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Research on Priority Selection for Green Transformation Projects in Existing Buildings

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Abstract: There were huge stock of existing buildings,most of them were high energy consumption buildings in China.Green transformation in existing buildings was the only way to improve building use function,reduce energy consumption,save resources,and improve the service life of buildings.While quantity of transformation was huge,priority selection of transformation project was necessary in shortage of social resources.The index system was established from fund raising,transformation efficiency,project implementation three aspects.Entropy method was used to determine the index weight,and the model of project priority selection was established based on fuzzy comprehensive evaluation.Finally,the feasibility of the model was verified through the example,and some policy suggestions were put forward.

1 Introduction

There were huge stock of existing buildings in China,Total construction area was more than 50 billion m^2,in which the green building area was only 162.7 million m^2.Due to the limitations of technology condition at that time,the living environment of existing buildings was poor,the resource consumption was serious.,the energy consumption was higher.They had the negative influence on the surrounding environment,could not satisfy the demand of sustainable development[1].However,it was not only a waste of resources,but also the two pollution and destruction to the ecological environment to demolish them.Green transformation in existing buildings could not only reduce the energy consumption and improve the efficiency of operation in existing buildings,but also improve the quality of our work life.It was an important starting point to promoting the city function,saving city space,improving people's livelihood and fulfilling the tasks of energy saving and emission reduction[2-3].Experts and scholars put forward their views and countermeasure from the economic efficiency,the ways of green transformation,the management mechanism,technical strategy and other aspects of green transformation in existing building.Such as,the cost-benefits of green transformation in existing building was analyzed based on the whole life cycle theory,and the suggestions of green transformation were put forward combined with the engineering case in the literature[4].Taking the case SDC2013 Australia,the ways of greening transformation were discussed in the literature[5].The management incentive of green transformation projects in existing buildings was explored in the literature[6].It was summarized analysis that technical and practical experience of green transformation in 2 existing office buildings in the literature[7].

Green transformation of existing buildings mainly experienced three stages:energy conservation transformation stage,comprehensive reform stage,green transformation stage in China[8].During the 12th five-year plan,some policies,regulations and technical specifications had been issued through continuous transformation experience,and the scientific researches of green transformation in existing building had been passed the acceptance on 2 August 2015,which was borne by the Shanghai Branch of China Academy of building research.It indicated the direction for the further work of the green transformation[9].

Due to the huge stock of existing building,green transformation was a long-term task,and the government financial support was limited.Therefore,it was necessary to select the major projects which their transformation potential was huge.The project priority selection can reduce the blindness of the transformation work,promote the rational allocation of social resources and improve the success rate of transformation,in order to obtain the maximum benefit.The index system of green transformation project selection was established from the project funds raising,transformation efficiency,project implementation three aspects.The index weight was calculated by the entropy weight method,the optimal model based on fuzzy comprehensive evaluation was constructed.Finally the validity of the model was illustrate by an example.

2 Establish evaluation index system

2.1Principle of establishing index system

Establishing a scientific index system is the premise of evaluation and prediction,and it will affect the objectivity and correctness of the evaluation results.In order to evaluate green transformation projects in existing building,the index must be able to reflect the transformation of the projects directly.The establishment of index system follows the following principles:

1) Science and Comparability

The selection of indicators should follow the principle of science,the indicators should have a clear meaning with a certain scientific connotation.The evaluation indexes of different projects are comparable,the boundary is clear,and the project is easy to be compared.

2) Systematic and Independence

As a complex system,the index system should cover all aspects of the system to form a multi-level and multi-factor index system.There should be a small correlation between indicators,so as to avoid multiple indicators reflect the same problem,which is not conducive to the evaluation of objectivity,but also affect the objectivity of the evaluation results.

3) Objectivity and Feasibility

Indicators can reflect the actual situation of the project itself,as well as the development trend of the project in the future.And the establishment of the index system can provide reference for similar decision-making,with practical feasibility,in order to facilitate the promotion of the use.

