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ATTITUDE INDEX GROUP DECISION-MAKING METHOD OF PERFORMANCE EVALUATION FOR COAL ENTERPRISES ENERGY CONSERVATION AND REDUCTION OF POLLUTANT EMISSIONS

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ABSTRACT

For the performance evaluation of coal enterprises energy conservation and reduction of pollutant emission, a new attitude index group decision-making method is proposed based on trapezoidal fuzzy numbers. Under the condition in which the information of attributes weights and decision maker weights is entirely, the attitude index is introduced firstly. By solving the fuzzy object programming for the entirely information, the weights of the attitude and decision making matrix are determined. Secondly, the value of group risk attitude is got by integrating the attitude index of the decision makers, and the group comprehensive attribute values of each alternative and the priorities are achieved. At last, the practical example of performance evaluation for coal enterprises energy conservation and reduction of pollutant emission shows the feasibility and effectiveness of the proposed method.

Keywords: *Attitude Index; Trapezoidal Fuzzy Number; Energy Conservation and Reduction of Pollutant Emission*

1. INTRODUCTION

Our economy has rapidly developed since the implement of the reform and opening up policy in 1978. As the third largest economy, our GDP reached 30 trillion RMB in 2008 with an average annual growth rate of 9.88%. Meanwhile, this achievement has also given rise to serious environmental and ecological problems. To protect environment and realize sustainable development, Chinese government has put forward the strategic objective to build a resource-saving and environment-friendly society. Therefore, energy conservation and reduction of pollutant emission becomes an important job among government departments. Before the 2010 Copenhagen conference, Chinese government has also announced its target of reducing CO2 emissions per unit GDP by 40–45% till 2020 with that in 2005 as the base. Under this condition, the policy executor entrepreneur especially coal enterprises receive more concerns gradually for their performance evaluation of energy conservation and reduction of pollutant emission. So, coal enterprises are passive in dealing with energy conservation and reduction of pollutant emission, which is adverse to the management of energy conservation.

At the data weighting and aggregation stage, multi-attribute group decision making (MAGDM) has recently gained much popularity in performance evaluation. MAGDM is a well-established technique that could help decision makers to evaluate existing or potential alternatives with multiple conflict criteria. In the past decades, MAGDM has been continuously studied and successfully applied in many application domains. But all these researches have not considered the decision makers' attitude index in the group. The results of the group decision making are different because the different attitude of decision makers. In this paper, a new attitude index group decision making is proposed based on trapezoidal fuzzy numbers. By this new method, this paper evaluates the performance of coal enterprises energy conservation and reduction of pollutant emission.

2. TRAPEZOIDAL FUZZY NUMBER

Definition 1 Generalized trapezoidal fuzzy

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numbers can be defined a vector $\tilde{A}=(a,b,c,d)$, $-\infty < c \le a \le b \le d < \infty$, and the membership function $\mu_A : R \to [0,1]$ is defined an follows:

$$\mu_A = \begin{cases} (x-a)/(b-a), a \le x \le b \\ 1, \quad b \le x \le c \\ (x-d)/(c-d), c \le x \le d \\ 0, \end{cases} \quad (1)$$

Definition 2 Let $\tilde{A}=(a,b,c,d)$ be a trapezoidal fuzzy number, then the left expected value and the right expected value of the trapezoidal fuzzy is defined by

$$I^L(\tilde{A})=\frac{1}{2}(a+b), \quad I^R(\tilde{A})=\frac{1}{2}(c+d)$$

and the expected value of the trapezoidal fuzzy number is defined by

$$I(\tilde{A})=\frac{1}{2}(I^L(\tilde{A})+I^R(\tilde{A})).$$

Let $X=[x_{ij}]_{mn}$ be the trapezoidal fuzzy number decision matrix:

$$X=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}.$$

For eliminating the difference of the property in dimension and scale, we must normalize the property of the indicators. Now give the standardized formula.

