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People-Oriented: A Framework for Evaluating the Level of Green Space Provision in the Life Circle from a Supply and Demand Perspective: A Case Study of Gulou District, Nanjing, China

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Abstract: Green space resources, in the context of urbanisation, cannot meet the actual needs of residents well, and the study of the balance of green space resource allocation based on the relationship between supply and demand is an urgent problem to be solved. This study quantitatively evaluates the green space supply level from four dimensions by constructing a framework for assessment in the community life circle. It also evaluates the matching of green space supply and demand, resource distribution fairness, and distribution equilibrium under group differentiation through the supply–demand coupling matrix, the Gini coefficient, and the Kruskal–Wallis H non-parametric rank-sum test, respectively. This study shows that: (1) A significant spatial imbalance exists in green space resource allocation in community life circles in different dimensions. (2) The comprehensive green space supply level in the community life circle matched the total demand of residents to a low degree. (3) There was significant inequality in green space resource allocation within the community life circle (the Gini coefficient of each evaluation perspective was >0.4). Based on the study results, we were able to identify community life circles with spatial mismatches, different supply and demand, and other green space resource allocation problems, which is of great significance to urban green space research and planning practice under the 'green justice' framework.

Keywords: green space; community life circle; provision level; resident demand; assessment framework; population model

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1. Introduction

Urban green spaces are important leisure and open spaces for urban residents [1]; they provide a wide range of ecological services and play an important role in the sustainable development of cities and the improvement of human well-being [2,3]. As an important part of urban green infrastructure, green space plays a key role in the urban environment, such as providing ecological services like runoff regulation and climate regulation [4]. It has been shown that rationally planning and laying out the location and area of green space is conducive to reducing and mitigating the impact of urban flooding [5]. We should therefore pay more attention to planning and improving green infrastructure to meet the complex challenges of urban planning and provide a higher level of urban resilience for contemporary and future cities. Simultaneously, urban green spaces are an important public good, and their public nature displays urban humanistic care characteristics. It is widely recognised that exposure to green spaces improves the quality of life and public health of urban residents [6]. Resident visits to blue and green spaces in cities shifted from optional to a necessary activity during the pre-COVID-19 pandemic period [7,8]. During the pandemic, urban green spaces provided social interaction spaces for residents [9]. The value of green spaces is highlighted because an increasing number of people are concerned about the built environment within walking distance of their homes [10].

However, in the context of rapid global urban expansion and population growth, urban green spaces are underprovided or poorly distributed, leading to spatial inequalities between green space spatial layout provision levels and the location of residents [11]. As a public service resource, the current supply conditions for urban green spaces are not aligned with actual daily needs of urban residents. If public services are not planned according to population needs, discriminatory allocation may occur [9]. Equity in public service resource allocation should align with resident needs and preferences [12]. The core fairness issue in urban green space resource allocation is spatial green space distribution. Therefore, focusing on the balance between supply and demand at the urban green space level and scientifically evaluating and improving public service capacity of urban green spaces is of great social value in enhancing the well-being of residents [13].

Some studies have found that social group inequality between different classes and races is more obvious in smaller-scale green spaces [14]; therefore, our research needs to focus on smaller spatial scales. In recent years, with the introduction of the life circle concept [15,16], related studies have begun to discuss urban life quality on the life circle scale [14,17–19]. Compared with traditional settlement planning, which is characterised by population size and geographical scope, life circle planning focuses more on needs and subjective evaluations of residents instead of static spatial perspectives and data statistics [20]. Currently, relevant practical application research is mainly focused on the service relationship and function of urban integrated public service facilities in the life circle; however, research on green spaces within the life circle is still relatively limited.

Community-related research has always been a popular topic in urban research [21–23], and considering people-centred urbanisation in China, an increasing number of studies have begun to focus on community life circles [24]. The community life circle is the basic unit of the life circle system, and its scope represents a community in which residents are willing to spend time sitting, walking, playing, or interacting with their neighbours [25]. Early studies have focused on public service facility spatial accessibility, such as access to healthcare, education, and parks [26], and research on community green spaces is inadequate. Therefore, the study of green spaces accessible to residents at the community scale can more accurately assess the supply of green spaces and its match with residents' needs and help explore the efficient use of green spaces in built environments.

Most of the previous studies on urban green space resource allocation have neglected the demand side and severed the interactive relationship between 'people' and 'city'. In order to make the urban green space supply level better adapt to the changing demand, this paper takes the demand side into consideration and improves the green space evaluation system in previous studies. Based on residents' daily living habits and needs, this study innovatively uses geographic information processing systems and tools such as Python to delineate the 15-min community life circle as the basic research unit, and constructs an evaluation framework for the green space supply level under the perspective of supply–demand matching by quantifying the supply level and demand level of green space respectively; conducts an empirical study in the Gulou District, Nanjing City; argues for the practicability of this framework; and answers the following questions: (1) Is the green space provision level in the community life circle balanced in terms of spatial allocation? (2) Does green space resource allocation match the actual demands of residents? (3) Is green space resource allocation equitable in terms of population distribution?

2. Conceptual Framework

2.1. Framework for Assessing Green Space Service Provision Levels in Community Life Circles

Previous research has identified and divided the spatial social life circle scope based on administrative boundaries [27–29], fixed spatial and temporal distances [30–32], and GPS survey data [33,34]. To comprehensively consider the actual environment and residents' needs, this study adopted a division method based on the idea of accessibility to delineate community life circle scope. We defined the community life circle as the spatial area covered by a 15 min walking distance radius in a residential neighbourhood.

The term 'performance' first appeared in the management field, reflecting the achievements and results of people engaged in a certain activity. Urban green spaces have complex and comprehensive service effectiveness, and their service performance characterises green space service capacity and effectiveness at a certain stage. In research perspective terms, scholars have mostly studied urban green space service performance from the supply–demand balance and spatial justice perspectives. Lee et al. measured actual green space accessibility through the spatial difference indicator between the green space service scope supply and resident demands [35], and Liu et al. developed a multidimensional spatial assessment framework consisting of scale and indicator dimensional frameworks [36]. In research unit terms, some scholars have quantitatively analysed the balance between green space service supply and demand using the residential community as a unit [37,38]. The evaluation method can be summarised in two dimensions: green space functional operational and spatial structural performance. Functional operational performance is primarily achieved through scene and sampling information evaluation and big data technology [39–42]. In spatial structural performance terms, the research is mainly based on accessibility indicators; for example, the Gaussian two-step search-and-move method is used to evaluate spatial configuration rationality of park green spaces from an accessibility perspective [43].

