Risk Evaluation about Green Building Engineering Development Projects Based on AHP-MF Model

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Received 21 October 2014, www.cmnt.lv

Abstract

To construct a risk assessment model which is appropriate for green building engineering development projects and provide scientific basis for project decisions and risk judgment, quantitative evaluation on risk indexes of green building project development are obtained based on AHP-MF model algorithm and in combination with example analysis. According to cycle and process of project development, risk factors affecting project objectives are divided into four primary indexes including risk at the decision-making stage, risk at the preparatory stage, risk at the implementation stage and risk at the rental, sales and operational stage. Besides, risk rating of indexes at each level of indexes is analyzed further, by which value of risk evaluation on each risk factor is obtained quantitatively. On the basis of example analysis, good effect is got.

Keywords: AHP-MF model, Green building project, Risk identification, Risk index

1 Introduction

In order to carry out risk evaluation on a project, we need build this on the basis that contract risk is identified sufficiently, analyze risk factors according to the process of and causes for risk generation and then construct assessment index system about risk [1]. In accordance with degree of risk influence, set up an evaluation model, calculate all indexes in the model and obtain comprehensive evaluation results [2]. AHP-MF model is a mathematical model that combines analytic hierarchy process (AHP) and fuzzy mathematical method, which has been widely applied to risk evaluation [3]. The basic principle of AHP is that it treats a complicated problem as a system, converts all factors of the complicated problem into methodic and orderly levels according to member relationship among factors inside the system, uses all factors on the same level to construct a judgment matrix by regarding factors on the upper level as criterion, carries out pairwise judgment and comparison and computes weight of each factor [4]. In accordance with comprehensive weight, decide an optimal scheme based on maximum weight principle and then obtain quantitative description about relative importance of schemes or objectives [5]. Fuzzy comprehensive evaluation method is a comprehensive evaluation approach on the basis of fuzzy mathematics, which converts qualitative evaluation into quantitative evaluation in accordance with membership theory of fuzzy mathematics, i.e., building subordinating degree function and fuzzy membership matrix to evaluate advantages and disadvantages of tested events comprehensively [6]. It is featured by clear results and strong systematicness and can solve problems that are fuzzy and cannot be quantized easily well, so it is appropriate for solving problems about uncertainty.

Building is one of the ways in which people affect and reform nature, while construction industry is an industry that consumes many natural resources and has obvious and prominent negative impacts on environment [7]. According to statistical analysis, people consume more than half the total substance and raw materials obtained from nature when they build various buildings and their accessory equipment; meanwhile, atmospheric contamination, noise pollution, light pollution and water pollution related to construction account for 34% of total environmental pollution and construction waste which equals to 40% of total rubbish caused by human activities is generated [8-9]. To reduce resource consumption, realize objectives of environmental protection and harmonious development with environment and have demonstrative effect on urban construction, a number of countries and regions in the world have developed their own green building evaluation system successively. Green buildings utilize the most novel design philosophy, the most advanced energy-saving and water-saving technique, the latest construction technology and the most environmental building materials for construction [10]. Currently, all countries treat developing green buildings as the only road to sustainable development of buildings [11]. Nowadays, the construction industry is staying at a stage of rapid development. Under the new situation that we construct a harmonious and conservation-minded society, green buildings are a revolution in the process of urbanization undoubtedly and will have significant impacts on reform of people's living concept, industrial development, management and technological updating [12]. Therefore, developing green buildings is a development direction for the construction industry in future. Since development of green buildings still stays at an initial stage, it is a new challenge for constructional subjects to contract to build green buildings. Challenges imply possibility of high income but indicate high risk to a larger extent.

In recent years, AHP –MF model has been widely applied to all kinds of risk assessment model, while research

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on risk evaluation about green building engineering development projects is not common. This research will construct a risk evaluation model that is suitable for green building engineering development projects based on theory and methods of AHP –MF model and provide scientific basis for project decisions and risk judgment.

2 Main risk factors of green building engineering projects

By consulting traditional ways used to analyze risk of engineering projects, it is found that green buildings emphasize risk factors may have negative effect on green building projects. From the perspective of green building project developers, workflow of development is used to classify risk factors into four parts including risk at the decision-making stage, risk at the preparatory stage, risk at the implementation stage and risk at the rental, sales and operational stage according to life cycle of projects.

(1) Risk at the decision-making stage
As the decision-making stage is a phase where there is maximum uncertain factor and the highest risk in green building project development, decision schemes directly relate to implementation of work at each stage of a project in future and may affect success or failure of green building project development largely.

