Research Article

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Establishment of a green degree evaluation model for wall materials based on lifecycle

Abstract: With the increasing demand for green and environmentally friendly building materials, the development of the building materials industry is gradually moving toward an ecological and sustainable direction. At present, there are various indicators for evaluating the greenness of wall materials, and the evaluation methods are mainly in view of personal experience. Therefore, this study designed a green degree evaluation model for wall materials. The model is first in view of the lifecycle of the wall material, considering factors that affect the greenness of the wall material. Then, an improved mathematical hierarchy process is used for modeling, and finally, indicator weights are calculated, and the model is simulated for application. The results indicate that the model can reasonably and accurately rate the greenness of wall materials with different characteristics and has high scientific and practical significance. The survey results show that the satisfaction level of the model is high, indicating that it has broad application prospects and development potential in practical applications and can provide strong support for promoting the sustainability and green development of the building materials industry.

Keywords: wall materials, building materials industry, lifecycle, greenness

1 Introduction

As people's attention to environmental protection, energy conservation, sustainability, and other issues deepens, the development of the building materials industry is gradually shifting toward green, ecological, and sustainable directions. As an important component of building materials, wall materials play a crucial role in the quality and environmental protection of buildings [1]. Nowadays, improving the environmental friendliness and greenness of wall materials has become an important development direction in the construction industry. The production, use, and disposal of wall materials throughout their entire lifecycle will have a certain impact on the environment, society, and economy. Therefore, in developing green wall materials, it is necessary to evaluate the greenness of wall materials and to provide a scientific basis for the selection and production of wall materials [2,3]. Traditionally, people evaluate the greenness of wall materials through empirical methods, single indicator methods, and other methods. However, these methods have many shortcomings: there is no complete evaluation system; the evaluation indicators are relatively single, making it difficult to make reasonable judgments; lack of standardized evaluation data; lack of scientific and comprehensiveness. These issues make it difficult for traditional wall material greenness evaluation systems to meet the needs of modern green buildings [4,5]. Therefore, many experts have conducted research on the general evaluation of building materials and greenness. To determine the relationship between green building factors and sustainable performance, Shurrab *et al.* conducted data collection and exploratory factor analysis by visiting multiple building professionals. The results delineated the relationship between green and sustainability in the construction industry and explored the impact of green management on sustainability [6]. Colorado *et al.* have taken actions to encourage sustainable development of materials in the areas of circular economy and material recycling to increase the possibility and awareness of using "additive manufacturing." They have conducted in-depth research on materials such as ceramics, metals, and composite materials. The results indicate that significant breakthroughs have been made in additive manufacturing technology, which has attracted the attention of all parties [7]. Jalaei *et al.* used building information modeling to evaluate the reduction of waste and environmental impacts during the construction phase of building materials. This model deeply analyzes the causes of waste generation, calculates the waste generated in each stage of building materials, and proposes corresponding solutions.

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The results indicate that the proposed model has good practical performance [8]. Michalopoulou *et al.* evaluated and analyzed the performance of nano lime dispersion to protect clay-based building materials in archaeology. The results indicate that nano lime dispersion has repair and protection effects on clay-based building materials [9].

However, these methods lack a systematic assessment of the entire lifecycle, making it difficult to fully reflect the environmental impact of wall materials at various stages such as production, use, and disposal. In contrast, the life-cycle-based evaluation method for green wall materials comprehensively considers the impact of wall materials on sustainable development from multiple aspects such as environment, society, and economy during their life-cycle. Cavalieri *et al.* proposed traditional RC column sleeve reinforcement and innovative solutions based on energy dissipation to address the insufficient seismic performance of prefabricated reinforced concrete industrial buildings during earthquakes. Then, the environmental impact of the two solutions was quantitatively evaluated through a life-cycle assessment (LCA) based on an Environmental Product Declaration, and the results showed that the energy dissipation-based solution was more environmentally friendly [10]. To reduce the environmental impact of logging, Gan *et al.* analyzed and evaluated the environmental impact of various stages of logging through LCA methods and proposed corresponding suggestions for reducing environmental impact [5]. Di Domênico *et al.* conducted an LCA on the environmental impact of the embedding and maintenance of social interest housing building systems. By evaluating two housing building systems, it was found that the production and transportation stages have the greatest environmental impact, while the use and maintenance stages have relatively small environmental impacts. This study has a certain guiding significance for the environmental sustainability of housing construction systems [11].

To achieve accurate green evaluation of wall materials, it is necessary to introduce the analytic hierarchy process (AHP). AHP is a systematic decision analysis method that can decompose complex multi-objective decision-making problems into multiple levels and provide a scientific basis for decision-making through a combination of qualitative and quantitative methods. Oztaysi *et al.* proposed a method in view of spherical fuzzy AHP scoring to artificially determine the price of goods in a location-based system. This method determines the weights of multiple factors on commodity prices and applies them to dynamic pricing models, making pricing more flexible and targeted. The results indicate that the model can accurately set prices in view of different scenarios [12]. Nuroji *et al.* used the AHP to compare the performance of two types of concrete rigid pavement. This method first analyzes the characteristics, advantages, and disadvantages of precast concrete and traditional concrete

rigid pavement and establishes a hierarchical structure model on this basis. Then, it determines the degree and priority of each factor's impact on the concrete pavement. The results indicate that prefabricated concrete is superior to traditional concrete rigid pavement in some aspects, but slightly inferior in other aspects [13]. Darko *et al.* reviewed the application of AHP in the field of architecture and analyzed its application in decision-making analysis in the field of architecture. They summarized the advantages and disadvantages of AHP in the field of architecture; then, further research directions and suggestions were proposed [14]. However, the disadvantage of this method is that the subjectivity of expert allocation of indicator weights is too strong. Therefore, this study improved it through expert clustering analysis and fuzzy matrix evaluation methods.

