Construction of Pocket Park Network Systems in Urban Built-Up Areas: A Case Study of Harbin City

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Abstract: Pocket park planning is an important tool for urban habitat enhancement, yet previous studies have not often considered pocket park network construction. In order to determine the spatial differences in the demand for pocket parks, this article adopts a systematic perspective and uses the built-up area of Harbin city as an example. It does this by extracting the existing green space network, evaluating the spatial suitability of pocket parks, and combining the two previous steps. The results show that the density of buildings and roads in the city are negatively correlated with the supply of ecological resources; there are differences in the demand for pocket parks among spaces in the built-up area. By comparing the current situation with the simulation, the designed network of 88 pocket park corridors will effectively alleviate the problem of green space shortage. In addition, from the perspective of the network system, we propose three strategies for constructing pocket parks for different spaces, providing a new approach to enhance the urban living environment and promote the harmonious development of humans and nature.

Keywords: Geodesign, pocket park system, morphological spatial pattern analysis, analytic hierarchy process

1 Introduction

An urban green space built-up area is a large densely populated human settlement. Rapid urbanization has resulted in the disorderly expansion of the city, the reduction of the green space area of the urban built-up area, the serious fragmentation of the ecological environment, and the inefficient use of urban construction land (ZHANG & HAN 2021). Pocket parks are characterized by high flexibility, small scale, human dimension, diverse functions and high accessibility. At first, addressing the problem of the shortage of urban green space resources, relevant studies show that successive pocket parks become places for leisure activities of urban residents (WU 2015) and provide ecological corridors for animal migration in the city (ALEXANDER et al. 1997). However, past studies seldom constructed pocket park networks from the perspective of landscape ecological network to solve the contradiction between biodiversity protection and human demand for natural resource in cities. Therefore, the urgent problems to be settled are how to construct pocket park networks, build pocket parks according to, and create a harmonious development of humans and nature.

As for the construction methods of urban green space networks, most of them pay attention to a city's scale and urban agglomeration. For example, the identification of landscape ecological networks based on minimum consumption distance (BEIER et al. 2008); the design of ecological networks with emphasis on species conservation based on electric current theory and random wander model (MCRAE et al. 2008); the identification of ecological networks

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from the consideration of the minimum cost path of species migration (BEIER et al. 2011). Previous studies have often been applicable to the scale of cities or urban agglomerations. However, for urban centers with dense buildings and insufficient green areas, relevant studies are not enough to achieve the goal of building micro-green space networks. For pocket parks, previous studies mainly focused on how to design and construct them, but did not integrate urban pocket park space from the perspective of network to form the network of pocket park space. For instance, design pocket parks from the difficulty of maintenance (NORDH et al. 2009); design the remaining spaces in the city as plant-related pocket parks (NAGHIBI et al. 2021); put forward the design strategy of traffic-oriented pocket park from the perspective of displaying urban culture and large flow (LIU 2019). Therefore, it’s difficult to intuitively quantify the spatial demand difference of pocket park space system and construct urban pocket park space pointedly.

Taking the built-up area of Harbin as an example, the article analyses the spatial demand of pocket parks and constructs a pocket park network system through methods such as landscape form spatial pattern analysis (MSPA) and hierarchical analysis (AHP). The specific objectives of this study are 1) to identify the green space network in the built-up area of the city using the MSPA method; 2) to construct a pocket park suitability assessment system and obtain a pocket park suitability assessment map through the AHP method; 3) to integrate the above assessments to obtain a pocket park spatial demand assessment map and design a pocket park network.

2 Materials and Methods

2.1 Study Region

Guidelines for the Preparation of Municipal Territorial Spatial Master Plans (for Trial Implementation), published in 2020 by Chinese government, emphasize the balance and accessibility of green spaces in urban centres and encourage the construction of more green spaces and open spaces for residents' activities in urban centres. The built-up area of Harbin city is located in the western part of Harbin, with a total area of about 495.02 km^2 accounting for 0.93% of the area of Harbin city, but only 78.13% of the total population of Harbin city (2021). The built-up area has a small land area and a high population density. According to *Harbin Yearbook 2018*, Harbin's urban gardening coverage rate is 33.7%, which is lower than the average of non-garden cities. 2021, to implement territorial spatial planning, the construction of a park city is proposed, and the formation of a “city park – community park – pocket park” three-type park system is improved to enhance the quality of the human living environment.

