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Research on Green Infrastructure Construction Strategies Based on Community Scale—The Case of Suojin Community in Nanjing City

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Abstract: *Currently, the frequent occurrence of unused vacant land and lack of green infrastructure in the process of urbanization is an increasingly serious urban disease, which not only puts great pressure on the ecological environment of cities, but also highlights the equity of green space. Particularly in China's older urban areas, green infrastructure is unevenly distributed and poorly connected to cover all areas of the neighborhood. Research on urban green infrastructure development will help to realize green space justice and have a practical impact on habitat construction. Based on the concepts of green infrastructure and other related concepts, this study focuses on micro-small scale urban settlements in China, and analyzes the current status of green infrastructure at the community level and establishes a framework for green infrastructure assessment through the grid analysis method. On this basis, we identify informal green spaces through GIS satellite data, transform informal green spaces into the main components of green infrastructure, fill in the service blind zones of formal green spaces, and maintain the ecological balance and sustainable development of the urban environment while beautifying the city's image.*

Keywords: *Green Infrastructure; Informal Green Spaces; Older Neighbourhoods; Building Strategies*

1. Introduction

Throughout China and abroad, many cities have experienced rapid development and the link between the region, the city and the community has been severed, and the phenomenon of insufficient green infrastructure around the old neighbourhoods is particularly serious, and does not take into account every community. The study of community-scale green infrastructure construction is conducive to the realisation of green space equity and is of practical significance to the construction of human settlements. Many cities in the West have addressed many social issues through the concept of green infrastructure, and when urban green spaces are combined with vacant urban spaces, national policies and planning mechanisms can be utilised to improve communities using green infrastructure in vacant urban spaces. An early success story of green infrastructure practice is the GI assessment programme in Maryland, USA. The Blackwell Community and Belle Meade Creek Corridor strategies, both of which use vacant space to improve community-scale green infrastructure construction issues from a micro perspective, provide references for the use of open space in high-density development cities at home and abroad [1].Green infrastructure is not a new concept in China today. Wu Wei and Fu Xi'e gave a relevant introduction to the origin and connotation of the concept of green infrastructure, the principles and methods of planning and design, and emphasised that the development of green infrastructure in China is very important for the sustainable development of cities and the sustainable use of land [2]. He Wei and Liu Binyi analysed the origin of the GI concept and highlighted the current challenges of the domestic implementation of GI [3]; Liu Binyi summarised the content of urban green infrastructure implementation in terms of location, city and urban planning. And he made suggestions for the future development of GI [4]. In recent years, China has also observed and researched the planning and construction of green infrastructure, and conducted practical studies in Shenzhen, Suzhou, Cangnan County of Wenzhou, and Huairen County of Chuzhou. Although the country has paid more and more attention to green infrastructure construction, most of the green infrastructure studies in China have been carried out in the overall scope of the city on the basis of general principles and environmental protection [5]. In order to better understand the benefits of green infrastructure for urban settlements, especially high-density cities, and to meet the needs of society, it is necessary to conduct more detailed and specific studies on green infrastructure at a finer scale.

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2. Methods

2.1. Study Site

In this paper, the Suojin Community in Xuanwu District of Nanjing is selected as a case study. The community is located in the northeastern part of Nanjing, adjacent to Xuanwu Lake, under Zijinshan Mountain, and connected to an important green infrastructure linkage in downtown Nanjing. It is a typical old neighbourhood built in Nanjing in the 1980s, with the presence of somewhat unsupported green spaces, and the area of its internal GI elements does not have the conditions to be a central control point or site in the urban area (Figure 1).

Figure 1: Research location.

2.2. Method Overview

In this paper, network analysis is used to simplify the network structure into point and line structure, calculate the network structure index, and quantitatively evaluate the network closure, accessibility and connectivity based on the calculation results. The theoretical basis of network analysis is graph theory and network theory. The graph theory theory can concisely transform the GI network into a two-dimensional topology, i.e., a series of points and a series of lines instead of the GI network, with the points indicating the central control points and the lines indicating the connecting channels. This method makes the relationship between elements more concise by turning the GI network structure into a two-dimensional topology by means of graph theory, while using network indices to assess the closure, access and connectivity of the network structure, and evaluating the network structure based on the final results [6]. Among the assessment indexes, α, β & γ indexes are the main assessment indexes (Table 1), which represent and measure network closure, network accessibility, and network connectivity, respectively. A green infrastructure network is composed of central control points, connectivity corridors, and sites. Centre control points generally refer to large natural areas covering protected areas, forests, parks and open spaces. Connecting corridors connect the centres and make the GI function as a network, covering green roads, green belts, etc. Sites are small habitats and recreational areas that are independent of large natural areas and complement the centre control point and connecting corridors.

$$\alpha = \frac{L-V+1}{2V-5} \tag{1}$$

$$\beta = \frac{L}{V} \tag{2}$$

$$\gamma = \frac{L}{3V-2} \tag{3}$$

Table 1: Green infrastructure network structure assessment index formula sheet.

Index	Element	Realm	Assessment Criteria
α	Network closure	[0,1]	The larger the value, the better the closure
β	Network Accessibility	[0,3]	The larger the value, the higher the connectivity between nodes
γ	Network Connectivity	[0,1]	The larger the value, the better the connectivity

(L indicates the number of connected channels, V indicates the number of centre control points.)