The research of numerous scholars, both domestically and internationally, indicates that the green development of building materials has become a hot topic in the field of architecture. As one of the important components of architecture, wall materials have attracted much attention in terms of their environmental friendliness and greenness. Researchers have also used various methods for evaluation in this field, such as LCA and AHP. However, due to the limitations and subjectivity of the method itself, further improvement is needed. Therefore, this study constructed a green degree evaluation model for wall materials in view of the lifecycle. This model deeply analyzes the various green degree indicators that affect the lifecycle of wall materials and uses an improved AHP to calculate weights. It is expected to accurately score the green degree of wall materials.

The research is mainly separated into four sections: The first mainly introduces the research on building materials by domestic and foreign experts, as well as the application of lifecycle and AHP; the second mainly explains the improvement strategy of AHP and the construction of a green degree evaluation model for wall materials; the third mainly calculates some parameters in the second section for the simulation application of wall material greenness; the fourth mainly analyzes the calculation and application results and points out the shortcomings of the research methods.

2 Improvement and model construction of green degree evaluation method for wall materials

The study proposes a construction method for a green degree evaluation model of wall materials in view of the

lifecycle, which adopts an improved AHP-fuzzy comprehensive evaluation method. This method comprehensively considers the environmental, social, and economic factors that affect the wall material. By analyzing and calculating the weight of evaluation indicators, the final comprehensive evaluation result of the green degree of the wall material is obtained. Meanwhile, this study also proposes improvements to the traditional AHP method, enhancing the reliability and credibility of the evaluation model, which can be used for evaluation in other fields.

2.1 Improvement strategy of AHP method in view of lifecycle

The AHP has been widely applied in LCA; AHP divides the entire lifecycle into multiple levels, and each level is organized according to certain rules to determine the weight relationship between each level in the hierarchical structure. Then, by calculating and comparing the weights of each level, the final comprehensive evaluation result is obtained. It establishes a hierarchical relationship structure among the elements of the wall material and determines the subordinate relationships between each element. It sets A_m as the criterion layer, assigns its appropriate weight in view of the proportion of B_1, B_2,..., B_n below the criterion layer, and then compares B_i and B_j through an expert system to determine their relative importance; then, in view of this, the importance of the indicators of n wall materials is measured using the proportional scale of 1–9 [15]. The judgment matrix in view of the comparison results between the two is shown as follows:

$$A = (a_{ij})_{n \times n}, \tag{1}$$

where i is the number of matrix rows; j is the number of matrix columns. The scale definition of weights is shown in Table 1.

In view of this, the judgment matrix B and its properties can be obtained as follows:

$$B(b_{ij})n \times n, \begin{cases} b_{ij} > 0 \\ b_{ij} = \dfrac{1}{b_{ji}} . \\ b_{ii} = 1 \end{cases} \tag{2}$$

Then, in view of the judgment matrix, the eigenvectors are obtained, and the weights are calculated as follows:

$$\begin{cases} W_i = \left(\displaystyle\prod_{j=1}^{n} b_{ij} \right)^{\frac{1}{n}} \\ W_A = \displaystyle\sum_{i=1}^{n} W_i \\ W_i^0 = \dfrac{W_i}{W_A} \end{cases} . \tag{3}$$

In Eq. (3), W_i is the eigenvector and W_i^0 is the weight of B_i relative to A_m. In the evaluation system for the greenness of wall materials, evaluators and experts cannot make accurate judgments on the comparison of i factor and j factor. Therefore, there may be some error in the eigenvalues obtained from the judgment matrix, so it is necessary to check the consistency of the matrix. The calculation method is shown as follows:

$$\begin{cases} \mathrm{CI} = \dfrac{(\lambda_{\max} - n)}{(n - 1)} \\ \mathrm{CR} = \dfrac{\mathrm{CI}}{\mathrm{RI}}, \end{cases} \tag{4}$$

where CI is the consistency indicator; CR is the consistency ratio, and if CR < 0.1, the matrix is considered consistent; $\lambda_{\max}$ is the maximum eigenvalue of the matrix; n is the order of the matrix; RI is a random one-time indicator, and its value can be obtained from Table RI. However, this traditional AHP has many problems: in the process of formulating weight standards, subjectivity is strong,

Table 1: Definition of weight scale

Scale	Definition
1	The i factor is as important as the j factor
3	The i factor is slightly more important than the j factor
5	The i factor is significantly more important than the j factor
7	The i factor is extremely important compared to the j factor
9	The i factor is absolutely more important than the j factor
2, 4, 6, 8	Represents the scale value corresponding to the intermediate state of the two judgments mentioned above
Count backwards	The judgment value of $a_{ij} = \frac{1}{a_{ji}}$, $a_{ii} = 1$ is obtained by comparing the i factor with the j factor

and its credibility and reliability are problematic; the weight standard relies on the subjective judgment of experts, and different experts have different standards, resulting in poor repeatability of data utilization; high computational complexity, *etc.* An improved AHP is proposed for this study. First, the consistency level of the evaluation matrix is adjusted, and the adjustment method is shown as follows:

$$F_i = (n + 2) - (\lambda_{\max})_i. \tag{5}$$

F_i is the consistency level of the matrix constructed by the i-th expert; n is the order of the matrix; $(\lambda_{\max})_i$ is the maximum eigenvalue of the matrix. After calculating the F_i value, the study uses a distance function to cluster the F_i value, where the proportion of weights is determined by the number of experts in the same category, and the weight coefficients of experts in the same category are the same. The calculation method for the expert weight coefficient is shown as follows:

$$\psi_i' = \frac{\psi_p}{\sum_{p=1}^{t} \psi_p^2}. \tag{6}$$

In Eq. (6), ψ_i' is the weight of the i-th type expert; ψ_p is the class capacity; and t is the number of categories in the individual sorting vector. The method for calculating the comprehensive weight of various experts is shown in Eq. (7) by modifying it with the age coefficient

$$K_i' = F_i \times \psi_i' \times \alpha. \tag{7}$$

In Eq. (7), K_i' is the comprehensive weight of various experts; α is a parameter for adjusting the number of years an expert has worked in the industry for three years, with a parameter of 1. The parameter increases by 0.1 for every two years of experience. The final comprehensive weight K_i' of the i-th expert normalized by K_i is calculated using the following equation:

$$K_i = \frac{K_i'}{\sum_{i=1}^{n} K_i'}. \tag{8}$$

After calculating the i-th expert evaluation criteria according to Eq. (8), the weight of the j-th indicator can be obtained. The calculation method is shown as follows:

$$\begin{cases} W_{ij} = [w_{i1}, w_{i2}, w_{i3}, ..., \ w_{ij}] \\ W_j = \sum_{i=1}^{n} K_i W_{ij}. \end{cases} \tag{9}$$

