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Study on fuzzy multilevel index comprehensive evaluation model of green building

Wenxue Zhu
Anhui Medical University, Anhui, 230032, (CHINA)

ABSTRACT

The definition of green building is that it gives a more specific explanation in the relationship between ecological environment and service quality; however in the comprehensive evaluation system on whether the building can meet the requirements of green construction is particularly important. This paper first takes the definition of evaluation system of green building as the premise, compare on its index system. And have a discussion on general problems for the selection of indicators, as well as the specific principles that should be improved. Second is a further exploration to the construction of evaluation system of green building, which mainly combines selection principle of evaluation index, preliminary screening of evaluation index and relevance determination between indicators these three aspects for further study, from which to lay a solid foundation for the effective establishment of evaluation index. On this basis, the construction of new three-dimensional evaluation model of green building is specifically described, from which to determine the index weight, the establishment and analysis of a three-dimensional evaluation model. This is the main idea of the body of research and exploration, which also gives full guarantee to the scientificity and rationality for this paper, and provides solid theoretical and data support for the construction of fuzzy multilevel comprehensive evaluation index model.

KEYWORDS

Green building; Multilevel fuzzy comprehensive evaluation model; Evaluation system; Evaluation index.

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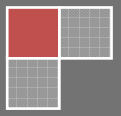

INTRODUCTION

Fuzzy multiple index comprehensive evaluation model has great impact on evaluation function of green building, it will make extremely positive role in promoting the coordinated development between building itself and ecological environment and economic benefits. In the process of study, this paper mainly combines with the evaluation system of green building in China, construction of evaluation system of green building and construction of new three-dimensional evaluation model of green building these three parts to specifically analyze, and have further discussion on the selection of evaluation index and factors of model construction, so as to provide more scientific and effective evidence for model construction.

EVALUATION SYSTEM OF GREEN BUILDING IN CHINA

Green building

In modern green building evaluation standard in China, the definition of green building is within the building life cycle for furthest effective conservation of resources, and have small damage to ecological environment, less pollution, at the same time can provide healthy and comfortable environment for people's life, enable the building space get a more reasonable utilization, and to be the building can be harmonious coexistence with nature. However, from this definition, the scope covered by green building is relatively broad and there is no clearer requirement for the function of the building.

Comparison of indicator system

In the study of evaluation system of green building in China, it can be seen that there is a certain gap with foreign evaluation system of green building, and the reflected deficiency is mainly shown in following aspects.

Lack of economic benefit evaluation

In the construction of green building need to get operators to introduce many ease in environmental protection to make environmental protection technology of green building can meet the requirements of national standards. But this will produce higher input costs, which makes a lot of building developers are not active in effectively update of buildings means. And the new techniques applied in building process will be attached to many users after the completion of the building, which will cause certain adverse effects on the effective promotion of green building, therefore in evaluation process of green building, the ability of economic benefits should be considered as an important evaluation factor[1].

Excessive qualitative indicators

From the related *Evaluation Standard of Green Building* can obviously see that there are excessive qualitative indicators involved in the standard, which will be hard for index quantification work. This process requires a corresponding issuance and arrange of questionnaires, and combines with corresponding experts to have effective analysis and effective scores. While this process can not enable the evaluation result to achieve fair, righteous and open. For designated process of evaluation index categories should be further perfect on quantitative criteria for great improved of its operability in evaluation process.

Single weight system

In the related *Evaluation Standard of Green Building* in China, the weight system mainly takes the first level linear weight as the theme, and only set the weight for six first-class indexes, so that the importance of second-class index weight can not be reflected. Inevitable result is that the building’s own advantage and the improve part will not be able to meet the requirements of the system, which makes the evaluation result has certain one-sidedness.

