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The Intuitionistic Fuzzy Sets on Evaluation of Risks in Projects of Energy Management Contract

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Abstract

This article describes the mechanism of energy management contract and the status of implementation of energy engineering projects in China's enterprises, takes the energy management contract projects as study object, and analyzes the risks of projects systematically. These risks include policy risk, financial risk, operational risk, efficiency risk and market risk. On this basis, this article discusses the risk evaluation index system of energy management contract project, proposes the analytic hierarchy process (AHP) and intuitionistic fuzzy sets to evaluate the risks of energy management contract project, then puts up with a quantitative method for the energy management contract companies.

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Keywords: energy management contract(EMC); intuitionistic fuzzy sets; risk; comprehensive evaluation; energy engineering

1. Introduction

Since the mid 1970, a new energy-saving mechanism based on the market---- energy management contract, which is short of EMC,is developing in market economy countries gradually. In the early 1990s, China officially introduces energy management contract mechanism. As a new energy mechanism, based on the market mechanism, EMC is important safeguard measures for us to build a resource-conserving society. In the process of implementation of energy-saving projects, customer contracts with energy service companies, then EMCo undertakes all project-related pre-investment and most of the project risks, solving the biggest problem for promoting energy efficiency projects. Although energy management contract has achieved great results, it still faces many problems, especially the project's risks. The risk evaluation of energy management contract projects can help EMCo identify the project risks, reduce the

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loss and increase revenue. As the various indicators of project risk is uncertainty and fuzzy, considering the status of China's economic development and the project risks of energy management contract existing in the process, this article use the intuitionistic fuzzy sets theory to evaluate indicators quantitatively, then analyzes the results of the evaluation.

2. Project risk index system of energy management contract

In China, energy management contract is still in early stage of development, through analysis of the implementation risks of energy management contract project, combining the characteristics of energy management contract, the risk factors of energy management contract projects have been analyzed and summarized. According to the principle of scientific, comparable, systematic and operational, choosing and confirming the representative index can reflect the target essential in an all-round way. The risk factors of energy management contract projects come from all sides, such as policy risk, financial risk, operational risk, efficiency risk, and market risk. Of which, policy risk is resulted from the shortage of laws and regulations and policies and the imperfect of regulations on energy conservation; financial risk is the exchange rate movements, inflation and fluctuations in interest rates during the implementation process of energy management contract project; operational risk is caused by the management, the capacity of staff within the company, project cash flow, quality of work and force majeure; efficiency risk is consisted of the risks of measuring energy saving and energy efficiency to share; market risk is results from the not smooth information, energy price changes and the maturity of technology and equipment, which can increase the transaction costs.

Each risk includes several affecting factors, so this article chooses the following indexes to evaluate the risks of EMC project. The indexes [1-2] are as follows:

Table1 the risk factors index system of energy management contract project

Risk factors index system of energy management contract project	Policy risk (0.04)	Domestic energy policies and decrees(0.7)
		Energy-saving equipment or system of license(0.2)
		Additional taxes or charge(0.1)
	Financial risk (0.08)	Exchange rate fluctuations(0.13)
		Inflation(0.15)
		Interest rate volatility(0.13)
		Energy prices(0.49)
	Operational risk (0.20)	Project management skills(0.25)
		Human resource service company energy reserves(0.25)
		Project cash flow (0.25)
		Quality of work (0.10)
		Project operation and maintenance(0.05)
		Force majeure cause of equipment malfunction(0.10)
	Efficiency risk (0.48)	Energy waste and diagnosis(0.20)
		Design scheme optimization(0.05)
		Expected energy-saving effect can be realized or not(0.12)

		Customer payment risk(0.63)
	Market risk (0.20)	Information (0.10)
		Technology advanced(0.25)
		Main equipment production cost(0.65)

3. Evaluation Method and Model

3.1.Determine the weight of each index according to AHP Method.

Index weight reflects the proportion of the overall evaluation in a quantitative manner. First, solve the issue of indicators comparability between the different types; second, make sure the accuracy and scientificity of the qualitative indicators to quantify; third, avoid duplication among the indicators. Index weights are very difficult to determine, in this article, combining expert survey method with AHP, it can make the result more persuasive. The analytic hierarchy process ,which is short of AHP method, is put forward by TLSaaty , the U.S. operations researcher, in the early 70s of 20th century. It is suitable for the evaluation index system with hierarchical structure and the decision-making problems that are difficult to describe in quantification.

