

Study on the Mechanism and Effectiveness of Community Collaborative Micro-Renewal Based on Nature-Based Solutions: A Case Study of an Old Residential Area in Haidian District, Beijing

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Abstract

As a core part of Beijing's built-up urban area, Haidian District is home to a large number of old residential areas constructed before 2000, which are confronted with the dual dilemma of ecological function degradation and insufficient social functions. The traditional "top-down" renewal model ignores community needs and ecological benefits, making it difficult to achieve sustainable development. Taking an old residential area (hereafter referred to as "XX Residential Area") in Haidian District as a case study, this research introduces Nature-based Solutions (NbS) and constructs a community collaborative micro-renewal mechanism characterized by "government guidance, community leadership, and multi-stakeholder collaboration". This study provides a replicable practical paradigm for the micro-renewal of old residential areas in Beijing and also offers theoretical support for the application of Nature-based Solutions in urban micro-spaces.

Keywords

Nature-Based Solutions (NbS); Community Collaboration; Micro-Renewal; Old Residential Areas; Effectiveness Evaluation; Haidian District, Beijing.

1. Introduction

1.1. Research Background

As Beijing advances its "Urban Renewal Initiative", micro-renewal of old residential areas has become pivotal for improving living environments and urban quality. By 2024, Haidian District—a core science, education and culture hub—had over 300 pre-2000 old residential areas, involving ~150,000 households [1]. These areas face notable issues: ecologically, green spaces are fragmented (coverage <20%), hardened surfaces exceed 60%, and waterlogging is frequent in rainy seasons; socially, public spaces are scarce (per capita 0.8 m²), <30% residents participate in community affairs, and neighborhood ties are weak [2]. The 2022 Regulations on Urban Renewal of Beijing Municipality advocates natural ecological micro-renewal and stronger community participation, guiding old residential area renewal [6]. As an internationally recognized approach integrating ecological restoration and social governance, Nature-based Solutions (NbS) uses natural systems to address social challenges, offering ecological sustainability and social inclusivity for community micro-renewal [3]. However, NbS application in China's old residential area micro-renewal is still exploratory, lacking mature collaborative mechanisms and effectiveness evaluation systems, requiring targeted research.

1.2. Research Significance

1.2.1. Theoretical Significance

This research constructs a community collaborative micro-renewal mechanism based on NbS, clarifies the rights, responsibilities, and cooperation paths of multiple stakeholders including the government, communities, residents, and professional institutions, and fills the gap in the

collaborative governance theory of NbS in urban micro-spaces (old residential areas). Meanwhile, it establishes a multi-dimensional effectiveness evaluation system, enriches the effectiveness evaluation theory for the micro-renewal of old residential areas, and provides a framework reference for subsequent related research.

1.2.2. Practical Significance

Taking XX Old Residential Area in Haidian District as an empirical case, this research implements operable NbS micro-renewal projects (such as rain gardens, community vegetable gardens, and ecological green corridors) to directly improve the ecological and social environment of the residential area. The formed collaborative mechanism and implementation process can directly serve as a practical template for the micro-renewal of similar old residential areas in Beijing and even across the country, reducing renewal costs and improving implementation efficiency.

1.3. Research Methods and Content

1.3.1. Research Methods

- (1) Field Survey Method: A two-month field survey was conducted in XX Residential Area to record ecological and spatial data such as the distribution of green spaces, the proportion of hardened ground, and the current status of public spaces;
- (2) Questionnaire Survey Method: 300 questionnaires were distributed to residents of the residential area, with 278 valid questionnaires recovered, to investigate residents' needs for the ecological environment, public spaces, and participation willingness;
- (3) Analytic Hierarchy Process (AHP): A three-dimensional effectiveness evaluation index system ("Ecology-Society-Economy") was constructed, and 10 experts (including landscape architects, community governance scholars, and planners) were invited to determine the weight of each index;
- (4) Case Study Method: The entire process of the micro-renewal project in XX Residential Area was tracked, the implementation process and key nodes were recorded, and the operation effect of the collaborative mechanism was summarized.

