International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 10 Issue 1 Series I || January 2021 || PP 51-56

Research on the Evaluation of the Success of Green Renovation Projects of Existing Buildings——Based on Fuzzy Analytic Hierarchy Process

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ABSTRACT: *Currently, old buildings in China generally have problems such as safety, environment, energy consumption and building life. Direct demolition will cause waste of resources and increase environmental pressure. Therefore, it is necessary to carry out reasonable energy-saving renovation of existing buildings. This study introduces economic benefits into the established evaluation index system for the success of the modified project, uses the analytic hierarchy process to determine the relevant weights, uses the fuzzy comprehensive evaluation method component evaluation model, and determines the success of the modified project based on the principle of maximum membership in the empirical analysis. . Research shows that key improvements and improvements to important indicators will help decision-makers to formulate the green renovation goals of existing buildings reasonably and accurately, and provide an effective reference for the formulation of relevant government policies.*

KEYWORDS- *Existing buildings; Green renovation; Analytic hierarchy process; Fuzzy comprehensive evaluation*

Date of Submission: 30-12-2020 Date of Acceptance: 11-01-2021

I. INTRODUCTION

At present, my country's existing buildings, especially non-residential buildings, emit a large amount of greenhouse gases during use [1]. As of the end of September 2016, China's existing building area has exceeded 60 billion m2, and the green building area is only 531.17 million m2, accounting for less than 1%, and only about 5% of energy-saving building standards are met [2]. For most of the existing buildings, the current standards can neither meet the green standards, nor can they meet the living environment requirements of the residents in a well-off society. Through green renovation of existing buildings, demolition and reconstruction can be effectively avoided, and greenhouse gas emissions can be reduced. Promoting the green transformation of existing buildings can intensively save and use resources, improve the safety, comfort and health of buildings, transform urban and rural construction models, break energy resource bottlenecks, and cultivate strategic emerging industries such as energy conservation, environmental protection, and new energy. It has a very important meaning and function [3]. Compared with newly built green buildings, the green renovation of existing buildings can bring more considerable social and economic benefits, and has a higher cost performance[4]-[5], and from the perspective of the future, both new construction and existing renovation will become the "new normal" of the development of my country's construction industry [6]. Through the research and analysis of the papers published by CNKI in the past ten years, the existing comprehensive evaluation research on the green renovation of existing buildings mainly focuses on single-factor analysis, and only 14.7% of the literature has conducted a multi-factor comprehensive impact analysis on existing projects. , The existing comprehensive evaluation index system is not perfect, and there is a lack of research on the evaluation of economic benefits. In order to ensure that the modified project can reach the established goal, combined with the characteristics of the modified project, a set of targeted and reasonable success evaluation system of the modified project is proposed to determine the target reasonably and improve the success of the modified project.

II. SUCCESS EVALUATION INDEX SYSTEM

2.1 Principles of constructing evaluation index system

The comprehensive renovation of existing buildings refers to the comprehensive renovation of buildings and structures, heating, ventilation, lighting, air conditioning, power supply and distribution, and water supply and drainage systems in existing buildings, applying high-tech and products to improve the level of operation and management. To achieve the goal of being safer, more comfortable, more environmentally friendly, and more energy-saving after the transformation. The index evaluation system for comprehensive renovation of existing buildings should follow the following principles:

Comprehensiveness and integration: The establishment of the evaluation index system should follow the principles of “comprehensiveness” and “integration”. The renovation of existing buildings is not only a renovation of one aspect of the building, but a comprehensive renovation of multiple aspects. The renovation must not only reflect energy conservation , but also reflect the principles of safety, comfort and environmental protection.

Integrity: The evaluation index, the evaluation index, and the overall result of the evaluation are an organic synthesis. The comprehensive evaluation of existing buildings is not a simple collection of single indicators. It is not only reflected in building renovation, structural renovation, or renovation of building plumbing and electricity. The relationship between functions and evaluation indicators must obey the overall goals and functions of the evaluation. Only when the overall function is realized and the economic requirements of the transformation are met, can the selection of the evaluation indicators be correct and perfect, and the evaluation results can reflect the integrity .

