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Exploration of Feasible Measures for Ageing-Ready Retrofitting of Public Space in Older Communities Based on AHP-Fuzzy Comprehensive Evaluation Approach

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Abstract: *At present, the aging population in China's big cities is increasing, and the construction of old community public space cannot meet the needs of the community's aging population for activities and socialising, so the ageing transformation of community public space is urgent. In this paper, through the AHP-fuzzy comprehensive evaluation and analysis method, the problems and transformation measures of community public space are systematically evaluated and graded; in which the AHP method is used to determine the weight of indicators, and the fuzzy comprehensive evaluation and analysis method is used to determine the specific transformation content and time sequence of each indicator. It is hoped that the use of this method can provide a more quantifiable basis for the ageing transformation of community public space, and provide effective and feasible decision-making ideas for the government to carry out ageing transformation of community public space.*

Keywords: *AHP; Fuzzy Comprehensive Evaluation Method; Community Public Space; Ageing Rehabilitation*

1. Introduction

The transformation of old communities is an important task for urban renewal during China's 14th Five-Year Plan. At present, the population of old communities is aging seriously, and community public space is an important place for the elderly to move around and socialize. How to transform community public space to suit the use of the aging population is an important part of community regeneration. However, due to the lack of scientific evaluation methods, the transformation of community public space is always unpopular. Therefore, a scientific and objective evaluation system for community public space renovation in line with China's national conditions is the focus of the current research on community renovation, and this paper is dedicated to the construction of this renovation evaluation model.

At present, in terms of community public space ageing retrofit, related research mainly focuses on community street space retrofit [1], community facility retrofit [2], community outdoor activity space retrofit [3], and community ageing-friendly micro-space retrofit [4]. The related evaluation system mainly focuses on the aspects of old community buildings, public service facilities, and community services [1-4], and mainly uses the AHP evaluation method for weight comparison. This paper further uses the fuzzy evaluation method on this basis to grade the renovation time sequence and give specific renovation measures to improve the assessment results.

This paper establishes an evaluation model for the transformation of public space in old communities, summarizes the direction of transformation of public space in old communities with regard to the physical health conditions, activities and behaviours of China's ageing population, forms a set of systematic evaluation models, and gives specific measures and time sequences for the transformation of public space at different levels of the problem. At the same time, this model is applied in the Apple Park Community of Apple Park Street, Shijingshan District, Beijing. A scientific method is used to quantitatively study and evaluate the community public space renovation problems. A set of evaluation system with strong practicality and logic is developed to help government departments and related researchers to make a scientific assessment of community transformation methods before the transformation of community public space.

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2. Research methodology

Based on the complexity of ageing renewal of public space in old communities, a set of evaluation system for complex problems is needed to ensure the objectivity of evaluation results. There are more than 20 specific methods of comprehensive evaluation method, including AHP-Hierarchical Analysis, WRSR Rank and Ratio, Composite Index, Fuzzy Comprehensive Evaluation Method, etc. As the evaluation process of community public space renovation involves many complex factors such as activity space, infrastructure, traffic, greening and so on. In this paper, the hierarchical analysis method (AHP) is selected to apply to the weighting analysis in the evaluation model, and the fuzzy comprehensive evaluation method is used to grade the factors. It quantifies the problems that are difficult to quantify, the results are clear and systematic, and it is suitable for dealing with complex problems with multiple indicators. By combining the two, a more ideal evaluation result can be obtained.

The AHP-fuzzy comprehensive evaluation method is used to construct an evaluation model of community public space transformation methods. The comprehensive evaluation steps are as follows: 1 Determine the evaluation objectives; 2 Decompose the evaluation objectives to form the target layer, guideline layer, and programme layer indicator system; 3 Survey, which can invite several industry experts and professionals who have been in the field for many years to participate in the survey; 4 Collect the questionnaire, analyse the questionnaire using AHP, and determine the weights of each indicator; 5 Combine the scores of the professional staff and the weights of each indicator, and calculate the subordinate degree of each target matrix, from which the comprehensive evaluation results are obtained. There are a large number of qualitative and quantitative indicators in the multi-evaluation indicators, so to ensure the credibility of the results, the weights are determined by expert scoring. This study invites professionals engaged in the field of urban renewal and government administrators to form a team of experts to compare the three-level indicators two by two, and finally calculate the weighting results through the hierarchical analysis method (Table 1).