2.2 Data Sources

The following data were used in the research for this article: 1) The 2020 Landsat8 OLI_TIRS satellite digital map, road network map, 250m×250m resolution Normalised Vegetation Index (NDVI) data and 30m×30m resolution Shuttle Radar Topography Mission (SRTM) data were obtained from the Resource and Environmental Science Data Centre of the Chinese Academy of Sciences (https:// www.gscloud.cn), the satellite digital maps were pre-processed using the maximum likelihood tool of ENVI 5.2 to obtain the site classification maps. 2) 2020 night time light data images (NPP-VIIRS) data from (https://www.mines.edu).

3) 2020 1km x 1km resolution World POP population density map data from (https://hub.worldpop.org), which was calculated and mapped at the initiative of the University of Southampton. 4) The full version of the bus stop and park attraction data has yet to be officially released. In order to analyse these data, the location coordinates of the stops and attractions were obtained by batch query in Gaode Map via Python, and the spatial coordinate system was corrected by a geographic coordinate system conversion tool.

2.3 Methods

The method can be divided into three steps (Figure 1). The first step was to extract the green space network pattern of the urban built-up area using the MSPA method and the connectivity index (PC). The second step is to establish the pocket park suitability evaluation system using AHP and obtain the pocket park suitability spatial assessment map. Based on the results obtained from the above two steps, pocket park network system are designed.

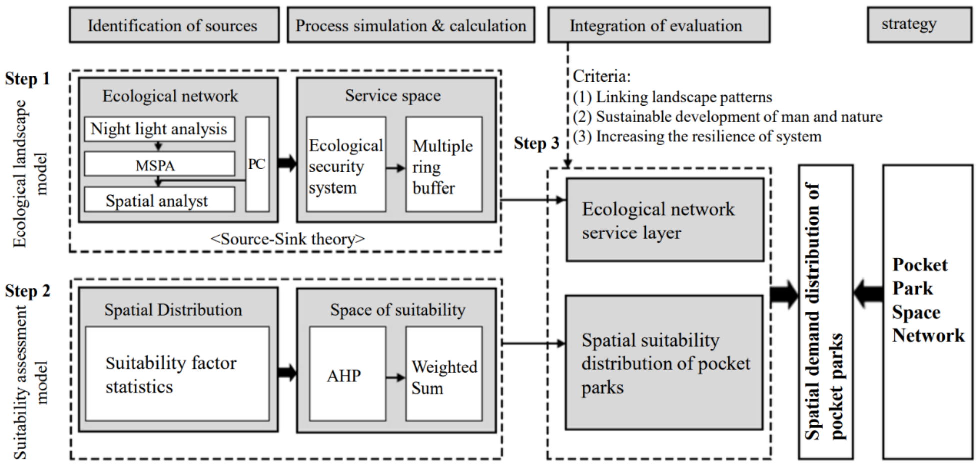

Fig 1: Pocket park network building framework

2.3.1 Greenspace Network Pattern Analysis Based on the MSPA Approach

2.3.1.1 Greenfield Core Identification

Ecological sources are identified, and data for resistance surface construction are obtained through MSPA, a technique for processing raster images based on the mathematical and morphological principles of erosion expansion, open and closed operations (GAO et al. 2019). The data is widely used in the ecological network planning to identify study area's structure and type of landscape. The article identifies habitat core areas (e. g. landscape areas, wetland parks, etc.) through MSPA. In the article, the core areas of habitats (e. g. landscape areas, wetland parks, etc.) identified by MSPA are selected for more than 3ha, the connectivity probability (PC) of the core area patches are calculated, and the importance of the core area patches is determined based on the PC assessment of connectivity.

$$\mathrm{PC} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} p_{ij}^{*} \cdot a_i \cdot a_j}{A_L^2}$$

In the formula, n denotes the total number of patches in the landscape, a_i and a_j denote the area of patches i and j, respectively, and p_{ij}^{*} denotes the maximum probability of direct dispersal of species in patches i and j. According to this formula, the ranking of the degree of contribution of the patch to the connectivity of the entire green space network is obtained and the relative importance percentage (dPC) of the patch is obtained. The connectivity indicators were calculated using conefor2.6 software, and the ecological sources were screened and the core areas of the green spaces were delineated according to the results of the indicators.