Scholars have conducted multidisciplinary research on green space service performance but have not formed a more unified evaluation framework. Based on the evaluation framework and indicator selection in existing studies [44], this study considered the demand side and improved on the green space evaluation system used in previous studies. This study attempted to construct a systematic assessment framework for the green space supply level from a supply–demand matching perspective (Figure 1). We assessed urban green space supply levels from four aspects: availability, accessibility, attractiveness, and visibility. On the demand side, we objectively simulated the demand for urban green space services from the resident population distribution and socioeconomic status perspectives.

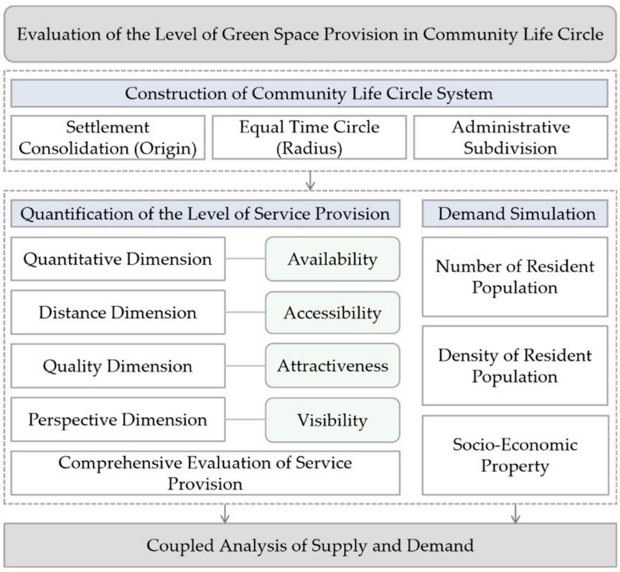

Figure 1. Framework for evaluating green space provision levels in a community life circle.

2.1.1. Supply-Side Indicator Selection

Previous studies have been conducted mainly from the perspective of quantity and distance on a two-dimensional plane, which can evaluate overall green space construction levels within the region; however, the evaluation dimension is relatively singular and lacks a certain degree of breadth. Therefore, we selected four types of indicators to evaluate the service level provided by green spaces for residents from various dimensions. In terms of the types of spaces providing services, accessibility and visibility are ‘all green space’ evaluations within a certain range, while accessibility and attractiveness are ‘mainly green space’ evaluations (including parks, green spaces, pocket parks, squares, and other places where people can gather and enjoy green spaces) that can be accessed within the scope of daily life.

In indicator measurement terms, we used NDVI for quantification of vegetation cover to describe green space availability. Green space accessibility is described by the cost of the path to the nearest green space for all residential neighbourhoods within the same community life circle; the accessibility and availability indicators do not represent urban green space attractiveness to residents; however, the quality of green spaces also affects the interaction between residents and green spaces. We used quality to evaluate green space attractiveness, as it is generally believed that high-quality green spaces can meet residents’ daily diversified behavioural needs and that their quality is positively correlated with the attractiveness of parks to residents. With reference to factor selection for evaluating green space quality in previous studies [45–48] and relevant normative documents, we adopted a ‘point system’ to classify the evaluation indicators into three categories: scale, internal, and neighbourhood environmental elements for measurement (Supplementary Table S1). Visibility can be used to evaluate opportunities for residents to visually engage with green spaces from a human perspective. Streetscapes can capture visual built environment perception at the human eye level and are now widely used in green visibility studies on urban streets [49–51]. In this study, we measured the ratio of green vegetation in images observable by the human eye by capturing streetscape images with the help of machine learning [51] to describe green space visibility. The specific operational method is shown in Supplementary Figure S1.

Simultaneously, to assess urban green space provision levels at a finer scale, and to accurately identify under-provisioned areas, we integrated indicator performance under each dimension to evaluate comprehensive green space provision levels.

2.1.2. Population Demand Simulation

Population distribution represents the potential demand of residents for urban green spaces. The spatial match between population distribution and urban green layouts directly affects green space service benefits. Many previous studies refer to the normative standards in the comprehensive residential area technical indicators, so that the number of users multiplied by the average number of people in a household leads to population data estimation on a fine scale. Some scholars have also expressed the resident population in the study area by dividing total residential building area by per capita area [52]. In this study, we modelled the level of demand using population distribution characteristics for a comparative supply and demand analysis.

As residential housing prices increase, superior green space services are increasingly recognised as an environmental advantage of upmarket neighbourhoods over disadvantaged ones [53]. There is a strong correlation between the housing characteristics and socioeconomic levels of residents, and some scholars have used house prices to characterise socioeconomic status [52]. To investigate whether green spaces in community life circles were unevenly distributed among people of different socioeconomic statuses, we characterised population socioeconomic attributes using housing characteristics.

2.1.3. Analytical Evaluation of Supply and Demand Interactions

Based on the constructed simulation model of the degree of residents’ demand for green spaces, this study quantitatively evaluated the interaction between supply and demand from three perspectives: matching the degree of supply and demand, distribution fairness, and distribution equilibrium under group differentiation.

1. Evaluating the match between supply and demand for green spaces in the life circle

Owing to the large differences in the development of each area within the built-up city area, the distribution of social group needs has a certain degree of concentration and segregation, which leads to the possibility of spatial mismatches between the allocation of green space resources and population needs. Based on standardised supply and demand indicator data, we constructed a coupling evaluation matrix of green space resource supply and demand in the life circle (Figure 2). Four evaluation zones were formed based on the coupling situation: low-level coordination, service lagging, service advancement, and high-level coordination. This was used to identify the mismatched green space supply and demand areas in the study area to avoid social inequality caused by the contradiction between resource supply and demand, which hinders sustainable city development.