In Eq. (9), W_{ij} is the weight set of the i-th expert corresponding to the j-th indicator; W_j is the weight of the j-th indicator obtained by combining i expert evaluation criteria. For a certain indicator of the wall material, it is

separated into q levels according to the expert evaluation criteria and evaluation needs, as follows:

$$\begin{cases} V = (V_1, V_2, V_3, ..., \ V_q) \\ U = (U_{i1}, U_{i2}, U_{i3}, ..., \ U_{in}). \end{cases} \tag{10}$$

In Eq. (10), V is the evaluation level; U is the evaluation index category for wall materials. The rating level of V is set to 5, corresponding to different scores as follows:

$$V = \{\text{ONE, TWO, THREE, FOUR, FIVE}\} \\ = \{0, 20, 40, 60, 80, 100\}. \tag{11}$$

The evaluation indicators for wall materials are evaluated in view of the evaluation level analogy. The fuzzy comprehensive evaluation matrix R_i can be obtained by calculating the proportion of experts in each indicator level to the total number of experts, as shown in the following equation:

$$R_i = \begin{bmatrix} r_{11} & r_{12} & ... & r_{1m} \\ r_{11} & r_{11} & ... & r_{2m} \\ ... & ... & ... & ... \\ r_{n1} & r_{n2} & ... & r_{nm} \end{bmatrix}. \tag{12}$$

The green degree rating indicators for wall materials designed in this study have three levels, so a multi-level comprehensive fuzzy evaluation model is needed. Multiplying the expert's evaluation weight W_j with the fuzzy comprehensive evaluation matrix R_i yields the first-level fuzzy evaluation matrix $R = (B_1, B_2, ..., \ B_N)^T$. The fuzzy comprehensive evaluation result is obtained by multiplying the weights of the first-level indicators and the first-level fuzzy evaluation matrix, as shown in the following equation:

$$B = W \cdot R. \tag{13}$$

According to Eq. (13) and combined with expert evaluation level V, the comprehensive score of the greenness of the wall material can be calculated as shown in the following equation:

$$P = V \cdot W \cdot R. \tag{14}$$

2.2 Construction of a green degree evaluation model for wall materials in view of lifecycle

The greenness evaluation of wall materials plays an important role in many aspects, such as helping major consumer groups choose more suitable wall materials for their own buildings and helping the government evaluate the greenness of enterprise wall materials. The general steps for

constructing a green degree evaluation model for wall materials are shown in Figure 1.

Figure 1 shows that the considerations for constructing a green degree evaluation model for wall materials in this study are as follows: first, define the evaluation objectives and clarify the focus of green degree evaluation for wall materials; then, it is divided into first- and second-level evaluation indicators; then, it determines the weights of these indicators; it reuses the improved AHP fuzzy comprehensive evaluation method for model construction; it collects relevant data to calculate indicator scores; finally, it is applied. This study uses the lifecycle method to analyze the possible influencing factors of wall materials. LCA is the assessment of the impact of a product or service on the environment and resources throughout its entire lifecycle. This method has important application value in green environmental protection and sustainable development. The input and output of the entire lifecycle of the wall material with the environment are shown in Figure 2.

Figure 2 shows that the lifecycle of comprehensively evaluating the greenness of wall materials mainly includes five stages: raw material stage, production and manufacturing stage, transportation stage, use stage, and recycling and reuse stage. The raw material collection stage requires the consumption of a large amount of natural resources (such as ore, wood, clay), which may lead to deforestation, land degradation, and ecosystem damage, as well as material loss, reducing resource utilization efficiency. The production and manufacturing stage consumes a large amount of energy (such as electricity and fuel), increases greenhouse gas emissions, and may also emit harmful gases, wastewater, and solid waste (such as excessive heavy metals

and volatile organic compounds [VOCs]), which are harmful to the environment and human health. Process selection and technological level have a significant impact on energy efficiency and pollutant emissions. The transportation phase consumes fuel and generates greenhouse gases such as carbon dioxide, and exhaust emissions affect air quality. During use, wall materials with good insulation performance and high durability can reduce energy and resource consumption, but may release formaldehyde and VOCs, which can affect indoor air quality and human health. In the recycling and reuse stage, reasonable waste disposal methods and equipment can reduce secondary pollution, high reuse rates can reduce resource waste and new material production demand, and pollutant emissions and treatment methods directly affect the environment [16]. Through the analysis of these five stages, the greenness of wall materials can be comprehensively evaluated, providing a scientific basis for the research and application of green building materials. This study comprehensively considers the influencing factors of each stage of the wall material lifecycle and constructs a two-level evaluation hierarchy for the green degree of wall materials. The details are shown in Figure 3.

Figure 3 shows the two-level evaluation hierarchy structure of the greenness evaluation of wall materials, mainly conducting comprehensive evaluation from three aspects: environment, society, and economy. The purpose is to construct a multidimensional evaluation model to ensure that the assessment of the greenness of wall materials is not limited to environmental factors, but also includes social and economic factors. The environmental aspect mainly includes five: energy consumption, greenhouse gas emissions, water consumption, and ecological
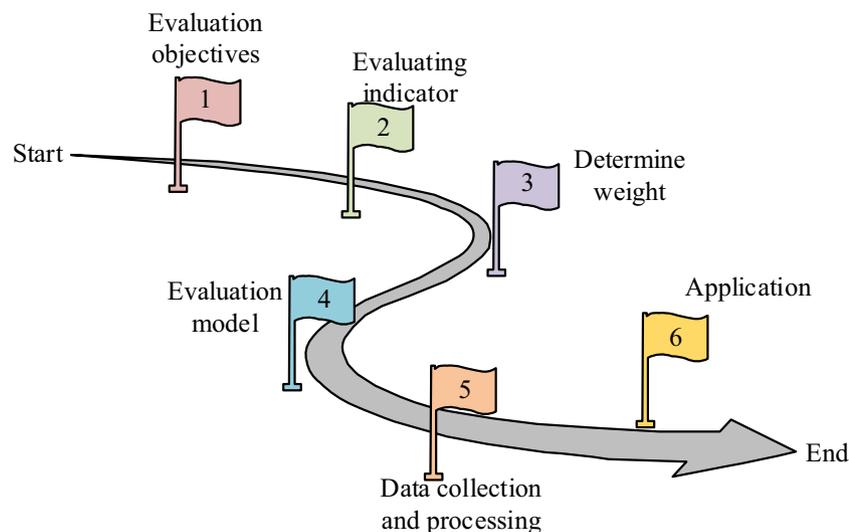

