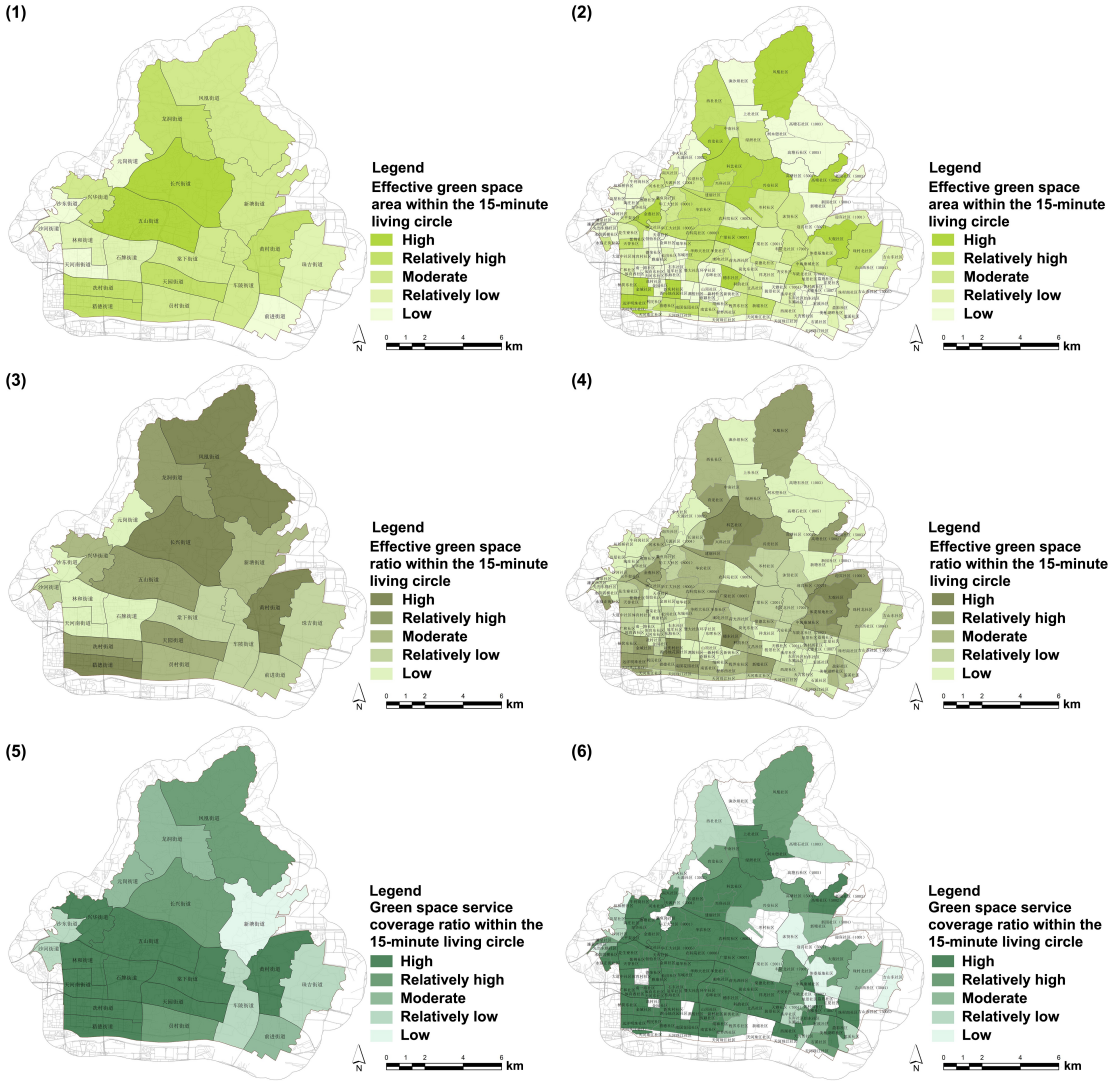

Figure 4 Assessment results for scale indicators ((1) Effective green space area within the 15-minute living circle (subdistrict level); (2) Effective green space area within the 15-minute living circle (community level); (3)Green space ratio within the 15-minute living circle (subdistrict level); (4) Green space ratio within the 15-minute living circle (community level); (5) Green space service coverage ratio within the 15-minute living circle (subdistrict level); (6) Green space service coverage ratio within the 15-minute living circle (community level))