Evaluation of the network structure consists of: 1) determining the composition of the green infrastructure network according to the relevant standards under the data analysis of the ArcGIS platform analysis, and forming the network structure; 2) topologising the network structure, that is, one-to-one correspondence between the central control points, connecting channels, and venues in the GI and the

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centres, connections, and nodes in the network structure [7], and ultimately into a topological map of the 'line-point structure'; 3) using network analysis methods to quantitatively calculate the relevant indicators of the topological map, and finally obtaining the results; 4) analysing the relevant indicators related to the assessment and evaluation standards of green infrastructure network structure. The topology of 'line and point structure'; 3) Quantitative calculation of the relevant indicators of the topology using network analysis methods, and finally get the results; 4) Analyse the calculation results related to the assessment and evaluation criteria of the green infrastructure network structure.

2.3. Data collection

The method used in this study to identify the network structure is based on remote sensing images and field research, using the area threshold method and the ArcGIS area selection function to identify the central control point and the site, as well as identifying the connecting roads based on shape and width.In the composition of the GI network of the Suojin Community, the central control point is an ecological space with extensive, rich spatial composition and integrated functions in the community, such as community parks and large green spaces; the connecting road mainly refers to the linear space dominated by the community's street greening, riparian greening, and rivers; the site, with its relatively independent internal elements and functional carrying capacity, is a relatively small ecological space within the community, which is mainly comprised of flower beds, small-scale woodlands, infrastructure projects, etc (Figure 2).

Figure 2: Green infrastructure network structure of Suojin Community.

3. Results

3.1. Results of the network analysis methodology assessment

Based on the above approach, the spatial structure of the green infrastructure network is reduced to a topological point and line structure, with central control points reduced to points and connecting pathways reduced to lines. Since the site is very small in the community scale, the possibility of being able to connect to the network is small, so the site is not considered as a point here (Figure 3). On this basis, a two-bit topology can be obtained and its network structure index can be calculated (Table 2).

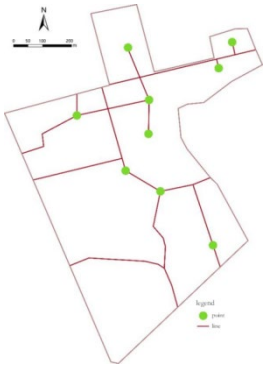

Figure 3: Network structure topology of green infrastructure in Suojin Community.

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Table 2: List of green infrastructure Network Structure Evaluation of Suojin Community.

Network Infrastructure	Point	Line	α	β	γ
Current State Network	9	16	0.62	1.78	0.64
Range			[0,1]	[0,3]	[0,1]

According to the numerical results and assessment criteria in the table, the number of 'points' and 'lines' in the network structure of the Suojin Community is 9 and 16, respectively. α-index is 0.62, which indicates that the network closure is average; β-index is 1.78, which indicates that the network accessibility is good; γ-index is 0.64, which means that the current network connectivity is moderate [8]. index is 0.64, which means that the current network connectivity is moderate.The data indicates that the network structure of the Suojin Communities has good accessibility, general closure and connectivity, and that the overall network structure is within acceptable limits.

3.2. Planning strategy for green infrastructure construction

Therefore, it is necessary to optimise the GI network structure of the Suojin Community. Among them, balancing the distribution of central control points and integrating and dredging green channels is the key to optimisation.

3.2.1. Informal green spaces converted to centre control points

In addition to densely populated residential areas and existing green spaces, there are still some plots of land with ambiguous attributes, including open spaces and roadside areas, also known as informal green spaces. If these parcels of land are well utilised, transforming informal green space into green infrastructure can enrich the lives of citizens.Some unused sites, spontaneous expansion of car parking spaces and some other old plots in the community can be suitably renovated or replaced. Various residual and corner areas, such as open spaces off the streets and irregular plots between buildings around the city, can also be developed and converted into green space open areas(Figure 4).

3.2.2. Connection channel maintenance

In the existing network structure connecting the canals, the greening of the riverfront is relatively good, the greening of urban roads and community greenways is not in a good condition, and it is imperative to restore greenery and protect the ecological environment. For example, measures such as opening up street gardens and courtyard green spaces, enhancing street greening, and upgrading grey infrastructure to make it ecologically friendly are being taken to alleviate the shortage of green spaces in high-density urban areas (Figure 5).

3.2.3. Well-structured network: multi-centred cross vertical and horizontal

On the basis of maintaining part of the original green infrastructure with reasonable structure, it optimises and adjusts the areas with missing original structure, transforms the informal green space into GI central control points and connecting passages, and gives full consideration to the original micro-community sites, evenly arranges the central control points, and forms a system of connecting passages with good continuity and connectivity, which together form the ideal spatial structure of the multi-centre cross vertical and horizontal (Figure 6).

Figure 4: Informal greenfield.

Figure 5: Optimised green channels.

Figure 6: Optimised network.

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4. Results

This paper focuses on exploring community-scale green infrastructure construction strategies, taking the Suojin Community in Xuanwu District of Nanjing as the study area, exploring human-centred transformation methods under urban population densification, and proposing methods for transforming informal green space into green infrastructure to improve the structure of the GI network. Due to the limited cost of retrofitting, the differences in feasibility, urgency and overall benefits of updating and transforming each informal green space into green infrastructure, as well as the degree of contribution to landscape connectivity after updating to green infrastructure, a more professional means is also needed to discern the degree of priority of converting informal green spaces into updating to green infrastructure, and targeting and phasing the retrofitting.

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