Figure 1: Construction steps of wall material evaluation model.
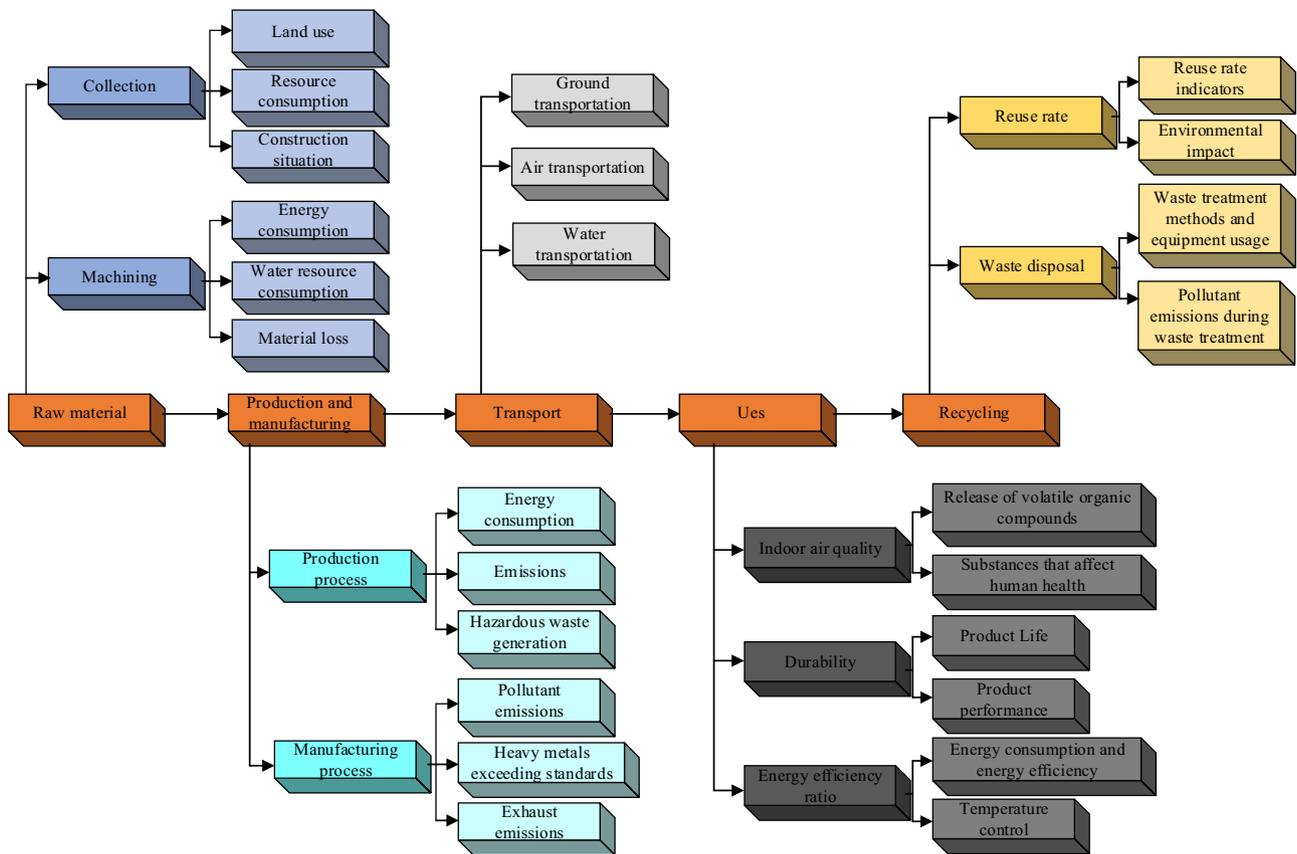
Figure 2: Analysis of influencing factors at different stages of the wall material lifecycle.

environment damage in various stages of the wall material lifecycle; the social aspect mainly includes two aspects: health and safety issues during the use of wall materials and social responsibility issues that are taken into account; the economic aspect mainly includes the cost of wall materials throughout their entire lifecycle, resource utilization and recovery rate, sales competitiveness, and wall material brand image [17]. In view of the evaluation criteria of experts in the field of wall materials and the relative importance of each indicator, a visual analysis is conducted on the weight of the first-level indicator for evaluating the greenness of wall materials, as shown in Figure 4.

Figure 4 shows that environmental factors are the most important among the three. Due to the need to consider issues such as resource, water, and carbon emissions throughout the entire lifecycle of raw materials, such as collection, production, transportation, and use, environmental factors are set to account for 50% of the total; social factors are the focus of evaluation, and it is necessary to consider the health and consumer needs of wall materials for practitioners, as well as the social welfare created by wall material products. Therefore, a social proportion of 30% is set; as a secondary factor in economic evaluation, it

is necessary to consider the social competitiveness and production costs of wall materials. The weight of the secondary indicator of green wall material's greenness is visualized and analyzed, as shown in Figure 5.

