

Research on post-evaluation of reconstruction effect of old residential area in cold region based on AHP-grey clustering method

Yuanhui Yang*, Harile An, Xintong Gong, Yanze Sun, Mutian Su

Department of Aulin, Northeast Forestry University, Harbin, China, 150040

*Corresponding author: yyh_1018@163.com

Abstract. With the improvement of people's living conditions and the advancement of urbanization, the transformation of old residential areas has attracted more and more social attention. The climate in different regions of China is very different, and the long-term ultra-low temperature and snow in the cold region are particularly serious to the damage of the buildings, which has also become the important and difficult point of the reconstruction project. In order to scientifically evaluate the implementation effect of the renovation project of the old residential area in cold region, a scientific post-evaluation index system is constructed by using the judgment matrix and membership degree analysis from five dimensions of safety benefit, comfort benefit, environmental benefit, economic benefit and social benefit. With the opinions of residents, government workers and relevant experts, a post-evaluation model based on AHP and grey clustering is constructed. The model will be applied to the residential renovation project of Harbin Keda community to verify the scientificity of the constructed index system and model, in order to provide suggestions and norms for the subsequent improvement of the residential area and the evaluation of similar projects in the future.

Keywords: Project Post-evaluation; Cold Regions; Renovation of Old Residential Areas; Analytic Hierarchy Process; Grey Clustering Method.

1. Introduction

According to data from the National Bureau of Statistics of China over the past five years, the urbanization rate of China's permanent population has increased from 60.2% in 2017 to 65.2% in 2022, achieving a historic transformation from agricultural population to urban population. This historic change not only advances China's urbanization process, but also poses a major challenge to housing indicators such as housing supply and demand, housing quality standards, etc. Renovation of old residential areas has become a focus of attention in Chinese society. In the process of renovation implementation, there are significant climate differences in different regions of China. Long term ultra-low temperatures, snow accumulation, and other conditions in severely cold areas have caused serious damage to buildings. At the same time, there is a lack of corresponding evaluation standards for the effectiveness of renovation implementation, which has become a key and difficult point in national renovation projects[1].

In recent years, many scholars have conducted research about renovation of old residential areas. Liang and Wang (2016) have conducted a research on old residential areas in Heilongjiang and Jilin provinces to determine the basic situation and model of renovation[2]. They found that old residential areas have complex property rights, energy-saving properties, and poor livability. Zhang (2019) constructed a performance evaluation index system for the comprehensive renovation of old residential communities from the perspectives of economy and efficiency[3]. Huang and Tan (2020) conducted a study on the performance of renovating old residential areas from the perspective of livability, and conducted in-depth research on the special climate, environment, economy, and regional culture characteristics in cold regions[4]. Zhao et al. (2020) proposed environmental renovation strategies in terms of spatial location, green layout, underlying surface materials, and facility accessories through observation and analysis of cold cities[5]. Xu(2022) analyzed different renovation models, and provided thoughts on the principles and commonly used models of renovation, including cultural preservation, sponge city, garbage classification, and ecological livability[6].

Chen(2023) provided relevant theoretical references for micro updates and renovations of old residential areas[7].At present, most of the research focuses on the livability of buildings, energy utilization efficiency, indoor environmental comfort, and other aspects. However, there is relatively little research on the long-term operational effects and social impacts brought about by the renovation. In addition, existing research mainly focuses on the eastern and central regions, with less research on other severely cold regions such as Heilongjiang Province. There are differences in climate conditions, building characteristics, and resident needs in different regions, so targeted research and scheme design are needed. This article will construct a scientific post evaluation index system from five dimensions: safety benefits, comfort benefits, environmental benefits, economic benefits, and social benefits, using judgment matrices and correlation analysis; Construct a post evaluation model based on AHP-grey clustering method, taking into account opinions of residents, government workers, and relevant experts; This model will be applied to the renovation project of Harbin University of Science and Technology residential area to verify the scientific validity of the constructed indicator system and model, in order to provide suggestions and norms for the subsequent improvement of the residential area and the evaluation of similar projects in the future.