2.3.1.2 Greenfield Network Resistance Surface Reviews

The article aims to extract the original green space network, so the resistance surface is constructed by selecting the original land types in the city as indicators and constructing the indicator system. MSPA identifies the landscape types and selects the core and bridge areas as evaluation indicators. The remaining core areas are divided into very important core areas (1<dPC≤3), important core areas (0.3<dPC≤1) and general core areas (dPC≤0.3); the bridges are divided into very important bridges (dPC>0.8), important bridges (0.2<dPC≤0.8) and general bridges (dPC≤0.2); the land use types are divided into seven categories as evaluation indicators. Different resistance values – ranging from 1 to 1000- were assigned to different indicators using expert evaluation based on how resistant they were to species migration.

2.3.1.3 Greenfield Network Building

Urban greenspace networks provide habitat for organisms in cities, while improving the ecological quality of habitats and promoting cities towards species diversity and landscape diversity (KONG & YIN 2008). First, the cost connectivity tool in the Spatial Analyst tool of ArcGIS 10.8 was used to generate the minimum paths between patches. The corridors connected by greenfield patches with dPC>1 were treated as important ecological corridors. In contrast, the corridors connected by the remaining patches were treated as general corridors to obtain the greenfield network map of the study area. The kernel density analysis can obtain the density of corridors in the surrounding space and provide key guidelines for enhancing the green space network. The nuclear density analysis tool in ArcGIS 10.8 was used to obtain a map of the nuclear density distribution of corridors in the study area.

2.3.2 AHP-based Spatial Suitability Assessment of Pocket Parks

AHP is a simple, flexible and practical multi-criteria decision-making method for quantitative analysis of qualitative problems. Many factors that influence the construction of pocket parks, so three groups of variables were considered when establishing the assessment index system: vegetation suitability, residents' demand and spatial accessibility (Table 1). The suitability was classified into four levels using the quantile classification method, with corresponding scores of 1, 2, 3 and 4, reflecting the suitability of the space. Through the expert scoring method, a hierarchical model of the selected factors was constructed on Yaaph software, and the expert scoring data was included to obtain the ranking weights of individual factors. Using the weighted sums in the Spatial Analyst tool in Arcgis 10.8, the spatial suitability distribution map of the pocket park was obtained.

Table 1: Pocket park requirements analysis framework

Target Layer	Criteria Layer	Indicator Layer	Standard				Weight
			4	3	2	1	
The demand of pocket park	Ecological suitability	Elevation (m)	[72,110.5)	[110.5,149)	[149,187.5)	[187.5,226]	0.0106
		Slope(%)	<5°	[5°,15°)	[15°,25°)	≥25°	0.0398
		The distance to the water area (m)	<600	[600,900)	[900,1200)	≥1200	0.0119
		NDVI(%)	[150,201]	[101,150)	[50,100)	[0,50)	0.0313
	The demand of Residents	Spatial distribution of population(person)	≥10084.5	[6782, 10084.5)	[3479.5, 6782)	<3479.5	0.3572
		The distance to Urban green space (m)	≥600	[450,600)	[300,450)	<300	0.1182
		The distance to urban infrastructure (m)	<100	[100,150)	[150,200)	≥200	0.0436
		The distance to community (m)	<200	[200,350)	[350,500)	≥500	0.1077
	Accessibility of the park	The distance to the bus stop (m)	<200	[200,350)	[350,500)	≥500	0.1921
		The distance to main road of the city (m)	<400	[400,600)	[600,800)	≥800	0.0522
		The distance to walk the road (m)	<200	[200,300)	[300,400)	≥400	0.0354

2.3.3 Pocket Park Network System Construction

2.3.3.1 Pocket Park Space Needs Assessment

Pocket park demand refers to the spatial distribution of demand for pocket parks in built-up urban areas based on the services provided by existing green spaces. The service radius of a pocket park is about 500m. Using the multi-ring buffer tool in Arcgis 10.8, the spatial distribution of green space network services is obtained by assigning values to the corridors and patches based on their distances from each other. After obtaining the spatial distribution of green space network services and the spatial suitability assessment map of pocket parks using the weighted sum tool, the spatial demand assessment map of pocket parks was obtained. Firstly, according to the assessed values, the park is divided into five levels, which are "low", "relatively low", "medium", "relatively high" and "high".

2.3.3.2 Pocket Parks Network

The pocket park's network are designed following an evaluation of its spatial requirements. Refer to the following basis: 1) To enhance the connectivity between landscape patches and promote the efficient flow of materials, energy and information. 2) As a complex human-nature-society mega-system, the pocket park network should be designed with the needs of people and nature in mind to achieve harmonious development between people and nature. 3) Respect the existing conditions of the city, rely on the existing urban pattern and green space network, and design a pocket park network between existing green space resources to enhance the resilience of the urban built-up area system. The pocket park network system is eventually obtained.