As shown in the figure, Figure 5(a) shows the proportion of secondary indicators in environmental factors, with resource energy consumption being the most important. This indicator measures the energy consumption of wall materials throughout their entire lifecycle, so a weight of 40% is set; with the continuous improvement of environmental awareness and carbon emissions becoming a global environmental problem, carbon footprint is also one of the core indicators in the green degree assessment, so the weight is set at 25%; water footprint measures the use and pollution of water throughout the entire lifecycle of wall materials. In recent years, the shortage of water resources has caused a series of problems, so a weight of 20% has been set; wall material waste can cause environmental pollution, with a weight set at 10%; balance of nature has little influence on the green degree of wall materials, and the weight is set at 5%. Figure 5(b) shows the proportion of secondary indicators in social factors. Health and safety are important indicators for evaluating
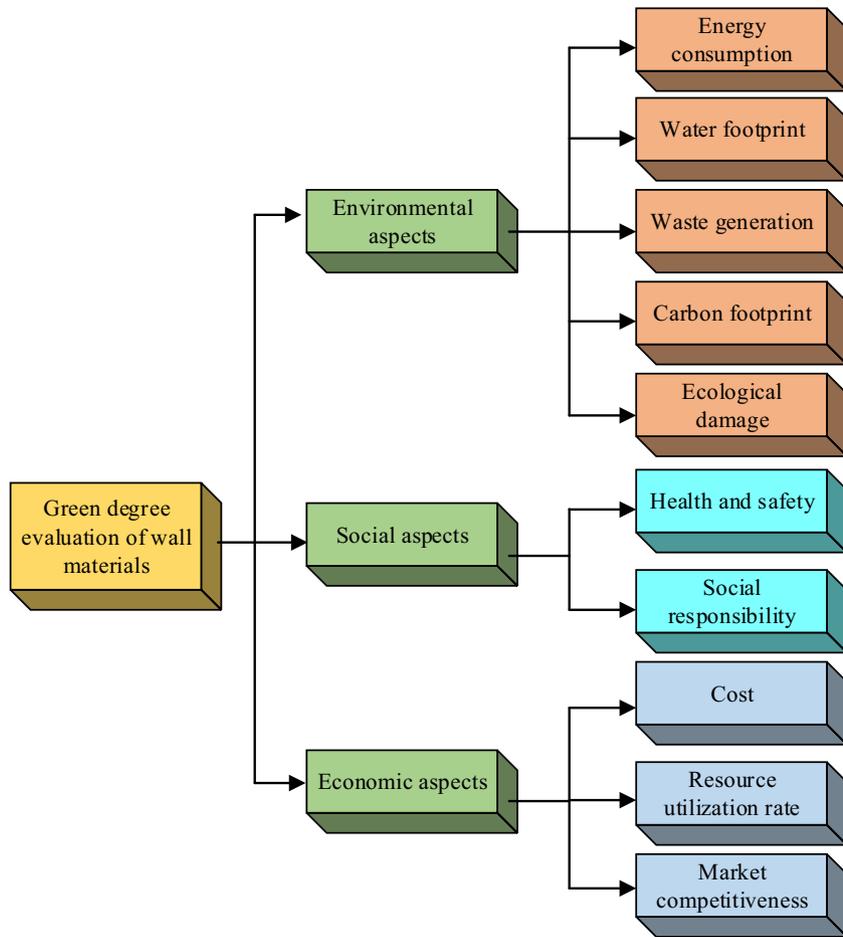
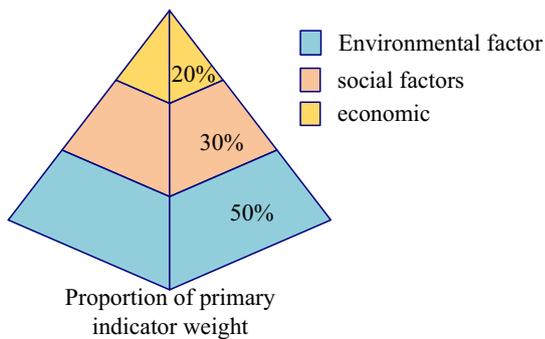**Figure 3:** Green degree evaluation index I and II of wall materials.

Figure 4: Weight proportion of first-level indicators for evaluating the greenness of wall materials.

the green degree of wall material products, set at 70%; social responsibility is set at 30%. Figure 5(c) shows the proportion of secondary indicators in economic factors. The cost considers all cost issues throughout the entire lifecycle of the wall material and must be reasonably controlled to achieve economic benefits and sustainable development of the wall material; the resource utilization rate

takes into account the utilization and recycling of wall material resources, but generally there is no recycling of wall materials, so a weight of 30% is set; market competitiveness can evaluate the market share and competitiveness of wall materials and has a relatively small impact on the evaluation of greenness. The weight is set at 10% [18,19].

3 Calculation results and application analysis of the green degree evaluation model for wall materials in view of lifecycle

This study calculates the weights of environmental, social, and economic aspects of wall materials. Finally, in view of the expert's rating of the green degree index level of wall materials, the green degree scores of each wall material are obtained. Through a questionnaire survey, it has been
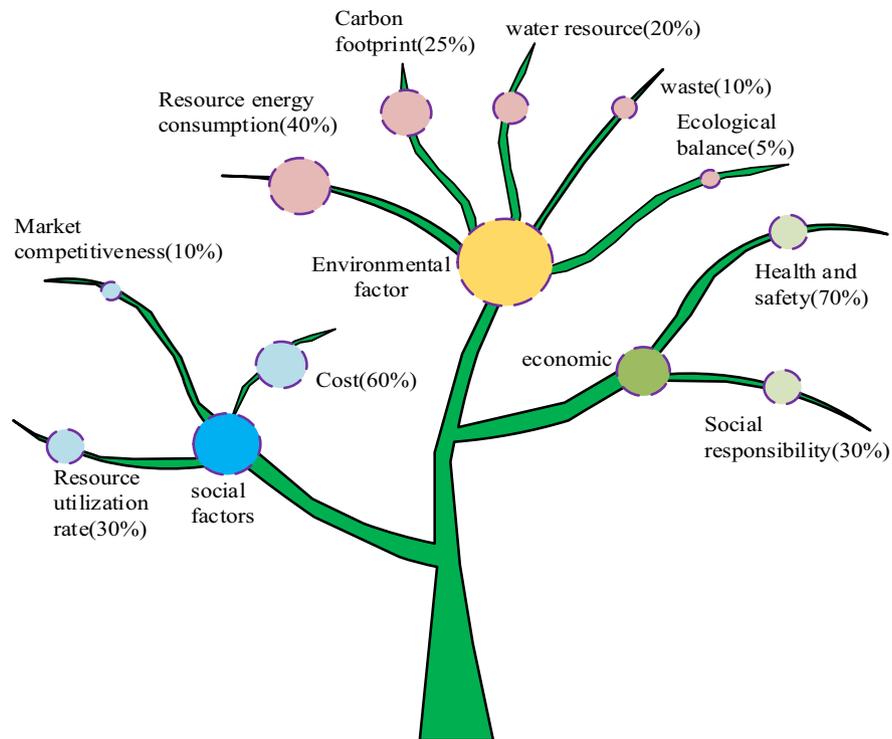
Figure 5: Weight proportion of secondary indicators for evaluating the greenness of wall materials.