(2)Assessment results for efficiency indicators

The efficiency dimension includes three indicators: Per capita green space area, shape indicator, and service overlap ratio within the 15-minute living circle. Per capita green space area represents the amount of green space available for residents' daily use; the shape indicator is used to evaluate the influence of boundary complexity on the service capacity of urban public green spaces of equivalent size; the service overlap ratio measures whether residents have access to multiple green space options within their daily activity range. Together, these indicators reflect the efficiency with which green spaces satisfy residents' everyday needs (Figure 5).

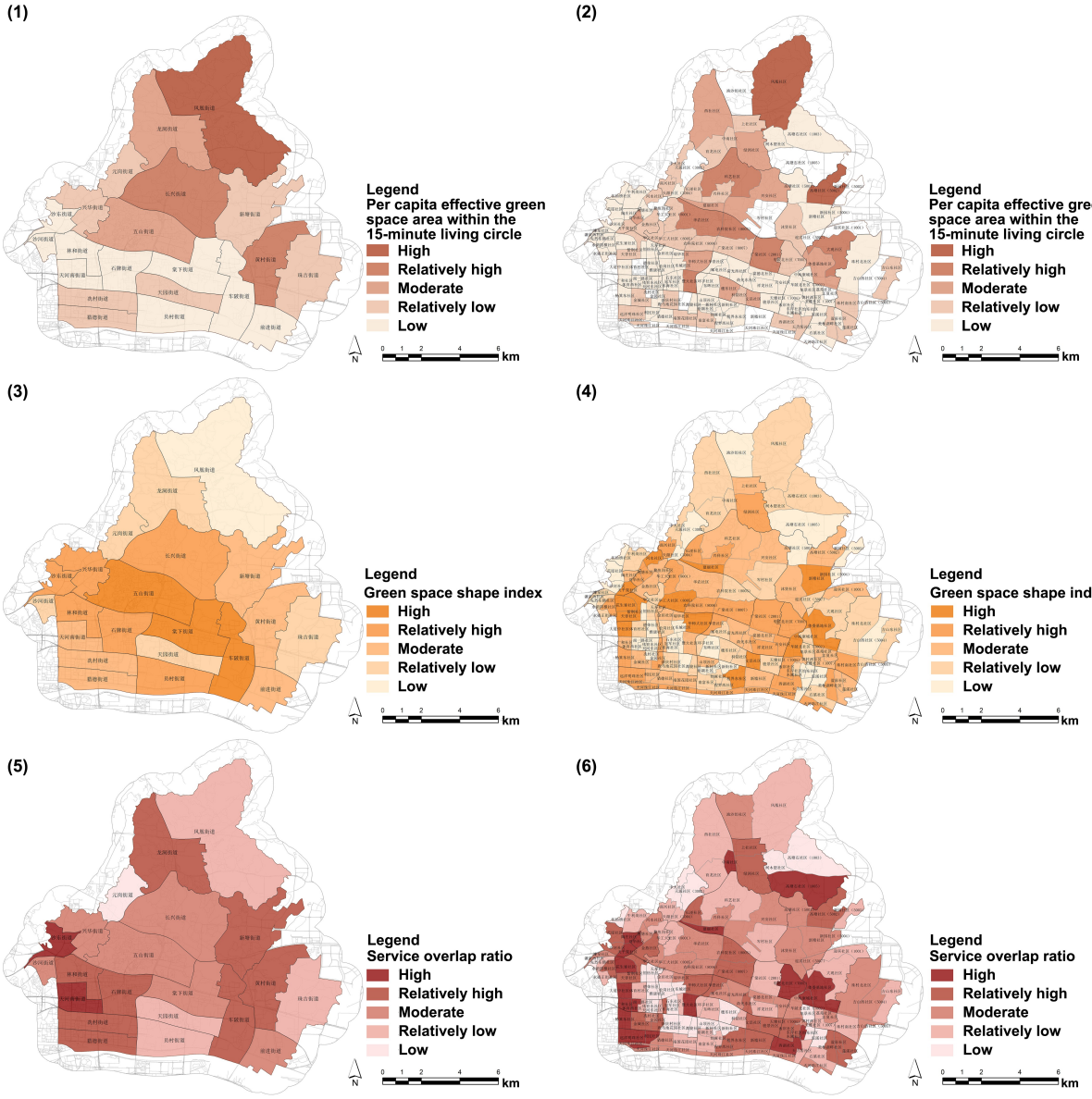

Figure 5 Assessment results for efficiency indicators((1) Per capita effective green space area within the 15-minute living circle (subdistrict level); (2) Per capita effective green space area within the 15-minute living circle (community level); (3) Shape indicator of effective green spaces within the 15-minute living circle (subdistrict level); (4) Shapeindicator of effective green spaces within the 15-minute living circle (community level); (5) Service overlap ratio of effective green spaces within the 15-minute living circle (subdistrict level); (6) Service overlap ratio of effective green spaces within the 15-minute living circle (community level))

(3)Assessment results for accessibility indicators

The accessibility dimension consists of road network density, minimum proximity distance, and comprehensive accessibility. Road network density reflects the ease with which residents can reach green spaces. Minimum proximity distance represents the minimum travel cost required to access the nearest

green space; comprehensive accessibility was measured at both the subdistrict and community levels using the Gaussian two-step floating catchment area (G2SFCA) method to assess green space accessibility within the 15-minute living circle. Collectively, these indicators reflect the ease with which residents can access and use green spaces in their daily lives (Figure 6).