3 Results

3.1 Greenfield Network Patterns

3.1.1 Greenfield Core Distribution

Based on the MSPA, below are the details: 1) the ecological core areas within the built-up area of Harbin city are primarily distributed in the southeast and northwest sides of the source land with better ecological resources connected by short distance corridors; the remaining core areas (>3ha) are relatively small in area, independent of each other and scattered within the built-up area of the city. 2) Among all land use types, the largest area of residential land is mainly distributed in the central-eastern part of the built-up area, with an area of about 25% of the total area, but the number of core areas only accounts for 7%; it can be concluded that the core areas of green space within the built-up area of Harbin city are unevenly distributed and relatively scattered. The north side of the Songhua River has an aggregated distribution with better ecological resources. In contrast, in the central and western parts of the built-up area, the supply of ecological resources decreases with the increase in floor area.

3.1.2 Resistance Surface Assessment

The results of the expert scoring show that the resistance values of buildings, roads, other sites and water bodies are more than ten times those of the other elements in the evaluation index. The resistance values of the urban built-up area are shown in figure (Figure 3). 1) The area with resistance values higher than 500 is 371.75 km^2, accounting for 75.18% of the total area, while the area with resistance values lower than 10 is 29.72 km^2, accounting for 6% of the total area; 2) The areas with higher resistance values are mainly located in the old urban areas of the city, especially the central areas of the built-up areas and the old urban areas of Dawai, while the areas with relatively low ecological resistance values are located in the built-up areas of the city. The areas with relatively low ecological resistance values are found in Jiangbei and the new Qunli district, on the border of the built-up area, and have the propensity to spread out along rivers and roads. In summary, it is concluded that 1) the ecological resistance of the existing built-up areas is directly related to the type of urban land use, with the older urban areas suffering from a serious lack of ecological resource supply due to the high floor area and road area; 2) In the built-up areas of Harbin, areas with low resistance values are located around areas with high resistance values and are poorly connected. In general, earlier urban planning needed to consider the layout of green space, which led to insufficient green space and limited distribution of construction land in built-up areas, resulting in high overall resistance values in built-up areas.

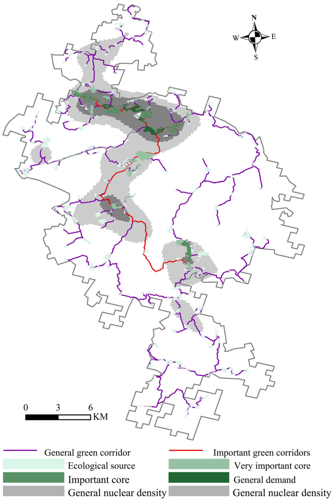

Fig. 2: Green space network system

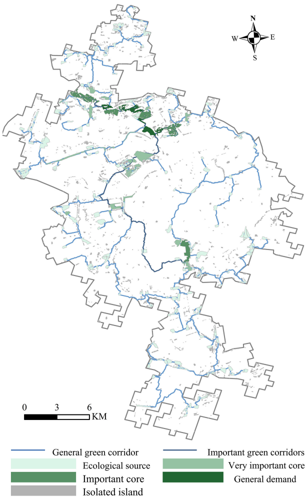

Fig. 3: Green space optimization diagram

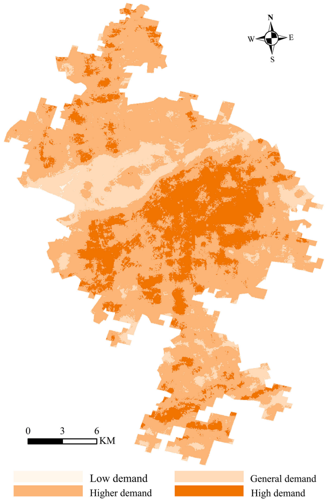

Fig. 4: Pocket park suitability assessment

3.1.3 Greenfield Network Building

As shown in the figure (Figure 2), 1) Harbin's built-up area has 13 significant green space corridors, totalling 48.80 km in length, forming a green space corridor through the north and south. In addition, there are also 208 general ecological corridors with a total length of 338.57 km, concentrated in the northern and western areas. 2) The green space network in the built-up area of Harbin forms three high-density zones, the northern part of the Songhua River, the Qunli New Area and part of Xiangfang. Many corridors connect the inner areas with strong material circulation, and corridors connect the high-density areas; the central and western areas have a small number of corridors and poor connectivity; the remaining areas have a fragmented distribution of corridors and patches (Figure 3). In summary, the green space network in the built-up area of Harbin could not be more evenly distributed and better connected, with small spatial clusters and sparse distribution in most areas.