proven that the evaluation model has high satisfaction among government, enterprises, residents, and other groups and has great potential for development.

3.1 Weight calculation and consistency analysis of the green degree evaluation model for wall materials in view of lifecycle

The weights of each indicator of the wall material reflect its greenness, so it is necessary to calculate the weights of each indicator. Establish a judgment matrix in view of the weight proportion set according to the expert evaluation criteria and the objective importance of the indicators mentioned above. Then, using the method provided by the research institute, three calculations were conducted on the MATLAB mathematical software, and the eigenvalues $\lambda_{\max}$, consistency index CI, and consistency ratio CR of the first-level indicator for evaluating the greenness of wall materials by eight experts were obtained in sequence. The results are shown in Figure 6.

Figure 6(a)–(c), respectively, represent the eigenvalues, consistency indicators, and consistency ratios of the primary indicators. It can be seen that all consistency

ratios are less than 0.1, so the judgment matrices of the eight experts meet the consistency requirements. Then, the weights of the first-level indicators are calculated, as shown in Figure 7.

Figure 7(a)–(c), respectively, show the weight calculation results of eight experts on the first-level indicators of wall material greenness, including environmental, social, and economic aspects. It can be seen that there is a relatively large difference in the fluctuation of each broken line, which may be due to the inconsistent standards of various indicators for the greenness of wall materials by experts. Therefore, according to the clustering analysis method in the study, using the above data, the weight results of eight experts were analyzed using stata mathematical statistical analysis software, as shown in Figure 8.

Figure 8 shows that through clustering analysis of the weights of the first-level indicators for evaluating the greenness of wall materials by experts, it can be roughly divided into three groups: one group is experts 1, 8, and 3; the second group consists of experts 7 and 5; three groups are experts 2, 4, and 6. In view of the clustering analysis results, the average weight coefficients of three groups of experts can be divided into: group $\psi_1' = 0.265$; two groups $\psi_1' = 0.265$; three sets of $\psi_1' = 0.470$. Finally, in view of the expert clustering analysis results and the consistency test results of the judgment matrix, the calculation was carried
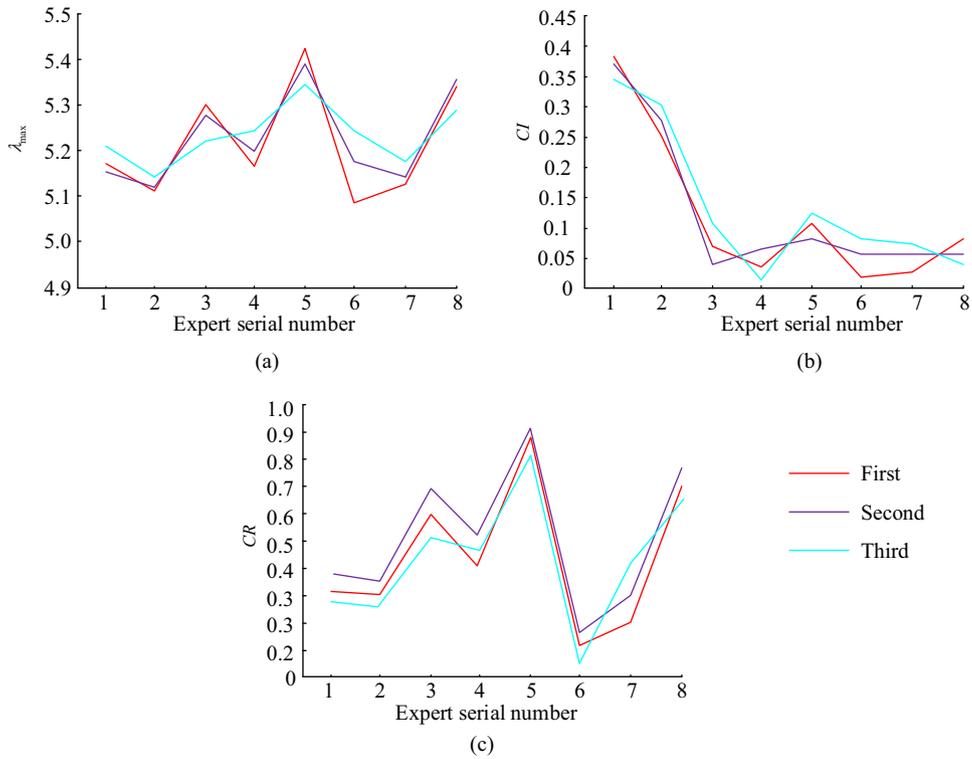
Figure 6: λ_{max}, CI, CR weight calculation results: (a) eigenvalue weight, (b) consistency indicator weight, and (c) consistency ratio weight.
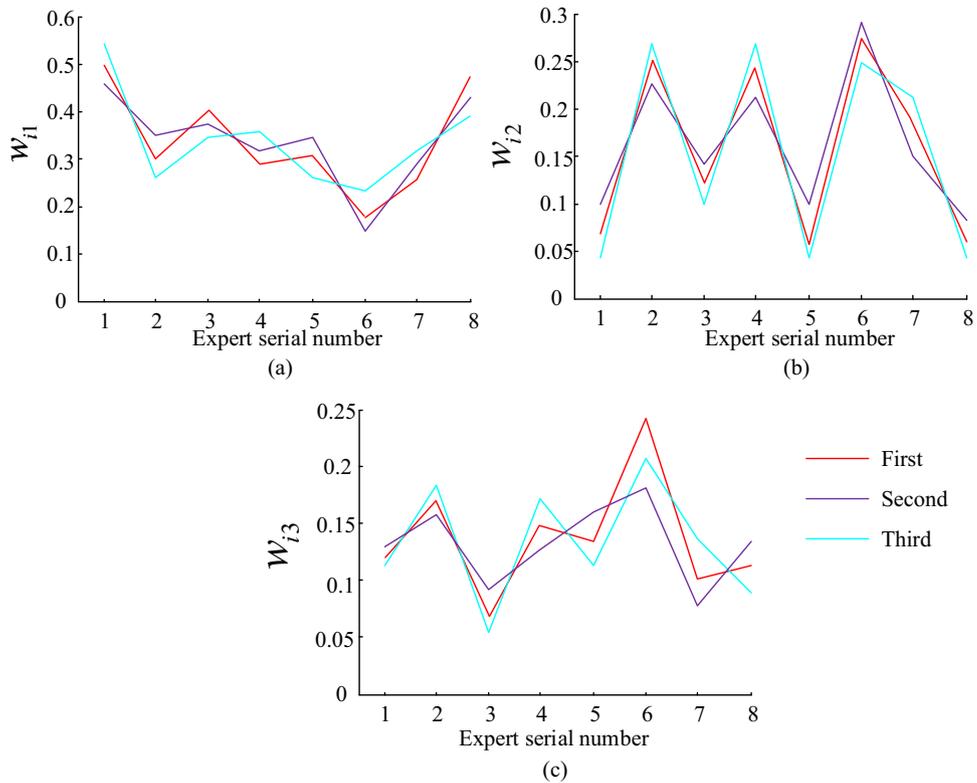

