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Study on green building evaluation methodology under ecological view

Liqun Wang
Shijiazhuang Vocational Technology Institute, Shijiazhuang, 050081, (CHINA)

ABSTRACT

In terms of policy, the Ministry of Construction has prepared and issued a Guidelines for Green Ecological Residential Area Construction Elements and Technical, China Ecological Residential Technology Evaluation Manual, Environmental Impact Evaluation Law of the People's Republic of China and other documents; in practice, economically developed areas combined with their own characteristics have carried out green building applications, such as the construction of green ecological district Vanke Langrunyuan, etc. What is worth mentioning is the 2008 "Beijing Green Olympics" and the 2010 "Shanghai Eco Expo" made green building concept deeply rooted in people's hearts. Although green building has aroused widespread attention among all walks of life, after all green building is still in its initial stage, we need to standardize the evaluation criteria, do further research in order to make green building enter a substantive application stage. Therefore, this study uses multi-level gray evaluation method, qualitative and quantitative combining method to evaluate green building. On the basis of research on the evaluation methods for ecological residence in foreign countries, such as British BREEAM, U.S. LEED, multinational GBTOOL and Chinese ecological residence, we absorb the essence and abandon the defects for the establishment of a green building evaluation under ecological view. In this study, gray comprehensive evaluation indicator is used to evaluate the green performance of building, which can better identify and compare the effectiveness of green buildings, and allow easier promotion and application across the country.

KEYWORDS

Ecological view; Green building; Evaluation methodology; Multi-level gray evaluation.

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INTRODUCTION

There are a lot scholars studying on green building, Ma Guanghong and Zhang Zhigang use analytic hierarchy process and fuzzy mathematics theory to establish a comprehensive evaluation model of ecological residential area, and by evaluating result disclosure mechanism, they allow consumers to understand the living area level[1]. Cao Shen and Dong Cong only conducted research on green building indoor environment evaluation methodology, and in the evaluation, they have introduced the concept of fuzzy sets and fuzzy analytic hierarchy process for the analysis. With the rating between the weighted Euclid distance metric evaluation results and the reference vector at different degrees, according to the principle of choice in proximity, they conduct identification on comprehensive evaluation results[2]. Chen Liuqin mainly builds green building evaluation system from refined evaluation criteria, quantitative evaluation, life cycle evaluation and third-party certification system aspects[3]. Zhang Jianxin and Wang Yue are mainly based on the ecological footprint reduction model at the green building construction phase and the operational phase to evaluate sustainability of the evaluation project[4]. Liu Yu, Chen Qunyuan and Liu Feiwu, Liu Chunjiang, Wang Zhuo et al[5-8] have conducted a certain degree of analysis from different perspectives on green building evaluation, which brings enlightenment to this study. This study uses multi-level gray evaluation method and the quantitative and qualitative combining method to evaluate green building for the purpose of making green building evaluation method simple to operate.

OVERVIEW OF GREEN BUILDING

Affected by the destruction of ecological environment and the energy crisis, the steel and glass building structure requires a lot of heating and cooling systems, and in order to mitigate the resulting energy load and destruction, maintain ecological balance, the developed countries such as the United States, France, Germany other countries have proposed green building's environmental philosophy. However, because the creation of green building is not very long, there is no unified title for green building, there are several concepts of sustainable construction, ecological construction that are similar. The green building is to provide the space people need to live, work and conduct activities, with the requirements of the full use of resources (materials, land, energy and water) in the building life cycle (such as material production, construction, building demolition, etc.), not adding curb and wasting resources, which will result in the depletion of resources, especially non-renewable resources, in order to achieve goal of minimal impact on the ecological environment of building. In other words, during the building process, we shall implement energy-saving design and construction, reduce energy consumption, and make the construction industry to achieve sustainable development. Thus, energy-efficient buildings is a key factor in achieving green building, but the environment is deemed as ecological height to be explored by green building. The ecosystem requires entire synergy of multiple interrelated ecological factors, enabling the exchange of matter, energy and information and achieving green building ecological balance.