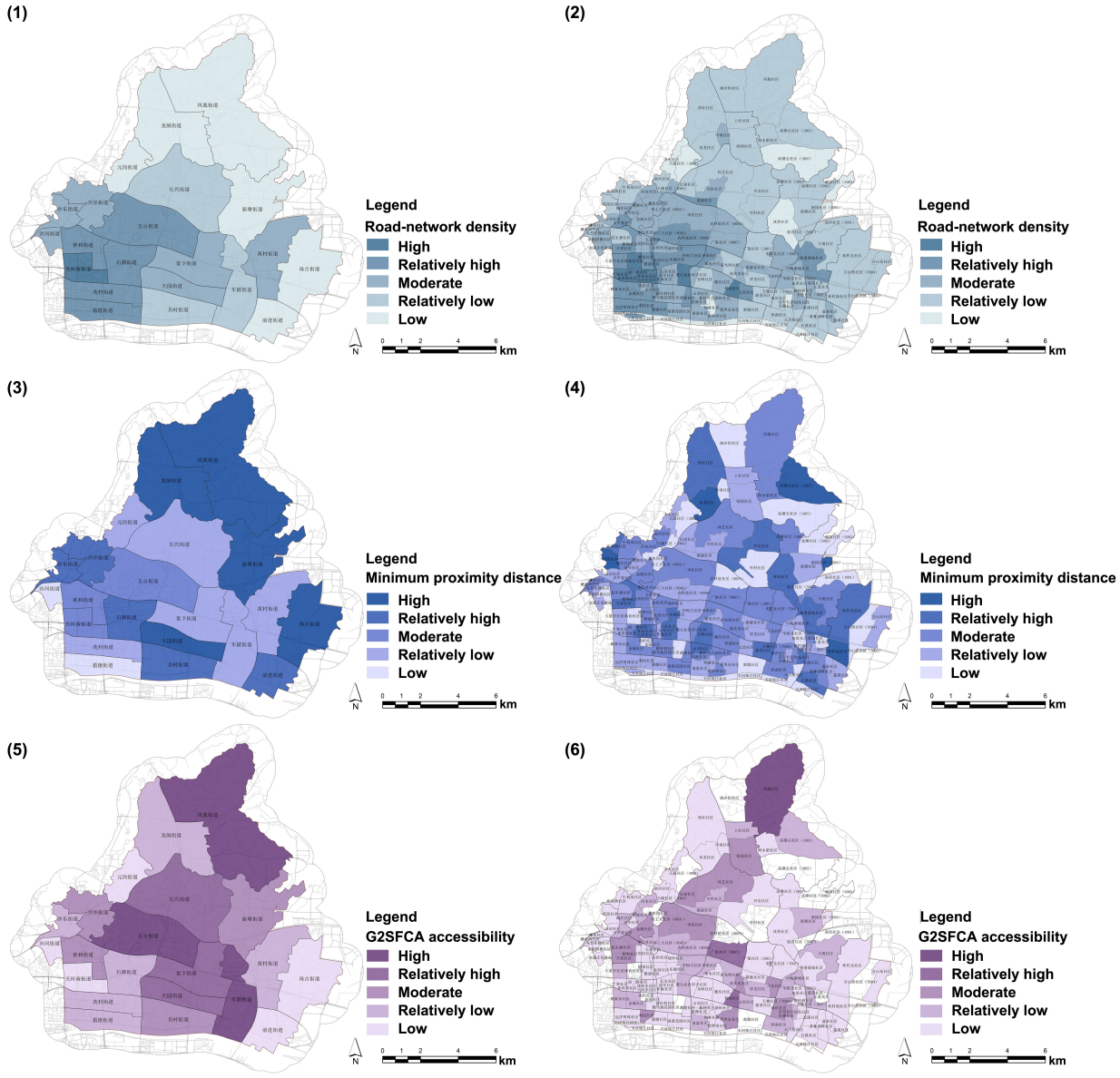

Figure 6 Assessment results for accessibility indicators((1) Distribution of road network density (subdistrict level); (2) Distribution of road network density (community level); (3) Meanminimum proximity distance from residential compounds to the nearest green space[3] (subdistrict level); (4) Mean minimum proximity distance from residential compounds to the nearest green space[3] (community level); (5) Comprehensive accessibility (G2SFCA, subdistrict level); (6) Comprehensive accessibility (G2SFCA, community level))

(4)Assessment results for quality indicators

The quality dimension comprises two indicators: Green space equity and functional mix, which represent the attributes of equity and convenience, respectively. Equity refers to the degree to which urban residents enjoy equitable access to public green spaces. At the overall scale, it is measured in terms of distributional evenness, whereas at the community scale it is measured through service availability. Convenience refers to the ease with which residents can access other types of public service facilities while enjoying public green space services, and is measured using the degree of functional mix surrounding urban public green spaces (Figure 7).