3. Construction of the evaluation model for the modification approach

3.1. Constructing the indicator system and determining the weights

Table 1: Indicator system and weighting values for evaluation of community public space renewal methods

target level	indicator layer	weights	factor level	weights	sub-factor level	weights
Older communities public space Adaptation of ageing	A1 Activity Space	0.4126	B1 Fitness Space	0.2125	C1 Fitness Space Internal Security	0.0172
					C2 Fitness facility completeness	0.0351
			B2 leisure space	0.3426	C3 Recreational Space Environmental Aesthetics	0.0132
					C4 Recreational Space Environmental Security	0.0266
	A2 green space	0.4035	B3 Green space	0.3302	C5 Green space area	0.0189
					C6 Seasonal changes	0.0108
					C7 Plant Landscape Diversity Situation	0.0325
					C8 Green space utilisation	0.0267
	A3 transport space	0.2257	B4 Vehicular traffic space	0.2256	C9 parking situation	0.0403
					C10 Fire road access	0.0791
					C11 road traffic movements	0.0485
			B5 Pedestrian transport space	0.1299	C12 Level of safety in pedestrian spaces	0.0319
					C13 Walking space accessibility	0.0286
	A4 Infrastructure	0.3149	B6 Accessibility	0.3352	C14 Degree of accessibility	0.0164
					C15 Level of accessibility	0.0549
			B7 Lighting facilities	0.3744	C16 Degree of lighting sophistication	0.0218
					C17 Brightness of lighting fixtures	0.0195
			B8 Signage facilities	0.0829	C18 Level of sophistication of signage facilities	0.0629
					C19 signage facility identifiability	0.0403

Note: According to the calculation method of fuzzy evaluation, we obtain the above data

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Through literature research, a hierarchical evaluation model system suitable for public space renovation in China's old communities is constructed. It includes a criterion layer, i.e. the highest layer, a sub-criterion layer and an indicator layer. Four dimensions, eight criteria and 19 indicators were identified. The analytical model was established through AHP hierarchical analysis, and the relationships were divided into: the highest level, the middle level, and the lowest level, and the weights were determined. Since the kernel of this analysis method is hierarchical evaluation, experts in the field are invited to evaluate the indicators and obtain the final weighting results [5]. (Table 1)

3.2. Classification of Indicator Levels of Fuzzy Comprehensive Evaluation Model

The indicators are classified into 3 levels, I, II and III. Where: I represents the worst, urgent transformation; II represents average, moderate transformation; III represents the best, slow-release transformation. The 19 indicator factors were classified and summarized (Table 2) to obtain the fuzzy relationship matrix of the three levels of indicators to facilitate the fuzzy evaluation of each space in the community.

