Research on AHP-based fuzzy evaluation of the spatial environment recovery of community parks in cold cities

Hongbo Zhang [*], Yaru Liang[a]

School of Architectural and Civil Engineering, Heilongjiang University of Science and Technology

ABSTRACT: Community parks provide many spatial environments and healing places in cold regional cities, and are important for human well-being, satisfaction and mood regulation. However, few studies have comprehensively explored the effects of weak support for health and recovery in cold cities. The new method integrated fuzzy mathematical evaluation into an analytical hierarchical process (AHP) approach to analyze the relationship between health restoration influence mechanisms and environmental elements, proposed four evaluation factors, including the restorability of the natural landscape, of psychological perception, of spatial facilities and of the surrounding environment, and constructed the basic framework of a spatial environmental restorability evaluation system in cold regions. Therefore, taking Harbin's Shangzhi Park as an example, this study uses AHP to construct an evaluation system for the spatial environmental recovery of community parks in cold cities. The research finds that natural landscape restorability is more important than other environmental factors, and plant species richness is important for healing physical and mental health.

1. INTRODUCTION

A large number of studies at home and abroad have shown that psychological and behavioral activities and the physical and mental health of the population are positively correlated with the natural environment [1-2]. Proposed optimizing the spatial layout and design of parks and establishing a park database to improve the health service level of urban parks in cold regions, aiming at the support of cardiovascular health behavior activities in urban parks in cold regions. Zhang et al. (2019) analyzed the influencing factors of winter activities in urban parks in cold regions through a fuzzy analytic hierarchy process and proposed optimization strategies from the aspects of characteristic landscapes, space facilities and management [3]. However, due to the cold and dry winter with long periods of snowy weather in cold cities, there is a reduction in outdoor activities and residents' enthusiasm for activities in winter, which is not conducive to the health recovery of residents in cold cities. In recent years, some scholars have studied the spatial environment characteristics of urban parks in cold regions and the behavior and activity characteristics of residents [4].

At present, the current evaluation studies of community parks are mainly based on age-suitability evaluation, Post Occupancy Evaluation (POE), health landscape evaluation and satisfaction evaluation [5]. The evaluation indicators are often quantified based on the objective spatial environment characteristics of one-way thinking or subjective satisfaction.

The evaluation research on park restoration mainly focuses on park soundscape evaluation, waterscape evaluation, landscape restoration and environmental preference, and more attention is given to the restoration of natural landscapes [6].

It is necessary to discuss the healthy restoration effect of the community park space environment in cold cities from the two aspects of the community park space itself and user behavior. At the same time, the restorative design of artificial space and facilities can make up for the scarcity of natural landscape resources in cold cities in winter, which is more conducive to improving the attractiveness and health restoration of community park space environments.

The spatial environment recovery of community parks in cold regions is directly related to the health recovery of urban residents in the "post epidemic" era. Therefore, it is necessary to construct a spatial environment recovery evaluation system, understand the health recovery needs of residents, and quantify the impact of different influencing factors on the spatial environment recovery of community parks.

2. RESEARCH METHODOLOGY

2.1. Analytic hierarchy process approach

2.1.1. classification of evaluation factors for the spatial environmental recovery of community parks in cold cities.

First, 20 experts in urban planning and landscape architecture were interviewed through expert interviews

[*] Corresponding author: hongbozhang@usth.edu.cn
[a]2430683612@qq.com

and universal surveys about "which spatial environmental characteristics in community parks are beneficial to promoting people's health". Second, through the network survey of "which spatial environmental elements in cold region community parks promote residents' health recovery", the factors with high frequency and strong health recovery effects were selected. The results show that residents' behavior in community parks is affected by 18 spatial environmental characteristics. This paper divides the impact of community park spatial environment recovery into four dimensions, natural landscape recovery, psychological perception recovery, spatial facilities recovery and surrounding environment recovery, and this information consists of 18 evaluation index layers. This study analyzes the connotation, mutual relationship and behavior activity relationship of each category to be suitable for evaluating the spatial environment recovery index of community parks in cold regions.

Psychological perception recovery stimulates people's psychological perception of the natural environment landscape, spatial characteristics, sites and facilities in cold regions, such as the sense of the spatial environment atmosphere, safety, shelter and environmental sanitation, and provides users with intuitive psychological feelings through physical representations such as form, function, proportion and structure [7]. This indirectly guides people's behavior activities to bring health recovery effects. Environmental preference is an important factor affecting the recovery of psychological perception, and aesthetic appreciation is an important factor affecting environmental preference.