2.2Establishment of index system

According to the principle of index selection,reference to *The civil building energy consumption standards for data collection*,*The existing building renovation green evaluation criteria* fully,as well as foreign evaluation system:*LEED(Leadership in energy and environmental design)*,*BREEA(Building Research Establishment Environmental Assessment Method)*,*CASBEE(comprehensive assessment system for building environmental efficiency)*,the transformation project potential was assessment from Fund raising,Transformation efficiency, project implementation.The establishment of the index system was shown in table 1:

Table 1.the evaluation index system of existing building green transformation

Attribute layer	Index layer	Evaluation factor
Fund raising U_1	Government investmentU_{11}	Proportion of government investment
	Owner investmentU_{12}	Proportion of owner's investment
	Resident investmentU_{13}	Proportion of residents' investment
Transformation efficiency U_2	Safety performance of building structureU_{21}	Structural safety inspection of buildings
	Residual service life of buildingU_{22}	Building surplus service life
	Energy consumption per unit areaU_{23}	Energy consumption per unit of building area
	Resource utilization statusU_{24}	The degree of improvement of resource utilization after construction
	Harmony with the surrounding environmentU_{25}	Adaptability of building and surrounding environment
Project implementationU_3	Transformation of the required fundsU_{31}	Total investment required for building renovation
	Project construction periodU_{32}	The time required for building renovation
	Project operation managementU_{33}	Resources investment in operation management after construction
	Influence of construction on surrounding environmentU_{34}	Influence degree of reconstruction and removal,strengthening and installation on the surrounding environment
	Transformation intentionU_{35}	Number of residents with the intention to transform

3 Construction of project priority selection model based on entropy weight method and fuzzy comprehensive evaluation method

3.1 Entropy weight method

Entropy was derived from the thermodynamics of physics,which describes the transfer of energy.Later,information theory was introduced to reflect the measurement of uncertain information.In recent years,entropy theory has been widely used in engineering field as an objective weighting method[10].The principle of entropy weight method is in index observation data difference,the greater the entropy value is smaller,the greater the weight of the index,says the greater the influence of index of the system.The calculation process is as follows:

The evaluated object is *m*,and the evaluated index is *n*,and the initial decision is obtained:

$$R=(r_{ij})_{m\times n}, i=1,2,\cdots m, j=1,2,\cdots n$$

1）The calculation of entropy of indexes：

$$H_j=-P\sum_{i=1}^{m} r_{ij}\ln r_{ij}, P=1/\ln m \quad (1)$$

2)The calculation of weights of indexes：

$$w_j=(\ln n-H_j)/\sum_{j=1}^{n}(\ln n-H_j) \quad (2)$$

3.2 Fuzzy comprehensive evaluation method

Fuzzy mathematics was proposed by Zadeh in 1965,which is used to study the fuzziness and uncertainty of the boundary of the object.Fuzzy mathematics is the theoretical basis of fuzzy comprehensive evaluation,which can overcome the fuzziness and subjectivity of evaluation results to a certain extent.Its calculation procedure is as follows:

1）The evaluated object is *m*,the evaluated index is *n*,and the index set *U* and the evaluation set *V* were set up：

$$U=(u_1,u_2,\cdots,u_n); V=(v_1,v_2,\cdots,v_m)$$

2）Establishing a comprehensive evaluation matrix *R*：

$$R=(r_{ij})_{m\times n}$$

r_{ij} is the membership degree of the evaluation scheme v_{ij} on the index u_{ij}.

3）Set the weight vector $W=(w_1,w_2,\cdots,w_j)$,and undertake fuzzy operation：

$$B=W\circ R=(w_1,w_2,\cdots,w_n)\circ(r_{ij})_{m\times n}=(B_1,B_2,\cdots,B_m)$$

4）The result of fuzzy comprehensive evaluation of the *i* evaluation object is obtained.：

$B_i = (b_{i1}, b_{i2}, \cdots b_{ik})$,*k* is the number of reviews， The membership degree of the *ith* evaluation object in *kth* reviews.

3.3 Optimal model based on entropy weight method and fuzzy comprehensive evaluation method

Assuming that the evaluated project is *m*,the evaluated index is *n*,the calculation steps of the optimal model are as follows based on the entropy weight method and fuzzy comprehensive evaluation method:

1）Establishing evaluation matrix and the comment set:：

$U_{ij} = (u_{11}, u_{22}, \cdots, u_{ij})$， u_{ij} is the *ith* project in the evaluation value of the *jth* index;

$V = \{v_1, v_2, v_3, v_4, v_5\} = \{very\ good, good, general, poor, very\ poor\}$,Its rating criteria are shown in table 2:

Table 2.index score standard

Evaluation level	***very good***	***good***	***general***	***poor***	***very poor***
Scoring criteria	100—90	89—80	79—70	69—60	59—50

2）Quantification of index:The indexes value is obtained by way of questionnaire survey.The questionnaire is issued from the government,research institutes,construction units and other related fields of experts,to obtain the index score for statistical analysis,the value of the evaluation index is the average value of the expert rating.