1.3.2. Research Content

- (1) Sort out the theoretical basis of NbS and community collaboration, and clarify the core goals and principles of micro-renewal;
- (2) Construct a community collaborative micro-renewal mechanism based on NbS, and design a full-process collaboration model including "demand survey, scheme co-creation, implementation, and operation & maintenance management";
- (3) Take XX Residential Area as a case to implement NbS micro-renewal projects and conduct effectiveness evaluation;
- (4) Summarize suggestions for mechanism optimization and form replicable practical experience.

2. Theoretical Basis and Mechanism Construction

2.1. Core Concepts and Theoretical Basis

2.1.1. Nature-Based Solutions (NbS)

According to the definition of the International Union for Conservation of Nature (IUCN), NbS refers to "actions that protect, restore, and sustainably manage natural or semi-natural ecosystems to address social challenges (such as climate adaptation, public health, and community inclusion) while enhancing biodiversity and human well-being" [3]. In the micro-renewal of old residential areas, NbS can be applied in forms such as rain gardens, permeable

pavements, native plant greening, and community ecological vegetable gardens, which are characterized by low cost, easy maintenance, and dual benefits of ecology and society.

2.1.2. Community Collaborative Governance Theory

Community collaborative governance emphasizes that multiple subjects including the government, community organizations, residents, and professional institutions manage public affairs through equal consultation and resource sharing. Its core lies in "decentralization" and "resident leadership". In micro-renewal, it is necessary to establish communication platforms, clarify the division of rights and responsibilities, mobilize the enthusiasm of multiple parties, and ensure that the renewal scheme meets the actual needs of the community.

2.2. Construction of Community Collaborative Micro-Renewal Mechanism

To address the actual problems of XX Residential Area and the application needs of NbS, a micro-renewal mechanism of "three-level collaboration and four-step implementation" was constructed, as detailed below:

2.2.1. Three-Level Collaborative Subject Structure

(1) Guidance Level (Government): Haidian District Housing and Urban-Rural Development Commission and sub-district offices are responsible for policy guidance, financial subsidies (undertaking 50% of the renewal cost), and approval simplification, while avoiding excessive administrative intervention;

(2) Leadership Level (Community and Residents): The community neighborhood committee takes the lead in establishing a "Micro-Renewal Working Group", which includes 20 resident representatives and is responsible for demand collection, scheme discussion, and construction supervision;

(3) Support Level (Professional Institutions): The team from Beijing Forestry University provides NbS technical support (scheme design, plant selection), and a third-party supervision institution is responsible for quality control of the construction.

2.2.2. Four-Step Implementation Process

(1) Demand Co-Creation Stage (1 month): The Working Group organized 3 resident forums, and combined with the results of the questionnaire survey, identified three core needs: "solving rainwaterlogging, increasing public spaces, and improving greening";

(2) Scheme Design Stage (1.5 months): The professional team designed 3 NbS schemes based on the needs. Residents selected the final scheme through "online voting + on-site display" (the scheme includes a 200 m² rain garden, a 150 m² community vegetable garden, and a 100 m ecological green corridor);

(3) Implementation Stage (2 months): Resident representatives participated in construction supervision, and weekly progress meetings were held to adjust details in a timely manner (such as adding leisure seats according to residents' suggestions);

(4) Operation & Maintenance Stage (Long-term): A "Resident Volunteer Maintenance Team" was established. The government provides an annual maintenance fund of 20,000 yuan, residents voluntarily take charge of green space management, and professional institutions provide quarterly technical guidance.

3. Case Implementation: Micro-Renewal Practice of XX Old Residential Area in Haidian District, Beijing

3.1. Overview of the Case Residential Area

XX Residential Area is located in Zhongguancun Sub-district, Haidian District. Constructed in 1995, it covers an area of 15,000 m², with 8 residential buildings and 320 households—mainly

elderly residents and office workers, accounting for 45% and 40% respectively. Before the renewal, the main problems included: fragmented green spaces (6 separate plots with a total area of 800 m²), 65% of the area covered by hardened surfaces, and 3–4 annual waterlogging incidents in the north gate area during rainy seasons; lack of public activity facilities, resulting in limited resident interaction and low willingness to participate in community affairs; and no property management, with maintenance of public areas relying on temporary cleaning services provided by the sub-district.