2.1.2. Establishment of the evaluation framework of community park space environment recovery in cold regional cities

The four dimensions of restorative environment characteristics provide a theoretical framework for the construction of a restorative evaluation system for the spatial environment of community parks in cold regions. With the deepening of theoretical research, measuring behavioral activities and psychological perception factors in the restorative experience and quantifying the restorative characteristics of the spatial environment have gradually become the focus of research [8]. First, based on the classification of the four dimensions of the spatial environmental recovery of community parks in cold regions, the evaluation framework of their spatial environmental recovery was constructed according to the principle of evaluation index determination of AHP and the characteristic elements of spatial environmental recovery of Community Park.

2.1.3. Establishment of the evaluation model of community park space environment recovery.

The evaluation model of the spatial environment recovery of community parks in cold regions was developed based on literature collation and analysis, analysis of residents' health restoration needs, and field investigation of the current situation of the spatial environment recovery of community parks in Harbin. As shown in Figure 1, the evaluation index hierarchy is divided into a target layer, standard layer and solution index layer.

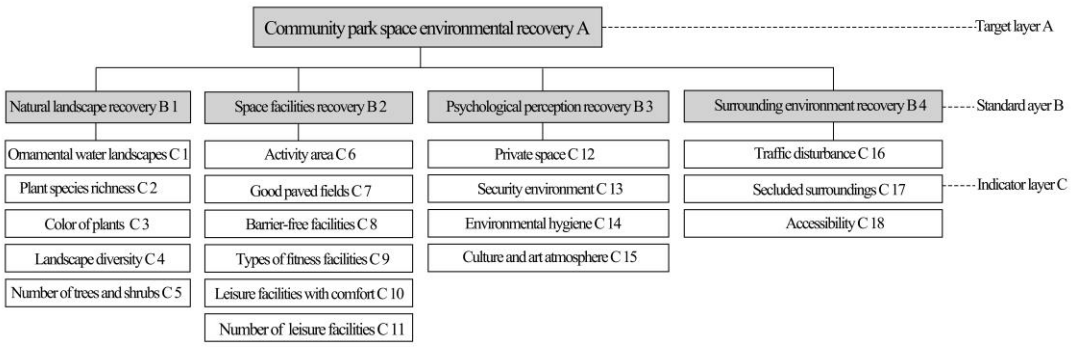

Figure.1. Hierarchical structure of spatial environmental restorative evaluation indicators

According to the different importance of each level index in the evaluation of the spatial environmental recovery of community parks in cold cities, 15 experts in the field of landscape architecture and urban and rural planning were invited to score and determine the weights. According to the importance degree calculated by Yaaph for each level evaluation index, the 1-9 degree scoring method was used for pairwise comparison, and the judgment matrix was constructed. The consistency test of the judgment matrix was conducted to finally determine the weight coefficients of the evaluation indicators at each level.

2.2. Fuzzy Comprehensive Evaluation Approach

Determine the index set and evaluation set of the space environment recovery evaluation. According to AHP, the first-level evaluation index and the second-level evaluation index set are constructed. Then, the evaluation set is constructed according to the five evaluation levels of excellent, good, general, poor and very poor. Finally, different rating levels were assigned by Likert's five-level scale. As shown in Table 1, through this method, the subjective evaluation of the restoration of the community park space environment can be transformed into a quantitative evaluation to reflect the comprehensive score of the restoration of the community park space environment.

Table 1. Community park space environment recovery evaluation grade division.

Evaluation grade	Excellent	Good	General	Poor	Very poor
Evaluation score (v_i)	$4 < v_i \leq 5$	$3 < v_i \leq 4$	$2 < v_i \leq 3$	$1 < v_i \leq 2$	$0 < v_i \leq 1$

3. CASE STUDY: APPLICATION OF THE RESEARCH FRAMEWORK

3.1. Survey design and data collection

Shangzhi Park is a typical residential district-level community park, as shown in Figure2.The users of Shangzhi Park are basically the residents near the park, and the walkability of the residents is high, and the walking time is basically controlled within 5-15 minutes. Badminton courts, table tennis courts, fitness equipment, fitness trails, children's recreational facilities and other facilities are built in the park. The functional partition is mainly divided into square activity area, sports and fitness area, children's play area, lake viewing area, recreation area and leisure and cultural area, which can meet the needs of different people.

Figure.2. Location map of Shangzhi Park.

As shown in Figure 3, 10 scene locations were selected from the sample park, and the behavior annotation method was used to investigate the behavior and activity characteristics and types of residents in the community park, the classification of behavioral activities is shown in Table 2. 20 users were randomly selected from each scene location to score the spatial environment characteristic factors of the park. A five-level Likert scale (1-5 points) was used for rating. A total of 200 questionnaires were randomly distributed in the survey, and 8 questionnaires with incomplete and inaccurate questionnaire information were eliminated. A total of 192 valid questionnaires were obtained, with an effective recovery rate of 96%.