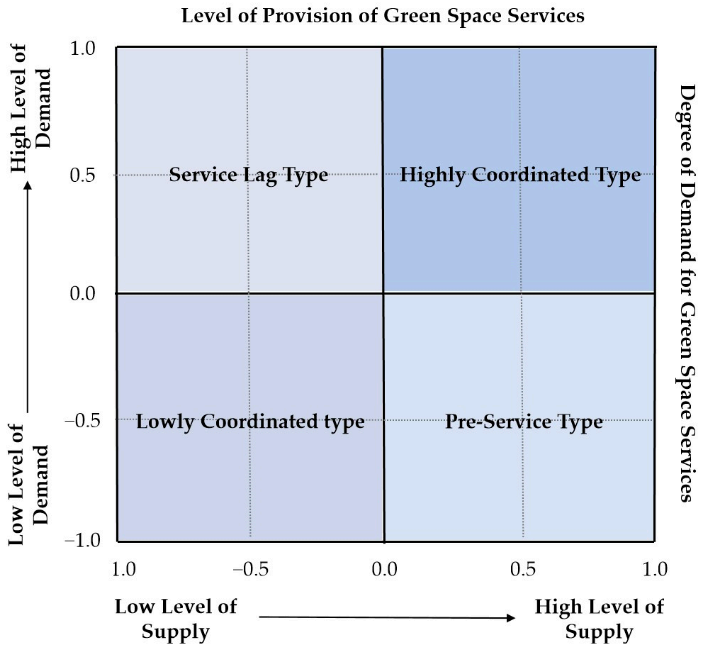

Figure 2. Coupled supply and demand evaluation matrix. The horizontal and vertical axes indicate the level of supply and the degree of demand from lowest to highest, respectively.

2. Equity evaluation in green space allocation

To investigate whether the match between green space resource supply and the actual demand of residents based on population distribution within the study area is reasonable, and whether there is inequality in resource allocation, this study analysed the proportion of green space resource distribution over the resident population by choosing the Gini coefficient as an indicator to study environmental green space fairness (Figure 3).

3. Distributional equilibrium evaluation under group differentiation

Some scholars have pointed out that resident socioeconomic status is closely related to their access level to green space services and that urban green space resource distribution is not always fair and just [54]. To investigate whether there are differences in green space provision levels for residents with different socioeconomic attributes in life circles, this study used the Kruskal–Wallis H non-parametric rank-sum test to compare the differences in green space provision levels between different life circle group levels.

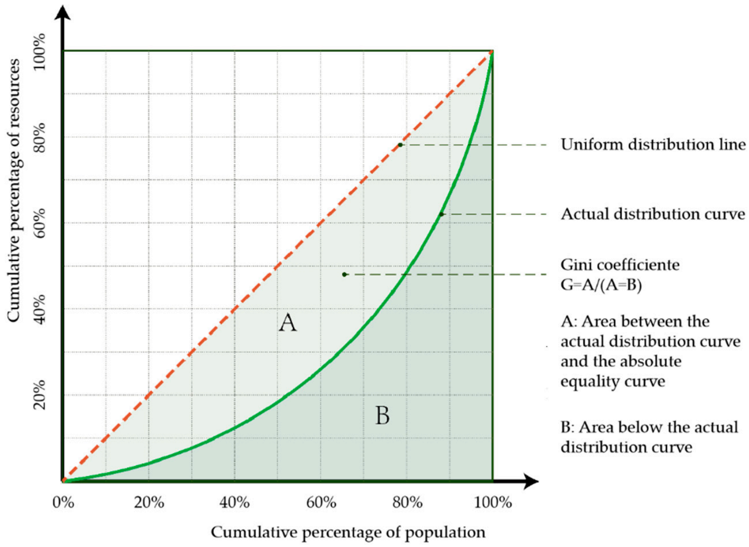

Figure 3. The Lorentz curve principle. The horizontal and vertical axes are the cumulative percentages of population and resources, respectively, and the function line represents the absolute average resource distribution, with the degree of curvature of the actual distribution curve reflecting the degree of equity in the resource distribution.

3. Methodology

3.1. Study Area

For this study, the Gulou District in Nanjing City was selected as the study area, comprising 13 streets and 120 neighbourhoods, with a total area of approximately 54.18 km^2. According to the Seventh Population Census Bulletin, published by the Nanjing Municipal Bureau of Statistics, as of 00:00 on 1 November 2020, the resident population of Gulou District was 940,387, accounting for 10.10% of the city's resident population. Gulou District is a high-density built-up urban area with complete infrastructure and a high population concentration, which is suitable for studying the interaction between residents' daily behavioural needs and urban green space supply. The scope of this study included 13 streets within the Gulou District administrative area (Figure 4). The life circle delineated based on the walking distance of residents is not bounded by administrative districts; that is, residents near the Gulou District administrative boundary inevitably interact with green spaces in neighbouring urban areas in their daily activities, resulting in a boundary effect. Therefore, a buffer zone of 1000 m was delineated in this study, with the administrative boundary used as the boundary to conduct subsequent studies.

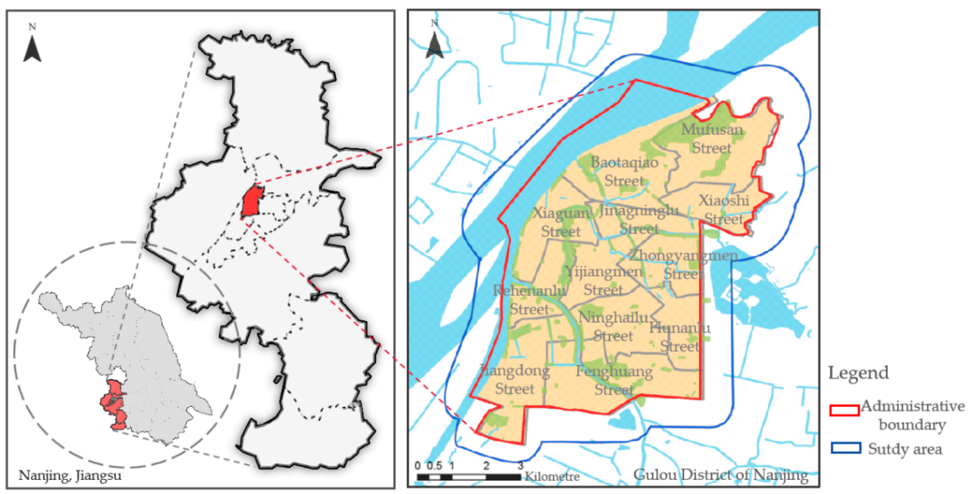

Figure 4. Study area location.