Applicability: The determination of the evaluation index system should reflect the principle of "adjusting measures to local conditions". There are huge differences in China's climate conditions, geographical environment, natural resources, urban and rural development and economic development, living standards and social customs. Therefore, the comprehensive needs for buildings are also different. The evaluation of existing buildings should reflect the characteristics of different regions and comply with local regulations and laws. At the same time, when evaluating different building types, such as residential buildings, public buildings and historical buildings, they must reflect different characteristics and requirements.

Existing: Since this indicator system is aimed at existing buildings, according to the characteristics of existing buildings, indicators that cannot or are difficult to change in the existing renovation, such as the orientation of the building and the geographic location of the building, are not considered.

2.2 Construction of evaluation index system

The "Evaluation Standards for Green Reconstruction of Existing Buildings" formulated by my country is applicable to all civil constructions, involving planning and construction, structure and materials, HVAC, water supply and drainage, electrical, construction management, operation management, improvement and innovation Eight aspects [7]. The green renovation of existing buildings is not simply a reconstruction of buildings, but a construction activity that uses appropriate technology, technology, equipment and materials to adjust, renew, and strengthen existing buildings to improve performance and function. It is not only related to the strategy and plan of transformation, but also involves construction control and operation management. The green renovation of existing buildings is a complex system project, which involves a wide range and is restricted by the building itself and regional characteristics. When evaluating green renovation, it is necessary to comprehensively consider the limitations of the original building and the functional requirements of the existing renovation [8]. Differences in evaluation standards will have a huge impact on the evaluation results , so constructing a reasonable evaluation index system will help improve the accuracy of the evaluation results of the success of the modified projects. References [9]-[10] combined with China’s existing standards and specifications, consulted relevant experts to adjust the evaluation indicators, and selected scientific, reasonable, quantifiable, rich and understandable evaluation indicators to form an existing building green renovation success evaluation system. Including economic benefits, building and structural renovation, material use, energy saving and energy utilization, water saving and water resource utilization, material saving and material resource utilization, land saving and outdoor environment, indoor environment, operation and management quality, a total of nine first-level indicators , 29 secondary indicators, as shown in Table 1.

Table 1 The success evaluation index system of the reformed projects

Serial number	*Index system*	
1	*Economic benefitA_1*	*Payback period U_{11}*
2		*Cost saving rate U_{12}*
3		*Total return on investment U_{13}*
4	*Architecture and structureA_2A_2*	*safety U_{21}*
5		*Durability U_{22}*
6	*Material useA_3*	*Environmental protection, durability U_{31}*
7		*Degree of prefabrication U_{32}*
8	*Energy saving and energy utilizationA_4*	*Perimeter structure U_{41}*
9		*Ventilation air conditioning and heating system U_{42}*
10		*Lighting system U_{43}*
11		*Energy consumption itemized measurement U_{44}*

12		*Renewable energy utilization U_{45}*
13	*Water saving and water resources utilizationA5A_5*	*Sanitary appliancesU_{51}*
14		*Green field irrigationU_{52}*
15		*Water supply and drainage systemU_{53}*
16		*Measuring instrument useU_{54}*
17		*Non-traditional water useU_{55}*
18	*Material saving and resource utilizationA6A_6*	*Saving of building materialsU_{61}*
19		*Use of renewable and energy-saving materialsU_{62}*
20	*Land saving and outdoor environmentA7*	*Venue acoustic environmentU_{71}*
21		*Site greeningU_{72}*
22		*Utilization of underground spaceU_{73}*
23	*indoor environmentA8*	*Indoor air qualityU_{81}*
24		*Noise and sound insulationU_{82}*
25		*Natural ventilation, sunshine and lightingU_{83}*
26		*Humid temperature environmentU_{84}*
27	*Operational management qualityA9*	*Operating systemU_{91}*
28		*Intelligent buildingU_{92}*
29		*Managerial qualityU_{93}*