EVALUATION SYSTEM CONSTRUCTION OF GREEN BUILDING

Selection principle of evaluation index

In the construction process of the multilevel index evaluation model of green building, put forward a corresponding forecast of the problem that may produce in evaluation system construction, so that the evaluation index can meet the fundamental needs of effective development of evaluation. The specific selection principle of evaluation index is as follows:

Adaptive principle

The selection of evaluation index of green building should combine with Chinese basic national conditions for effective selection. Among which should fully consider the people's basic living habits, behavior, and the corresponding cultural factors. So for the selection of indicators can keep strong elasticity, for a new change can satisfy in the maximum extent, and improve the adaptability of evaluation index.

Operating principle

The selection of evaluation index need to meet the requirements of not complex and not single with strong rationality, this process involved the technology parameters and the corresponding characteristics of green building, and also has the ability to effectively avoid the complication of the weight, so the quantity of evaluation work will be fully reduced to make the accuracy of evaluation work continuously improve.

Quantitative priority principle

For the selection of evaluation index should try to achieve the purpose of the easy access, for the qualitative index number should be under effective control. However in the acquisition process of difficult effective quantitative indicators and important indicators requires a corresponding issuance and arrange of questionnaires, and combines with corresponding experts to have effective analysis and effective scores[2].

Preliminary screening of evaluation index

The analysis and study of evaluation index of green building mainly combine with the Germany DGNB sustainable building evaluation system, the British BREEAM sustainable building evaluation system and the related evaluation index in Chinese evaluation system of green building for effective analysis. To ensure the selected evaluation index has the same evaluation project which mainly involves the indoor environment quality, resource conservation and so on, and to unified define the higher similarity evaluation index contained in evaluation project as the basic evaluation index. To have a systematic evaluation on economy, the green and other corresponding index, after preliminary screening process, the result of evaluation index system of green building is shown in TABLE 1.

Correlation determination between the indicators

In preliminary screening of evaluation index (as shown in TABLE 1), combine with related literature review to have effective selection, there will be a phenomenon of information overlapping between indicators. Therefore in the indicator analyzing process will have the situation of analysis complex, and the results of the analysis can not guarantee strong accuracy. However, to avoid this case, this paper mainly used principal component analysis for effective screening of evaluation index[3].

TABLE 1 : Initial evaluation index system of green house

First-class Index	Second-class Index	First-class Index	Second-class Index
Economic quality	Design cost	Water resources utilization	Less water
	Construction cost		Waste water treatment
	Construction operation cost		The amount of waste water discharged into sewers
	Proportion of investment in green technology		Reduce rainwater runoff
	Rate of return on investment		Reclaimed water utilization
	Customer satisfaction		Reuse water utilization
Outdoor ecological environment	Residential location	Material resources utilization	Source of building and decoration materials
	Infrastructure		Local material utilization ratio
	Virescence		Use of energy-saving materials
	Traffic condition		Environmental impact
	Noise abatement		The wastes utilization
	Microclimate	Indoor environmental quality	Indoor air quality
	Public accessibility		Indoor thermal environment
Energy utilization	Building envelope structure		Indoor luminous environment
	CO2 discharge		Indoor acoustical environment
	Renewable energy utilization		Barrier free design
	Use of clean power		Moistureproof quality
	Energy-saving electrical equipment	Process management	Construction site management
	Large home appliance consumption		Construction quality assurance
	Lighting system		Garbage disposal
	Air-conditioning system consumption		Residential security
	Living hot water consumption		

In correlation judgment and study process of evaluation index, the first part is aimed at the importance of the indicators to have effective exploration, from which to have corresponding quantitative process on its importance to enable

the basic data to be clearly shown. The importance of evaluation index in this paper is divided into five levels, respectively completely not important, not important, in general, relatively important, and very important. And replace all the 5 levels respectively with the numbers 1, 2, 3, 4, 5, and distribute the five evaluation indexes to 35 experts to score. In this process because of the large number of involved evaluation indexes, scores between uncorrelated indicators may also be similar, which will produce a lot of inconvenience for statistical process of indexes. In such cases divided the first-class index into seven samples, after the effective analysis of the seven samples data upload them to professional data analysis software, to form correlation matrix and component matrix, so as to effectively judge that whether the index information have the status of overlapping[4].