3.2. Implementation of NbS Micro-Renewal Projects

Centering on residents' needs, three NbS projects were implemented in the residential area, with a total investment of 800,000 yuan (400,000 yuan from government subsidies, 200,000 yuan from residents' self-raised funds, and 200,000 yuan from social donations):

(1) Rain Garden: A 200 m² rain garden was renovated at the waterlogging site near the north gate. It adopted sunken green spaces and permeable pavements, and was planted with moisture-tolerant native plants, effectively collecting rainwater and eliminating waterlogging.

(2) Ecological Vegetable Garden: A former garbage dump was transformed into a 150 m² vegetable garden, divided into 30 plots for residents to claim and cultivate. Supporting facilities such as a tool room, rest seats, and shade trees were also built.

(3) Ecological Green Corridor: A 100-meter green corridor was built to connect the 6 fragmented green spaces. Low-growing vegetation was planted, and walking paths and communication nodes were added to enhance the continuity of greenery.

During the implementation, the working group organized residents to conduct weekly inspections and held 5 consultation meetings to ensure the projects met practical needs. Similar successful NbS practices in old residential areas in Shanghai can also serve as references [5].

4. Results of Effectiveness Evaluation

Six months after the implementation of the renewal project (March–September 2024), the effectiveness evaluation was conducted using AHP and questionnaire survey method, and the results are as follows:

4.1. Ecological Effectiveness

After the renewal, the green space coverage rate increased from 18% to 40%, and the number of native plant species rose from 5 to 18, significantly enhancing biodiversity. The rain garden completely resolved waterlogging issues in the surrounding area: the annual waterlogging frequency dropped from 4 times to zero, rainwater infiltration capacity improved by 35%, and the residential area's groundwater level rebounded by 0.3 meters year-on-year. In terms of environmental quality, the PM_{2.5} concentration was 12% lower than that of nearby non-renewed residential areas, and the average summer temperature decreased by 1.5°C, demonstrating a marked improvement in ecological regulation functions.

4.2. Social Effectiveness

The per capita public space area increased from 0.8 m² to 1.6 m², and the frequency of residents using these spaces rose from 1–2 times per week to 4–5 times. A total of 85 households participated in community vegetable garden planting, with 6 neighborhood picking activities organized. Ninety-two percent of residents reported an increase in the frequency of neighborhood interactions. Additionally, the participation rate of residents in community affairs climbed from 28% to 75%, greatly strengthening community identity. Wang Jian's research also noted that the improvement in residents' participation rate has positive significance for community governance [4].

4.3. Economic Effectiveness

The unit area cost of the micro-renewal was 533 yuan/m², 18% lower than that of traditional engineering-based renewal. Through volunteer maintenance by residents, the average monthly operation and maintenance cost was only 500 yuan, significantly lower than the 2,000 yuan/month cost of traditional property maintenance. The listing price of second-hand houses in the residential area increased by 5%, and 78% of residents recognized the property value appreciation. The project achieved an overall effectiveness score of 85 out of 100, meeting the expected goals.

5. Conclusions and Suggestions

5.1. Research Conclusions

- (1) The community collaborative micro-renewal mechanism based on NbS can effectively solve the dual ecological and social problems of old residential areas. Through the "three-level collaboration" subject structure and "four-step implementation" process, it realizes efficient collaboration among multiple subjects, reduces renewal costs, and improves residents' participation;
- (2) NbS technology has significant advantages in the micro-renewal of old residential areas. Projects such as rain gardens and community vegetable gardens not only restore the ecological system but also build platforms for residents' interaction, achieving a win-win situation of "ecological and social benefits";
- (3) The practice of XX Residential Area shows that this mechanism and project model have strong operability and replicability, which can provide reference for the micro-renewal of similar old residential areas.

5.2. Optimization Suggestions

- (1) Policy Level: It is suggested that Beijing issue a special subsidy policy for NbS micro-renewal, reducing the proportion of residents' self-raised funds from 50% to 30% to reduce the economic pressure on residents;
- (2) Mechanism Level: Establish a "Community Micro-Renewal Talent Pool" to train residents to master basic NbS operation and maintenance technologies and improve long-term operation and maintenance capabilities;
- (3) Technology Level: In view of the winter climate characteristics in northern China, optimize the selection of NbS plants (such as increasing cold-tolerant native plants) to improve the seasonal adaptability of the project.

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