The revenue type standardized formula:

$$x_{ij}=[\frac{\min_i \min_j a_{ij}}{d_{ij}}, \frac{\min_i \min_j b_{ij}}{c_{ij}}, \frac{\min_i \min_j c_{ij}}{b_{ij}} \wedge 1, \frac{\min_i \min_j d_{ij}}{a_{ij}} \wedge 1]$$

The cost type standardized formula:

$$x_{ij}=[\frac{a_{ij}}{\max_i \max_j d_{ij}}, \frac{b_{ij}}{\max_i \max_j c_{ij}}, \frac{c_{ij}}{\max_i \max_j b_{ij}} \wedge 1, \frac{d_{ij}}{\max_i \max_j a_{ij}} \wedge 1]$$

3. ATTITUDE INDEX GROUP DECISION MAKING BASED ON TRAPEZOIDAL FUZZY NUMBER DECISION MATRIX

In a group decision making, there are p decision makers, and the weights of them are $\lambda=\{\lambda_1,\cdots,\lambda_p\}$. Let $X=\{x_1,x_2,\cdots,x_m\}$ be a set of alternatives, and let $C=\{c_1,c_2,\cdots,c_n\}$ be a set of criteria. The weights of criteria are $W=(\omega_1,\cdots,\omega_n)$ satisfying $\sum_{i=1}^{n}\omega_i=1$ and $\omega_i \ge 0$, $i=1,\cdots,n$. The evaluation value of decision maker e_k about criteria c_j on an alternative x_i is represented by the following matrix $X^{(k)}$, where the element of the matrix is trapezoidal fuzzy number $x_{ij}^{(k)}=[a_{ij}^{(k)},b_{ij}^{(k)},c_{ij}^{(k)},d_{ij}^{(k)}]$. In order to facilitate, we let the standardized matrix still be $X^{(k)}$.

Let Θ be a set of mathematical expression in which the formation about weights of the criteria is completed unknown. The set is divided into six types: ①$\omega_i \ge \omega_j$; ②$\omega_i - \omega_j \ge \alpha_i$; ③$\omega_i \ge \beta_i\omega_j$; ④$\gamma_i \le \omega_i \le \gamma_i + \varepsilon_i$; ⑤$\theta_i\omega_j \le (\theta_i+\varepsilon_i)\omega_j$ or $\theta_i \le \omega_i/\omega_j \le (\theta_i+\varepsilon_i)$, $\omega_j \ne 0$; ⑥$\omega_i - \omega_j \ge \omega_k - \omega_l$, $i \ne j \ne k \ne l$, where $\alpha_i,\beta_i,\varepsilon_i,\theta_i,\gamma_i$ is non-negative.

3.1 Attitude Index Of Trapezoidal Fuzzy Number

Definition 3 Let $\tilde{A}=(a,b,c,d)$ be a trapezoidal fuzzy number, we denote

$$I^L(\tilde{A})=\frac{1}{2}(a+b), \quad I^R(\tilde{A})=\frac{1}{2}(c+d)$$

$$I(\tilde{A})=\frac{1}{2}(I^L(\tilde{A})+I^R(\tilde{A})),$$

$$D(\tilde{A})=\frac{1}{2}(I^R(\tilde{A})-I^L(\tilde{A})).$$

Definite the function on [0,1] as the following:

$$F_{\tilde{A}}(\alpha):[0,1]\to(a,b,c,d),$$

$$F_{\tilde{A}}(\alpha)=I(\tilde{A})+(2\alpha-1)D(\tilde{A}).$$

So call α as the trapezoidal fuzzy number attitude index of the decision maker. Obviously $F_{\tilde{A}}(\alpha)$ is a increasing function on [0,1] and

(1) If $\alpha=0$, then $F_\alpha(\alpha)=I(\tilde{A})-D(\tilde{A})$ $=\frac{1}{2}(I^L(\tilde{A})+I^R(\tilde{A}))-\frac{1}{2}(I^R(\tilde{A})-I^L(\tilde{A}))= I^L(\tilde{A})$.
It indicates the decision makers have pessimistic attitude;

(2) If $\alpha=1$, then $F_\alpha(\alpha)=I(\tilde{A})+D(\tilde{A})$ $=\frac{1}{2}(I^L(\tilde{A})+I^R(\tilde{A}))+\frac{1}{2}(I^R(\tilde{A})-I^L(\tilde{A}))= I^R(\tilde{A})$.
It indicates the decision makers have optimistic attitude;

(3)If $\alpha=0.5$, then $F_\alpha(\alpha)=I(\tilde{A})$. It indicates the decision makers have moderate attitude.

