The post-evaluation of green residential building in Ningxia

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Abstract. Green residential buildings are concerned by more and more people. However, the development of green residential buildings has been limited due to the single-standard requirements and lack of the multi-objective performance. At same time, the evaluation criteria system of green residential building is not comprehensive enough. So first of all, using SPSS software, residents questionnaire surveys are figured and found that the judge of experts and residents about the green elements is inconsistent, so the owners' satisfaction is included in the post-evaluation criterial systems of green residential building from five aspects-the preliminary work of construction, construction process, economic, social benefits and owners satisfaction in Ningxia area, combined with expert interviews. Secondly, in the post-evaluation, it is difficult for many experts judgment matrix to meet the requirement of consistency, in this paper using MATLAB program, judgment matrix consistency is adjusted. And the weights of the criteria and sub-criteria and experts weights using group AHP method are determined. Finally, the grey clustering method is used to establish the post-evaluation model and the real case of Sai-shang project is carried out. It shows that the result obtained by using the improved criteria system and method in this paper is in a high degree of agreement with the actual result.

1 Introduction

With the development of economy, the real industry in our country urgently needs to change from extensive development to sustainable development. More and more people focus on the deterioration of environment and concerned on the concept of "green" of residential environment. Ningxia as a energy conservation focus areas, insist on continuous promoting energy-saving technology in the improvement of the application of industrial recycling technology at the same time. Ningxia in 2009 by the Department of housing and urban and Rural Construction issued "the detailed rules for the implementation of evaluation standard for green building in Ningxia Hui Autonomous Region". However, the current green residential building highly input, making developers flinch, the implementation of the technical measures of green residential building only meet the requirements of low standard and lacks the different level demands of green for the owners, but also lacks the regional characteristics[1, 2]. Huang and Wang[3, 4] only construct the evaluation system of green residential building from the point of view of the construction of the building. In this paper, through the questionnaire survey of Ningxia region characteristic is analyzed, in order to establish a suitable for Ningxia area post-evaluation criteria system of green residential building, in addition to the full life-cycle of the construction process, the factor of owners' satisfaction is proposed, at the same time, also from the horizontal view, social, economic is proposed. Li[5] combines the characteristics of Fujian Province to introduce the concept of green measure of evaluation of green housing, but lacks a number of experts to evaluate the build-up problem. In this paper, the AHP method of group evaluation is used to gather and determine the important degree of each criterion and sub-criterion.

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To sum up, green residential buildings in Ningxia were investigated and analyzed and the post-evaluation criteria system of green residential of the Ningxia Hui Autonomous Region is proposed, and the grey cluster model is used to evaluate the Sai-shang construction.

2 Determine the post-evaluation criteria of green residential building

In the elements of green building, consumers think that "healthy and comfortable working and living environment" is the most importance, on the contrary, the technology experts think the most important is the "conservation of resources". This inconsistent phenomenon shows that the consumer demand for green residential building should not simply apply academic theory to express the green residential building. Considering the technical experts and consumers in the green building elements judge the inconsistent[6], while use of life cycle theory and interview with experts to build and select the post-evaluation criteria system of green residential building[7-10]. Therefore, to building the post-evaluation criteria system of green residential building, not only the preliminary work of construction, construction stage, economic, social was considered, and owners' satisfaction is brought into the post-evaluation criteria system (see Table1).

Table 1: The post-evaluation criteria system of green residential building

Objective	Criteria	Sub-criteria
Green residential building	a. Preliminary work of construction	a1. Site selection
		a2. Site quality
		a3. Pre-service facilities planning
		a4. Pre-traffic planning
		a5. Preliminary planning of water resources
		a6. The use efficiency of land
		a7. Indoor and outdoor design environment quality
		a8. Section material and material resources
		a9. Energy saving and Energy use
		a10. Water saving and water resource utilization
	b. Construction process	b1. Site water saving and water resource utilization
		b2. Energy saving and energy utilization in construction site
		b3. Section material and resource utilization of construction site
		b4. Construction site environment
		b5. Construction, living garbage and waste disposal
		b6. noise control
	c. Economic	C1. National economic evaluation
		C2. Full life cycle cost
		C3. Green price
	d. Social	d1. Regional
		d2. Peripheral facilities
	e. Owners' satisfaction	e1. Green management
		e2. Material resources
		e3. energy utilization
		e4. water resource
		e5. Indoor environmental quality

3 Determination of the criteria and sub-criteria weight of evaluation system of green residential building

The expert evaluation matrix is obtained by using the questionnaire survey, in order to avoid the evaluation of a logical error, using the MATLAB program, all the experts' evaluation matrix are consistency adjustment, the matrix after modification become the basis of the experts and criteria weight determined. (Process see Fig1)