2. The basic fundamental of AHP-grey clustering method

2.1. Establishment of initial indicators for post-evaluation

In order to construct a rigorous and objective set of evaluation criteria and ensure the accuracy and rigor of index setting, this paper conducts field research in the spirit of literature research. Referring to the relevant policies of the government industry and designing a questionnaire. Starting from five dimensions: safety benefits, comfort benefits, environmental benefits, economic benefits, and social benefits. Then dozens of indicators were proposed for questionnaire survey. The main scope of the questionnaire survey is the project construction unit, the owner unit, etc., and the main form of distribution is online release, and the 5-point Likert scale is used for statistics based on the results of field investigation[8].In order to ensure the validity of the questionnaire survey, the respondent group was required to be residents of old communities in severe cold areas, of which a total of 400 questionnaires were distributed, and 358 valid questionnaires were recovered, with an effective questionnaire recovery rate of 89.5%.Among them, 43 indicators have a high mention rate, so they are used as the evaluation basis for this article.

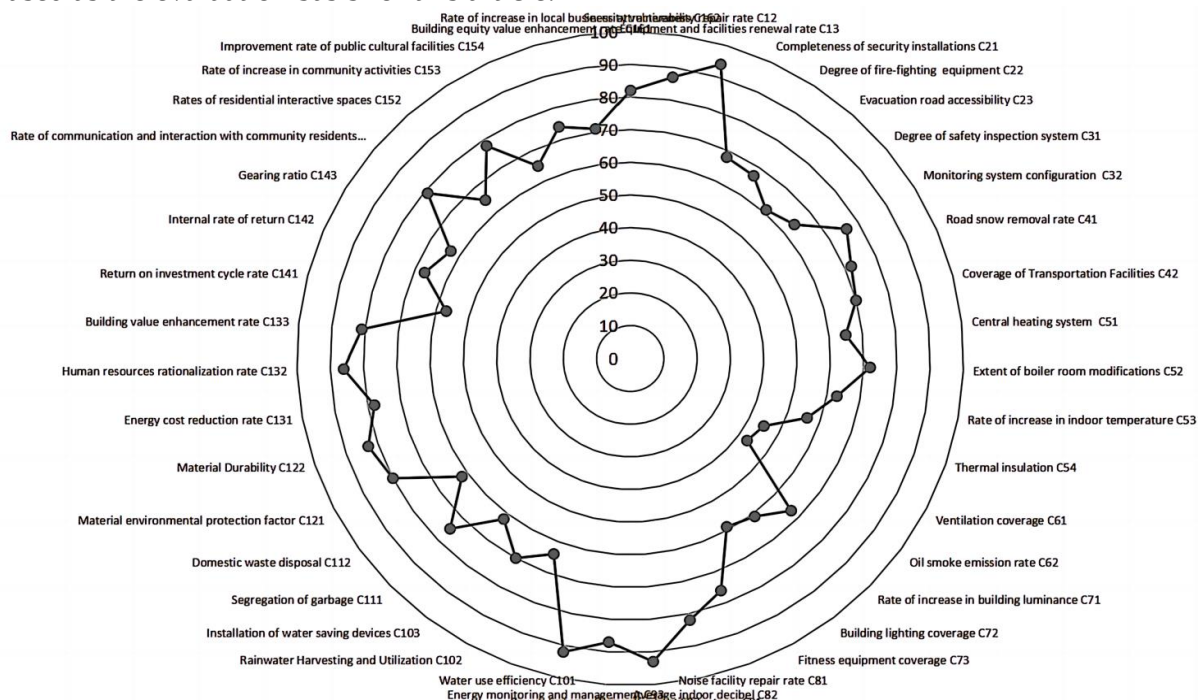


Figure.1. Indicator mention rate percentage chart

2.2. Post-project evaluation weight calculation

Considering that it is difficult to carry out simple quantitative evaluation of complex evaluation involving multiple factors and multiple levels, this study combined analytic hierarchy process (AHP) and cluster analysis to determine the weight of the evaluation index of the renovation effect of old communities in severe cold areas. The main process consists of the following three steps.

2.2.1 Use analytic hierarchy process to establish subjective weights

Considering the characteristics of the evaluation index system for the renovation of old residential areas in severely cold areas, using a 1-9 level to evaluate the importance of evaluation indicators may lead to significant deviation and excessive subjectivity[9]. Therefore, this study chose to evaluate the importance of evaluation indicators for the renovation of old residential areas in severely cold areas using levels 1-5, as shown in Table.1.