Based on the examples of energy utilization indexes (specific in TABLE 2 and TABLE 3), in the indexes of "renewable energy utilization" and "use of clean power" the reflected correlation coefficient are 0.785, but the clean power belongs to renewable energy, so it can be merged into the evaluation index of renewable energy utilization. In addition, emission of carbon dioxide is one of the main indicators to effectively measure the green building, and its value is not only depends on the amount of energy utilization, but also be affected by water resource utilization and material utilization. The definition of energy utilization obviously has irrationality. Through component matrix can effectively establish indicators of energy utilization, and effectively retain the six indicators, and through this method to have corresponding analysis on the relevance judgment of other indicators.

TABLE 2 : Correlation matrix of index on energy utilization

Index	Building envelope structure	CO2 discharge	Renewable energy utilization	Use of clean power	Energy-saving electrical equipment
Building envelope structure	1.000	-.020	.213	-.060	.185
CO2 discharge	-.020	1.000	-.227	.074	.021
Renewable energy utilization	.213	-.227	1.000	.785	.089
Use of clean power	-.060	.074	.785	1.000	.040
Energy-saving electrical equipment	.185	.021	.089	.040	1.000
Large home appliance consumption	-.020	-.047	-.160	.144	.892
Lighting system	-.048	.096	.203	-.100	.252
Air-conditioning system consumption	-.297	.026	-.336	-.225	-.047
Living hot water consumption	.168	-.221	.419	.022	.100

Index	Large home appliance consumption	Lighting system	Air-conditioning system consumption	Living hot water consumption
Building envelope structure	-.020	-.048	-.297	.168
CO2 discharge	-.047	.096	.026	-.221
Renewable energy utilization	-.160	.203	-.336	.419
Use of clean power	.144	-.100	-.255	.022
Energy-saving electrical equipment	.892	.252	-.047	.100
Large home appliance consumption	1.000	.036	-.114	-.134
Lighting system	.036	1.000	.089	.237
Air-conditioning system consumption	-.114	.089	1.000	-.043
Living hot water consumption	-.134	.237	-.043	1.000

TABLE 3 : Component matrix of index on energy utilization

Index	Component					
	1	2	3	4	5	6
Building envelope structure	.464	-.026	-.087	-.609	.499	.218
CO2 discharge	-.270	.216	-.150	.425	.764	.188
Renewable energy utilization	.800	-.338	.003	.224	-.052	-.033
Use of clean power	.821	.022	-.551	.575	-.172	.266
Energy-saving electrical equipment	.414	.778	.213	-.078	.011	.152
Large home appliance consumption	.174	.866	-.121	-.066	-.274	-.028
Lighting system	.266	.170	.679	.391	.255	.378
Air-conditioning system consumption	-.552	.023	.540	.140	-.199	.492
Living hot water consumption	-.077	-.301	.483	-.013	.578	.308
Note: Valid questionnaire for 31 copies						

In order to ensure that the evaluation results can reach the purpose of objective and fair, to make the construction quality and the impact of environment and economy can get a more comprehensive response, the evaluation index in this paper is mainly divided into three major categories, the first one is economic quality, the second one is low carbon and resource conservation, the last one is the service quality of construction, the concrete evaluation index is shown in TABLE 4.

CONSTRUCTION OF NEW THREE-DIMENSIONAL EVALUATION MODEL OF GREEN BUILDING

The current evaluation method of green building in China is usually that with the expert scoring to determine the score of each evaluation index, sum up the score of each evaluation index to get a total evaluation index score, then to define the level of evaluation index. However, this method can not fully reflect the specific difference of the content between each indicator, which makes the attached connotation of green building become fuzzier, inter evaluation indexes can not achieve the goal of coordinated development[5]. On the basis of TABLE 4, this paper concretely constructed for the space model of evaluation system of green building, and has a further exploration of the evaluation results comprehensiveness of green building by this model.