Table 2: Hierarchy of tertiary indicators

Tertiary indicators	rating		
	Class I	Class II	Class III
C1 Fitness space internal security	0-2 points	2-3 points	4-5 points
C2 Improvement of fitness facilities	0-2 points	2-3 points	4-5 points
C3 Aesthetics of recreational space environments	0-2 points	2-3 points	4-5 points
C4 Environmental safety in recreational spaces	0-2 points	2-3 points	4-5 points
C5 Green space area	S Public green space per capita <0.33 m²/person	0.33m2 <S public green space per capita <0.66m2	0.66m2 <S public green space per capita <1m2
C6 Seasonal changes	Vegetation space without seasonal landscape changes	There are seasonal changes in the plant landscape, but they are not significant	The plant landscape changes significantly and beautifully in all seasons
C7 Plant Landscape Diversity Situation	0-2 points	2-3 points	4-5 points
C8 Green space utilisation	0-2 points	2-3 points	4-5 points
C9 Parking situation	Less than 0.7	0.7-0.8	Greater than 0.8
C10 Fire road access	No fire lane, no fire fighting surface, no access for fire engines	There are fire lanes but they are not plentiful and are not guaranteed to be open at all times	Fire lanes are available, firefighting landing surfaces are provided, and fire lanes are unobstructed
C11 Road traffic movements	Carriageway width <4m	Carriageway width = 4m	Carriageway width >4m
C12 Level of safety of walking spaces	Poor road conditions; high traffic volumes; no pavements; lack of safety features	Pavement less than 2.5m; high traffic flow; inadequate safety facilities	Road surface in good condition; moderate traffic flow; appropriate pavement width; good safety features
C13 Walking space accessibility	0-2 points	2-3 points	4-5 points
C14 Degree of accessibility.	Spaces without accessible ramps, handrails, uneven paths, non-slip resistance	Spaces with accessible ramps, levelled paths, non-slip but without accessible handrails	Space with accessible ramps, handrails, smooth non-slip paths
C15 Ease of use of accessible facilities	2 or more spaces that do not meet facility scale standards	1 space that does not meet facility scale standards	Spaces that meet facility scale standards
C16 Degree of lighting sophistication	Spaces requiring a torch to assist passage	Spaces where there is dead space for light	No light dead space, number of facilities in accordance with the specification space
C17 Brightness of lighting fixtures	Average horizontal illuminance <2lx	2-5lx＜average horizontal illuminance＜15-20lx	Meets average horizontal illuminance of 15-20lx.
C18 Level of sophistication of signage facilities	0-2 points	2-3 points	4-5 points
C19 signage facility identifiability	0-2 points	2-3 points	4-5 points

Note: 1) C1, C2, C3, C4, C7, C8, C13, C18, and C19 are graded by surveying residents' satisfaction, with 0-2 points being graded as Level I, 2-3 points as Level II, and 4-5 points as Level III. (Satisfaction survey based on the judgement criteria derived from the 200 questionnaires distributed)
2) C5 Green space area, C6 Seasonal changes, C11 Road traffic access, C12 Safety degree of walking space. Graded according to the provisions of the Code Design Standards for Urban Residential Areas (GB50180-2018) [6].

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3) C9 Parking situation. According to the Urban Parking Planning Code (GB/T51149-2016) [7]. It is required that the number of parking spaces / total number of sets ≥ 1.0. Combined with the current situation of parking in old neighbourhoods, the indicator can be relaxed, i.e., 0.7 or less is class I; 0.7-0.8 is class II; the number of parking spaces is sufficient; and 0.8 or more is class III.
4) C10 Fire road access. According to the Code for Fire Protection in Building Design (GB/T 50016-2014)[8], the inaccessibility of fire engines is class I; the inability to meet the passage of fire engines is class II; and the smooth passage of fire engines is class III.
5) C14 Degree of perfection of barrier-free facilities, C15 Degree of ease of use of barrier-free facilities; according to the content of the "Code for Barrier-Free Design of Urban Roads and Buildings" (GB 50763-2012) [9], the evaluation criteria are extracted.
6) C16 Degree of perfection of lighting facilities, C17 Degree of brightness of lighting facilities. Based on the content of Design Code for Urban Nightscape Lighting (JGJ/T 163-2008) [10], the evaluation criteria of the lighting facilities are refined.

4. Application of the Evaluation Model of Public Space Renovation Methods in Older Communities: The Example of Apple Park II and III Districts in Shijingshan District, Beijing

4.1. Overview of apple orchard zones II and III

Built in the 1990s, Apple Park II and III, with a total land area of 38.1 hectares and a total of 40 buildings, is a living area for Shougang employees and their families. The community contains infrastructure such as the Apple Park Health Service Centre, Apple Park Police Station, supermarkets, etc. The surrounding facilities are perfect to meet the needs of residents' lives.

Public space includes four components: activity space, green space, transport space and infrastructure.