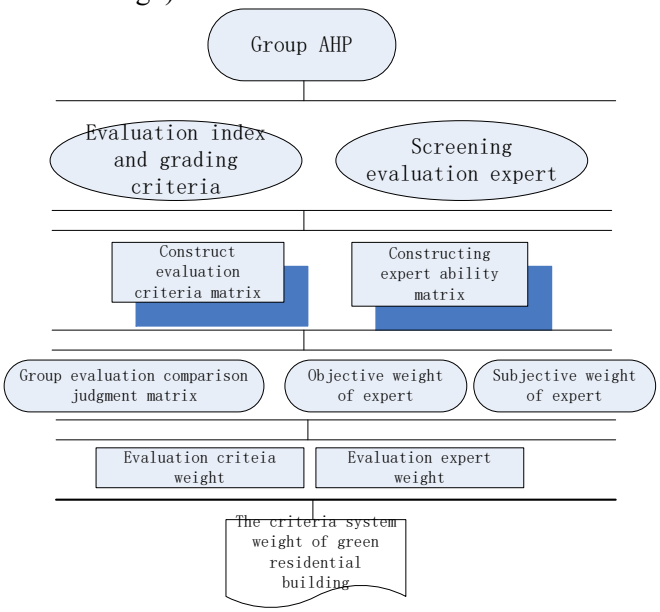

Figure1: The frame of the post-evaluation criteria weight and expert weight

3.1 Expert weights

In the post-evaluation of green residential building, according to the ability level of the experts, the visibility and degree of familiarity with the problem of the evaluation to determine weight defined as the subjective weight. But often only by virtue of subjective weight, the influence degree of evaluation cannot truly reflect, so the objective weight is used, that is the evaluation weight is determined using experts of all evaluation results and relationship between them.

The objective weights of criteria are determined by means of gathering the criteria judgment matrix of the experts, and the values are as follows:

$$\beta_k^{(1)} = (0.2682, 0.2680, 0.2689, 0.2688, 0.2687, 0.2691, 0.2688, 0.2690, 0.2687, 0.2687)^T$$

Based on the AHP, the subjective weights of the experts are as follows:

$$\beta_k^{(2)} = (0.0312, 0.0444, 0.0997, 0.0638, 0.0919, 0.0520, 0.0997, 0.1743, 0.1656, 0.1775)^T$$

The weight coefficient is introduced. Using Eq1, the final criteria weights of green residential building are determined.

$$\omega_k = t \cdot \beta_k^{(1)} + (1-t)\beta_k^{(2)}, k = 1, 2, ..., s \quad (1)$$

$$W = (0.1023, 0.1115, 0.1504, 0.1253, 0.1449, 0.1171, 0.1504, 0.2027, 0.1965, 0.2040)^T$$

3.2 Criteria and sub-criteria weight of the post-evaluation

Assuming that s experts participate in the importance degree of the criteria and sub-criteria of green residential building and experts respectively give the n order judgment matrix using AHP, and the expression is $A^{(k)}(k = 1, 2, ..., s)$. The decision matrix of the group decision-making can be constructed as

follows:

$$A = (a_{ij})_{n\times n} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & & 1 \end{bmatrix}$$

$$a_{ij} = \left[\prod_{k=1}^{s} a_{ij}^{(k)}\right]^{\frac{1}{s}}$$

The element of the matrix A is composed of the average geometric value of the corresponding element of the expert judgment matrix. For each k, if the matrix meet the consistency, the matrix A is also consistent. After calculating the group evaluation matrix, the weight of the evaluation criteria and sub-criteria is obtained by AHP method and the consistency test is carried out. The relative weight and absolute weight of the criteria and sub-criteria of green residential building can see Table2

Criteria	weight	Sub-criteria	Relative weight	Absolute weight
a. Preliminary work of construction	0.3946	a1. Site selection	0.1652	0.0652
		a2. Site quality	0.0952	0.0376
		a3. Pre-service facilities planning	0.0850	0.0335
		a4. Pre-traffic planning	0.0915	0.0361
		a5. Preliminary planning of water resources	0.0924	0.0365
		a6. The use efficiency of land	0.0903	0.0356
		a7. Indoor and outdoor design environment quality	0.0845	0.0333
		a8. Section material and material resources	0.0949	0.0374
		a9. Energy saving and Energy use	0.0951	0.0375
		a10.Water saving and water resource utilization	0.1059	0.0418
b. Construction process	0.1571	b1. Site water saving and water resource utilization	0.2017	0.0317
		b2. Energy saving and energy utilization in construction site	0.1860	0.0292
		b3. Section material and resource utilization of construction site	0.1490	0.0234
		b4. Construction site environment	0.1538	0.0242
		b5. Construction, living garbage and waste disposal	0.1577	0.0248
		b6. noise control	0.1516	0.0238
c. Economic	0.1524	C1. National economic evaluation	0.4364	0.0665
		C2. Full life cycle cost	0.2114	0.0322
		C3. Green price	0.3522	0.0537
d. Social	0.1584	d1. Regional	0.5673	0.0899
		d2. Peripheral facilities	0.4327	0.0685
e. Owners' satisfaction	0.1375	e1. Green management	0.2341	0.0322
		e2. Material resources	0.1659	0.0228
		e3. energy utilization	0.2192	0.0301
		e4. water resource	0.1913	0.0263
		e5. Indoor environmental quality	0.1895	0.0261