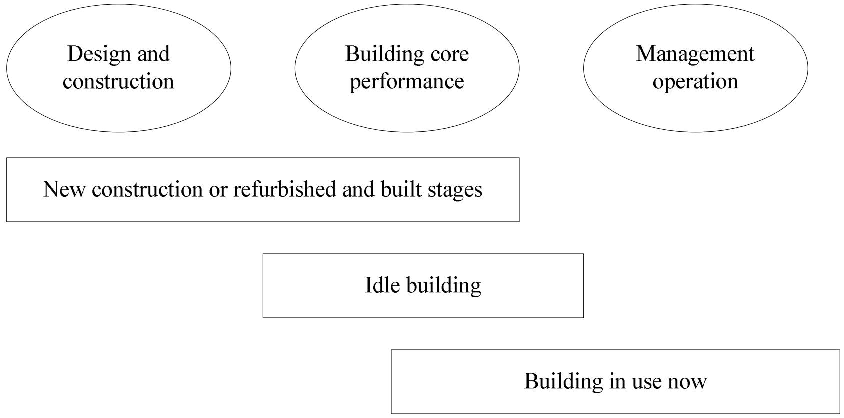
The promotion of green building must depend on establishing clear evaluation system to be implemented in a wide range of architectural practice, and to achieve this goal is not at the expense of the original building that should have the health, comfort and safety features, but we advocate raising energy efficiency, changes in energy use pattern, which means promoting the use of renewable and clean energy (such as geothermal, solar energy, etc.), or we will take effective measures to reduce energy consumption (such as fluorescent lamps to replace incandescent lamps, etc.). Of course, green building is not for the purpose of a certain type or a function of building, but it applies to all buildings, which can minimize greenhouse gas emissions with minimal impact on the climate, make the environmental system free from being contaminated, maintain the biological diversity, and thus achieve the overall interoperability ecosystem.

INTRODUCTION TO GREEN BUILDING EVALUATION METHODOLOGY AT HOME AND ABROAD

British BREEAM

British BREEAM is the first set of green building evaluation method used in international market and management, and initially it was mainly designed based on increasing the use function of office building. With good feedback after that, it has been used in all construction types. BREEAM weighting system originally adopted the "simple evaluation", after that the "clear weigh" is used, which means using different weighting coefficients to set; evaluation indicators of BREEAM include the impact of construction on the global, regional, venues and indoor environments, and its evaluation contents include the building core performance, design, construction and management operation. For newly constructed and renovated buildings, the evaluation starts with building core performance, design and construction; for the existing building in use, the evaluation starts with building core performance, management and operation; for existing idle buildings, the evaluation starts with the building core performance, as shown in Figure 1:

BREEAM evaluation entries include pollution, regional ecology, land use, raw materials, water, transport, energy, health and comfort, management, a total of nine areas, and a number of entry points are included in each entry, each of which shall be calculated with score, and the environment weighting factor can be used in evaluation (shown as Figure 2).



aFigure 1 : Evaluation procedure composition diagram of BREEAM for office

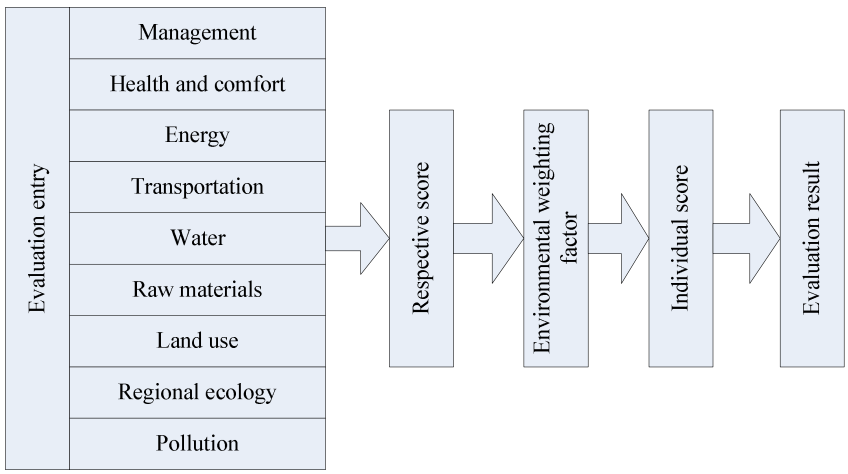


Figure 2 : BREEAM evaluation scoring flowchart

U.S. LEED

U.S. LEED is an evaluation system developed from the perspective of the whole life of building, and most of its evaluation provisions is given the same weight, including the green evaluations in terms of energy and atmosphere, efficient use of water resources, indoor environmental quality, sustainable site design, process design and innovation, raw materials and resources, a total of six aspects. Each aspect is also set with subprojects. With integral evaluation conducted, it finally concludes the total cumulative score (shown as TABLE 1).

