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Cloud Model-Based Research in Maturity Evaluations for Low Carbon Building System

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Abstract: Low carbon building has far-reaching significance in energy conservation, relieving domestic environmental and social pressures and international pressure and to achieve sustainable economic and social development. Launching low carbon building becomes the inevitable trend. Maturity model provides a systematic framework for improving or getting expecting things. By taking the existing maturity model as reference, this paper constructs the low carbon building maturity with three dimensions and four levels and constructs preliminary indicator system, in which three dimensions are indicators domain, whole life-cycle assessment levels and four grades—"germination" "beginning period" " revise ""perfect". Finally, this paper adopts could model to evaluate the maturity level which can integrate the fuzziness and randomness of qualitative concepts organically.

Keywords: Low Carbon Building System; Maturity Model; Cloud Model

1. Introduction

In the 21st century, China's resources and environment contradiction in economic and social development becomes more apparent and the domestic demand for Energy saving and emission reduction gradually improves. In the era of globalization, China's carbon emission has become a global focus. According to the 2012 edition of the World Energy Outlook China's emissions in 2012 rose 3.8 percent to 300 million tons[1]. Building as the main source of greenhouse gases, its relatively low cost to reduce emission, easy to form carbon lock-in effect and its energy saving potential makes developing low carbon buildings the inevitable trend with both pressures at home and abroad.

Current research on low carbon building standards involves macroeconomic policies, implementation, quantization of carbon emissions, and so on. Research on macro policy involves factors analysis and countermeasures research, but the integrity of their analysis is not enough strong and it's difficult to achieve comprehensive improvements. Existing maturity model mainly adopts interview or questionnaire method to evaluate the maturity level, the subject is mainly qualitative description with subjectivity. This article takes the cloud model to evaluate the maturity level which reduces the dependence on the subjective factor.

2. Construction of Low Carbon Building System Model

The connotation of low-carbon buildings based on the whole life cycle, from whole life cycle of low carbon building life cycle can be divided into decision-making, design, construction, operation and scrap removal five phases, involving the government and relevant government departments, research and development institutions, developers, design units, construction units, materials and equipment suppliers, financial institutions, property management units, consultancy, consumers[2].

Low carbon building system includes the micro level--formation of low carbon construction entity of materials, components and operation equipment and other material basis, medium level--building life cycle of the five stages in the process of coordination work, and at the head of the overall macro level--the laws and regulations, policies and measures, technical standards and market system, macro elements to realize the supervision and guidance of medium level as well as guiding and supporting the micro-level[3]. the three levels and government, developers, construction units, design units, the property management units, materials and equipment suppliers, consultancy, credit institutions, and many other participants as the backing, in addition low carbon building system constructed by the participants through the interaction to achieve a low-carbon ultimately building.

Thus this article from the view of participants designs nine main factors of low carbon building system maturity evaluation: the government, developers, design units, construction units, research and development institutions, property management units, materials and equipment

supplies, consultants and consumers. The mutually diagram of participants is as Figure 1.

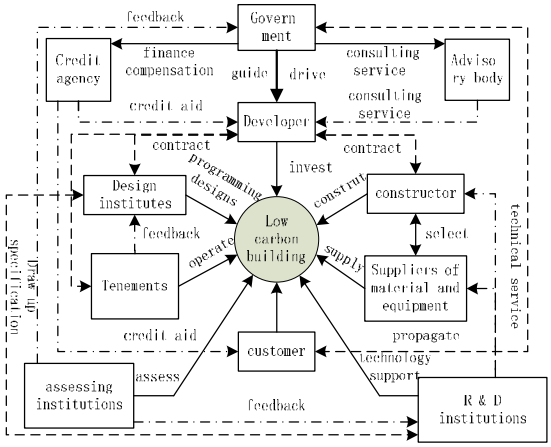

Figure 1. Participants relationship of low carbon building system

3. Low Carbon Construction Maturity Model Structure

By referencing to the CMM, OPM3 and other types of maturity model, this paper constructs three dimensions of low carbon building system maturity evaluation model[4][5]First dimension is the four grades of maturity levels; the second dimension is various stages of the low carbon building life cycle; the third dimension is index system of the low carbon building. The frame structure as shown in Figure 2.

3.1. The First Dimension-maturity Levels

This paper presents a model LCBS-PMI, according to the step of achieved and improved low carbon architecture system which divides the four grades, which constitute four levels followed by germination, primary, modification and improvement, As shown in Figure 3.

3.2. The Second Dimension-project Life Cycle

The connotation of low-carbon building is based on the perspective of the whole life cycle with stage dynamic. Through the analysis of the participants in different life period of the low carbon building variation, can be designed in different life cycle period to measure low carbon building system maturity. According to the building life cycle characteristics and combined with the analysis of the participants ,the life cycle is divided into investment decision, design, construction, operation and scrap removed five stages.