3.2. Data Source

This study includes three data sets. The green space data were mainly obtained from the BigeMap map download platform, a Nanjing green space system planning document, and the Baidu Map API. The basic urban data set used to delineate the community life circle was obtained from BigeMap, the data platform, the Nanjing planning document, and the Gaode map open platform. The data on the city's resident population and its socioeconomic attributes used to simulate green space demand were obtained from the Nanjing Bureau of Statistics, Baidu Map API, and BigeMap websites. The specific data are shown in Supplementary Table S2.

3.3. Data Processing

3.3.1. Community Life Circle Delineation

In this study, the 15 min walking range of residents was taken as the community life circle range by summarising daily walking travel range. After integration and processing, 98 community life circles were obtained for the Gulou District, Nanjing (Figure 5). The community life circle division steps are as follows:

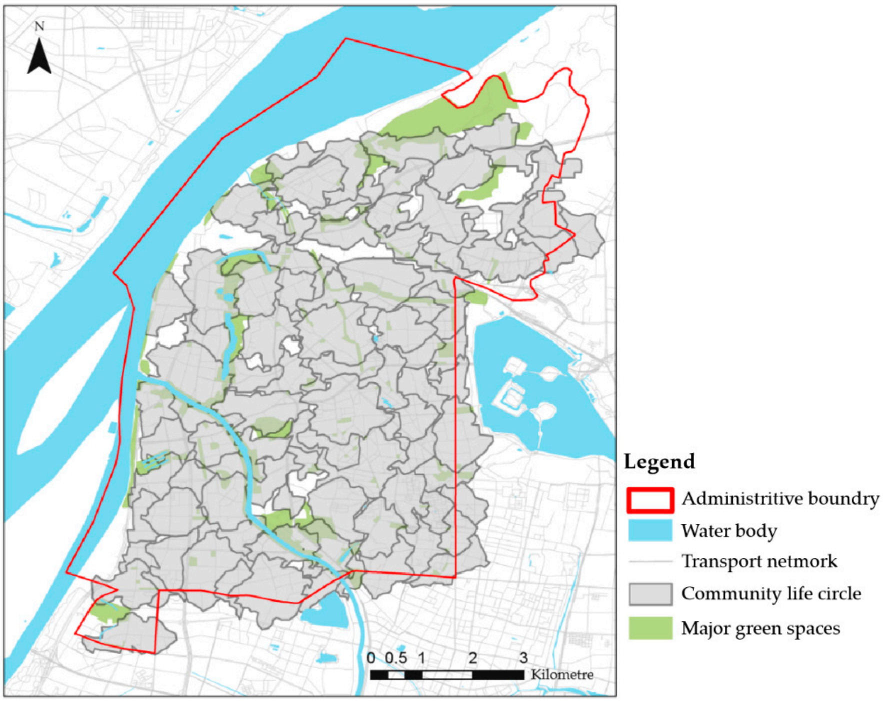

Figure 5. Community life circle delineation results in Gulou District.

First, we obtained POI data, including name type, latitude and longitude coordinates, and specific addresses of 932 residential communities in Gulou District, Nanjing, based on the Baidu Map API. We imported them into the ArcGIS platform according to their geographic coordinates, and then integrated the adjacent residential communities according to a certain distance threshold. Then, the 213 residential sites obtained from the consolidation were used as the origin for delineating the community life circle, and the 15 min travelling time was used as the radius to delineate the 15 min resident group travelling range within the life circle using the prefabricated program. Finally, the boundaries were delineated according to the geographic coordinates of the 213 settlements, and a life circle range file of the surface element type was generated and imported into ArcGIS. Concurrently, we merged two or more community life circles that shared a large amount and overlapped by more than half and eliminated those that were too small in size.

3.3.2. Constructing a Refined Population Model

We calculated the refined population distribution to quantify the degree of green space demand in each community life circle. The entire process was divided into three main steps: data preprocessing, extraction, and normalisation (Figure 6). First, the TIF raster information was extracted from the Baidu population heat map of Nanjing, street information corresponding to the raster points was obtained, and the information was stored in a point element file. Next, we established a conversion table between the TIF raster image channels and the fine population density (Supplementary Table S3), and the population density distribution point element shapefile within the life circle coverage was generated based on the geographic coordinates of the image raster points, streets to which the raster points belong, and the estimated value of the fine population density of the raster points. Finally, the total density and statistical population of the street were compared and normalised, and the population density data within the street were transformed into the actual population number of each raster point to obtain the estimated value of the refined population distribution.