(2) Risk at the preparatory stage
At the beginning of a project, it is necessary to build a project organization and management institution to organize and manage the whole project and arrange appropriate managers and their management teams. Besides, w need consider losses caused by unreasonable preparation for the project.

(3) Risk at the construction stage
When the project is being built, we usually need face with various specific problems, such as material and equipment purchasing, green construction, project delay and design change etc. Thus, green building project management need consider losses caused by various events during the construction period of the project.

(4) Risk at the rental, sales and operational stage
Except a small part of building projects developed by developers is used by themselves, most of industries are used to obtain return on investment via selling or renting. At the rental, sales and operational stage, it is essential to consider risk in the aspects of marketing, contract and real estate.

3 Evaluation steps of a risk model about green building projects

(1) In accordance with nature of problems and total objectives that should be satisfied, problems are decomposed into different factors which are assembled and combined according to different levels based on correlative influence and membership among factors. A multi-level risk evaluation index system is formed, as shown in Formula 1.

$$U = \{u_1, u_2, u_3, ..., u_n\} \quad (1)$$

Where n is the number of projects.

(2) Establish risk grade evaluation criterion. According to grade of risk factors, build evaluation criterion to obtain corresponding evaluation sets. Establishment about risk grade evaluation criterion is shown in Table 1.

TABLE 1 Risk grade evaluation criterion

Risk grade	**1**	**2**	**3**	**4**	**5**
Risk level	Low risk	Lower risk	Medium risk	Higher risk	High risk
Risk grade	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0
Assignment	1	2	3	4	5

(3) Decide weight vector. In accordance with experts' evaluation and marking, construct $A = (a_{ij})_{n\times n}$ a judgment matrix about risk evaluation, introduce Matlab software, calculate proper value of the judgment matrix and its corresponding feature vector and implement normalization processing for the matrix finally. The processing procedure is shown as follows:

$$b_{ij} = \frac{a_{ij}}{\sum a_{ij}} \quad (i, j = 1, 2, 3, ..., n) \quad (2)$$

Carry out summation according to lines. Then, we may get

$$v_i = \sum_j^i b_{ij} \quad (i, j = 1, 2, 3, ..., n) \quad (3)$$

Implement normalization. Then, we may obtain

$$w_i = \frac{v_i}{\sum v_i} \quad (i = 1, 2, 3, ..., n) \quad (4)$$

Where w_i is an approximate value of the feature vector, i.e., rating about relative importance of risk factor? Finally, implement single hierarchical arrangement, its consistency check and consistency check on total hierarchical arrangement.

(4) Establish fuzzy evaluation matrix. In another word, evaluate all risk factors in the index set and establish fuzzy mapping, i.e., $U \to V$. For different index systems, different evaluation grades can be established. According to the evaluation grade given by experts to each level and each factor, implement statistics about fuzzy evaluation vectors of the evaluated object's each factor.

(5) Multi-factor comprehensive assessment.

$$B = W * R = (w_1, w_2, ..., w_n) \cdot \begin{bmatrix} r_{11} & r_{11} & \cdots & r_{11} \\ r_{11} & r_{11} & \cdots & r_{11} \\ \cdots & \cdots & \cdots & \\ r_{11} & r_{11} & \cdots & r_{11} \end{bmatrix} \quad (5)$$

At last, the final risk evaluation value is:

$$E = B \times V^T \quad (6)$$

4 Examples about engineering application

4.1 PROJECT PROFILE

Project development of a green ecological demonstrative urban district is taken for example to construct project risk index system and implement evaluation calculation. The project is a medium and high-end urban complex project that its developer devotes itself to developing and the first batch of green ecological demonstrative urban district approved by Ministry of Hosing and Urban-Rural Development. Total planning area of the district is about 10 square kilometers, including about 5,600-mu construction land of the project. The planned resident population is about 0.17 million. The planned floor area of the project is about 1,200 square meters (excluding future development land), calculated plot area is about 9 million square meters, plot ratio of the project is 8% and greening rate is 45%. Area of dwelling structure is about 410 square meters, floor area for commercial use is about 460 square meters, floor area for clubs is about 70,000 square meters and floor area of supporting public facilities is about 360,100 square meters. There have been four urban roads and one loop expressway in the project. It is planned to build two new lines along urban main roads and 16 community roads. Floor area of the project is quite large, but it is required that construction cycle should be short and quality should be high. Hence, development and management teams undertake rather heavy construction tasks. Land consolidation starts the first level and civil auxiliary projects of the whole project are undertaken by the developer during implementation of the project. At the same time, road traffic cannot be interdicted and comprehensive improvement in watercourse and water environment should be started simultaneously. Difficulty in coordinating with all tasks is high and mutual construction interference is obvious as well.