2.3 Evaluation model construction

The green renovation of existing buildings should consider unifying the dimensions of different indicators, and some factors in the renovation cannot be absolutely affirmed or absolutely denied, and some factors are vague, and the fuzzy comprehensive evaluation method can solve the ambiguity and inconsistency of judgment. Certainty. In addition, the result of fuzzy comprehensive evaluation is a vector, which overcomes the defect of the single result of traditional mathematical methods, and the evaluation result contains more information. However, fuzzy comprehensive evaluation is difficult to solve the repetition caused by the correlation of evaluation indicators, and the determination of the weight of each factor is subjective, so the method of fuzzy comprehensive evaluation cannot be used only. In order to overcome the subjectivity of factor weight determination, a more suitable method must be selected to determine the weight of evaluation indicators. The determination of the weight of the evaluation index system is a complicated task, which will affect the accuracy of the evaluation results to a large extent. Therefore, scientifically determining the weight of indicators is a prerequisite for improving the quality of evaluation. This paper uses the analytic hierarchy process to determine the weight of the index, avoiding the commonly used insufficiency of determining the weight of the evaluation index based on the practical experience and subjective judgment of the evaluator, greatly enhancing the scientificity and effectiveness of the evaluation process, and making it more accurate. Reflect the results of decision-making.

AHP analyzes the factors and related relationships contained in the complex system, organizes and hierarchizes the problem, constructs a hierarchical analysis structure model, compares the elements of each level in pairs, and obtains the relative importance according to a certain scale theory. Comparing the scale and establishing a judgment matrix, calculating the maximum eigenvalue of the judgment matrix and its eigenvector, and obtaining the order of importance of each level element to an element of the upper level, thereby establishing a weight vector. The main steps are as follows:

(1)According to the scaling theory, construct a pairwise comparison judgment matrix$A = (a_{ij})_{n\times n}, (i, j = 1,2, \dots\dots, n)$,$a_{ij} = 1 / a_{ji}$。

(2)Normalize the columns of the judgment matrix A:$\bar{a}_{ij} = a_{ij}/\sum_{k=1}^{n} a_{kj}\,, (i, j = 1,2, \dots\dots, n)$

(3)Find the sum of the elements in each row of the judgment matrix A:$\bar{w}_i = \sum_{j=1}^{n} \bar{a}_{ij}\,, (i = 1,2, \dots\dots, n)$

(4) Perform normalization to get:$w_i = \bar{w}_i/\sum_{i=1}^{n} \bar{w}_i\,, (i = 1,2, \dots\dots, n)$

(5) Find the maximum eigenvalue and its eigenvector according to it.

(6) Consistency test: Calculate the consistency index; find the corresponding average random consistency index RI; calculate the consistency ratio CR=CI/RI; when CR<0.1, it means that the consistency test is acceptable, otherwise, the matrix A Fix.

In a complex system, there are many factors to consider, and there are hierarchical distinctions between the factors, the multi-level fuzzy comprehensive evaluation method is used, which can better solve the system safety evaluation problem. The specific steps are as follows:

(1)Establish comment sub-target set$U = (U_1, U_2, \dots\dots, U_S)$.

(2) Establish the sub-goal weight distribution set according to the results of the analytic hierarchy process$A = (A_1, A_2, \dots\dots, A_S)$, and meet the conditions, $0 < A_i \le 1, \sum_1^S A_i = 1, (i = 1,2, \dots\dots, s)$.

(3) Each sub-objectiveU_i is affected by each indicator$u_{i1}, u_{i2}, \dots\dots, u_{ik}$, then the indicator set

$u_i = (u_{i1}, u_{i2}, \dots\dots, u_{ik}), (i = 1,2, \dots\dots, s)$.

(4)Determine the weight distribution set $w_i = (w_{i1}, w_{i2}, \dots\dots, w_{ik}), (i = 1,2, \dots\dots, s)$ of each indicatoru_i according to the results of the analytic hierarchy process.

(5)According to the success of the project, select several evaluation sets to form an evaluation set $V = (V_1, V_2, \dots\dots, V_m)$.

(6)Ask a number of experts to vote for each indicator to obtain an evaluation matrixR_i:

$$R_i = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{k1} & r_{k2} & \cdots & r_{km} \end{bmatrix}$$

(7)Obtain the comprehensive evaluation vector of each sub-objective: $B_i = w_i \circ R_i, (i = 1,2, \dots\dots, s)$

(8)Get the sub-goal evaluation matrix $B = (B_1, B_2, \dots\dots, B_s)^T$.