Table2: The relative weight and absolute weight of the criteria and sub-criteria of green residential building

4 A case study-Sai-shang project in Ningxia

In the actual post-evaluation, the green residential building is assessed star, the extension of concept is very clear, that is, the level of green is determined, but it is not clear for the specific line of star. So the post-evaluation of the green residential building is a typical grey system problem. In this paper, from the factors of the preliminary work, the construction process, the social, economics and owners' satisfaction, Saishang-green residential building is assessed and graded by the grey clustering method to post-evaluation this project. In the evaluation system, the value range of each criterion is divided into three categories, respectively, corresponding to one star, two star and three star. The implementation values of each sub-criterion are shown in Table3.

Criteria	weight	Sub-criteria	Score	weight
a. Preliminary work of construction	0.3946	a1. Site selection	90	0.0652
		a2. Site quality	85	0.0376
		a3. Pre-service facilities planning	80	0.0335
		a4. Pre-traffic planning	15	0.0361
		a5. Preliminary planning of water resources	20	0.0365
		a6. The use efficiency of land	27	0.0356
		a7. Indoor and outdoor design environment quality	9	0.0333
		a8. Section material and material resources	30	0.0374
		a9. Energy saving and Energy use	70	0.0375
		a10.Water saving and water resource utilization	85	0.0418
b. Construction process	0.1571	b1. Site water saving and water resource utilization	5	0.0317
		b2. Energy saving and energy utilization in construction site	6	0.0292
		b3. Section material and resource utilization of construction site	18	0.0234
		b4. Construction site environment	5	0.0242
		b5. Construction, living garbage and waste disposal	7	0.0248
		b6. noise control	3	0.0238
c. Economic	0.1524	C1. National economic evaluation	80	0.0665
		C2. Full life cycle cost	70	0.0322
		C3. Green price	1.3	0.0537
d. Social	0.1584	d1. Regional	80	0.0899
		d2. Peripheral facilities	85	0.0685
e. Owners' satisfaction	0.1375	e1. Green management	7	0.0322
		e2. Material resources	15	0.0228
		e3. energy utilization	80	0.0301
		e4. water resource	80	0.0263
		e5. Indoor environmental quality	85	0.0261

Table3: The implementation values of the sub-criterion of "Sai-shang"

According to the sub-criteria of three different grey class whitening weight function, all the criteria

of the three different grey class whitening weight function values were calculated, and finally get the values shown in Table4.

Sub-criteria	$f_j^1(x)$	$f_j^2(x)$	$f_j^3(x)$	Sub-criteria	$f_j^1(x)$	$f_j^2(x)$	$f_j^3(x)$
C1	0.0000	0.5000	0.8000	C14	0.0000	0.5000	0.8000
C2	0.2000	0.7500	0.6000	C15	0.0000	0.5000	0.8000
C3	0.4000	1.0000	0.4000	C16	0.8000	0.5000	0.0000
C4	0.3750	0.9412	0.2500	C17	0.4000	1.0000	0.4000
C5	0.5000	0.8889	0.3077	C18	0.8000	0.5000	0.0000
C6	0.1538	0.8333	0.5000	C19	0.3333	1.0000	0.2500
C7	0.6667	0.6667	0.0000	C20	0.4000	1.0000	0.4000
C8	0.9020	0.4314	0.0000	C21	0.2000	0.7500	0.6000
C9	0.8000	0.5000	0.0000	C22	0.0000	0.5000	0.8000
C10	0.2000	0.7500	0.6000	C23	0.1333	0.7692	0.5714
C11	0.6667	0.6667	0.0000	C24	0.4000	1.0000	0.4000
C12	0.3333	1.0000	0.4000	C25	0.4000	1.0000	0.4000
C13	0.5000	0.8333	0.1818	C26	0.2000	0.7500	0.6000

Table 4: The grey class whitening weight function values of the sub-criteria of Sai-shang project

The grey clustering coefficient of K is calculated as follows:

$$\sigma^1 = \sum_j f_j^1(x_j)\eta_j = 0.3648 \quad \sigma^2 = \sum_j f_j^2(x_j)\eta_j = 0.7722 \quad \sigma^3 = \sum_j f_j^3(x_j)\eta_j = 0.4005$$

$$\max\{\sigma_i^k\} = 0.7722 = \sigma^2$$

From the above data, the project of Sai-shang belongs to the grey class K=2, which belongs to the class of “two star green”.

5 Conclusion

The project of Sai-shang has been considered the green building requirements from the five aspects of the preliminary work, construction stage, social, economic and owners’ satisfaction. From the final post-evaluation results, the project fully reflects the green, environmental protection, livable, sustainable characteristics, which belongs to the two- star rating system, and the result is basically consistent with the professional evaluation (2010 annual green residential building design logo certification) and good social recognition.

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