Determine the index weight

The process evaluation index of green building selection have strong hierarchy, through the importance of multilevel index to effectively layer to enable the weight of evaluation index in all levels can be effectively obtained, the concrete evaluation index weight is shown in TABLE 5.

Construction and analysis of three-dimensional evaluation model

Preliminary screening of two-dimensional model

The data in TABLE 5 shows that in the process of evaluating green building, the main evaluation index is saving resources and the creation of healthy and comfortable environment, if the basic requirements of the two aspects can not achieve then the building can not be called green building. So in the process of the two kinds of indexes division should with the effective screening at the same time, the economic evaluation should be as an important evaluation standard[6]. However, during the construction process, there is contradiction between resource saving and service quality, the building itself to the promotion of life quality will inevitably produce certain resource waste, but to a certain extent can be more obvious to fully embody the two relations, so it should compare the specific points of the two evaluation indexes, and the ratio will be represented by K. However, there is certain difference between weight values of the two indicators, so for the target layer the produced contribution also have differences. After a comprehensive consideration above, divided the service quality and resource consumption these two dimensions into four parts, and it is specifically shown in Figure 1.

In Figure 1, X axis is usually defined as the situation of corresponding points of a building in the construction process and the resource consumption, however there is a certain gap between the largest score and the score of architecture saving resources, and the greater the gap between them fully proves that the more serious in the process of construction for the resources consumption. The Y refers to the points of service quality evaluation of building itself. In this process the upper limit of each evaluation index is set to 10 points, with corresponding scoring by experts and through the weight in TABLE 3 to calculate the final score of each index. The scores are respectively within A, B, C three regions, which means the building is in accordance with its own characteristics of green building and requirement of resource saving and healthy and comfortable life can fully achieve. On this basis, economic quality of evaluation index can be effectively analyzed through this model, and the score is in the region of D, which reflects the state of imbalance between service quality of building itself and resource consumption, which is not the characteristics of green building should have, therefore the subsequent evaluation process does not need to carry on.

TABLE 4 : List of green building evaluation index system and related instructions

First-class Index	Second-class Index	Third-class Index	Illustration
Economic quality U1	Cost U11	Construction cost U111	Cost in implementation phase
		Construction operation cost U112	Maintenance fees of materials and equipment, property management fees
	Benefit U12	Customer satisfaction U121	Users' perception results of the house
		Extra cost payback period U122	Increase cost payback period
Low-carbon and resource conservation U2	Energy utilization U21	Building envelope structure U211	Heat transfer coefficient of external wall, ground, roof, external window, etc, building shape coefficient and other indicators
		Renewable energy utilization U212	Renewable energy utilization ratio
		Energy saving electrical equipment U213	Energy-saving transformers, electrical components and other utilizations
		Lighting system U214	Efficient lighting tool in public places, the use of automatic energy-saving control
		Energy consumption of air-conditioning system U215	Equipment performance coefficient, energy saving ratio
		Living hot water consumption U216	Hot water system power consumption and transmission efficiency
	Water resources utilization U22	Less water U221	Water-saving appliances and water-saving measures
		Waste water treatment U222	Wastewater discharge amount and processing amount
		Non-traditional water use planning U223	Non-traditional use of rainwater, recycled water, etc.
		Water saving U224	Water resources use excess carbon emissions
	Material resources utilization U23	Local material utilization U231	Local materials accounted for the proportion of material consumption
		Use energy-saving materials U232	The proportion of energy-saving materials
		Environmental impact U233	Material production carbon emissions
		Waste utilization U234	Waste recovery and recycling rates
Buildings use quality U3	Outdoor ecological environment U31	Residential location U311	The content of harmful substances in the soil, the original river, wetland
		Infrastructure U312	Facilities, barrier free facilities
		Virescence U313	Green space ratio
		Traffic condition U314	Underground garage proportion, public accessibility
		Noise abatement U315	Noise sound pressure and noise reduction measures
		Microclimate U316	Settlements humidity, harmful content and measuring ratio of external settlements
	Indoor environmental quality U32	Indoor environmental quality U321	Air quality, light environment, acoustic environment, thermal environment
		Moistureproof quality U322	Rain and snow weather indoor humidity
	Operation management U33	Garbage disposal U331	Garbage classification and flow control
		Residential security U332	Intelligent systems, unit area and security number

Note: In the table except for a few determined implementation of indicators in design stage, other indicators need to review the real situation in final acceptance or operate more than one year.