3.2 Pocket Park Spatial Suitability Assessment

The weighting results of the elements (Figure 4) show that residents' needs are the most important of the three elements and dominate the suitability assessment. The proportion of each element and its sub-elements is shown in the table (Table 1). The first category (vegetation suitability) accounts for only 9.36% of the total, and factors such as slope, elevation and NDVI account for less than 5%, which shows that they have a relatively small impact on the suitability assessment. The second category (residents' demand) accounts for 62.67% of the total, becoming the dominant variable in the suitability distribution, and the distribution of population accounts for 35.72%, far exceeding the other sub-elements. The third category (spatial accessibility) accounts for 27.97% of the total, with the distance to the bus station accounting for about 10% more than the first category. In summary, the construction of pocket parks is influenced by the accessibility of the surrounding residents and space, while

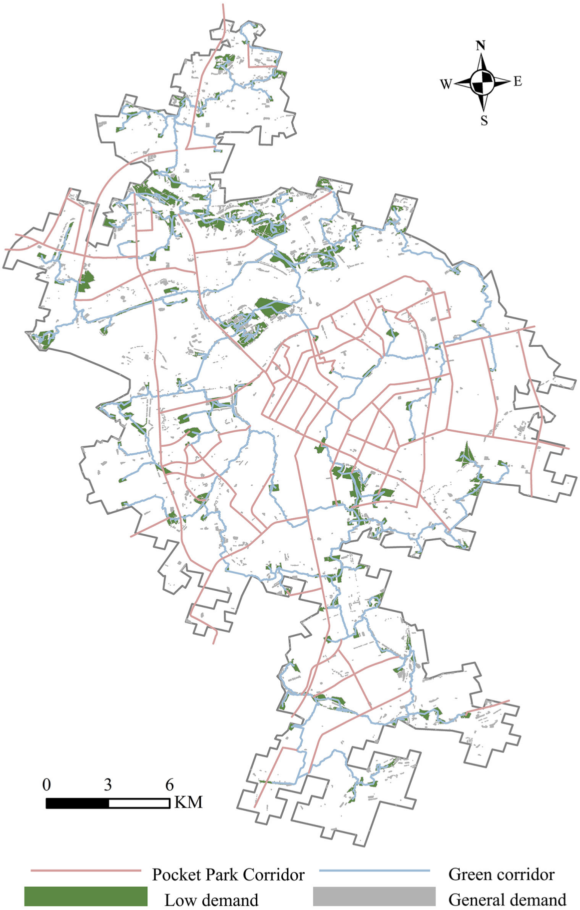

Fig. 5:
Pocket park needs assessment

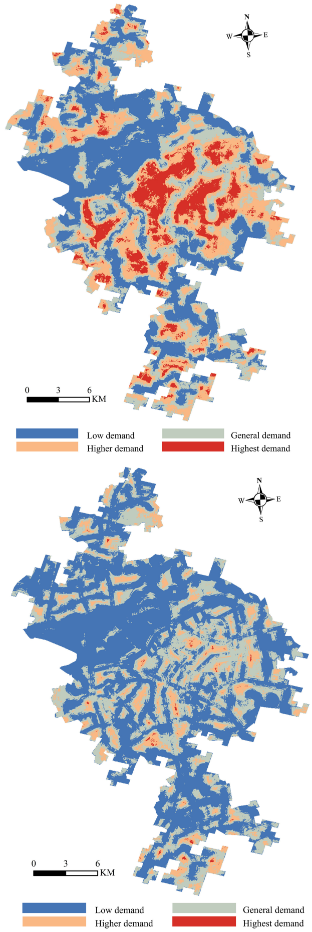

Fig. 6 & 7:
Pocket park network system (above); Pocket park demand optimization (below)

the suitability of the space for planting is less influenced. Pocket parks are suitable in areas with high population density and dense road networks.

The spatial suitability assessment of pocket parks based on the above table shows that the suitability is higher in the economic centre (Songlei, Zhuozhan Shopping Centre), cultural centre (Central Avenue, Sophia Cathedral) and political centre (Harbin Municipal Government) of the city, while the suitability is relatively low in scenic areas, parks and wetlands.