4.2. Results of the spatial assessments

The spaces in apple orchard zone 2 were categorized as α1-6; the spaces in apple orchard zone 3 were categorised as β1-9 (Figure 1), and the results of evaluating each space by the above criteria are as follows (Table 3):

Table 3: Summary of public space ratings for Apple Park Zones 2 and 3

serial number	Name of space	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11	C 12	C 13	C 14	C 15	C 16	C 17	C 18	C 19
1	α1	II	II	III	III	III	I	I	II	I	I	I	I	I	II	I	III	III	I	I
2	α2	I	I	II	II	II	II	II	I	I	I	I	I	I	III	II	II	II	I	I
3	α3	III	I	III	II	II	II	II	III	II	I	I	II	I	III	I	III	III	II	II
4	α4	III	III	III	II	II	II	I	I	I	I	I	II	II	III	II	II	III	I	II
5	α5	II	III	II	II	II	II	III	III	II	II	II	II	II	III	II	III	III	II	I
6	α6	II	II	III	II	II	II	III	III	II	II	I	III	II	II	II	III	III	II	III
7	β1	III	II	II	II	III	II	I	III	II	I	III	III	II	III	III	III	III	I	II
8	β2	III	III	III	II	III	II	I	III	II	II	III	III	II	III	III	III	III	II	II
9	β3	III	III	III	III	III	II	III	III	III	II	III	III	II	III	III	III	III	II	II
10	β4	III	I	I	I	II	II	III	II	II	II	II	I	II	III	III	III	III	II	I
11	β5	III	I	II	III	II	II	III	II	II	II	II	III	II	III	I	I	III	II	II
12	β6	II	II	II	I	III	III	III	II	II	III	II	III	II	III	II	II	II	I	II
13	β7	II	II	II	II	III	III	III	III	II	II	II	I	II	III	I	III	III	II	II
14	β8	III	III	II	I	I	II	II	I	II	I	II	III	II	I	I	I	I	II	II
15	β9	I	II	II	II	I	II	II	II	I	I	II	III	II	I	I	I	I	I	II

4.2.1. Public status assessment

In terms of the internal security of the fitness space, the internal security of the fitness space in β1 and β8 spaces is high; the security of α5 and α6 spaces is average; and the integrity of α2 and β9 spaces is poor. Regarding the perfection of fitness facilities, the perfection of fitness facilities in β1 and β8 spaces is high; the perfection of facilities in α4 and α5 fitness spaces is average. (Figure 2)

In terms of the aesthetics of the leisure space environment, α4 and β3 have good environmental aesthetics; α6 and α7 have average aesthetics; and β6 has poor aesthetics. As for the safety of leisure space environment, α1, α5, β3 have high safety; α2, α6, β1, β2 have average safety; β2, β6, β8 have poor safety. (Figure 2)

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In terms of green space area, α3, β5 and centralised green space are larger, while β8 and β9 are smaller. In terms of seasonal changes, β6 and β7 green seasonal changes are more obvious. Plant landscape diversity situation. For example, α1, α4, β1, β2 greening landscape diversity is single, and the body of plants is poor; α5, β3, β4 have more plant species and obvious landscape design. In terms of green space usage, α2 and α4 have poor localised green space usage. (Figure 3)

In terms of parking, β5, β6 and β7 have more parking spaces; β8 and β9 have poor parking conditions; and α4 and α6 have no parking spaces. As for fire road access, β6 has better access; α5, β2, β3 and so on are average; α1, α2, β1 and so on are poor. As for road traffic accessibility, β1, β2 and β3 have better overall accessibility; β4, β5 and β6 are average; and α1, α2 and α3 are poor. (Figures 4 and 5)

Regarding the degree of safety of walking space, α6, β1 and β2 have a high degree of walking safety; α3, α4 and α5 are average; and α1, α2, β4 and β7 are low. Regarding the degree of walking space accessibility, α1, α2 and α3 have a low degree of walking traffic space accessibility. (Figure 4, Figure 5)

In terms of the degree of perfection of barrier-free facilities, the degree of perfection of barrier-free facilities in public spaces in the district is high, and only spaces such as α1 and α6 are not perfect. In terms of the degree of ease of use of barrier-free facilities, the degree of ease of use of barrier-free facilities in public spaces in front of buildings such as α1 and β5 is average; the degree of ease of use of more than half of the spaces is significantly poorer. (Figure 6)

In terms of the degree of improvement of lighting facilities, most public spaces have good lighting facilities; α2, α4, and α5 have dead ends; and β5, β8, and β9 have very few lighting facilities. In terms of the brightness of lighting facilities, most public spaces have a high degree of brightness; α2 and β6 have darker lighting; and β8 and β9 have close to no lighting at the green space in front of the house.