3）Standardization of indicators:

$$r_{ij} = (u_{ij} - \min_i u_{ij}) / (\max_i u_{ij} - \min_i u_{ij}), i = 1, 2, \cdots m; j = 1, 2, \cdots, n \quad (3)$$

The standardization of the index is obtained by means of formula(3),.: $R = (r_{ij})_{m \times n}$.

4）The weight of index is calculated by entropy weight method,and the weight vector is obtained: $W = (w_1, w_2, \cdots, w_j)$.

5）Constructing fuzzy evaluation matrix:the fuzzy subset of the *jth* index in the evaluation set V was calculated by Fuzzy statistical method:

$$\tilde{r}_{ij}(v_k) = \frac{\text{Number of experts on } kth \text{ comment}}{\text{Total number of experts}} \quad (4)$$

6）The fuzzy subset of the comprehensive evaluation is calculated:

$$B_i = W \circ \tilde{R}_i = \{b_{i1}, b_{i2}, b_{i3}, b_{i4}, b_{i5}\} \quad (5)$$

Fuzzy operator $\circ$ use $M(\cdot,+)$ modern,The characteristic is that the influence of all indexes is considered,the matrix operation is as follows:

$$b_{ik} = \sum_{j=1}^{k} w_j \tilde{r}_{ij}(v_k), k = 1, 2, 3, 4, 5 \quad (6)$$

B_i is normalized: $\hat{b}_{ik} = b_{ik} / \sum_{k=1}^{5} b_{ik}, k = 1, 2, 3, 4, 5$ (7)

7）Sort of evaluation results:

① Ranking according to the maximum membership degree:The evaluation results of the project are based on the comment of the maximum membership degree.It is applicable to the evaluation of a single project.

② Ranking according to the optimal membership degree:The projects were sort the optimal membership degree,when the optimal evaluation value is the same,the membership degree of the sub optimal evaluation is sorted,and so on.

③ Ranking according to the comprehensive score:A *Score set* is set: $C = (c_1, c_2, \ldots c_k)$,*k is number of comments.So the score of the evaluated projects：* $A_i = B_i C_k^T$.

4 Instance verification

According to statistics,The stock of existing building to be transformed was huge in Qingdao,about 30 million m^2.Especially in the Laoshan area,Shinan area,many buildings were built in 1980s.They did not take the outside wall heat preservation measures.After years of wind and rain,they have a" Hot in Summer and Cold in Winter"situation,their energy consumption was relatively high,and the utilization of resources situation was not ideal.Therefore,this paper selected six projects in Qingdao as the research object.100 questionnaires were distributed to the Qingdao urban and Rural Construction Committee,research institutes,construction units and other relevant experts,78 were recovered.Statistical computation was carried out.the calculation steps of the optimal model were as follows based on the entropy weight method and fuzzy comprehensive evaluation method:

1）The results of the standardization of the index values were shown in Table3 by the formula(3):

Table 3. Evaluation index value standardization results of green transformation project in existing building

Evaluating indicator		P_1	P_2	P_3	P_4	P_5	P_6
Fund raising	Government investment	0.400	0.300	0	0.500	1.000	0.300
	Owner investment	0.667	0.83	1.000	0.500	0	0.800
	Resident investment	0.167	0.467	0.767	0.200	1.000	0
Transformation efficiency	Safety performance of building structure	0.444	0.222	0.778	0	0.557	1.000
	Residual service life of building	0	0.400	0.700	1.000	0.600	0.200
	Energy consumption per unit area	0.769	0.615	1.000	0	0.539	0.077
	Resource utilization status	1.000	0.579	0	0.632	0.842	0.211
	Harmony with the surrounding environment	0.316	1.000	0.263	0.632	0	0.842
Project implementation	Transformation of the required funds	0	0.200	0.600	0.880	0.280	1.000
	Project construction period	0.125	0.250	0.719	0.875	1.000	0
	Project operation management	0.600	0.800	1.000	0.400	0.650	0
	Influence of	0.226	0	0.950	1.000	0.325	0.250

	construction on surrounding environment					
	Transformation intention	0	0.9268	1.000	0.025	0.195	0.220