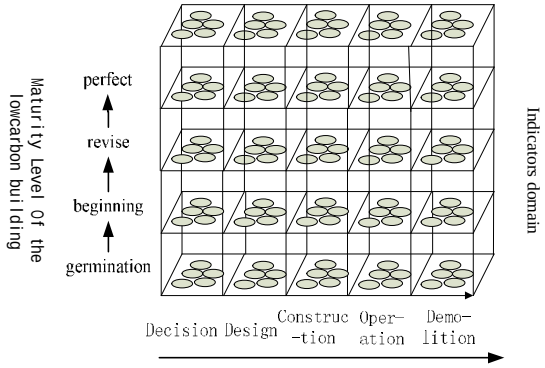

Figure 2. The structure diagram of low carbon building system maturity model

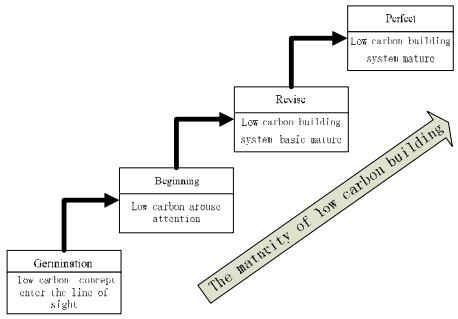

Figure 3, maturity level of low carbon building system

3.3. Third Dimension-evaluation Index System of Low Carbon Building

The evaluation index system of low carbon building is shown as Table 1.

Table 1. Evaluation index system of low carbon building

The first indicators	The second indicators	The third indicators
The maturity of low-carbon building system	The government and relevant government departments (U1)	Low carbon relevant policy system (U11)
		Low carbon laws and standards system (U12)
		Low carbon regulation system (U13)
	Developers (U2)	Market capacity (U21)
		Low carbon consciousness (U22)
		investment income levels of low-carbon buildings (U23)
		Sales (U24)
	Design unit (U3)	Low carbon design capability (U31)
		Low carbon design concept (U32)
		Collaboration with the participants (U33)
		Learning ability (U34)

	Construction unit (U4)	Low carbon construction technology, technical (U41)
		Low carbon construction scheme and comprehensive management ability (U42)
		Learning ability (U43)
	materials and equipment supplies (U5)	Low carbon materials and equipment manufacturing level (U51)
		Service and maintenance level (U52)
		Collaboration with the participants (U53)
	Low carbon technology research and development institutions (U6)	Low carbon technology research and development capabilities (U61)
		Collaboration with the participants (U62)
		Learning ability (U63)
	property management unit (U7)	Property management level (U71)
		Low carbon operation concept (U72)
		Collaboration with the participants (U73)
	consumers (U8)	Demographic characteristics (U81)
		Psychological factors (U82)
		Consumer lifestyle (U83)
	Consultancy (U9)	Low carbon service level (U91)
		Credibility of consulting services (U92)
		Low carbon service basis (U93)

4. Maturity Model Evaluation of Low Carbon Building System

The model uses the improved AHP to determine the index weights and applied the cloud model theory to evaluate the maturity of low-carbon building system. The calculation process is as follows:

4.1. Constitute a Model Index Set. Index Set of the Model Constitution by the Two Levels

The first level of the index set

$$U=\{U_1,U_2,\mathrm{L}\ U_i,\mathrm{L}\ U_n\} \tag{1}$$

U_i is the second level of the index set:

$$U_i=\{U_{i1},U_{i2},\mathrm{L}\ U_{in}\} \tag{2}$$

4.2. To Determine the Weighing Values of Index System of Evaluation Grades

The improved AHP was applied to determine the weight of each index[6]

① Establish seven scale comparison matrix $D^{(k)}$

$$D^{(k)}=[d_{ij}^{(k)}]_{n\times n}\ \ i,j=1,2,\mathrm{L}\ ,n\ k=1,2,\mathrm{L}\ ,r \tag{3}$$

Where $d_{ij}^{(k)}$ represents the k expert compared with each other indicators u_i and u_j

②To calculate the index u_i importance of degree and sorting index

$$r_i^{(k)}=\sum_{j=1}^{n}d_{ij}^{(k)} \tag{4}$$

③To construct judgment matrix $E^{(k)}=[e_{ij}^{(k)}]_{n\times n}$

$$e_{ij}^{(k)}=\begin{cases} r_i^{(k)}-r_j^{(k)} & r_i>r_j \\ 1 & r_i=r_j \\ \left[r_j^{(k)}-r_i^{(k)}\right]^{-1} & r_j>r_i \end{cases} \tag{5}$$

④ To calculation mutual anti-symmetric matrix $F^{(k)}=[f_{ij}^{(k)}]_{n\times n}=[\lg e_{ij}^{(k)}]_{n\times n}$, and ultimately determine weights.