In summary, residential areas and urban centres with high population density and dense buildings are more suitable for pocket parks and are distributed in a faceted manner. Areas with low suitability are those with a good existing ecological environment and low density of buildings and road networks. Based on the definition and characteristics of pocket parks, the small size and flexible layout of pocket parks, which are mostly built on the streets of cities, provide convenient leisure space for residents and support the reliability of the article's results.

3.3 Pocket park Network System Construction

3.3.1 Pocket Park Space Needs Assessment

By integrating the above data, the spatial distribution map of pocket park demand is obtained and shown in figure (Figure 5). The demand for pocket parks in the city's center and the historic district of Dawai is high, accounting for more than 75% of the total high-demand area. The demand is distributed in a face-to-face aggregation, and the demand on the west side is distributed in a face-to-face pattern, but the demand is lower than that in the central-eastern area. The high demand on the north and south sides is spread sporadically, with large spatial differences in demand. To sum up, there are distinct regional variances in the demand for pocket parks, with the demand being highest in old urban areas with a high population density, densely populated roads, and limited green space.

3.3.2 Pocket Parks Network

The roads are used as a backbone to connect small green spaces, creating a green vein that can provide a place for leisure activities for the city's residents. A total of 88 pocket park network were designed according to the demand, with a total length of 298.66 km (Figure 6). By comparing the spatial demand of the pocket parks before and after the design, it was found that the area of the high demand area decreased from 53.631 km^2 to 1.07 km^2, the area of the low and lower demand areas increased from 63.6% to 90.6%, and the connectivity of the original green space network improved. In summary, the pocket park network effectively complements the existing urban green space network, satisfies residents' demand for green space, promotes the flow of material and energy, and confirms the accuracy of the study's findings.

4 Discussion

This paper takes the built-up areas of Harbin as an example. The research results show that the lack of green space in built-up areas is mainly due to the high density of buildings and road network in early urban planning: Because of the concentration of population the demand is not proportional to the supply and results in a poor quality of human settlements. Consequently, this paper increases corridors according to the specific needs of space and improves the living environment in the planning of pocket park network. This paper develops a method of constructing pocket parks by using the graph theory of minimum cost distance and landscape suitability. This study constructs the pocket park network system based on the source-sink theory and landscape suitability theory. The process follows two main objectives of extracting the green space network through MSPA and minimum cost distance, maintaining the connectivity of landscape. The second is to analyze the space demand of pocket park from the perspective of space suitability. This study proposes a network construction method based on different scales and multi-party requirements. It’s beneficial to the restoration of urban ecology and the long-term harmonious coexistence between man and nature in practice. This study provides a reference for the improvement of pocket park construction in terms of methods and results. Firstly, based on green space network, this paper supplements the micro-green space virtual network and further integrates landscape ecology and space suitability principle. Secondly, different from the design and construction of the existing pocket parks, this study incorporates the space network, and also refers to the needs of residents, animals and plants. Such pocket park networks can maintain the harmonious development of human and nature in urban built-up areas, maintain the connectivity of landscape in urban built-up areas, meet urban residents' yearning for natural environment, make the construction of pocket parks more pointed, and improve the service function of urban green space system.

5 Conclusion and Outlook

This paper makes the following conclusions:

1) In 2020, green space resources in Harbin's built-up urban areas were negatively correlated with building and road network density. More green space and expensive land prices lead to high costs for building large green parks and scenic areas. Building pocket parks to meet residents' green space needs is more appropriate.

2) There are differences in the demand for pocket park networks in different areas of Harbin's built-up urban area. Older urban areas have the most urgent need for pocket parks and are suitable for building a high-density pocket park network; newer urban areas are suitable for linking high-demand areas in series to form intersecting pocket park corridors; urban areas are connected by micro-green space wandering lines.

3) In the upgrading of green spaces in built-up areas of the city, a network of pocket parks can be established by designing network according to local conditions, improving the effectiveness of the network and rational pre-planning.

In response to the low efficiency of green space in well-developed communities and the imbalance between supply and demand, a scientific method of constructing a pocket park network is proposed, which not only interfaces with the existing greenbelt network of the city, but also provides guidance for the selection of sites for the construction of pocket parks. Demand for recreation varies between residents, but the paper failed to specify the target population, so it needs to be further developed.

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