Figure.3. Scene point analysis map of Shangzhi Park.

Table 2. Community park behavior activity type classification.

Activity type	Activity content	
Static behavioral activities	Natural experience	Enjoy the scenery, read books and newspapers, get in touch with nature, and play with children etc.
	Leisure and relaxation	Sit still, play musical instruments, sing songs, broadcast live
	Social interaction	Gossiping, partying, playing cards, mahjong, drinking tea etc.
Dynamic behavioral activities	Physical exercise	Shuttlecock, fitness equipment, Tai Chi, sword dance, ice skating etc.
	Site activities	Square dance, badminton, table tennis and other ball games.

Through behavioral activities	Walking	Walk, run, walk pets, walk through the park etc.

The reliability test was carried out by the Cronbach reliability coefficient, and the results showed that the Cronbach reliability coefficient of 18 variables was 0.924, all greater than 0.8, indicating that the data results of this study passed the reliability test.

At the same time, the KMO and Bartlett spherical tests were carried out by SPSS 26 software, the KMO value was 0.812, and the sig of the Bartlett spherical test was obtained. The value is 0.000, as shown in Table 3. When the KMO value is > 0.8, the significance of the sphericity test is significant. A value < 0.05 indicates that the sample is sufficient and that there is correlation between each variable, which is suitable for factor analysis.

Table 3. KMO and Bartlett's sphericity test.

Kaiser Meyer Olkin measurement of sampling adequacy		0.812
Bartlett's sphericity test	Approximate chi-square	575.854
	Degree of freedom	153.000
	Significance	0.000

3.2. Determining the evaluation index weight of community park space environment recovery

Through the current situation investigation degree of residents' demand for each type of restorative dimension space environment, and combined with expert advice to determine the relative importance of each dimension, and by using the method of 1 to 9 scale evaluation index to construct the judgment matrix, evaluation criteria as shown in Table 4 at every level, and the data results are normalized processing, comparing two determine the weights of evaluation. For cri-terion layer B, a judgment matrix can be constructed.

Table 4. Score criterias for each level.

Evaluation indicators	Definition and Description
1	The two elements are of equal importance.
3	Comparing two elements, one element is slightly more important than the other.
5	Comparing two elements, one element is obviously more important than the other.
7	Comparisng two elements, one element is more important than the other.
9	Comparing two elements, one element is extremely more important than the other.
2,4,6,8	Indicates the middle value of the above two element judgments.
Reciprocal	If the ratio of importance of factor 1 to factor 2 is a, the ratio of importance of factor 2 to factor 1 is 1/a.

3.2.1. Consistency test of the judgment matrix

The consistency test of the judgment matrix was conducted through SPSS, and the final results $C_R$were all less than 0.1, as shown in Table 5, indicating that the data of this survey were finally determined to be real and effective according to the consistency test results.

$$C_1 = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

Consistency proportion calculation： $C_R < 0.10$ can pass the test.

$$C_R = \frac{C_1}{R_I} \quad (2)$$

Table 5. Criterion layer consistency ratio.

A_k	Consistency ratio
Natural landscape restoration B_1	0.0421
Space facility restoration B_2	0.0487
Psychological perception restoration B_3	0.0497
Surrounding environment restoration B_4	0.0904

3.2.2. Determine the weight coefficient of the evaluation index

This study comprehensively determines the weight of each level of the evaluation model through the investigation of the current situation and soliciting the opinions of many experts in urban and rural planning and landscape architecture, as shown in Table 6. The weight coefficient indicates the relative importance of various spatial environment elements affecting the recovery of the community park space environment. Among the weights of each criterion layer, the natural landscape elements have the largest weight on the recovery, which is consistent with the results of previous relevant literature. In the open-ended questionnaire described above, the frequency of natural landscape elements was high, and the willingness of residents to pay attention to the species and color richness of plants was strong, followed by the elements of the space environment and facilities. Residents were more concerned about whether the types and quantities of fitness venues and activity areas are sufficient. Finally, there are psychological perception elements and surrounding environment elements, which occupy relatively small weight, and residents paid more attention to the degree of environmental health and site accessibility.

Table 6 Evaluation model weights calculation.