3.2. Evaluation model

3.2.1 Concept of intuitionistic fuzzy sets

Intuitionistic fuzzy sets is proposed by Atanassov, which takes into account the degree of membership, non-membership and hesitancy. It can portray a more delicate ambiguity of the objective world. Therefore, this theory has been widely used.

Definition 1[3]: Set X is a nonempty set, $X=(x_1,x_2,\cdots, x_n)$, $A=\{[x,\mu_A(x),v_A(x)] / x\in X\}$ is called intuitionistic fuzzy sets. $\mu_A(x)$ is membership of x to A, and $v_A(x)$ is non-membership of x to A, where $\mu_A(x) \in [0,1]$, $v_A(x) \in [0,1]$ and $0\leqslant\mu_A(x)+ v_A(x) \leqslant 1$. For every intuitionistic fuzzy sets of X, $\pi_A(x)=1-\mu_A(x)- v_A(x)$ is hesitation or uncertainty of x to A. There is a intuitionistic fuzzy number $\alpha=(\mu_\alpha,v_\alpha)$, where $\mu_\alpha \in [0,1]$, $v_\alpha \in [0,1]$, so $s_\alpha=\mu_\alpha-v_\alpha$ is score function of α, and $h_\alpha=\mu_\alpha+v_\alpha$ is exact function of α.

Definition 2[4]: Supposed $\alpha_1=(\mu_1,v1)$, and $\alpha_2=(\mu_2,v_2)$, score function is $s(\alpha_1)=\mu_1-v_1$ and $s(\alpha_2)=\mu_2-v_2$; exact function is $h(\alpha_1)=\mu_1+v_1$and $h(\alpha_2)=\mu_2+v_2$,so:

（1）If $s(\alpha_1)<s(\alpha_2)$，then $\alpha_1<\alpha_2$;

（2）When $s(\alpha_1)=s(\alpha_2)$,if $h(\alpha_1)=h(\alpha_2)$,then $\alpha_1=\alpha_2$;if $h(\alpha_1)<h(\alpha_2)$,then $\alpha_1<\alpha_2$;if $h(\alpha_1)>h(\alpha_2)$, then $\alpha_1>\alpha_2$.

Definition 3[5-6]:For $\alpha_j=(\mu_j,v_j)$ $(j=1,2,\cdots,n)$,supposed $IFWA: Q^n\to Q$,if

$$\begin{aligned}&\mathrm{IFWA}_\omega(\alpha_1,\alpha_2,\cdots,\alpha_n)\\&=\omega_1\alpha_1\oplus\omega_2\alpha_2\oplus\cdots\oplus\omega_n\alpha_n\\&=\left(1-\prod_{j=1}^{n}\left(1-\mu_j\right)^{\omega_j},\prod_{j=1}^{n}v_j^{\omega_j}\right)\end{aligned}\tag{1}$$

Then $IFWA$ is intuitionistic fuzzy weighted averaging operator. There $\omega=(\omega_1,\omega_2,\cdots,\omega_n)$ is weight

vector of $\alpha_j (j=1,2,\cdots,n)$, where $0 \leqslant \omega_j \leqslant 1$, $\Sigma\omega_j = 1$.

3.2.2 Evaluation steps

For the multi-attribute decision making problems, $X=(x_1,x_2,\cdots,x_n)$ is evaluation object, $U=(U_1,U_2,\cdots,U_m)$ is attribute set, and $\omega=(\omega_1,\omega_2,\cdots,\omega_n)$ is weight vector, where $0 \leqslant \omega_j \leqslant 1$, $\Sigma\omega_j = 1, (j=1,2,\cdots,m)$. $d_{ij}=(\mu_{ij},v_{ij})$ express eigenvalue of xi to U_j.That is to say: μ_{ij} is degree of atisfaction of x_i to U_j, and v_{ij} is degree of non- satisfaction of x_i to U_j.It can be expressed by Table 2.

Table 2 Intuitionistic fuzzy decision matrix

	U_1	U_2	.....	U_m
x_1	(μ_{11}, v_{11})	(μ_{12}, v_{12})	.....	(μ_{1m}, v_{1m})
x_2	(μ_{21}, v_{21})	(μ_{22}, v_{22})	.....	(μ_{2m}, v_{2m})
.....	.....	.....	.....	.....
x_5	(μ_{n1}, v_{n1})	(μ_{n2}, v_{n2})	.....	(μ_{nm}, v_{nm})

The steps are as follows:

Step 1: To obtain weights by using AHP method;

Step 2: The establishment of intuitionistic fuzzy decision matrix. We can make the eigenvalue of x_i to U_j by using intuitionistic fuzzy weighted averaging operators $d_i=IFWA_\omega(d_{i1},d_{i2},\cdots,d_{im})$, then gain the overall values d_i.