Set A is the overall standard deviation of expert evaluation, there are

$$d_{ij}=\sqrt{\frac{1}{r-1}\sum_{k=1}^{r}[f_{ij}^{(k)}-\frac{1}{r}\sum_{k=1}^{r}f_{ij}^{(k)}]^2} \tag{6}$$

When $d_{ij}<1$, considered the views of the expert group was more consistent, Expert Group structure with arithmetic judgment matrix corresponding average value of each element as a result of the group's judgment, that was $F=[f_{ij}]_{n\times n}$, $f_{ij}=\frac{1}{r}\sum_{k=1}^{r}f_{ij}^{(k)}$, calculated the optimal transfer matrix $G=[g_{ij}]_{n\times n}$, $g_{ij}=\frac{1}{n}\sum_{l=1}^{n}(f_{il}-f_{jl})$,thus established a consistent quasi optimal transfer matrix $E^*=[10^{g_{ij}}]n\times n$, the maximum characteristics eigenvalue of the normalized corresponds to E^* vector to get weight $W=(w_1,w_2,\mathrm{L}\ ,w_n)$

When $d_{ij}>1$, consider the views of the expert group was lager differences, using the optimal transfer matrix as a group judgment result.

Making $J=\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{r}(f_{ij}-f_{ij}^{(k)})^2$ minimum of optimal transfer matrix $F=[f_{ij}]_{n\times n}$, $f_{ij}=\frac{1}{rn}\sum_{i=1}^{n}\sum_{k=1}^{r}\left[f_{ii}^{(k)}-f_{ji}^{(k)}\right]$.

Let be $C=[c_{ij}]_{n\times n}=[a^{f_{ij}}]_{n\times n}$, a is the two adjacent evaluation objective important ratio in the type which value of 1.1~1.3 . Matrix C can consult $d_{ij}<1$ when calculating method to calculate the weight, is the group judgment matrix with consistency.

4.3. Establish Evaluation Set

Using index approximation. Comment on the existence of a bilateral constraints can use the expectations as median expectations of constraint conditions, the main role of the regional area for cloud bilateral constraints to approximate this comment[7].Cloud parameters calculated :

$$\begin{cases} Ex=(C\min+C\max)/2 \\ En=(C\max-C\min)/6 \\ He=k \end{cases} \quad (7)$$

Where k is a constant, according to the degree of blurring to adjust itself comment.

For the comment of unilateral constraints, determined the first to the default boundary parameters or default expectations. Such as a comment "very good" default expectation is 100% (refers to Satisfaction), then referring to the above formula and calculate the cloud parameters, with half a liter and a half down to describe .

In $[0,1]$, the universe can be divided into four assessment grade “Germination”, “Primary”, “Modification”, “Improvement”, Corresponding cloud model Cloud1(1,0.083,0.013), Cloud2(0.625,0.047,0.008), Cloud3(0.375,0.047,0.005), Cloud4(0,0.083,0.008).

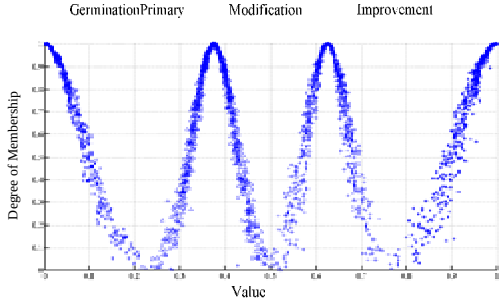

Figure 4. Evaluation Cloud

4.4. Multilevel Comprehensive Evaluation

The low level of each factor was evaluated, then multiplying Evaluation of cloud and the weight of each factor in the this level , Get on the layer of Comprehensive Evaluation Cloud.

With the secondary index as an example to comprehensive cloud calculate the index on the secondary indexes[8], Formula is as follows

$$Ex=\frac{Ex_1*En_1*W_1+Ex_2*En_2*W_2+\mathrm{L}+Ex_n*En_n*W_n}{En_1*W_1+En_2*W_2+\mathrm{L}+En_n*W_n} \quad (8)$$

$$En=En_1*W_1*n+En_2*W_2*n+\mathrm{L}+En_n*W_n*n \quad (9)$$

$$He=\frac{He_1*En_1*W_1+He_2*En_2*W_2+\mathrm{L}+He_n*En_n*W_n}{He_1*W_1+He_2*W_2+\mathrm{L}+He_n*W_n} \quad (10)$$

Where Ex , En , He are the cloud model parameter index of U_i ; Ex_1 , Ex_2 ... Ex_n are expectations for the secondary indicators; En_1 and En_2 .. En_n cloud model of entropy for the secondary indicators; He_1 , He_2 ... He_n , the hyper entropy of each secondary index cloud model; The number of n as secondary indexes; W_1 , W_2 , W_3 … W_n are the weight of each secondary index. Then according to seek out the parameters of the comprehensive to draw the cloud picture of total evaluation cloud, to arrive at the final evaluation results based on cloud pictures.

5. Conclusion

This paper through the analysis of low carbon building system, on the basis of referencing to the existing several mainstream maturity evaluation model ,designed the evaluation factors and index system of low carbon building system maturity model, and applied the cloud model to evaluation of the low carbon building system maturity, making up drawbacks on existing maturity model evaluation method for its strong subjective factor, for the development of low-carbon building system provided a improved direction.

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