TABLE 1 : LEED 2.1 Breakdown Score and Percentage

LEED V2.1	Scores	Percentage in total point
Sustainable site design	14	20
Efficient use of water resources	5	7
Energy and atmosphere	17	25
Raw materials and resources	13	19
Indoor environmental quality	15	22
Design and innovation	5	7
Total	69	100%

GBTOOL of many countries

GBTOOL is a development of green building evaluation methodology sponsored by Canada with a number of countries participating. Which use of specific weight to the weighted evaluation system, it allows customers to re-determine the decentralized weights, consisting of 120 indicators in six areas, and the performance of the building to be assessed will be expressed in a graphical form (shown as TABLE 2).

TABLE 2 : Evaluation results in design stage

GBTool 2005	Active Weights	Weighted scores
Location/Planning/Development	10%	2.3
Energy and resource consumption	25%	1.1
Environmental load	25%	3.0
Indoor environmental quality	15%	2.9
Function of building system	5%	0.5
Long-term performance	10%	1.8
Social and economic performance	10%	1.4
Total		2.0

Comparison of different green building evaluation methodologies

In order to better compare the different green building evaluation methodologies, we can set several parameters to be considered in order to show the features and main aspects of evaluation methodology so as to learn and absorb from each other, and thus design a more sustainable green ecological building. The comparison parameters set according to the importance are universality, effectiveness, adaptability, flexibility, cost and practice, compatibility, integration, consistency (shown as TABLE 3).

TABLE 3 : Comparative analysis of environmental evaluation methodology

Parameters	LEED	BREEAM	GBTool
Extensiveness	Good	Satisfied	Good
Effectiveness	Good	Satisfied	Satisfied
Adaptability	Poor	Poor	Good
Flexibility	Poor	Good	Good
Costs and practices	Satisfied	Satisfied	Poor
Affinity	Poor	Satisfied	Good
Integration	Good	Satisfied	Good
Consistency	Good	Good	Good

Chinese ecological residential evaluation methods

China first released the *China Ecological Residential Technology Evaluation Handbook* in 2001, after that the evaluation manual has been upgraded. Now, the 2003 version of the evaluation methodology is described, which is divided into five sub-items, i.e. residential environment planning and design, energy and environment, indoor environmental quality, residential water environment, and materials and resources, and each sub-item has their assessments from many aspects, respectively. For example the materials and energy are evaluated from green building materials, local materials, residential interior decoration, recycling, and waste disposal, a total of five aspects. The most classic use of green building evaluation system is the building in 2008 Olympic Games. In accordance with the principles of process monitoring, stage evaluation (including the planning phase, design phase, construction phase, inspection and operation management phase), and learning from Japanese CASBEE quality and the environmental load indicators, the appropriate weighting coefficients are developed, and evaluated from five major aspects.

CREATION AND APPLICATION OF GREEN BUILDING EVALUATION METHODOLOGY UNDER ECOLOGICAL VIEW

Establishment of evaluation indicator system

Basis of establishing evaluation indicator system

First is the full life cycle analysis, focusing on process control, in order to detect and solve problems promptly, and thus minimizing consumed resources and maintaining ecological balance. Second is adhering to the principles of sustainable development, the factors affecting sustainability are included in the scope of evaluation indicators, so as to avoid or mitigate the excessive consumption of resources. Third is the operational principle. The indicator system is set to be as simple and feasible as possible. Do not increase the assessment cost, which requires selecting the factors that have an important influence on building environment to evaluate. Fourth is the principle of advancing with the times. This evaluation indicator is on the basis of certain social conditions and technical level, but with the development of the times, the original evaluation phase is not suitable with the social development, which requires improved indicators with the development of times and the enhancement of construction techniques.

Content and level of evaluation indicator system

By comprehensive analysis of domestic and international green building evaluation methodologies, i.e. LEED, BREEAM, GBTooI and China's methodologies, the study has a certain degree of deepening on the evaluation methodology and divide the green building performance W into 4 Level I indicators and Level II indicators (shown as TABLE 4).