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Suppose $\alpha_k, \alpha_k \in [0,1]$ is the attitude index of the decision maker e_k, the trapezoidal fuzzy number matrix $X^{(k)}$ is transformed into the decision making matrix with attitude index

$$F^{(k)}(\alpha_k) = (f_{ij}^{(k)}(\alpha_k))_{mn}$$

where $f_{ij}^{(k)}(\alpha_k) = I(x_{ij}^{(k)}) + (2\alpha_k - 1)D(x_{ij}^{(k)})$

$$= [\frac{a_{ij}^{(k)} + b_{ij}^{(k)} + c_{ij}^{(k)} + d_{ij}^{(k)}}{4}] + (2\alpha_k - 1)$$
$$[\frac{c_{ij}^{(k)} + d_{ij}^{(k)} - a_{ij}^{(k)} - b_{ij}^{(k)}}{4}].$$

$f_{ij}^{(k)}(\alpha_k)$ is considered as value of the objective preferences. The value $v_i^{(k)} = [w_i^{(k)}, x_i^{(k)}, y_i^{(k)}, z_i^{(k)}]$ of the subjective preferences also is transformed into the value with attitude index

$$v_i^{(k)}(\alpha_k) = [\frac{w_i^{(k)} + x_i^{(k)} + y_i^{(k)} + z_i^{(k)}}{4}]$$
$$+(2\alpha_k - 1)[\frac{y_i^{(k)} + z_i^{(k)} - w_i^{(k)} - x_i^{(k)}}{4}].$$

3.2 Integration Of Individual Alternative And Solution Of Criteria Weights

Due to the restriction of various conditions, there are some deviations between the objective and subjective preferences. The absolute deviation between the objective and subjective preferences is expressed as $\sigma_{ij}^{(k)}(\alpha_k) = \left| f_{ij}^{(k)}(\alpha_k) - v_i^{(k)}(\alpha_k) \right|$. So for the decision maker e_k, the deviation between the alternative x_i and subjective preference is expressed as $\sum_{i=1}^{m}\sum_{j=1}^{n}\sigma_{ij}^{(k)}(\alpha_k)\omega_j^{(k)}$. Establish optimiza-tion model of the minimum deviation between the objective and subjective preferences, by which the weights of the criteria are solved:

$$\min \sum_{i=1}^{m}\sum_{j=1}^{n}\sigma_{ij}^{(k)}(\alpha_k)\omega_j^{(k)}$$
$$s.t.\begin{cases} W^{(k)} \in \Theta, \\ \sum_{j=1}^{n}\omega_j^{(k)} = 1, \\ \omega_j^{(k)} \ge 0, \end{cases} \quad (2)$$

3.3 Integration Of Group Alternative And Solution Of Decision Makers' Weights

Definite $Z(x_i) = \sum_{i=1}^{p}\lambda_i\sum_{i=1}^{m}\sum_{j=1}^{n} f_{ij}^{(k)}(\alpha_k)\omega_j^{(k)}$, so we know $Z(x_i)$ is a trapezoidal fuzzy number. The solution of decision makers' weights by the following model:

$$\max Z(x_i) = \sum_{i=1}^{p}\lambda_i\sum_{i=1}^{m}\sum_{j=1}^{n} f_{ij}^{(k)}(\alpha_k)\omega_j^{(k)}$$
$$s.t.\begin{cases} \lambda \in \Theta, \\ \sum_{i=1}^{p}\lambda_i = 1, \\ \lambda_i \ge 0, \end{cases} \quad (3)$$

3.4 Integration Of Group Risk Attitude And Order Method

Each decision maker has an attitude index and a corresponding weight, so the risk attitude value of the group is $\eta = \sum_{k=1}^{p}\lambda_k\alpha_k$ .Because the information of the decision maker' weight is uncertain, so the risk attitude value of the group may not be only one. But we can get an optimal value λ of the decision maker' weight by the model (3). And then we can solve the risk attitude value of the group η by $\eta = \sum_{k=1}^{p}\lambda_k\alpha_k$. Integrate $Z(x_i)$ and the risk attitude value of the group using the following method:

$$F_\eta(Z(x_i)) = I(Z(x_i)) + (2\eta - 1)D(Z(x_i))$$

According the order from small to large, we get the whole order of the alternative.