4.2 IDENTIFICATION ABOUT RISK FACTORS OF THE PROJECT

Via a flow chart about green building development projects, literature consultancy and consultation about experts' opinions, risks are divided into risk at the decision-making stage, risk at the preparatory stage, risk at the construction stage and risk at the rental, sales and operational stage according to life cycle of green buildings. The risk at the preparatory stage contains political risk, economic risk, funding risk and land risk; the risk at the preparatory stage includes risk related to the project's organizational structure, risk about prospective design, risk about special design of green buildings, risk about bid inviting and contract models and risk related to design identification authentication of green buildings; the risk at the construction stage contains risk about material and equipment purchase, green construction risk, duration risk, development cost risk, quality risk, design change risk and security risk; and the risk at the rental, sales and operational stage involves marketing risk, rental and sales contract risk, property management risk and sign identification risk at the operational stage of green buildings.

4.3 RISK EVALUATION ON THE PROJECT

Based on AHP-MF model algorithm and actual situations of the project, evaluate risk of the project according to the following steps:

(1) Use AHP to establish a judgment matrix and introduce Matlab software to calculate and obtain its maximum feature value and vector. In doing so, decide weight vector of primary indexes. Similarly, weight of secondary indexes can be obtained. Results of weight vector are shown in Table 2.

(2) Establish an evaluation set by using the evaluation criterion about risk grade shown in Table 1, invite some experts to evaluate all risk factors of the green engineering project and calculate the evaluation matrix about all primary indexes by a rating matrix. Experts' rating results are shown in Table 3.

In accordance with experts' rating results, we may obtain a membership matrix about each risk factor. Considering political risk, 30% of people deem it as low risk and 70% of people consider it to be lower risk. Thus, the membership matrix about the risk factor is;

$$A=[0.3, 0.7, 0.0, 0.0, 0.0] \quad (7)$$

TABLE 2 Risk index weight at the implementation stage of the project

Primary index	Primary index weight	Secondary index	Secondary index weight
Risk at the decision-making stage	0.402	Political risk	0.389
		Economic risk	0.252
		Funding risk	0.207
		Land risk	0.152
Risk at the preparatory stage	0.291	Risk related to the project's organizational structure	0.301
		Risk about prospective design	0.263
		Risk related to design identification authentication of green buildings	0.212
		Risk about bid inviting and contract models	0.115
		Risk related to design identification authentication of green buildings	0.109
Risk at the construction stage	0.127	Risk about material and equipment purchase	0.193
		Green construction risk	0.183
		Duration risk	0.173
		Development cost risk	0.114
		Quality risk	0.117
		Design change risk	0.109
		Security risk	0.111
Risk at the rental, sales and operational stage	0.180	Marketing risk	0.373

		Rental and sales contract risk	0.221
		Property management risk	0.118
		Sign identification risk at the operational stage of green building	0.288

TABLE 3 Results of experts' rating

specialist	Risk factors																			
	U11	U12	U13	U14	U21	U22	U23	U24	U25	U31	U32	U33	U34	U35	U36	U37	U41	U42	U43	U44
1	3	2	2	2	2	1	2	1	1	2	2	2	2	2	1	2	2	1	3	2
2	2	3	2	2	2	1	2	3	1	2	3	2	2	2	2	1	2	1	2	3
3	3	2	2	3	1	2	1	2	3	2	1	2	2	2	2	2	2	1	2	2
4	2	2	1	2	3	2	2	1	1	1	2	2	2	2	2	2	1	2	2	2
5	3	2	1	2	2	1	1	2	2	2	2	2	2	2	2	2	1	1	2	2
6	3	2	1	1	1	2	2	2	1	2	3	2	2	2	1	2	1	2	1	2
7	2	1	2	2	2	2	2	1	1	2	2	1	2	2	2	2	2	1	2	2
8	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	2	1	2	2
9	2	1	2	1	2	2	1	1	1	2	2	2	2	2	2	1	2	2	2	1
10	2	2	2	1	3	3	2	2	2	2	1	2	3	2	1	1	2	1	1	2

(3) For U_{1-4} an evaluation index at the criterion level, its corresponding membership matrix is shown as follows, respectively.