TABLE 4 : Green building evaluation system

Target W		Level I indicator U_t	Level II indicator V_{tj}
Green Building Performance W	Load	Resource consumption U_1	Energy usage V_{11}
			Efficient use of land resources V_{12}
			Efficient use of water resources V_{13}
			Efficient use of materials V_{14}
		Environmental loads U_2	Atmospheric Environmental Impact V_{21}
			Water pollution V_{22}
			Light pollution V_{23}
			Noise pollution V_{24}
			Solid waste disposal V_{25}
	Quality	Indoor environmental quality U_3	Indoor air quality and ventilation V_{31}
			Indoor thermal environment V_{32}
			Indoor light environment V_{33}
			Indoor acoustic environment V_{34}
		Outdoor physical environment quality U_4	Outdoor atmospheric environment V_{41}
			Outdoor thermal environment V_{42}
			Outdoor light environment V_{43}
			Outdoor acoustic environment V_{44}

Determining evaluation criteria and weights

Determining evaluation criteria

When selecting the indicator value of building environmental standards, we shall act in accordance with the principles of qualitative and quantitative indicators and in conjunction with the advancement principles and regional principles, take the existing norms and standards as an indicator basis. For quantitative issue, we can use the industry statistics and international standards data as a reference, and for the qualitative issue, we need subjective judgment of experts to carry out actions, therefore the system classify indicators into soft indicators that cannot be measured with the use of quantify standard and the hard indicators that can be measured with the use of quantify standard. In addition, the soft indicators can only be judged with the use the text description, but the hard indicators can be measured with the use of data scoring, i.e. grading method. In the design of secondary indicators, we shall determine according to the specific circumstances of indicators whether to divide the planning stage, the design stage, the construction stage, the stage of acceptance and operation management, and then combine qualitative and quantitative methods to set evaluation parameters, and divide the standards for being excellent, good, fair and poor for the determining of evaluation level. We should note that this study classifies the “water environment” into “effective use of water resources” and “water pollution”, and for the efficient use of water, the evaluation of construction and operation phases is added

Determining evaluation indicator weight

Weights are generally expressed by the weighting factor, and the study's main reference is BREEAM weight system. By giving each evaluation provision different weighting coefficients, we indicate their importance in the evaluation system. However, taking into account that China is a vast country with diverse climate, there are many differences in resources, customs, etc., so we need to adjust measures to local conditions in terms of weight design of evaluation system, and determine the changes in weights with combination of climatic and environmental. requirements appropriately. The green building evaluation method basically adopts the weight system on the basis of “consensus”, namely complete the development by receiving opinions of professionals in different places, such as material manufacturers, experts, scholars and other aspects, on the basis of the parties reaching a “consensus”.

Establishing a multi-level gray evaluation model

Grey system is named by color, and “gray” means some of the information is clear, but the other information is not clear. It is an intermediary system between white system with fully known information and the black system with completely unknown information. Now, there is fuzzy comprehensive evaluation method, analytic hierarchy process, and gray comprehensive evaluation method, etc. The gray evaluation method is a comprehensive evaluation method featured by the combination of qualitative and quantitative analysis, which can better solve the indicator problems that are difficult to accurately quantify and subject to statistics. In addition, it can be calculated directly using the raw data without the need for normalization, and it is featured by strong objectivity, and allow changes in indicators according to the specific situation, therefore this study intends to conduct green building evaluation with the use of gray system evaluation.

According to the above evaluation indicator system, U means the evaluation indicator Ui set, recorded as $U=\{U_I,U_2,U_{3,}U_4\}$, $U_i\left(i=1,\ 2,\ 3,\ 4\right)$. The collection representing the secondary evaluation indicators V_{ij} is recorded as $V_i=\{V_{i1},V_{i2},\ldots\ldots Vin\}$. It is set that in a certain area the green buildings in evaluation $S\left(S=1,2\ldots\ldots q\right)$, $W^{(S)}$ representing the s evaluation receiver’s the value of comprehensive evaluation, then the multi-level gray evaluation steps are as follows:

First, the evaluation means the V_{ij}’s rating standard, and the qualitative indicators V_{ij} will be converted into quantitative indicators, using expert scoring method to convert V_{ij} to be evaluated into excellent, good, fair, poor level, and to give a certain score. The higher the score is, the better the indicator rating will be.