With regard to the completeness of signage facilities, the establishment of public spaces throughout the community, α1, α2, α4, β1 and β6 lack signage facilities. In terms of identifiability of signage facilities, α1, α2, α5, and β4 have low identifiability of spatial signage facilities. (Figure 6)

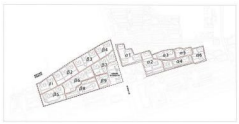

Figure 1: Spatial Distribution Map of Apple Park Community Wards 2 and 3

Figure 2: Activity space distribution map

Figure 3: Green space distribution map

Figure 4: Road width map

Figure 5: Traffic status map

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Figure 6: Distribution of Barrier Facilities and Signage

4.3. Classification of transformation based on the fuzzy comprehensive evaluation method

The fuzzy comprehensive evaluation of the 15 public spaces in the second and third districts of Apple Park was launched, and the results as shown in (Table 4) were obtained, so the most accurate renewal method for each space was derived:

Table 4: Assessment results of each spatial renewal method in apple orchard zone 1 and zone 2

serial number	Building Name	degree of affiliation (statistics)			in the end	
		b1	b2	b3	Maximum affiliation level	Update method
1	α1	0.4791	0.3352	0.4928	I	Urgently in need of a makeover
2	α2	0.3459	0.5324	0.3875		
3	α4	0.2415	0.5232	0.3316		
4	β8	0.4316	0.4529	0.2685		
5	β9	0.2319	0.5521	0.3312		
6	α3	0.3529	0.4602	0.2239	II	adaptation
7	β1	0.5529	0.2316	0.3328		
8	β4	0.3411	0.5032	0.1229		
9	β5	0.3619	0.2256	0.4998		
10	α5	0.4025	0.3319	0.3028	III	delayed-release modification
11	α6	0.3883	0.3481	0.4025		
12	β2	0.4116	0.4204	0.2189		
13	β3	0.2364	0.4269	0.3369		
14	β6	0.1657	0.5263	0.2177		
15	B7	0.1632	0.4045	0.1214		

4.4. Discussion

As can be seen from the evaluation results, through the weight values and the corresponding transformation levels, based on the fuzzy analysis model, the community urgently needs to be transformed, and the most important spaces that should be transformed are: α1, α2, α4, β8, and β9. Considering the two methods described in this paper, and through the evaluation of level weights, it can provide a more rigorous and scientific transformation idea for the transformation of the community. From the data, it can be seen that the community should carry out large-scale transformation and perfect management for the front space, square green space and barrier-free facilities, in order to build an optimal service model. Compared with the single status quo evaluation, the results of this paper's comprehensive hierarchical analysis are more convincing and scientific than a single method.

In summary, this paper tries to use the scientificity analysis method to construct a quantifiable transformation evaluation model for community public space relying on the space to be renewed in the old community, so as to provide a more accurate and scientific evaluation system for the ageing transformation of public space in the old community. The method circumvents the problem that the evaluation results are greatly influenced by subjectivity. The method is more scientific and objective, and the results are more intuitive and easy to understand and use, and the method is not affected by factors such as geography, space, and the nature of the base, so it has strong universality.

Admittedly, there are some limitations in the research described in this paper, and the base of the research is only the Apple Park community in Shijingshan District, Beijing.

The sample capacity of the data obtained is small, and there is still room for extension of the evaluation levels and index factors, such as the greening space can still be refined to different plots, and the data obtained can be more accurate. For communities with different characteristics, the focus of the list should also be adjusted, in order to seek a more accurate and efficient transformation method, and to provide effective feasible measures for the transformation of public space in ageing communities.

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