(9)Calculate the overall target evaluation vector $C = A \circ B$.

(10) Take the maximum degree of membership to obtain the success level of the modified project.

III. SUCCESS EVALUATION APPLICATION

3.1 Determination of index weight

According to the characteristics of the reformed project, combined with the regional characteristics, in line with the principle of "system security, clear hierarchy, concise science, dynamic universal", establish a scientific and reasonable evaluation index system. Invite a number of experts and related technical management personnel in the field of the reformed project to score each indicator in the success evaluation index system of the reformed project based on their professional knowledge and experience. In order to overcome the arbitrariness and irrationality of the expert scoring, the scoring results were tested for consistency, and the results showed that the scoring results all met the requirements of consistency testing. According to the calculation process of analytic hierarchy process, the weight of each secondary index is shown in Table 2.

Table 2 Weights of secondary indicators

Serial	*Index system*		*Weights*
1	*Economic benefitA_1 0.163*	*Payback period U11*	*0.2297*
2		*Cost saving rate U12*	*0.1220*
3		*Total return on investment U13*	*0.6483*
4	*Architecture and structureA_2 0.034*	*safety U21*	*0.7500*
5		*Durability U22*	*0.2500*
6	*Material useA_3 0.026*	*Environmental protection, durability U31*	*0.8000*
7		*Degree of prefabrication U32*	*0.2000*
8	*Energy saving and energy utilizationA_4 0.170*	*Perimeter structure U41*	*0.0592*
9		*Ventilation air conditioning and heating*	*0.4463*
10		*Lighting system U43*	*0.2227*
11		*Energy consumption itemized*	*0.1335*
12		*Renewable energy utilization U45*	*0.1382*
13	*Water saving and water resources utilization 0.100*	*Sanitary appliancesU51*	*0.1401*
14		*Green field irrigationU52*	*0.0729*
15		*Water supply and drainage systemU53*	*0.1919*
16		*Measuring instrument useU54*	*0.0570*
17		*Non-traditional water useU55*	*0.5381*
18	*Material saving and resource utilizationA_6 0.044*	*Saving of building materialsU61*	*0.2500*
19		*Use of renewable and energy-saving*	*0.7500*
20	*Land saving and outdoor environmentA_7 0.050*	*Venue acoustic environmentU71*	*0.6250*
21		*Site greeningU72*	*0.1365*
22		*Utilization of underground spaceU73*	*0.2385*
23	*indoor environment 0.119*	*Indoor air qualityU81*	*0.1906*
24		*Noise and sound insulationU82*	*0.2707*
25		*Natural ventilation, sunshine and*	*0.4182*
26		*Humid temperature environmentU84*	*0.1205*
27	*Operational management quality 0.294*	*Operating systemU91*	*0.5584*
28		*Intelligent buildingU92*	*0.1220*
29		*Managerial qualityU93*	*0.3196*

According to the above-mentioned model, the reconstruction of a university complex is the evaluation object, and the building has obtained LEEDEBOM gold certification. Combined with the established success evaluation model, the project's success is quantitatively evaluated.

3.2 Fuzzy comprehensive evaluation model

According to the project success evaluation method, the success of the project can be divided into five levels: complete success, basic success, partial success, unsuccessful and failure. Based on the characteristics of the modified projects, this article divides the success of the modified projects into four levels: complete success (level I), basic success (level II), partial success (level III), and failure (level IV). According to the calculated weights of the primary and secondary indicators, the overall target evaluation vector C is obtained.Taking economic benefits A1 as an example, the comprehensive evaluation matrix Bi of each secondary index is obtained from

$$B_i = w_i{}^\circ R_i : B_1 = w_1{}^\circ R_1 = [0.2297 \quad 0.1220 \quad 0.6483]^\circ R_1 = [0.5058 \quad 0.1378 \quad 0.1439 \quad 0.2125]$$