Second, determine the evaluation indicator U_i and V_{ij} weights. Weights generally use certain methods to determine, such as Delphi method and statistical analysis method, etc. The collection composed by a set of weights is called weight set.

It is supposed that the Level I evaluation indicator $U_i\left(i\ =1,2,3,4\right)$ has the weights assigned to $a_i\left(i=1,2,3,4\right)$, the indicator weight vector $A=\left(a_1,a_2,a_3,a_4\right)$, and satisfies $ai\geq 0$, $\sum_{i=1}^{4}a_i=1$, $A=\left(a_1,a_2,a_3,a_4\right)$. Secondary indicators $V_{ij}\left(i=1,2,3,4;\ j=1,2,\ldots i_n\right)$ has the weights assigned to $a_{ij}\left(i=1,2,\ldots,7;\ j=1,2,\ldots,i_n\right)$, the weight vector each indicator is $A_1=\left(a_1,a_2\ldots\ldots a_n\right)$ and satisfies $a_{ij}\geq 0,\sum_{j=1}^{n}a_{ij}=1$.

Third is rater scoring and seeking evaluate sample matrix. Calculate the S evaluation receiver’s evaluation sample matrix $D^{(s)}$.

$$D^{(s)}=\begin{bmatrix} d_{111}^{(s)} & d_{112}^{(s)} & d_{113}^{(s)} & d_{114}^{(s)} & d_{115}^{(s)} \\ d_{121}^{(s)} & d_{122}^{(s)} & d_{123}^{(s)} & d_{124}^{(s)} & d_{125}^{(s)} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ d_{441}^{(s)} & d_{442}^{(s)} & d_{443}^{(s)} & d_{444}^{(s)} & d_{445}^{(s)} \end{bmatrix}\begin{bmatrix} V_{11} \\ V_{12} \\ \ldots\ldots \\ V_{44} \end{bmatrix}$$

Fourth, determine the evaluation gray class and evaluation coefficient and calculate the gray evaluation weight vector and the weight matrix. The four gray evaluation categories are identified as “excellent”, “good”, “fair”, “poor”, f_e is white function of gray number g. As for evaluation indicator V_{ij}, the S evaluation receiver’s gray class has the gray evaluation coefficient recorded as $x_{ij}^{(s)}$, then there is $x_{ij}^{(s)}=\sum_{j=1}^{s}x_{ij}^{(s)}$, gray evaluation weight vector and gray evaluation weight matrix are, $r_{ij}^{(s)}=(r_{ij1}^{(s)},r_{ij2}^{(s)},r_{ij3}^{(s)},r_{ij4}^{(s)})$ and $R_i^{(s)}=\begin{bmatrix} r_{i1}^{(s)} \\ r_{i2}^{(s)} \\ \ldots\ldots \\ r_{in}^{(s)} \end{bmatrix}\begin{bmatrix} r_{i11}^{(s)} & r_{i12}^{(s)} & r_{i13}^{(s)} & r_{i14}^{(s)} & r_{i15}^{(s)} \\ r_{i21}^{(s)} & r_{i22}^{(s)} & r_{i23}^{(s)} & r_{i24}^{(s)} & r_{i25}^{(s)} \\ \ldots. & \ldots. & \ldots. & \ldots. & \ldots. \\ r_{in1}^{(s)} & r_{in2}^{(s)} & r_{in3}^{(s)} & r_{in4}^{(s)} & r_{in5}^{(s)} \end{bmatrix}$ respectively.

Five is comprehensive evaluation of U_i and W for and calculation of comprehensive evaluation value.

Determining the rating of evaluation results

The evaluation is just provides the green building with “excellent, good, pass, fail”, a total of four levels, therefore determine the results of evaluation in accordance with the principle of maximum membership degree, if the building is rated as “excellent”, it is a green building. However, there is the need for accurate discrimination to compare each building, then it can not apply the principle of maximum membership degree, but the appropriate value shall be given by the elements in the evaluation set *V*, followed by calculation of the final score $W^{(s)}$, and then determine the order of green performance of the green building according to the value of $W^{(s)}$.

CONCLUSIONS

In this study, on the basis of learning from the green building evaluation methods at home and abroad, with the use of multi-level gray evaluation method, the green buildings under ecological view next are analyzed, which is featured by simple operation, and is easy to implement in the construction practice. However, the quantitative aspect is slightly insufficient in this study, which needs further study in the future.

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