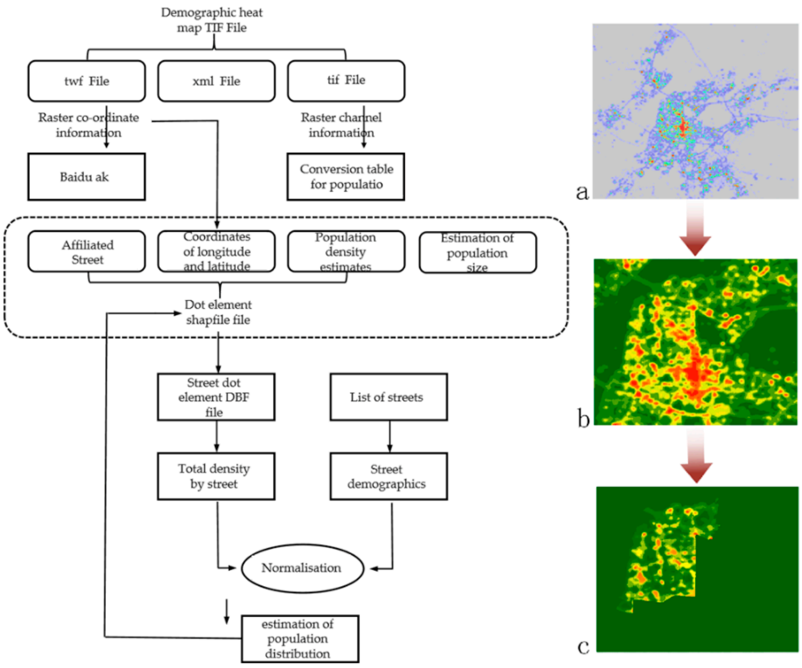

Figure 6. Refined flow chart of population distribution simulation. (**a**) Nanjing Baidu population heat map. Baidu heat map color and corresponding RGB channel values and population density values are shown in Supplementary Table S3. (**b**) Generation of point element shapefile files of population density distribution within life circle coverage. Extract the grid information of TIF, obtain the street information corresponding to the grid point, and store the information to the point element file based on Baidu Map Open Platform. (**c**) Results of the actual population quantity estimation. Save the calculated estimates to the new point feature properties in the previously generated shapefile file.

3.3.3. Comprehensive Green Space Service Provision-Level Evaluation

A comprehensive green space provision-level evaluation requires the integration of the four evaluation indicators into the four dimensions to identify differences in spatial distribution. To improve the data comparability of each indicator, the z-score standardisation method, which can measure the degree of difference from the mean and standard deviation, was chosen to standardise the indicators, eliminating the scale influence of each indicator, thus weakening their interpretability. After the standardisation process, the mean value of each indicator was 0, and the standard deviation was 1. The average value of the four indicators was obtained as a comprehensive evaluation result according to the 1:1:1:1

weights, and the summary was mapped to the [−1, 1] interval. The calculation formula is as follows:

$$Z_j^x = \frac{x_j - xavj}{xstdev} \tag{1}$$

In Equation (1), the item (1) indicator value was obtained after z-score standardisation and indicator mean value and standard deviation, respectively. This calculation method is applicable to accessibility, attractiveness, and visibility indicator standardisation, which are positively correlated with green space supply level; that is, the larger the evaluation result value, the higher the supply level is. As for the negatively correlated accessibility indicators in the distance dimension, the greater the distance from the path of the green space, the greater the evaluation value, and the lower the supply level; the sign of the z-score standardisation results needs to be reversed.

$$\text{Norm}_j = a + \frac{b-a}{\overline{z}max - \overline{z}min}\left(z_j - \overline{z}min\right) \tag{2}$$

In Equation (2), the normalised value was mapped to the [−1, 1] interval, representing the maximum and minimum values of each indicator, respectively, after normalisation and averaging according to the 1:1:1:1 weights. Finally, the integrated green space supply capacity was described by the score with values between [−1, 1]. In Equation (2), the normalised value was mapped to the [−1, 1] interval, representing the maximum and minimum values of each indicator, respectively, after normalisation and averaging according to the 1:1:1:1 weights. Finally, the integrated green space supply capacity was described via the score with values between [−1, 1].

4. Results

4.1. Spatial Variability in Green Space Provision Levels

The visualisation analysis results show that there is some variability in the spatial distribution of the green space provision evaluation indicators (Figure 7). Overall, the accessibility and visibility indicators show rough consistency in spatial distribution, with high values clustered centripetally in the southeastern city centre. Low values mainly appeared in the northern and western fringes of the region, while the accessibility indicator showed a large number of high values in the northern region. The attractiveness indicator was mainly affected by green space quality, and high values were mainly distributed axially along the Qinhuai River. Some life circles located in urban centres have high values for accessibility and visibility of green space resources, but poor performance for attractiveness. However, some life circles in the northern fringe have high accessibility services, but all other indicators show low values.

The indicators were standardised and the comprehensive evaluation numerical results were classified into five levels using the natural discontinuity grading method (Tables 1 and 2). In terms of the comprehensive evaluation value of the green space provision levels, the score interval was [−1, 1], the mean value was −0.011726195, the standard deviation was 0.400305457, and 36.73% of the life circles did not reach the mean value. In spatial distribution terms, the green space provision levels in Gulou District are not uniform, which will also directly lead to inequitable access distribution to green space resources for residents living in different areas.

Table 1. Indicator standardisation for green space service supply.

Evaluation Indicators	Maximum Value	Minimum Value	Average Value	SD
Availability	2.87	−2.25	0.00	1.00
Accessibility	2.69	−5.26	0.00	1.00
Attractiveness	2.24	−1.32	0.00	1.00
Visibility	2.24	−2.66	0.00	1.00
Overall assessment	1.00	−1.00	−0.01	0.40

Table 2. Community life circle green space service supply rating grading.

Level	Comprehensive Supply Level Score	Number of Life Circles	Percentage
Level 1	−1.0 to −0.49	14	14.29%
Level 2	−0.49 to −0.17	20	20.41%
Level 3	−0.17 to 0.12	30	30.61%
Level 4	0.12 to 0.44	22	22.45%
Level 5	0.44 to 1.00	12	12.24%