Target layer A	Guideline layer B	Guide layer	Indicator layer C	Indicator layer C-A weights	Indicator layerC-B weights
Evaluation of space environment restoration of Harbin community park - A	Natural landscape restoration B_1	0.5130	High ornamental waterscape C_1	0.0549	0.1069
			High plant species richness C_2	0.1780	0.3470
			Rich plant color C_3	0.1646	0.3208
			Landscape diversity C_4	0.0697	0.1358
			Trees and shrubs are abundant C5	0.0459	0.0895
	Consistency ratio: 0.0421; $\lambda_{max} = 5.1888$				
	Space facility restoration B_2	0.3350	Adequate activity space C_6	0.0801	0.2390
			High pavement comfort C_7	0.0227	0.0678
			Complete barrier-free facilities C_8	0.0169	0.0503
			Complete types of fitness facilities C_9	0.1133	0.3381
			High comfort of rest facilities C_{10}	0.0305	0.0909
			Sufficient rest facilities C11	0.0717	0.2139
	Consistency ratio: 0.0487; $\lambda_{max} = 6.3065$				
	Psychological perception restoration B_3	0.0897	Space environment with high privacy C_{12}	0.0130	0.1444
			High environmental security C_{13}	0.0134	0.1496
			High environmental sanitation C_{14}	0.0575	0.6406
			Strong culture and art atmosphere C15	0.0059	0.0654
	Consistency ratio: 0.0497; $\lambda_{max} = 4.1327$				
	Surrounding environment restoration B_4	0.0623	Low traffic interference in the surrounding area C_{16}	0.0121	0.1947
			Secluded surrounding environment C_{17}	0.0055	0.0881
			High site accessibility C18	0.0447	0.7172
	Consistency ratio: 0.0904; $\lambda_{max} = 3.0940$				

3.3. Fuzzy Comprehensive Evaluation for Restorative Quality

Using the fuzzy mathematics comprehensive evaluation method to sample the park's natural landscape in Harbin, the restorative nature of the spatial facilities, the restorative mental perception and the restorative quality of the surrounding environment evaluation on the four dimensions of the spatial environment, according to the five levels of evaluation in table 3 "excellent", "good", "general", "poor" and "very poor", are evaluated with a satisfaction score for the spatial environment recovery of Shangzhi Park, and the frequency distribution results of each index are shown in Table 7.

The satisfaction score of each criterion layer is calculated according to the evaluation result matrix, as shown in Table 8. The result of the fuzzy comprehensive evaluation of the recovery of the spatial environment of Shangzhi Park shows that the total score of the target layer is 3.6715, and the recovery grade is "good". In the criterion layer, the evaluation scores of the four dimensions of "natural landscape restoration", "space facilities restoration", "psychological perception restoration" and "surrounding environment restoration" were all between 3 and 4, and the evaluation grade was "good". Among them, the evaluation score of natural landscape restoration was the highest, with an evaluation score of 3.8979. The evaluation score of recovery of space facilities was the lowest, with an evaluation score of 3.3151. From the index layer, the score of plant species richness was the highest.

Table 7 Questionnaire survey results on the restoration satisfaction of the space environment.

Guideline layer B	Indicator layer C	very poor	poor	general	good	excellent	average
Natural landscape restorationB_1	C_1	2.04%	6.12%	36.73%	18.37%	36.73%	3.816
	C_2	2.04%	2.04%	14.29%	51.02%	30.61%	4.061
	C_3	8.16%	6.12%	28.57%	24.49%	32.65%	3.673
	C_4	4.08%	2.04%	8.16%	42.86%	42.86%	4.184
	C_5	6.12%	10.20%	20.41%	30.61%	32.65%	3.735
Space facility restoration B_2	C_6	2.04%	6.12%	36.73%	34.69%	20.41%	3.653
	C_7	4.08%	7.14%	32.65%	27.55%	28.57%	3.694
	C_8	12.24%	20.41%	44.90%	12.24%	10.20%	2.878
	C_9	12.24%	21.43%	36.73%	14.29%	15.31%	2.990
	C_{10}	8.16%	10.20%	30.61%	30.61%	20.41%	3.449

	C_{11}	8.16%	7.14%	38.78%	30.61%	15.31%	3.378
Psychological perception restoration B_3	C_{12}	2.04%	10.20%	40.82%	20.41%	26.53%	3.592
	C_{13}	6.12%	22.45%	30.61%	20.41%	20.41%	3.265
	C_{14}	3.06%	2.04%	26.53%	37.76%	30.61%	3.908
	C_{15}	2.04%	8.16%	40.82%	33.67%	15.31%	3.520
Surrounding environment restoration B_4	C_{16}	15.31%	10.20%	28.57%	25.51%	20.41%	3.255
	C_{17}	2.04%	2.04%	44.90%	26.53%	24.49%	3.694
	C_{18}	1.02%	8.16%	39.80%	20.41%	30.61%	3.714

Table 8 Evaluation score table of spatial environmental recovery of Shangzhi Park.