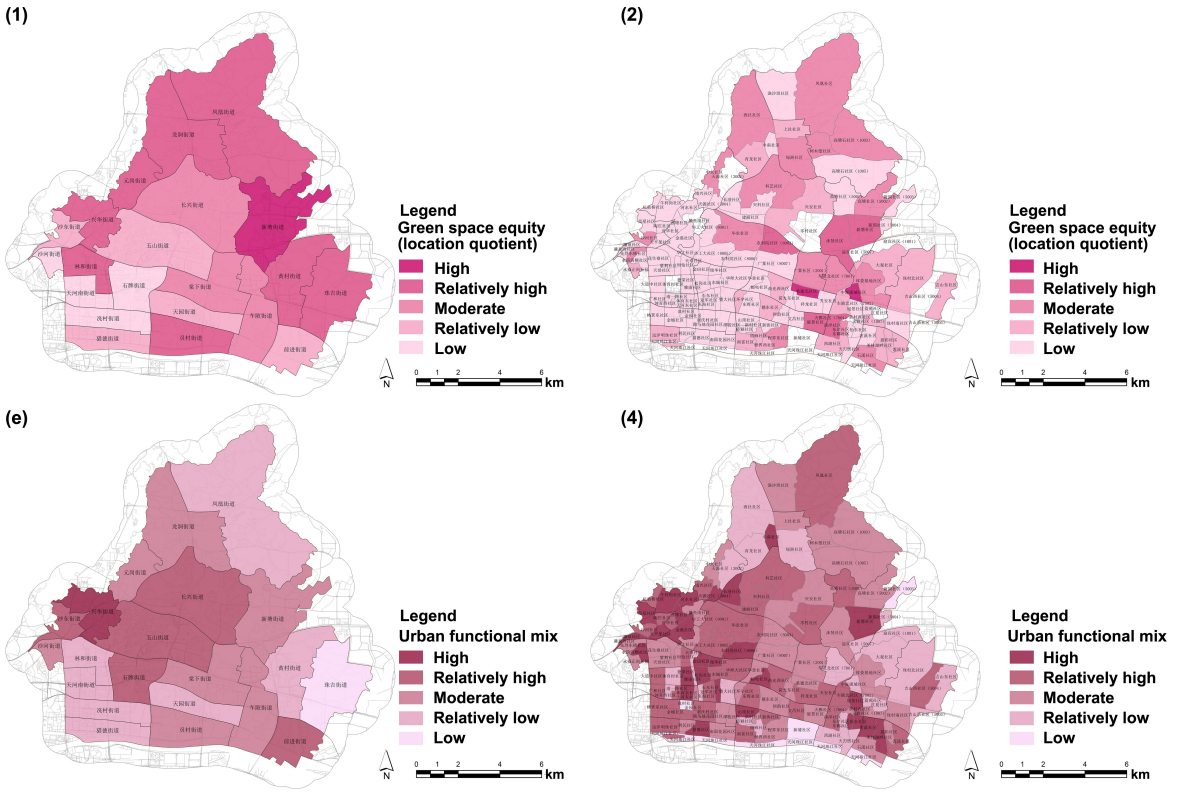

Figure 7 Assessment results for quality indicators((1) Green space equity (by location entropy, subdistrict level); (2) Green space equity (by location entropy, community level); (3) Distribution of urban functional mix (subdistrict level); (4) Distribution of urban functional mix (community level))

3.2.2 Selection of the weighting method

(1) Indicator correlations

Because the indicators may contain overlapping information and mutual influences, bivariate correlation analysis was conducted to examine the relationships among indicators and to identify an appropriate weighting method.

At the significance level of $p < 0.05$, several indicators exhibited notable correlations. Effective green space area within the 15-minute living circle showed a strong positive correlation with green space ratio. Effective green space service coverage ratio also displayed moderate positive correlations with per capita green space area and comprehensive accessibility. Effective green space service coverage ratio exhibited a moderate positive correlation with road network density. Service overlap ratio likewise showed a moderate positive correlation with road network density. Per capita green space area was moderately positively correlated with comprehensive accessibility, and effective green space area also exhibited a moderate positive correlation with comprehensive accessibility.

(2) Weight adjustment

The independence-weighting method provides a more objective approach for assigning weights to indicator systems exhibiting multicollinearity. Given a set of indicators X_1, X_2, ⋯, X_n, a larger multiple correlation coefficient between indicator X_k and the remaining indicators indicates stronger collinearity and greater redundancy of information. Accordingly, a lower weight should be assigned to that indicator.

Indicator weights at both the subdistrict and community levels were determined using theindependence-weighting coefficient method and subsequently adjusted to obtain the final weights (Table 5).

3.2.3 Comprehensive assessment by subdistrict and community

Using the adjusted weights, scores for scale, efficiency, accessibility, quality, and overall performance of urban public green space services were calculated for each subdistrict (Figure 8) and community (Figure 9).

Table 5 Adjusted indicator weights

A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2
0.0508	0.0508	0.0639	0.0884	0.0766	0.0874	0.0811	0.1185	0.0869	0.2132	0.0825