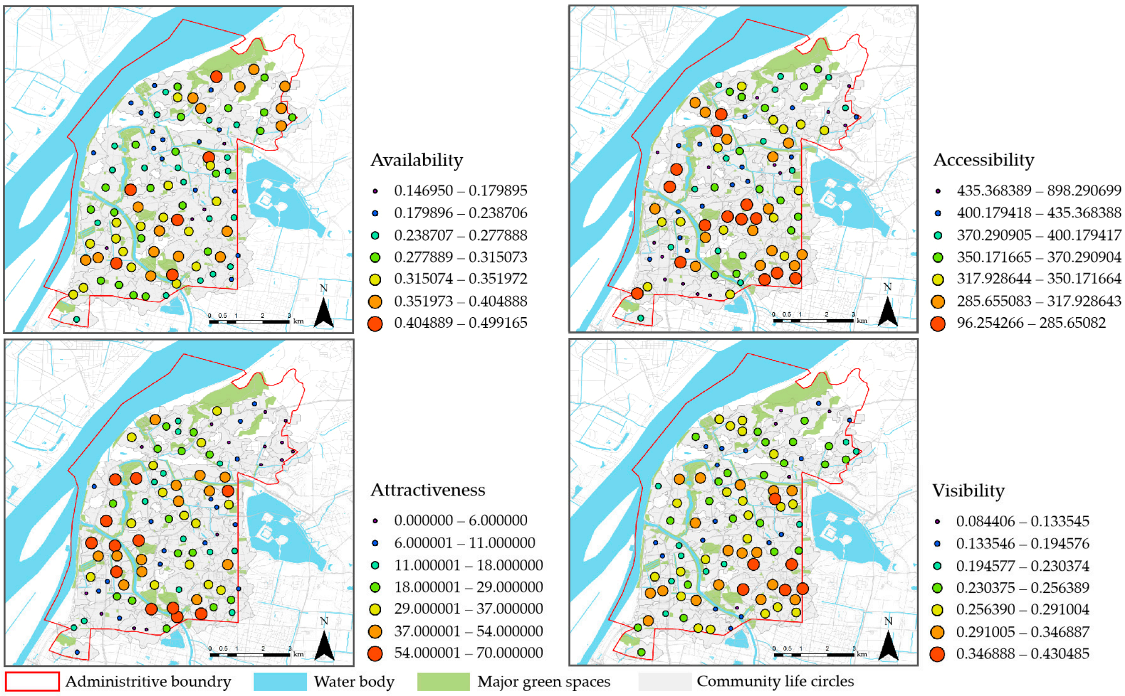

Figure 7. Visualisation of four green space provision level indicators in the life circle.

4.2. Green Space Provision Adaptability to Residents' Needs

According to the supply–demand coupling model, the 98 community life circles in Gulou District were classified into four categories according to the matching degree of supply and demand (Figure 8). The evaluation results show that there was an imbalance between the comprehensive green space supply levels in Gulou District and the total demand by residents, and the degree of matching was low. There were 50 high-level coordinated and service-advanced community life circles, accounting for 51.02% of the population. Furthermore, there were nine high-level coordinated community life circles, accounting for only 9.18%; 14 low-level coordinated community life circles, accounting for 14.29%; and 31 service-lagging community life circles, accounting for 31.63%.

4.3. Equity in Green Space Resource Population Distribution

According to the Lorenz curve as well as the Gini coefficient results (Figure 9), it can be observed that there is obvious inequality in green space resource allocation in the Gulou District, Nanjing life circle. From the Gini coefficient evaluation value, the Gini coefficient of each evaluation angle was between 0.4 and 0.6, and all of them were evaluated as having a large difference in resource distribution according to the economics field division. Among them, the Gini coefficient of the comprehensive green space resource supply level was 0.50, which means that 60% of the resident population in Gulou District enjoys only 25% of the green space resources.

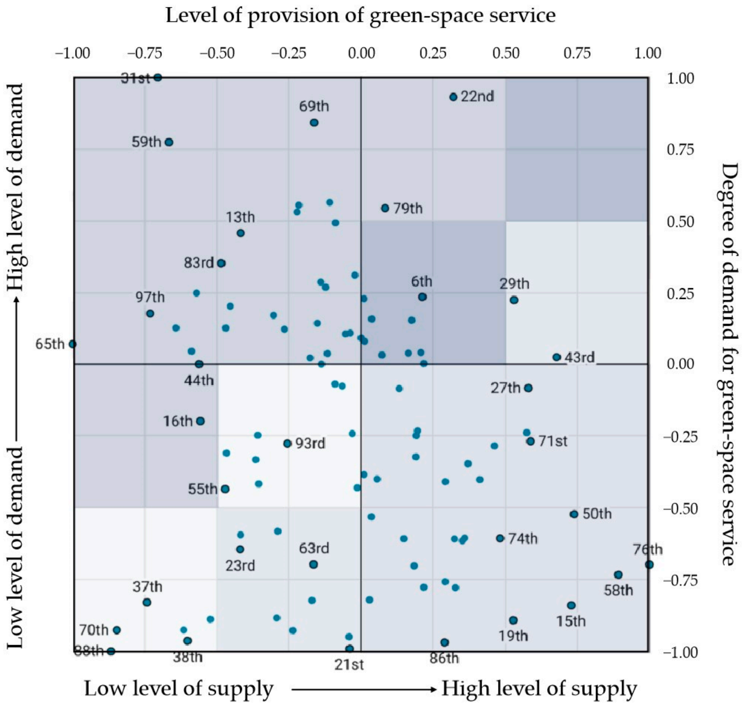

Figure 8. Visualization of four green space provision level indicators in the life circle.

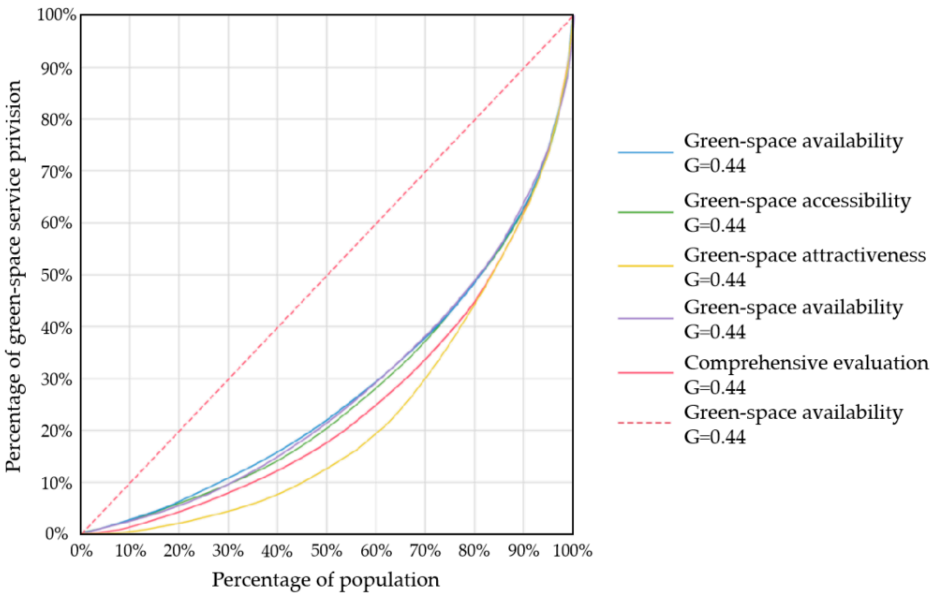

Figure 9. Lorenz curve and Gini coefficient of green space services in the life circle.