4. NUMBERICAL EXAMPLES FOR EVALUATION OF COAL ENTERPRISE ENERGY CONSERVATION AND REDUC-TION OF POLLUTANT EMISSION

Select 3 coal enterprises of Yanzhou City, Shandong Province as evaluation objects, and use sample survey approach to evaluate the performance of energy conservation and reduction of pollutant emission. We invite two experts to evaluate them from three criteria: resource output c_1, resource consumption c_2, pollution emission c_3. The standard evaluation is seen table 1 and table 2.

The information about the weight is the following:

$H_1 = \{0.15 \le c_1 \le 0.3, 0.2 \le c_2 \le 0.4, 0.16 \le c_3 \le 0.35\}$

$H_2 = \{0.1 \le c_1 \le 0.35, 0.1 \le c_2 \le 0.4, 0.4 \le c_3 \le 0.45\}$.

The weights of the decision makers are $\{\lambda_1 \le \lambda_2, 0.3 \le \lambda_2 \le 0.58\}$.

The attitude indexes of the two experts are $\alpha_1 = 0.4, \alpha_2 = 0.7$, and the subjective preference

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value are (0.5,0.6,0.6,0.7), (0.5,0.6,0.6,0.7), (0.5,0.6,0.6,0.7).

(1)Integration of individual alternative and solution of criteria weights

Using the model (2), we solve the criteria's weights:

$$\omega^1 = \{0.3, 0.35, 0.35\},$$

$$\omega^2 = \{0.15, 0.4, 0.45\}.$$

For the expert e_1, the integration of the alternative is

Table 1 : The Evaluation Of E_1

	c_1	c_2	c_3
A	(0.6,0.78, 0.78,1)	(0.6,0.78, 0.78,1)	(0.4,0.56, 0.56,075)
B	(0.6,0.78, 0.78,1)	(0.6,0.78, 0.78,1)	(0.6,0.78, 0.78,1)
C	(0.6,0.78, 0.78,1)	(0.8,1, 1,1)	(0.6,0.78, 0.78,1)

Table 2 : The Evaluation Of E_2

	c_1	c_2	c_3
A	(0.6,0.78, 0.78,1)	(0.4,0.56, 0.56,075)	(0.2,0.33, 0.33,0.5)
B	(0.8,0.9, 0.9,1)	(0.6,0.78, 0.78,1)	(0.6,0.78, 0.78,1)
C	(0.6,0.78, 0.78,1)	(0.8,1, 1,1)	(0.6,0.78, 0.78,1)

$$A:(0.530, 0.700, 0.700, 0.913),$$
$$B:(0.600, 0.778, 0.778, 1.000),$$
$$C:(0.670, 0.856, 0.856, 1.088).$$

For the expert e_2, the integration of the alternative is

$$A:(0.340, 0.489, 0.489, 0.675),$$
$$B:(0.630, 0.811, 0.811, 1.038),$$
$$C:(0.680, 0.867, 0.867, 1.100).$$

(2)Integration of group alternative and solution of decision makers' weight.

Using the model (3), we solve the experts' weights: $\lambda = (0.42, 0.58)$. Then the group integration is

$$A:(0.420, 0.578, 0.578, 0.775),$$
$$B:(0.617, 0.797, 0.797, 1.022),$$
$$C:(0.676, 0.862, 0.862, 1.095).$$

(3)Integration of group risk attitude and order method.

The risk attitude is $\eta = \lambda_1\alpha_1 + \lambda_2\alpha_2 = 0.42\times0.4$ $+0.58\times0.7 = 0.574$. By the formula, we can get the order of the 3 coal enterprises group: A:1.026, B:1.374, C:1.424, namely $C \succ B \succ A$.

5. CONCLUSION

This paper proposed a new attitude index group decision-making method based on trapezoidal fuzzy numbers. Under the condition in which the information of attributes weights and decision maker weights is entirely, the attitude index is introduced. By solving the fuzzy object programming for the entirely information, the weights of the criteria and decision maker are determined. And the group comprehensive attribute values of each alternative and the priorities are achieved. At last, using the method we evaluated the performance for coal enterprises energy conservation and reduction of pollutant emission.

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