Figure 7: Calculation results of environmental, social, and economic weights: (a) environmental indicators, (b) social indicators, and (c) economic indicators.
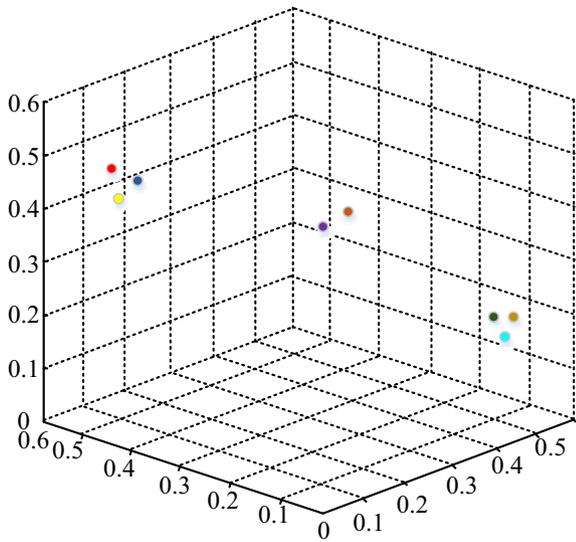
Figure 8: Expert cluster analysis results.

out according to the research improvement method, and the calculated results are shown in Figure 9.

Figure 9(a)–(c), respectively, represent the consistency level F_i, comprehensive weight K_i', and final weight K_i. It then calculates the weights of the first- and second-level indicators according to this method. The final average weights for environmental, social, and economic aspects are 0.6034, 0.1964, and 0.2002, respectively. Finally, in view of the expert's rating of the greenness index level of the wall material, the greenness score of the wall material can be calculated.

3.2 Application analysis of green degree evaluation model for wall materials in view of lifecycle

To demonstrate the practicality of the wall material greenness evaluation model constructed by the research institute, clay wall materials, concrete wall materials, wood wall materials, and stone wall materials produced by a certain enterprise were selected as the evaluation objects for wall material greenness. The score results are shown in Figure 10.
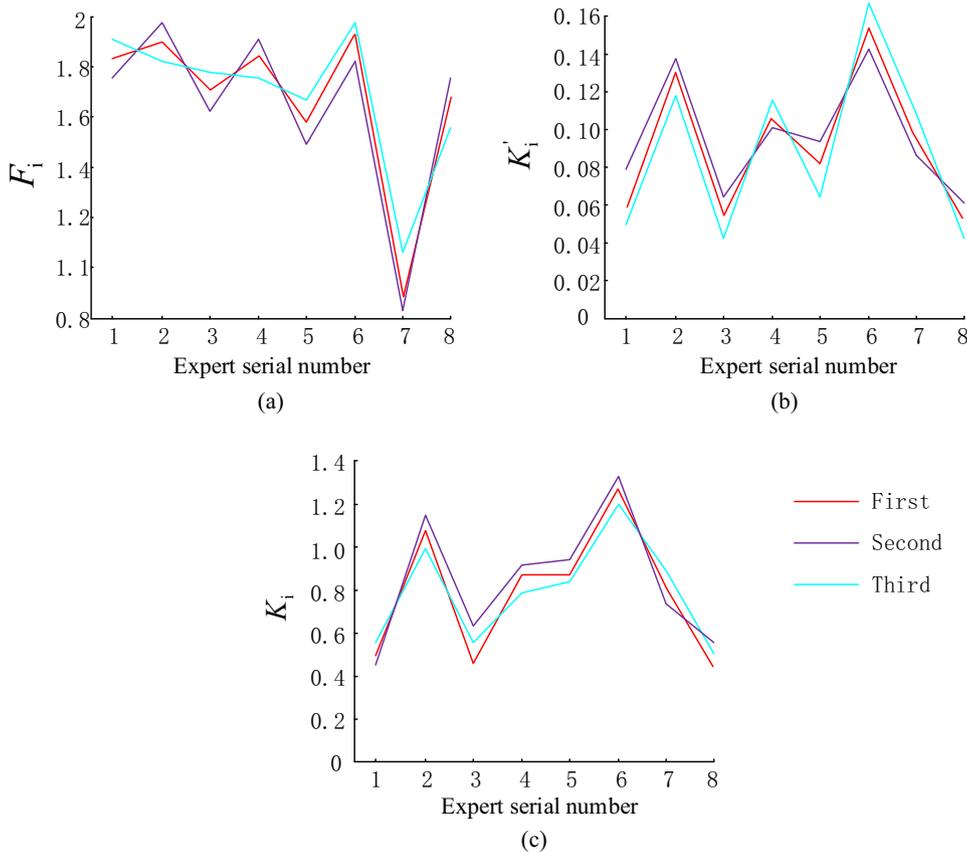