Inequality in green space attractiveness resource distribution was the most serious problem, with a 0.55 Gini coefficient, which means that >50% of the resident population enjoys <20% of the green space attractiveness services when assessed from the attractiveness perspective. The green space availability and accessibility Gini coefficients were 0.44 and 0.46, respectively, which are relatively low compared to those of other indicators; however, there is still an inequitable resource distribution, indicating that <60% of the resident population enjoys <30% of the green space resources when analysed from the availability and accessibility perspectives. Analysis results show that most green space resources were occupied by small populations, resource allocation was highly differentiated with serious polarisation, and green space resource utilisation rate and fairness in the community life circle need to be improved.

4.4. Equilibrium in Green Space Resource Distribution under Group Differentiation

We divided the 98 community life circles within the study area into five socioeconomic classes (Table 3) and compared green space resource distribution among the life circle groups at different levels (Supplementary Table S4). From the analyses results, green space provision indicator *p*-values within the community life circles at different levels, except for the accessibility indicator, were all <0.05, indicating a significant difference. This means that, overall, as residents socioeconomic levels increased, the comprehensive green space supply level owned in the community life circle also improved. However, lower values for attractiveness and visibility indicators were observed in the high-grade tiers. Moreover, anomalously higher accessibility values appeared in life circles with low-grade socioeconomic attributes.

Table 3. Classification of community life circle socioeconomic attributes.

Level	Average Housing Price in Residential Areas	Number of Cases	Percentage
Low grade	<32,000 Yuan/square	20	20.41%
Lower grade	32,000~38,000 Yuan/square	21	21.42%
Middle grade	38,000~46,000 Yuan/square	24	24.49%
Higher grade	46,000~52,000 Yuan/square	15	15.31%
High grade	>52,000 Yuan/square	18	20.57%

5. Discussion

5.1. Sharing Based on a Guaranteed Amount of Green Space Resources

The results of this study show that there is an imbalance in spatial green space availability distribution in the life circles of Gulou District, Nanjing. As the central area of the old city was developed and built earlier, the neighbourhoods are old and have high building density, so there is relatively less green infrastructure in and around the residential area. In addition, green space accessibility along rivers or railway lines is rated as low, mainly because of the existence of a large amount of wasteland and bare land in the surrounding area, which has not yet been fully developed and constructed. To achieve fair green space resource distribution in a life circle, it is necessary to minimise variability in provision levels between different community life circles and maximise green space resources enjoyed per capita.

On the basis of ensuring the quantity, rational green space spatial allocation patterns will also further affect accessible green space supply levels. Ngom et al. found that linear green space can play a role in balancing green space resource variability distribution, which can help to improve equity [55]. We found that green spaces in established communities are often fragmented and lack mutual articulation. Therefore, we should pay attention to the overall effect of green spaces in our research to improve resource allocation openness and sharing. In terms of optimisation, we can adopt the slow-moving system represented by ‘greenways’ and ‘blueways’ to promote the formation of a ‘multi-centre, multi-level, networked’ shared and participatory community green space network system for life circles (Figure 10).

5.2. Enhancing Accessibility to Community Green Spaces

The results of this study show that accessibility green space provision levels in established neighbourhoods is unsatisfactory, especially in older neighbourhoods where vacant green spaces are often used inefficiently. This may be due to the fact that there are walls, railways, rivers, and waterways between various types of spaces with different ownerships that cannot be traversed by residents on foot, which makes it impossible to conveniently visit some green spaces despite their close proximity and requires a diversion.

Figure 10. Schematic diagram of community life circle green space structural mode.

Accessibility is an important factor affecting residents' access to green space resources and services and is closely related to the frequency of residents' visits. Scholars have explored the threshold relationship between green space accessibility and residents' demands, and most scholars believe that the green space threshold is 300 m, that is, approximately a 5 min walk, and that residents' willingness to visit green spaces will be greatly reduced if this threshold is exceeded [56]. A higher accessibility level can provide residents with opportunities for contact and interaction with nature and, simultaneously, create more social and health benefits by indirectly promoting physical activity among residents. Therefore, appropriate measures should be taken to improve green space resource accessibility. For example, green space accessibility and openness can be enhanced by improving community microtransportation and reducing green space barriers to increase residents' opportunities to come into contact with nature and realise convenient sharing among various communities.

5.3. Promoting Equity in Green Space Resource Provision from a Fitness Perspective

The core issue of equity in the allocation of urban green space resources lies in the green space spatial allocation and whether the allocation process caters to the diversified needs of different groups. In this study, we found that the distribution of the supply and demand levels of green space resources on the spatial scale of the life circle is differentiated, and the degree of matching of the supply and demand is low. Dong et al. used the Gaussian two-step floating catchment area (Ga2SFCA) method to analyse the relationship between green space supply and demand [57], and the results of the study showed that green space resources had an imbalance between supply and demand at the administrative district, street, and community levels. In a study by Wang et al. evaluating the fairness of park green space supply [58], there was a spatial mismatch between the total park green space supply and the total population of the sub-district, as well as significant differences in the matching relationship between supply and demand with different social groups. By comparing the results of the study, we can find that there is an imbalance in the matching of supply and demand for green space resource allocation at different spatial scales, and these matching results are closely related to factors such as natural geographic features, regional built environment and group differentiation.