In the same way, $B_2, B_3, \ldots\ldots, B_9$ can be obtained, and then the overall evaluation matrix B of the secondary indicators is formed by the comprehensive evaluation matrix of each secondary index:

$$B = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \\ B_5 \\ B_6 \\ B_7 \\ B_8 \\ B_9 \end{bmatrix} = \begin{bmatrix} 0.5058 & 0.1378 & 0.1439 & 0.2125 \\ 0.5750 & 0.1750 & 0.1000 & 0.1500 \\ 0.4900 & 0.1700 & 0.1800 & 0.1600 \\ 0.2689 & 0.1879 & 0.3119 & 0.2313 \\ 0.3891 & 0.1105 & 0.2006 & 0.2998 \\ 0.6125 & 0.1625 & 0.1000 & 0.1250 \\ 0.2807 & 0.2102 & 0.1443 & 0.3648 \\ 0.3607 & 0.3015 & 0.2540 & 0.0838 \\ 0.6431 & 0.2564 & 0.0625 & 0.0381 \end{bmatrix}$$

Then calculate the overall target evaluation vector C:

$$C = A^\circ B = [0.163 \quad 0.034 \quad 0.026 \quad 0.17 \quad 0.1 \quad 0.044 \quad 0.050 \quad 0.119 \quad 0.294]^\circ B$$
$$= [0.4723 \quad 0.2047 \quad 0.1648 \quad 0.1581]$$

According to the principle of maximum membership, the success level of the modified project is level I, which is a complete success level, indicating that most of the goals of the project have been achieved, in line with the actual situation of the building's LEEDEBOM gold certification.

IV. CONCLUSION

Aiming at the current situation that the existing building green renovation success evaluation system is not yet perfect, this paper is based on the analytic hierarchy process to establish the existing building green renovation success evaluation system; at the same time, combined with the fuzzy comprehensive evaluation method, the advantages of these two methods can be fully utilized. Considering various factors affecting system security, combining qualitative and quantitative analysis organically, it can not only fully reflect the ambiguity of evaluation factors and evaluation process, but also minimize the abuses caused by personal subjective assumptions, which is better than the general evaluation score. Such methods are more in line with objective reality, so the evaluation results are more credible and reliable. Introducing economic benefits into the evaluation index system can effectively prevent decision makers from greening existing buildings in pursuit of short-term benefits regardless of costs, and provide theoretical support for decision makers to make relevant decisions. Through the analysis of the weights of evaluation indicators, it can be seen that effective analysis can be carried out on indicators with larger weights. It is helpful to summarize experience, and can focus on improving and perfecting indicators with significant weight, and at the same time formulating relevant policies for government departments. reference.

Since the determination of the mutual weights and the degree of membership between the indicators is determined by expert evaluation, the completeness of the expert's experience knowledge and background materials determines the accuracy of the evaluation system to a certain extent. Therefore, the collection of the number, quality, and background materials of the experts should be Give high attention. The analytic hierarchy process treats the research object as a system, and makes decisions according to the decomposition, comparison and judgment, and comprehensive thinking mode. The weight setting of each layer in the analytic hierarchy process will eventually directly or indirectly affect the results, and every level in each level The degree of influence of each factor on the results is quantified, very clear and clear. The green renovation evaluation of existing buildings involves multiple disciplines and multiple factors, and the evaluation indicators are wide and involve a large number of evaluation indicators that are difficult to quantify. The introduction of fuzzy evaluation method has great advantages: quantitatively, fuzzy mathematics will lack quantitative indicators in the evaluation system Load the mathematical model and use the mathematical language to establish the threshold analysis; in the objective evaluation, because the influence of human subjective factors is weakened, the evaluation of the green renovation of existing buildings is more reliable. The object of this article is mainly civil buildings. As the leading industry of our national economy, industrial buildings play an important role. The energy-saving renovation of old industrial buildings is worthy of further discussion. Due to the large number of evaluation indicators in this study, the internal connection between the indicators is not clear, and the path of mutual influence between the indicators is the focus of subsequent research.

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RunGuo Li, et. al. "Research on the Evaluation of the Success of Green Renovation Projects of Existing Buildings——Based on Fuzzy Analytic Hierarchy Process." *International Journal of Engineering Science Invention (IJESI)*, Vol. 10(01), 2021, PP 51-56. Journal DOI- 10.35629/6734