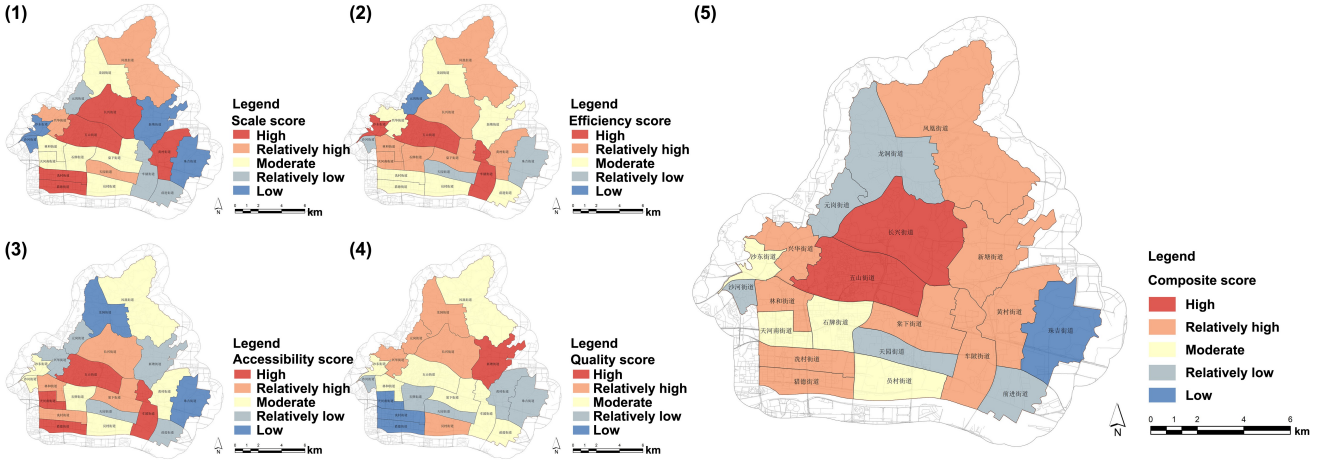

Figure 8 Classification of urban public green space service levels and overall composite scores by subdistrict
((1) Scale score; (2) Efficiency score; (3) Accessibility score; (4) Quality score; (5) Composite score)

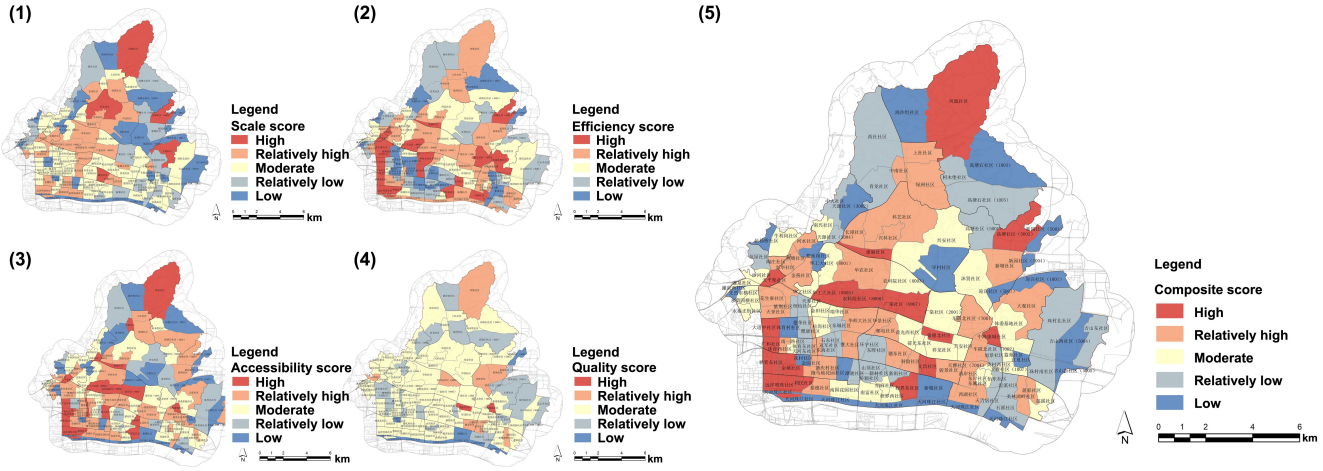

Figure 9 Classification of urban public green space service levels and overall composite scores by community
((1) Scale score; (2) Efficiency score; (3) Accessibility score; (4) Quality score; (5) Composite score)