Target layer A	Score	Guideline layer B	Score	Evaluation results	Indicator layer C	Score	Evaluation results
Evaluation of space environment restoration of Shangzhi Park - A	3.6715 good	Natural landscape restoration B1	3.8979	good	C_1	3.816	good
					C_2	4.061	excellent
					C_3	3.673	good
					C_4	4.184	excellent
					C_5	3.735	good
		Space facility restoration B2	3.3151	good	C_6	3.653	good
					C_7	3.694	good
					C_8	2.878	general
					C_9	2.990	general
					C_{10}	3.449	good
					C_{11}	3.378	good
		Psychological perception restoration B3	3.7410	good	C_{12}	3.592	good
					C_{13}	3.265	good
					C_{14}	3.908	good
					C_{15}	3.520	good
		Surrounding environment restoration B4	3.6231	good	C_{16}	3.255	good
					C_{17}	3.694	good
					C_{18}	3.714	good

4. DISCUSSIONS

4.1. Diversification of rating objects

The object of this sample is mainly to evaluate the characteristic factors that affect the health restoration effect of community parks and the restorative effect of the space environment of observers. In future research, the application scope of the restorative effect of the space environment of community parks should be further expanded. The natural landscape space, leisure space, green space, sports and fitness space and privacy space should be explored in cold cities, focusing on the user space perception, preference and experience of the space, and the guiding public space for user behavior activities to evaluate and optimize the design.

4.2. Systematization of evaluation factors

Due to the complex interaction between community park users and the spatial environment, recovery evaluation factors lack universality, so it is necessary to understand the current situation of community park space environment recovery based on field observations and questionnaire surveys to determine the evaluation factors for recovery.

The shortcomings of this study are that it obtained most of the data from the residents of community park space environment rehabilitation by subjective evaluation and that the users of the spatial environment have a common concern about the area which may lead to a positive bias. The environmental rehabilitation evaluation factors are subjective, so a restorative community park space environment evaluation index system should be built and the existing evaluation factors should be actively expanded and supplemented, which will provide a reference for future empirical research.

4.3. Diversification of evaluation methods

In this paper, the AHP and FCE fuzzy comprehensive evaluation methods are used to evaluate the recovery of the community park space environment, and the combination of these two methods can compensate for the

other's deficiencies. FCE has the advantage of tight organization and strong systematization, which can help solve abstract and difficult-to-quantify indicators. AHP can solve the problem of determining the weight of each evaluation index before PCE, and the combination of the two can build a scientific and reasonable evaluation index system.

With the development of medical technology, it is the current research trend to obtain quantitative indicators of residents' physical and psychological health recovery through medical instrument testing experiments [9-11]. GIS analysis, facial muscle observation and eye movement are also widely used in questionnaires and experiments. These methods can quickly obtain the characteristics of the park space environment and residents' health recovery data, which provide new technical methods for discussing the characteristics of the park space environment and residents' health recovery and behavior.

5. CONCLUSION

This paper considers the drawback that the objective assessment results and the subjective health recovery needs of the residents are separated from each other in the assessment of the current situation of the spatial environmental recovery of community parks in a cold urban area such as Harbin. Additionally, this paper introduces an innovative research idea of spatial environment recovery based on the role of the spatial environment in health restoration and analyzes the necessity of spatial environment recovery of community parks in cold regions based on the conceptual connotation and action mechanism of "environmental recovery".

This study takes Shangzhi Park of Harbin as the research object, adopts the method of AHP and fuzzy comprehensive evaluation to evaluate the restorability of community park space environment, establishes the evaluation index system of community park space environment restorability, and provides a new quantitative method for the establishment of community park space environment and population health.

The results show that the restorability of natural landscape environment elements in Shangzhi Park is the highest, and the landscape elements in the park are rich and the natural characteristics are distinct. The space facility element is not perfect, need to increase the number of fitness facilities and improve the barrier-free facilities. At the level of psychological perception, plants and landscapes need to form a semi-private space to meet the needs of people in mental health recovery. Spaces with high accessibility in the surrounding environment are more attractive to people, and Spaces with high accessibility can bring greater health recovery benefits.

In future studies, the number of samples can be expanded to enrich the spatial environment recovery evaluation system, and improve the scientific and integrity of the evaluation system. More types of space environment can be included in the restorative evaluation of space environment in community parks, and the perception variables of people such as hearing, smell and touch can be included in the evaluation system, so as to further increase the accuracy of the evaluation system.

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