Figure 9: F_i, K_i', K_i calculation results: (a) consistency level, (b) comprehensive weight, and (c) final weight.
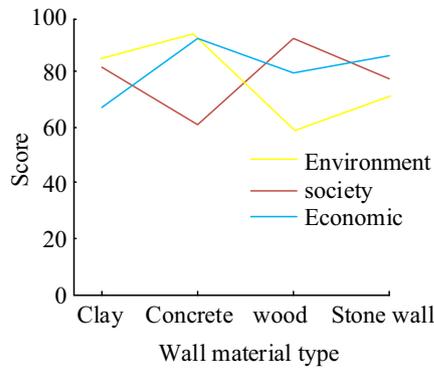
Figure 10: Green degree scores of four types of wall materials.

Figure 11: Satisfaction results of questionnaire survey.

Figure 10(a) shows that the clay wall material has a higher score of 84 in terms of environmental aspects. This wall material will not generate significant waste gas and wastewater throughout its entire lifecycle, making it more environmentally friendly. The score for concrete wall material is 62 points, as it generates a large amount of CO_2 and other exhaust gases during the production and manufacturing process and consumes a large amount of water resources during the construction process. Therefore, the greenness of this wall material is not high; the wood wall material has a score of 90 points, which has little impact on the environment during production and use. It has good ecological characteristics and high greenness. The stone wall material has a score of 77, which can effectively reduce the content of dust and pollutants in the air. However, certain energy and water resources are also consumed during the mining and transportation process. Figure 10(b) shows that the social clay wall material has a score of 67, which is simple in craftsmanship and cannot make much contribution to local economic development; the concrete wall material is 88 points, which is widely used and easy to use, and can promote the development of related enterprises and increase employment opportunities; the score for wooden wall material is 81 points, which reflects people's concern for the natural environment and promotes the development of relevant talents; the stone wall material scores 85 points, which promotes the development of related industries. Figure 10(a) shows that the economic value of clay wall material is 83 points, which has a lower production cost and higher resource utilization; the concrete wall material is 91 points, which has a low cost of use; wood costs 61 points, which is a relatively expensive material and is not commonly used; the stone wall material costs 69 points, which has high production and processing costs, is difficult to mass produce, and has low resource utilization. To further demonstrate the superiority of the model constructed by the research institute, this study selected three groups of
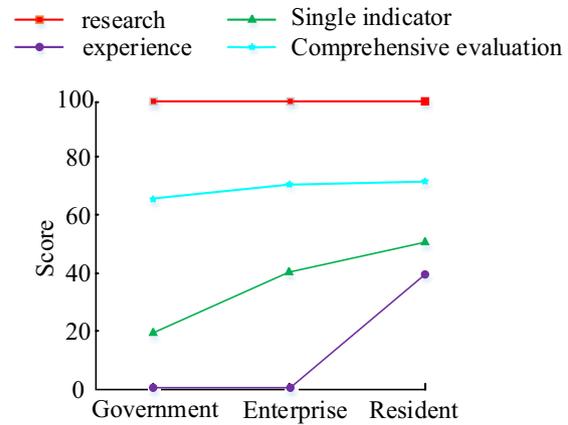
governments, enterprises, and residents from different regions to conduct a satisfaction questionnaire survey on the green degree evaluation method of wall materials, with 1000 questionnaires each. Then, it uses traditional empirical evaluation methods, single indicator evaluation methods, and comprehensive evaluation methods as references, and the survey results are shown in Figure 11.

Figure 11 shows that the satisfaction of government departments with the evaluation model, empirical method, single indicator method, and comprehensive evaluation method constructed by the research institute is 100, 0, 20, and 65%, respectively; the satisfaction of enterprises with the above four evaluation methods is 100, 0, 40, and 70%, respectively; residents' satisfaction with these four evaluation methods is 100, 10, 50, and 70%, respectively. This indicates that the wall material greenness evaluation model constructed by the research institute is widely recognized by the public.

4 Conclusion

The precise evaluation of the greenness of wall materials is an important link in the building materials industry. This study is in view of the lifecycle of wall materials, and deeply analyzes the numerous influencing factors of wall materials from the collection of raw materials to the recycling and reuse stage. It establishes primary and secondary indicators mainly focusing on environmental, social, and economic aspects. Then, the expert clustering analysis method is used to improve the traditional AHP method, and the improved AHP method and fuzzy matrix evaluation method are used for modeling. Finally, it calculates the weight value indicators and conducts simulation

application analysis. The results show that the results of all judgment matrices are less than 0.1. It meets the consistency requirements. The weight coefficients of the three groups of experts after cluster analysis are 0.265, 0.265, and 0.470, respectively. The first-level indicators for environmental, social, and economic factors are 0.6034, 0.1964, and 0.2002, respectively. The environmental scores of clay wall materials, concrete wall materials, wood wall materials, and stone wall materials are 84, 62, 90, and 77, respectively; the social scores are 67, 88, 81, and 85, respectively; the economic scores are 83, 91, 61, and 69, respectively. In the questionnaire survey, the government satisfaction rates of the model established by the research institute, empirical method, single indicator method, and comprehensive evaluation method were 100, 0, 20, and 65%, respectively; the satisfaction rates of enterprises are 100, 0, 40, and 70% respectively; the satisfaction rates of residents are 100, 10, 50, and 70%, respectively. The above data indicates that the model established by the research institute can evaluate the greenness of different wall materials, and the market recognition rate is 100%. This indicates that the model has good practicality and potential development potential. However, this method still cannot fully solve the problem of subjectivity in evaluation, and there are problems such as long data sorting time in various stages. Therefore, further improvement is needed in the objectivity of results and evaluation efficiency.

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