Step 3: Calculate the score of d_i by using score function $s_\alpha=\mu_\alpha-v_\alpha$.

Step 4: Based on the score of d_i, we can sort evaluation object. If the score is equaled, then sort evaluation object by using exact function $h_\alpha=\mu_\alpha+v_\alpha$.

4. Empirical Analysis

In this article, based on the evaluation model, we analysis the risks of three energy management contract projects of the EMCo, using the intuitionistic fuzzy sets to evaluate the risks of energy management contract project, and then sort them.

(1) We invite 10 experts and every expert gives a score,then we can gain the weights of every index by using AHP method.

(2) Establish the intuitionistic fuzzy decision matrix.We devide the value of the risk of energy management contract projects into three ranks: strong, medium, and weak. Based on the opinion of experts,we can establish matrix, here table 3.

Table 3 Intuitionistic fuzzy decision matrix

	U_{11}	U_{12}	U_{13}	U_{21}	U_{22}
1	（0.8,0.1）	(0.6,0.3)	(0.1,0.6)	(0.2,0.4)	(0.3,0.3)
2	(0.6,0.2)	(0.5,0.1)	(0.3,0.5)	(0.3,0.6)	(0.5,0.1)
3	（0.5,0.1）	（0.5,0.3）	（0.2,0.6）	（0.2,0.6）	（0.4,0.2）
	U_{23}	U_{24}	U_{31}	U_{32}	U_{33}
1	(0.3,0.2)	(0.4,0.5)	(0.8,0.1)	(0.7,0.1)	(0.5,0.2)
2	(0.6,0.1)	(0.1,0.6)	(0.7,0.1)	(0.8,0.2)	(0.6,0.1)
3	（0.5,0.1）	（0.3,0.6）	（0.5,0.1）	（0.8,0.1）	（0.5,0.1）
	U_{34}	U_{35}	U_{36}	U_{41}	U_{42}
1	(0.2,0.6)	(0.6,0.3)	(0.1,0.3)	(0.5,0.2)	(0.6,0.1)
2	(0.1,0.8)	(0.6,0.3)	(0.2,0.5)	(0.6,0.2)	(0.6,0.1)
3	（0.2,0.6）	（0.5,0.1）	（0.1,0.8）	（0.5,0.2）	（0.7,0.2）
	U_{43}	U_{44}	U_{51}	U_{52}	U_{53}
1	(0.8,0.2)	(0.5,0.5)	(0.4,0.2)	(0.5,0.1)	(0.7,0.1)
2	(0.7,0.1)	(0.4,0.3)	(0.6,0.1)	(0.6,0.2)	(0.6,0.2)
3	（0.6,0.3）	（0.5,0.4）	（0.5,0.2）	（0.5，0.2）	（0.7,0.1）

(3) Make the eigenvalue of x_i to U_j by using intuitionistic fuzzy weighted averaging operator $d_i=IFWA_\omega(d_{i1},d_{i2},\cdots,d_{im})$, then gain the overall values d_i, as follows:

$d_1=IFWA_\omega(d_{11},d_{12},\cdots,d_{120})$= (0.9886,0.0004)

$d_2=IFWA_\omega(d_{21},d_{22},\cdots,d_{220})$= (0.9767,0.0006)

$d_3=IFWA_\omega(d_{31},d_{32},\cdots,d_{320})$= (0.9728,0.0004)

(4) Calculate the score of three projects, that is to say:

$s(d_1)$=0.9886-0.0004=0.9882

$s(d_2)$=0.9767-0.0006=0.9761

$s(d_3)$=0.9728-0.0004=0.9724

According to the above calculation, we sort for the evaluation results of three energy contract management project: here, project 1> project 2> project 3. That is to say the risk of project 1 is the smallest and the effect is the best.

5. Conclusion

As a new energy-saving mechanism, energy management contract provides effective measures for EMCo to realize large-scale energy saving benefits. At present, energy management contract of the project exists many problems in the process of implementing. We study these questions specifically, establish a suitable risk evaluation index system of energy management contract project, and quantitative analysis the risks of energy management contract projects, so that our energy companies can understand and control risk better, and accelerate the process of energy management contract effectively.

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