With respect to scale, relatively high levels of green space provision were observed in Wushan Subdistrict and Keyi Community in Changxing Subdistrict in central Tianhe District; Xiancun and Liede subdistricts in the southwest; Daguan Community in Huangcun Subdistrict in the east; and Fenghuang Community in the north. In central Tianhe, this performance is largely attributable to public green spaces associated with the South China Botanical Garden, Huolu Mountain Forest Park, and the open campuses of South China University of Technology and South China Agricultural University. In the southwest, major contributors include large public squares and green spaces such as Huacheng Square and Zhujiang Park. In eastern Huangcun subdistrict, green spaces surrounding Grand World Scenic Park play an important role, while in the north the influence of Fenghuang Mountain Forest Park is particularly significant. In terms of efficiency, relatively high performance was observed in Wushan Subdistrict in central Tianhe District, Shadong Subdistrict in the west, and the Huasui Road area. Wushan benefits from both an

abundant supply and an even distribution of green spaces. Although Shadong possesses comparatively limited green space resources within its own boundaries, its proximity to Guangzhou Zoo, Luhu Park, and Baiyun Mountain enables residents to enjoy a relatively high level of green space services. Regarding accessibility, higher scores were concentrated in areas characterized either by dense road networks or exceptionally abundant green space resources, such as the Zhujiang New Town area in the southwest and the surrounding area in the university districts in Wushan. For quality, Xintang Subdistrict achieved relatively high scores owing to its balanced distribution of green spaces and the relatively even provision of other urban services.

Overall, the areas surrounding Wushan in central Tianhe District, Huacheng Square in the southwest, and Fenghuang Mountain Forest Park in the north exhibit relatively high levels of urban public green space services. In contrast, the Yuangang-Longdong area in the northwest and the Zhuji-Qianjin area in the east perform relatively poorly in terms of service provision.

3.3 Optimization strategies for urban public green space services

Low service effectiveness and uneven spatial distribution remain the principal challenges facing urban public green spaces in Tianhe District. Guided by residents' daily needs and the principles of optimizing existing resources, open sharing, and balanced coordination, this study proposes targeted strategies addressing different dimensions of service deficiencies, together with recommendations for the three stages of planning, design and construction, and governance. The aim is to provide references for improving the effectiveness of urban public green spaces in serving everyday life.

3.3.1 Optimization strategies

(1) Optimize spatial layouts in areas with adequate scale but low efficiency. Such areas typically possess abundant green space resources while also accommodating relatively large populations. Given their high level of urban development and limited opportunities for large-scale green space expansion, improvements may be achieved through increasing overall greenery and optimizing spatial distribution. Potential measures include expanding vertical greening and rooftop greening, as well as supplementing existing large green spaces with smaller, more dispersed green areas.

(2) Improve resource utilization in areas with adequate scale but poor accessibility. These areas are commonly located outside urban centers, where green space resources are abundant but population densities are relatively low. Although substantial green resources exist, they often fail to effectively serve residents' daily needs. Building upon existing road networks, complete, accessible, and safe pedestrian systems can be developed. Measures such as improved wayfinding, upgraded pedestrian crossing facilities, and encouraging public buildings to open internal circulation routes can help reduce travel time and enhance accessibility.

(3) Unlock the potential of existing urban spaces in areas with low efficiency but good accessibility. This situation is commonly found in highly urbanized central districts, where green space resources are insufficient and opportunities for expansion are extremely limited. Existing buildings and sites may be used more intensively to accommodate diverse public service facilities. In addition, micro-scale regeneration of underutilized spaces can be undertaken. Neglected urban spaces—such as street corners, riverbanks, and areas beneath elevated roads—can be revitalized through interventions including opening visual and physical connections to greenery, introducing landscape elements, expanding green infrastructure, and incorporating pocket green spaces to improve the scenery, functions and service facilities. Such measures can alleviate shortages of public green space, create small-scale recreational environments for residents, improve the overall urban environment, and stimulate urban vitality.

(4) Enhance green space service quality in areas with good accessibility but relatively low quality. These areas are often located around the core zones of highly developed urban centers. Although accessibility is generally high, their overall service quality remains lower than that of surrounding areas. The provision of complementary urban public services within or adjacent to green spaces can increase functional diversity, improve supporting public service facilities, and enhance environmental quality.

(5) Promote interdistrict connectivity in areas with low accessibility but high quality. Such areas typically possess well-developed internal services but maintain weak connections with surrounding districts, so that they showed a degree of spatial isolation. Strengthening transportation connectivity with adjacent areas and promoting the sharing of public service facilities are therefore recommended.