2）Entropy and Weights were calculated by the formula(1),(2):

$$H = \begin{bmatrix} 0.9996 & 0.9942 & 0.9942 & 0.9996 & 0.9994 & 0.9990 & 0.9979 \\ 0.9981 & 0.9958 & 0.9915 & 0.9973 & 0.9874 & 0.9836 & \end{bmatrix};$$

$$W = \begin{bmatrix} 0.0057 & 0.0926 & 0.0927 & 0.0072 & 0.0099 & 0.0157 & 0.0342 \\ 0.0300 & 0.0668 & 0.1363 & 0.0425 & 0.2027 & 0.2636 & \end{bmatrix}.$$

3）Taking project 1 as an example,the fuzzy evaluation matrix was determined by the formula(4):

$$\tilde{R} = \begin{Bmatrix} 0.7 & 0.2 & 0.1 & 0 & 0 \\ 0.3 & 0.3 & 0.2 & 0.2 & 0 \\ 0.2 & 0.3 & 0.5 & 0 & 0 \\ 0.1 & 0.2 & 0.3 & 0.3 & 0.1 \\ 0.2 & 0.1 & 0.4 & 0.2 & 0.1 \\ 0.3 & 0.3 & 0.3 & 0.1 & 0 \\ 0.3 & 0.4 & 0.3 & 0 & 0 \\ 0.4 & 0.2 & 0.4 & 0 & 0 \\ 0.5 & 0.1 & 0.3 & 0.1 & 0 \\ 0.2 & 0.4 & 0.4 & 0 & 0 \\ 0.4 & 0.4 & 0.1 & 0.1 & 0 \\ 0.3 & 0.3 & 0.2 & 0.1 & 0.1 \\ 0.1 & 0.5 & 0.3 & 0.1 & 0 \end{Bmatrix}$$

In the same way,other items can be obtained by the fuzzy evaluation matrix.

4）The evaluation results were calculated by the formula(5),(6),(7):

$$B_1 = \begin{bmatrix} 0.2448 & 0.3544 & 0.2970 & 0.0818 & 0.0220 \end{bmatrix}$$

In the same way: $B_2 = \begin{bmatrix} 0.2726 & 0.2359 & 0.2857 & 0.1952 & 0.0106 \end{bmatrix}$;

$$B_3 = \begin{bmatrix} 0.2143 & 0.3357 & 0.1713 & 0.1912 & 0.0875 \end{bmatrix};$$

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$B_4 = [0.2004 \quad 0.3350 \quad 0.3608 \quad 0.0875 \quad 0.0163]$;

$B_5 = [0.3584 \quad 0.4248 \quad 0.1429 \quad 0.0501 \quad 0.0238]$;

$B_6 = [0.4478 \quad 0..2068 \quad 0.1494 \quad 0.1798 \quad 0.0162]$.

5）Ranking of evaluation results:

① According to the principle of maximum membership,the P_6 belong to the"*very good*"level,the P_1,P_3,P_5 for the"*better*"rating,P_2,P_4 for the"*general*"level.

② Ranking according to the optimal membership degree: P_6 f P_5 f P_2 f P_1 f P_3 f P_4.

③ Set *Score Set*: $\{very\ good, good, general, poor, very\ poor\} = \{90, 80, 60, 70, 50\}$

The overall scores of the projects were: 77.182, 75.647, 73.900, 76.157, 80.439, 78.902.

5 conclusions and recommendations

1)In this paper,the index system of project evaluation was constructed,the project priority selection model was established,and the feasibility of the model was verified by an example.It laid the theoretical foundation for the transformation ideas that the transformation work was integrated to promote from easy to difficult,from whole to casual,and it also provided a theoretical basis for the next step of transformation work.

2)In the calculation results,the weight of the two indexes which were *Influence of construction on surrounding environment and Transformation intention* was relatively was high.Therefore,it was the focal point of the transformation work how to reduce the influence of transformation construction on the surrounding environment;on the other hand,we should strengthen the propaganda,raising public awareness of energy conservation,thereby enhancing the transformation of willingness to support green transformation in existing buildings.

3)The index value was concerned about the contrast before and after the transformation,that was to say,the degree of improvement before and after the transformation.It did not be considered whether the architecture meets the green building standards after transforming.

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