Table.1. Modalities of the five-level scale method and their meanings

Sequence	Degree of importance	Assignment of B_{ij}
1	C_i and C_j are equally important	1
2	C_i is slightly more important than C_j	2
3	C_i is significantly more important than C_j	3
4	C_i is more strongly important than C_j	4
5	C_i is most important than C_j	5
6	Intermediate values of adjacent judgements	1/2, 1/3, 1/4, 1/5

The judgment matrix is normalized to obtain approximate weights:

$$w_i = \frac{1}{n} \sum_{j=1}^n \frac{b_{ij}}{\sum_{k=1}^n b_{kj}} \quad (i=1, 2, \dots, n) \quad (1)$$

Calculate the consistency test and the consistency ratio:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (2)$$

$$CR = \frac{CI}{RI} \quad (3)$$

If $CR < 0.10$, the consistency test is passed.

Where λ_{max} , C.I. (Consistency Index), R.I. (Random Consistency Index), and n are the maximum eigenvalue, consistency index, average random consistency index, and judgment matrix order, respectively.

2.2.2 Using cluster analysis to establish objective weights

Construct the expert weight matrix according to the expert's judgment of the importance of each index:

$$W = [w_1 \quad w_2 \quad w_3 \dots w_n] \quad (4)$$

Cluster analysis was performed using SPSS to calculate inter-class weights:

$$\lambda_i = \frac{\eta_i}{\sum_{q=1}^n \eta_q} \quad (5)$$

The consistency ratio of the weight matrix was examined and intra-class weights were calculated:

$$a_i = \frac{CR_i}{\sum_{i=1}^n CR_i} \quad (6)$$

2.2.3 Calculate comprehensive weight

Combining the hierarchical analysis weights with the cluster analysis weights resulted in a composite weight:

$$w_i^* = w_i \lambda_i a_i \quad (7)$$

2.3. Post-evaluation model calculation based on gray clustering method

2.3.1 Construct gray matrix

For an old district renovation project C in a frigid region, first select P experts to evaluate the sustainability of renovation of old districts, according to the quantitative standard of each index C_{ij} of old district renovation in a frigid region[10]. Then we will construct the index scoring grey matrix C based on the results of the expert evaluation:

$$C = \begin{bmatrix} c_{111} & c_{121} & \cdots & c_{1n_11} & c_{211} & c_{221} & \cdots & c_{2n_21} & \cdots & c_{m11} & c_{m21} & \cdots & c_{mn_m1} \\ c_{112} & c_{122} & \cdots & c_{1n_12} & c_{212} & c_{222} & \cdots & c_{2n_22} & \cdots & c_{m12} & c_{m22} & \cdots & c_{mn_m2} \\ \vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \vdots & \cdots & \vdots \\ c_{11p} & c_{12p} & \cdots & c_{1n_1p} & c_{21p} & c_{22p} & \cdots & c_{2n_2p} & \cdots & c_{m1p} & c_{m2p} & \cdots & c_{mn_mp} \end{bmatrix}^T \quad (8)$$

Where: C_{ijp} —the score of the p th expert on the evaluation indicator

m—number of first-level indicators

n_m —number of second-level indexes in the first-level indicators

P—number of experts

2.3.2 Establish the whitening weight function

Since this paper divides the evaluation level of an old district renovation project in a cold area into four levels, four gray categories are set corresponding to each evaluation level. The whitening weight function of each gray category level is shown in Table.2. And the gray clustering level value matrix is:

$$Z = (Z_1, Z_2, Z_3, Z_4) = (1, 2, 3, 4) \quad (9)$$

Table.2.Whitening weight functions for each gray class

Gray grade	Schematic diagram of the whitening weight function	Albino weight function
1		$f_j^1 = \begin{cases} 0 & x \notin [2, \infty) \\ (x-2)/2 & x \in [2, 4) \\ 1 & x \in [4, \infty) \end{cases}$
2		$f_j^2 = \begin{cases} 0 & x \notin [1, 5] \\ (x-1)/2 & x \in [1, 3) \\ (5-x)/2 & x \in [3, 5] \end{cases}$
3		$f_j^3 = \begin{cases} 0 & x \notin [0, 4] \\ x/2 & x \in [0, 2) \\ (4-x)/2 & x \in [2, 4] \end{cases}$
4		$f_j^4 = \begin{cases} 0 & x \notin [0, 3] \\ 1 & x \in [0, 1) \\ (3-x)/2 & x \in [1, 3] \end{cases}$