$$R_1 = \begin{pmatrix} r_{11} \\ r_{12} \\ r_{13} \\ r_{14} \end{pmatrix} = \begin{pmatrix} 0.3 & 0.7 & 0 & 0 & 0 \\ 0.3 & 0.7 & 0 & 0 & 0 \\ 0.4 & 0.6 & 0 & 0 & 0 \\ 0 & 0.2 & 0.8 & 0 & 0 \end{pmatrix} \quad (8)$$

$$R_2 = \begin{pmatrix} r_{21} \\ r_{22} \\ r_{23} \\ r_{24} \\ r_{25} \end{pmatrix} = \begin{pmatrix} 0.4 & 0.6 & 0 & 0 & 0 \\ 0.3 & 0.7 & 0 & 0 & 0 \\ 0 & 0.3 & 0.7 & 0 & 0 \\ 0.2 & 0.8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.7 & 0.3 \end{pmatrix} \quad (9)$$

$$R_3 = \begin{pmatrix} r_{31} \\ r_{32} \\ r_{33} \\ r_{34} \\ r_{35} \\ r_{36} \\ r_{37} \end{pmatrix} = \begin{pmatrix} 0 & 0.6 & 0.4 & 0 & 0 \\ 0.7 & 0.3 & 0 & 0 & 0 \\ 0.3 & 0.7 & 0 & 0 & 0 \\ 0.2 & 0.8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0.2 & 0.8 & 0 & 0 & 0 \\ 0.3 & 0.7 & 0 & 0 & 0 \end{pmatrix} \quad (10)$$

$$R_4 = \begin{pmatrix} r_{41} \\ r_{42} \\ r_{43} \\ r_{44} \end{pmatrix} = \begin{pmatrix} 0.7 & 0.3 & 0 & 0 & 0 \\ 0 & 0.2 & 0.8 & 0 & 0 \\ 0.2 & 0.8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.8 & 0.2 \end{pmatrix} \quad (11)$$

(4) According to Formula 5 and Formulas 8-11, we may know evaluation results of evaluation indexes at the criterion level are shown as follows, respectively.

$$B_1 = W_1 * R_1 = (0.359 \quad 0.282 \quad 0.207 \quad 0.152)$$

$$B_2 = W_2 * R_2 = (0.331 \quad 0.233 \quad 0.243 \quad 0.115 \quad 0.109)$$

$$B_3 = W_3 * R_3 = (0.243 \quad 0.183 \quad 0.223 \quad 0.114 \quad 0.117 \quad 0.109 \quad 0.111)$$

$$B_4 = W_4 * R_4 = (0.373 \quad 0.221 \quad 0.118 \quad 0.288)$$

(5) In accordance with Formula 6 and Formulas 12-15, results of the project's comprehensive risk evaluation is:

$$B = W * R = W * (B_1 \quad B_2 \quad B_3 \quad B_4)^T$$
$$= (0.489 \quad 0.252 \quad 0.107 \quad 0.152)$$

$$E = B \times V^T = 2.874$$

Similarly, we may know:

$E_1 = B_1 \times V^T = 3.343$, $E_2 = B_2 \times V^T = 3.598$, $E_3 = B_3 \times V^T = 2.432$, $E_4 = B_4 \times V^T = 2.123$.

4.4 ANALYSIS ABOUT RESULTS OF RISK ASSESSMENT OF THE PROJECT

According to the final risk evaluation value obtained by AHP-MF model algorithm, we may draw this conclusion, i.e., total project risk of this green ecological demonstrative urban district stays between lower risk (risk evaluation value is 2) and ordinary risk (risk evaluation value is 3), so it is essential to pay attention to risk control and warning work in the process of project development.

In accordance with the weight matrix about primary evaluation indexes of the project, it is shown that weight proportion occupied by risk at the decision-making stage is large, which indicates that the degree to which risk at the decision-making stage affects risk evaluation on the whole project is the largest and risk at the preparatory stage ranks second. The ratio of the two approaches 70% of total project risks. Risk control of the two stages should be emphasized in the process of project development.

In addition, evaluation value of risk at the decision-making stage and risk at the preparatory stage is 3.343 and 3.598, respectively, which is higher than average risk of the project and stays in the range above ordinary risk. From this perspective, we should pay much attention to risk control of the two stages.

5 Conclusion

Based on AHP-MF model algorithm, this thesis discusses ways to indentify development risk of green building projects and obtain good effect on the basis of example analysis. Research results of this thesis may provide reference for risk management (such as risk avoidance, risk transfer, risk retention and risk diversification) in development of green building projects. In the process of risk evaluation, we may not only obtain risk evaluation grade of the whole project but also analyze risk grade of all indexes at the level of risk criterion further via AHP-MF model algorithm. In doing so, risk evaluation value of each risk criterion can be obtained and visual judgment basis can be provided for risk response.

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