Therefore, when evaluating the fairness of green space resource distribution, we need to study the differences in supply and demand of different regions and groups more deeply to accurately analyse the matching of green space supply and demand. As far as this study is concerned, owing to the diversity of the location, type, function, and potential of each community life circle, different strategies should be adopted according to individual conditions when optimising their green space layout in the future, so that green space resources can be organically and elastically distributed in the region. Meanwhile, we should also take into account the needs of different user groups so as to achieve the fit matching of supply and demand.

5.4. Focusing on the Needs of Different SocioEconomic Groups

In a study of green space resource distribution under group differentiation, we found that green space resources appeared to have lower values for attractiveness and visibility indicators in the high-grade tier. One potential reason for this is the impact of educational resources on housing prices, with unusually high housing values occurring in community life circles around some primary schools, but not enjoying better green space resources because of their location in the heart of the city and older infrastructure from earlier development and construction. In contrast, many low-grade life circles are located in the northern fringe of Gulou District. Although they have better natural ecological resources, they are still not fully developed and cannot provide residents with better space for rest and recreation, so they enjoy a higher accessible green space supply level and a relatively lower attractiveness and visibility supply level.

Lower socioeconomic groups have poorer access levels to green spaces, and they often rely on green open spaces as a public urban resource because of the poor internal environment of their neighbourhoods and the lack of private green spaces. Therefore, lower socioeconomic groups and the areas in which they congregate are key targets and areas for future planning, construction, and renewal, and priority should be given to intervening in such groups and the areas in which they congregate to avoid imbalanced and unjust social problems such as low-income group 'marginalisation'. However, as urbanisation and economic development advance, the lack of land resources may exacerbate the conflict between equity in resource allocation and efficiency in land use. Therefore, in practical urban planning, while maximising the efficiency of land use, the allocation of green space resources should be optimised to maintain a relative balance between efficiency and equity. For example, we can develop green buildings and green transport to reduce the occupation and pollution of land resources, and guide the rational flow of resources between different uses to meet the needs of different social groups.

5.5. Limitations and Future Studies

The green space supply level assessment system constructed in this study from four dimensions systematically analysed the role of green spaces and their ecological service benefits and characterised the ability of the population to access green space services. The system did not cover all services provided by green spaces. In future research, green space ecosystem services can be evaluated and analysed in a more systematic and comprehensive way.

In this study, only two factors—population distribution and residential housing prices—were used to construct the demand model for residential services; however, factors such as age, health status, and education level may also affect people's demands for green spaces. Future research should further explore and summarise the relevant influencing factors to improve the demand model multidimensionality and authenticity. Meanwhile, in the study on the equity of green space resource distribution under group differentiation, although there is a high correlation between house price and residents' socioeconomic level, it is also closely related to factors such as urban planning, topographical traffic, school distribution, etc., and a neighbourhood having high house prices does not necessarily mean that it is also served by a better green space resource, so using house price as the basis for categorizing different socioeconomic groups may have an impact on the results of the study. In future studies, the classification criteria should be adjusted by in-depth and comprehensive examination of the actual environmental conditions in different regions.

Furthermore, there are some uncertainties in the measurement of the indicators in this study that have an impact on final evaluation accuracy. For example, in attractiveness measurement, a point system was used to cover a variety of indicators in a more comprehensive manner; however, the weight differences between indicators were not considered, and equal weights were used for summary statistics. Indicator factors such as eco-efficiency and safety can be added to future research. Similarly, in the comprehensive evaluation of the level of green space service provision, due to the difficulty of clearly comparing the weight relationship of each indicator we have directly assigned equal weights to them. However, this way of integration is not rigorous enough, and in future research we need to explore more appropriate ways to improve our assessment framework through more samples and surveys.

Finally, it is worth noting that the interaction between green spaces and urban residents is a dynamic and complex system. Owing to data acquisition and technology limitations, only a static assessment of the current green space supply level was conducted in this study, which lacks more accurate and complete dynamic big data. Future research can make use of network big data, such as social platform big data, and spatial and temporal behavioural data collection technology, such as mobile phone signalling, to conduct demand simulation in a more refined and precise manner and make corresponding predictions of future changes and trends to conduct spatial and temporal optimisation of green space allocation.

6. Conclusions

As an important natural resource in the city, green spaces not only provide a wide range of ecosystem services for the city but also provide urban residents with opportunities to access nature. Existing studies have mostly assessed green space resource allocation efficiency and fairness from a land-use spatial layout perspective, but have not paid sufficient attention to green spaces within the actual scope of residents' activities. In this study, we focused on the interaction between green space resource supply levels and demand-side 'people' from the 'people-oriented' perspective and the supply and demand balance, and established the community life circle as the basic research unit of residents' daily behavioural activity to initiate the study. We assessed green space supply levels by considering the community life circle as the basic research unit. We constructed an evaluation framework for green space supply levels from four dimensions: availability, accessibility, attractiveness, and visibility. We studied objective demand level matching of the residents, which was evaluated and analysed from three perspectives: the match between supply and demand, resource distribution fairness, and resource distribution balance among the different groups.

The results show that green space resource allocation in the Gulou District of Nanjing is spatially unevenly distributed, and green space service supply levels are less compatible with residents demands. In addition, green space resource distribution is inequitable in terms of population demand and group differentiation. By analysing the interaction between the actual demand of residents and the supply of green space services, we were able to portray the problems in the green space allocation pattern more precisely. Simultaneously, we propose corresponding planning and design optimisation strategies that are of great significance for balancing green space resource distribution, maintaining spatial equity and justice, and creating a comfortable and liveable urban environment.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16030955/s1, Figure S1. DeepLabV3+ architecture. DeepLabV3+ uses the hollow space convolutional Atrous Spatial Pyramid Pooling structure to achieve multi-scale feature extraction; Table S1. Major urban green space attractiveness evaluation factors; Table S2. List of research data; Table S3. List of research data; Table S4. Community life circle green space service supply index socio-economic difference evaluation.

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