2.3.3 Calculate the overall rating

Let the evaluation index C_{ijp} belongs to the k th gray category, according to the evaluation value of each expert on the index C_{ijp} and the whitening weight function of each gray category above, the gray evaluation coefficient of each index can be calculated x_{ij}^k :

$$x_{ij}^k = \frac{1}{p} \sum_{i=1}^p f_j^k(c_{ijp}) \quad (10)$$

From the gray evaluation coefficients x_{ij}^k of each indicator, the corresponding gray weights r_{ij}^k for each gray category can be obtained.

$$r_{ij}^k = \frac{x_{ij}^k}{\sum_{k=1}^4 x_{ij}^k} = \frac{\frac{1}{p} \sum_{i=1}^p f_j^k(c_{ijp})}{\sum_{k=1}^4 \frac{1}{p} \sum_{i=1}^p f_j^k(c_{ijp})} \quad (11)$$

Determine the gray weight matrix of the indicator :

$$R_1 = \begin{bmatrix} r_{i1} \\ r_{i2} \\ L \end{bmatrix} = \begin{bmatrix} r_{i1}^1 & r_{i1}^2 & r_{i1}^3 & r_{i1}^4 \\ r_{i2}^1 & r_{i2}^2 & r_{i2}^3 & r_{i2}^4 \\ L & L & L & L \end{bmatrix} \quad (12)$$

Calculate the composite score and determine the evaluation level:

$$B_i = W_i R_i = (b_1^i, b_2^i, b_3^i, b_4^i) \quad (13)$$

Where W_i is the weight of each indicator, which leads to an overall score of :

$$S = BZ^T = (B_1, B_2, L, B_4)(1, 2, 3, 4)^T \quad (14)$$

2.3.4 Setting of evaluation standards

According to the provisions in the "Guidelines for Post-Evaluation of Fixed Asset Investment Projects of Central Enterprises", the evaluation grades of project results are divided into four: success, basic success, partial success, and failure. At the same time, in order to facilitate statistics, a corresponding score interval is assigned to each evaluation grade. Finally, it will be scored on-site by the old neighborhood renovation experts in the severe cold region according to the evaluation criteria on a scale of 1-5. The details are shown in Table.3.

Table.3.Evaluation levels and specific scoring criteria

rating	Total score	Grade Connotation
Successes	(4,5]	The objectives of the project are fully achieved or exceeded; the project achieves significant benefits and impact relative to costs.
Basic Success	(3,4]	Most of the project's objectives have been met; the project has achieved the expected benefits and impacts relative to its costs.
Partial Success	(2,3]	The project achieved some of its original objectives only some benefits and impacts were achieved relative to costs.
Fail	(1,2]	The objectives of the project were unrealistic and unachievable; the project had to be terminated relative to the costs.

3. Results

3.1. The establishment of simulation model

This paper selects the Harbin Keda community as a case study, most of the buildings in the community were built in the 1990s, where is in the center of Nangang District. The location of Harbin Keda community is important, which is about the appearance of the city. The renovation project has 27 buildings included in the old neighborhood renovation project, a large amount of surface, which has a certain degree of representativeness. We conducted empirical analysis based on the survey questionnaire distributed and the renovation data of the project[7].

Firstly, we collect the data of the Renovation and Enhancement Project of Harbin Keda community, and interview with the authoritative experts in the field. Then we construct the weight matrix G of 8 experts about the first-level indicators by using the hierarchical analysis method. The first level are five elements: safety benefits (O_1), comfort benefits (O_2), environmental benefits (O_3), economic benefits (O_4), and social benefits (O_5).

$$G = \begin{bmatrix} 0.4300 & 0.2380 & 0.1327 & 0.0693 & 0.1300 \\ 0.4818 & 0.2636 & 0.0818 & 0.0992 & 0.0736 \\ 0.4120 & 0.1587 & 0.1120 & 0.1285 & 0.1888 \\ 0.4661 & 0.2746 & 0.0661 & 0.0682 & 0.1250 \\ 0.4156 & 0.2515 & 0.1056 & 0.1118 & 0.1155 \\ 0.4769 & 0.3040 & 0.0591 & 0.0831 & 0.0769 \\ 0.4386 & 0.2727 & 0.0986 & 0.0966 & 0.0935 \\ 0.3646 & 0.2278 & 0.1975 & 0.0785 & 0.1316 \end{bmatrix} \quad (15)$$

Then the expert weight matrix G was clustered and analyzed with the help of SPSS software as shown in Figure.2. below:

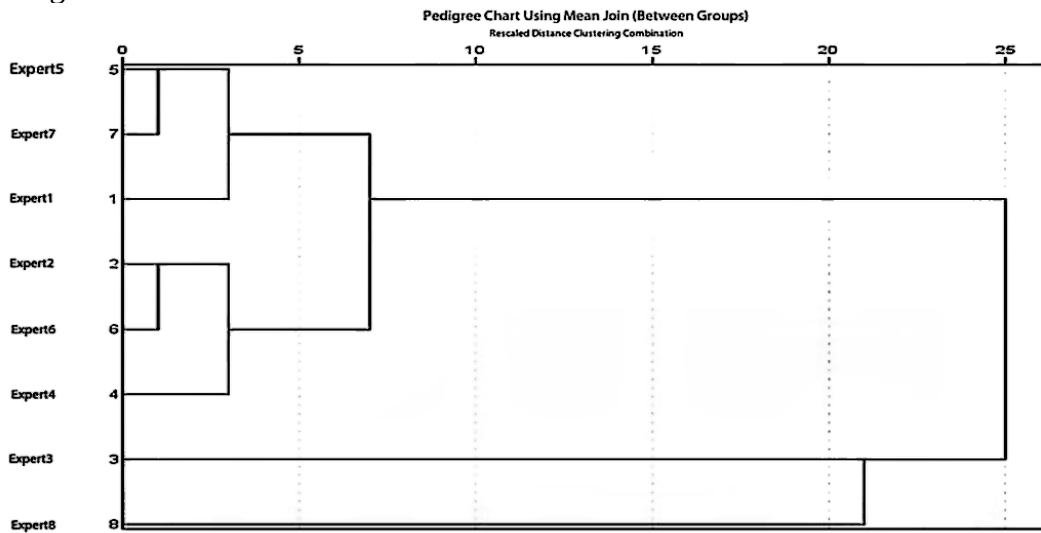


Figure.2. Matrix G Cluster Analysis Plot

The comprehensive weights of the first-level indicators can be obtained by synthesizing the expert hierarchical analysis weights and the expert inter-class and intra-class weights after cluster analysis:

$$W_1=0.4426, W_2=0.2564, W_3=0.1032, W_4=0.0924, W_5=0.1054 \quad (16)$$

The same method can also be used to obtain the comprehensive weights of all 43 secondary indicators separately.

3.2. Analysis of experimental results

At the same time to the transformation of old districts related to the six Northeast old reform planning, design and construction units, old district transformation related fields of scientific research

institutes to send a scoring form in accordance with the 1-5 points of the rating principle of the Harbin Science and Technology large districts renovation and upgrading of the project of the indicators for the evaluation of the construction of the index scores of the grey matrix.

Take the safety of the main body of the house(C_1)as an example:

$$C_1 = \begin{bmatrix} 2 & 3 & 3 & 3 & 3 & 2 \\ 3 & 4 & 4 & 3 & 4 & 4 \\ 3 & 4 & 4 & 3 & 3 & 2 \end{bmatrix} \quad (17)$$

Calculate the gray weight matrix from the scoring gray matrix of the indicator:

$$R_1 = \begin{bmatrix} r_{11} \\ r_{12} \\ r_{13} \end{bmatrix} = \begin{bmatrix} 0.08 & 0.32 & 0.43 & 0.17 \\ 0.04 & 0.27 & 0.42 & 0.27 \\ 0.05 & 0.25 & 0.36 & 0.34 \end{bmatrix} \quad (18)$$

Comprehensive evaluate the safety indicators of the main body of the house(C_1) :

$$\begin{aligned} B_i = W_i R_i &= [0.3834 \quad 0.3444 \quad 0.2722] \begin{bmatrix} 0.08 & 0.32 & 0.43 & 0.17 \\ 0.04 & 0.27 & 0.42 & 0.27 \\ 0.05 & 0.25 & 0.36 & 0.34 \end{bmatrix} \\ &= [0.0581 \quad 0.2837 \quad 0.4075 \quad 0.2507] \end{aligned} \quad (19)$$