TABLE 5 : Evaluation index weight

Index	Weight	Index	Weight	Index	Weight
U1	0.24	U121	0.54	U232	0.28
U2	0.43	U122	0.46	U233	0.16
U3	0.33	U211	0.31	U234	0.15
U11	0.48	U212	0.15	U311	0.09
U12	0.52	U213	0.08	U312	0.12
U21	0.55	U214	0.08	U313	0.32
U22	0.22	U215	0.23	U314	0.21
U23	0.23	U216	0.15	U315	0.16
U31	0.37	U221	0.24	U316	0.10
U32	0.53	U222	0.12	U321	0.80
U33	0.10	U223	0.27	U322	0.20
U111	0.64	U224	0.37	U331	0.67
U112	0.36	U231	0.41	U332	0.33

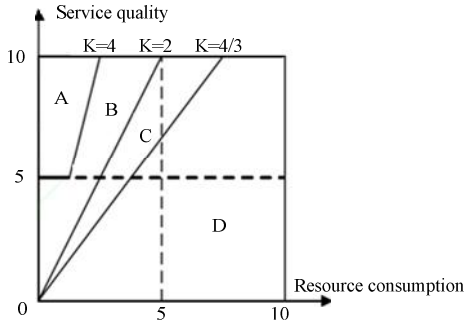

Figure 1 : Ratio distribution of construction quality and resource consumption

In the figure above, the quality dimensions are effectively added to make the three-dimensional evaluation model of green building can get more scientific construction (concrete is shown in Figure 2), in the Z coordinate to divide in the range of the final result into two parts, so the whole three-dimensional evaluation model can be divided into six parts[7].

The first part embodies the quality of the building itself is relatively good, the resource consumption is low, can achieve high economic benefits at the same time, so this is the optimal level of green building.

And the second part and the third part mainly manifest the service quality and economic quality is relatively good, but the resource consumption and environmental negative image is relatively large, so they belong to a relatively optimal level of green building.

And the fourth part mainly reflects the low resources consumption but building with relatively good service quality, and its economic efficiency is not high, so this is also a relatively optimal level of green building.

And the last fifth and sixth parts' two single evaluation index are relatively low, the two parts can only be defined in the category of certification level of green building.

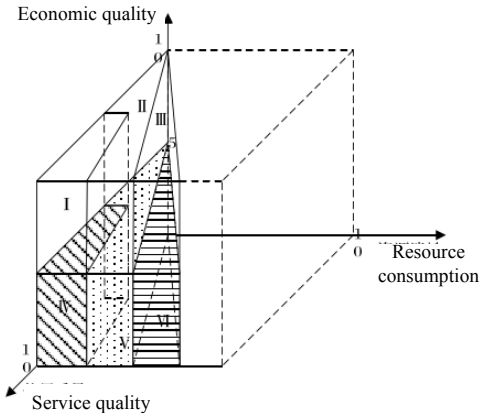

Figure 2 : Space evaluation model diagram of green house

In Figure 2, the scores of the three latitudes are respectively replaced by x, y, z, through the position of latitude in evaluation model to effectively determine the level of green building.

CONCLUSION

Above is the related research and discussion about the construction of fuzzy multilevel index comprehensive evaluation model of green building and the paper is mainly focus on the construction of evaluation system of green building and the construction of a new three-dimensional evaluation model of green building. The paper also study on the selection of evaluation index of evaluation model and basic elements of model construction, so as to provide a strong basic condition for the fuzzy multilevel index comprehensive evaluation model, and to provide strong support for the promotion of green building and ecological environment harmonious development.

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