3.3.2 Recommendations

(1) Rational spatial allocation during the planning stage. An effective assessment of existing public service provision constitutes an essential prerequisite for planning. This study explores an approach for applying the living-circle concept to the evaluation of public green spaces in built-up areas. The assessment results can inform future planning processes. Furthermore, planning units should be delineated from a living-circle perspective to promote the balanced and coordinated provision of public service facilities.

(2) Refined improvement during the design and construction stage. Following the principles of balance and coordination, diversified public service facilities should be arranged through intensive land-use strategies to promote compact mixed-use development. At the same time, pedestrian accessibility should be enhanced through improvements to high-density road networks and walking systems. Green spaces that currently perform poorly—such as abandoned pocket squares, roadside green strips, and spaces beneath elevated roads—should be redesigned and transformed into active public spaces. Public participation in the design and construction process should be encouraged to better understand residents' needs and strengthen their sense of involvement. Sustainability, durability, and ease of maintenance should also be fully considered in the construction of green spaces and public plazas.

(3) Orderly sharing during the governance stage. One of the major constraints on public accessibility arises from issues related to long-term management and maintenance. Therefore, the concept of "Urban Entrepreneurialism" should be introduced to promote the shared use of green spaces located within residential compounds, university campuses, industrial parks, and other non-public or semi-public environments. Public participation should also be emphasized in the operation and maintenance of public green spaces. Public facilities should be encouraged to provide public access through internal passageways, thereby improving the continuity of pedestrian networks. Efforts should also be made to enhance the quality of street frontages and the comfort of pedestrian environments. In addition, vibrant and diverse systems of urban "gray spaces" can be created by utilizing elevated ground-floor spaces (pilotis), entrance areas, and similar transitional spaces.

Conclusion

To address the limitations of existing evaluation approaches, this study proposes an assessment framework for urban public green space services from the perspective of the 15-minute living circle. The framework aims to provide a comprehensive evaluation of green space service effectiveness based on residents' daily needs. Through the development and empirical application of a systematic, scientifically grounded, and operational evaluation method, three principal conclusions are drawn:

(1) Evaluation standards that have long emphasized the quantity of green spaces produce results that increasingly diverge from contemporary service demands and are no longer compatible with people-oriented urban development objectives. Compared with the traditional perspective dominated by land-resource allocation, a perspective grounded in residents' daily needs better reflects actual patterns of service use and represents a shift in planning logic from a focus on resources to a focus on people.

(2) Based on the literature review and the "Living Circle Guidelines", urban public green space services can be evaluated from four dimensions: scale, efficiency, accessibility, and quality. Scale is primarily influenced by the quantity of green space both within and around the area concerned. Efficiency is mainly affected by the amount and spatial distribution of green spaces. Accessibility depends largely on green space amount and road-network density. Quality is determined principally by the equity of green space distribution and the balance of other urban services.

(3) Through dimension-specific assessment, differen-

tiated improvement strategies can be formulated according to local deficiencies. Areas with adequate scale but low efficiency should prioritize layout optimization; areas with adequate scale but poor accessibility should improve resource utilization; areas with low efficiency but good accessibility should focus on unlocking the potential of existing spaces; areas with good accessibility but low quality should prioritize improvements in service quality; and areas with low accessibility but high quality should strengthen integration and coordination with surrounding districts.

Sources of Figures and Tables

All figures and tables in this paper were prepared by the authors.

Notes

1) Includes residential compounds, villas, and mixed residential-commercial developments, but excludes urban villages. Data are current as of the end of 2020.

2) Owing to the limited timeliness and insufficient spatial resolution of the Sixth National Population Census data, population data were derived from the "number of households" information for individual residential compounds obtained from real-estate websites (including residential compounds, villas, and mixed residential-commercial developments; data are current as of the end of 2020). Using this method, the estimated permanent resident population of Tianhe District was 1.663 million, compared with 1.747 million reported in the "Tianhe Yearbook 2019". The overall error is within 5%, indicating a relatively high level of reliability.

3) As the minimum proximity distance is a negative indicator, darker colors indicate greater distances to the nearest green space and therefore poorer performance for this indicator.

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