Similarly, the gray weight matrix of other indicators can be calculated, and finally the gray weight matrix of the first-level indicator R is obtained:

$$R = \begin{bmatrix} 0.0708 & 0.3166 & 0.4292 & 0.1834 \\ 0.0530 & 0.2669 & 0.4482 & 0.2319 \\ 0.0065 & 0.3625 & 0.3840 & 0.2470 \\ 0.0754 & 0.3878 & 0.4325 & 0.1043 \\ 0.1308 & 0.3438 & 0.4083 & 0.1171 \end{bmatrix} \quad (20)$$

$$\begin{aligned} B &= WR = [0.4426 \quad 0.2564 \quad 0.1032 \quad 0.0924 \quad 0.1054] \\ &\times \begin{bmatrix} 0.0708 & 0.3166 & 0.4292 & 0.1834 \\ 0.0530 & 0.2669 & 0.4482 & 0.2319 \\ 0.0065 & 0.3625 & 0.3840 & 0.2470 \\ 0.0754 & 0.3878 & 0.4325 & 0.1043 \\ 0.1308 & 0.3438 & 0.4083 & 0.1171 \end{bmatrix} \\ &= [0.0664 \quad 0.3180 \quad 0.4275 \quad 0.1881] \end{aligned} \quad (21)$$

Calculate the final score to determine the evaluation level:

$$S = BZ^T = (0.0664, 0.3180, 0.4275, 0.1881)(1, 2, 3, 4)^T = 2.7373 \quad (22)$$

The total comprehensive evaluation score for the Harbin Keda District Renovation and Enhancement Project is 2.7373 . It can be determined that the project's comprehensive evaluation rating is Partially Successful.

Through a comprehensive evaluation of the renovation and improvement project of Harbin Keda community, we can find that the renovation of old residential areas in severely cold areas currently performs well in terms of safety benefits, but has many shortcomings in terms of economic and comfort benefits, such as poor insulation effect, high winter energy consumption, many idle resources in small areas, and low building value improvement rate.

4. Conclusions

In order to scientifically evaluate the effectiveness of the renovation of old residential areas in severely cold areas, this article selects five primary indicators, including safety benefits, comfort benefits, environmental benefits, economic benefits, and social benefits, and introduces the AHP grey

clustering evaluation model for empirical research, proposing relevant suggestions. This article can provide useful references for post evaluation projects or other related projects in the renovation of similar old residential areas. Old residential areas are an important part of urban renewal and construction. Through gradual standardization and scientific transformation, they can better meet the needs of the people for a better life, establish a high-quality environment and a good social atmosphere, and promote sustainable urban development.

Acknowledgements

This work was financially supported by Undergraduate Training Programs for Innovations by NEFU [grant number 202310225559].

References

- [1] Hu Zhizong. Feasibility study on social capital intervention in the renovation of old residential areas [D]. Shandong Jianzhu University, 2023.
- [2] Liang Chuanzhi, Wang Chaoxia. Investigation and Reflection on Comprehensive Upgrading and Renovation of Old Residential Communities: Taking Heilongjiang and Jilin Provinces as Examples [J]. Urban Housing, 2016,23 (05): 29-34
- [3] Zhang Zhihong, Zhang Yu. Research on Performance Evaluation of Comprehensive Renovation and Renovation Projects for Old Residential Communities - Taking the Renovation of Old Residential Communities in Shandong Province as an Example [J]. Financial Science, 2019 (1)
- [4] Huang Guilin, Tan Zhaoqiu. Research on Performance Evaluation of Renovation of Old Residential Areas from a Livable Perspective: A Case Study of Renovation of Old Residential Areas in Cold Regions [J]. Price Theory and Practice, 2020, (09): 168-171+180.
- [5] Zhao Xin, Jiao Zhongshan, Cheng Yingnan. Strategies for Improving the Quality of Outdoor Space Environment in Old Residential Areas in Cold Cities: A Case Study of Jichai Community in Changchun City [J]. Planner, 2020,36 (S2): 58-63
- [6] Xu Chenchen. Analysis of renovation models for old urban communities [J]. China Architecture Decoration and Renovation, 2022, (12): 147-149
- [7] Chen Qi Research on Micro renovation Design of Old Residential Areas in Harbin under the Background of Urban Renewal [D].
- [8] Song Xiaoyu, Zhang Xing, Chen Chuwen. Investigation and Countermeasures of the Current Situation of Old Residential Areas under the Background of Urban Double Renovation [J]. Zhejiang Architecture, 2019, 36 (06): 5-10.
- [9] Tan Zhaoqiu. Research on Sustainable Evaluation of Green Transformation in Old Residential Areas in Heilongjiang Province [D]. Northeast Forestry University, 2021.
- [10] Zhang Weijiang. Research on Safety Evaluation of Prefabricated Building Construction Based on ANP Grey Clustering Model [D]. Yangzhou University, 2022.