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Research Article

Fuzzy MADM Method for Power Customer Credit Evaluation

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Abstract: Aiming at the power customer credit evaluation problem, a new multi-attribute decision making method based on the relative ratio method is proposed. This method firstly uses the coefficient of variation method to determine the index weight and then calculate comprehensive evaluation value, further rank and select the best credit customer. Finally an application example is given to illustrate the effectiveness and practicability of the proposed method in this study.

Keywords: Coefficient of variation, multi-attribute decision making, power customer credit evaluation, relative ratio method

INTRODUCTION

In recent years, due to some customers to steal the leakage, consumption and leakage electricity of power supply enterprises in China to bad behavior caused a great economic loss, so the customer credit evaluation of the electric power industry not only relates to the healthy development of the electric power enterprise and is related to the orderly development of market economy and cause the power supply industry and even the whole society attention (Zhou *et al*., 2005). About customer credit evaluation of the electric power industry has attracted the attention of many scholars and research. For the customer credit evaluation of the electric power industry, many method are developed, such as Gray Relation Analysis (GRA) (Niu and Xu, 2007), matter-element analysis (Zhou *et al*., 2009a), catastrophe progression method (Zhou *et al*., 2009b), Support Vector Machine (SVM) (Ren and Jiang, 2008), PCA and BP neural network method (Song *et al*., 2009), cloud model (Ju and Zeng, 2009), subjective and objective weighting method (Huang *et al*., 2012). These documents in power customer credit evaluation has achieved good results, but in some evaluation index, such as business enterprise image, the legal representative of the character, market prospects *et al*. can't accurately measure, but the fuzzy number or linguistic variables can overcome this shortcoming.

Fuzzy approach has been used to evaluate much type of performances such as product and marketing, finance, education and more (Arbaiy and Suradi, 2007). Xing (2008) considered the power customer credit evaluation problem use a fuzzy multi-attribute decision making method based on Fuzzy expected value of triangular fuzzy numbers.

This study will focus on power customer credit evaluation problem, on the basis of the concept of relative ratio method, using coefficient of variation method to determine the evaluation index weights and then proposed an extended fuzzy relative ratio multi-attribute decision method.

METHODOLOGY

Preliminary knowledge:

Definition 1: A triple $\tilde{A} = [a, b, c]$ called triangular fuzzy number, if its membership function is defined as:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, x \le a \\ \dfrac{x-a}{b-a}, a \le x \le b \\ \dfrac{c-x}{c-b}, b \le x \le c \\ 0, x \ge c \end{cases}$$

Definition 2: Let $\tilde{A} = [a_1, a_2, a_3]$ and $\tilde{B} = [b_1, b_2, b_3]$ are two any triangular fuzzy numbers, the operations of the two fuzzy numbers are express as follows:

$$\tilde{A} + \tilde{B} = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$$

$$k\tilde{A} = (ka_1, ka_2, ka_3), k \in R$$

Let $\tilde{A} = [a_1, a_2, a_3]$ and $\tilde{B} = [b_1, b_2, b_3]$ be two triangular fuzzy numbers. Then the vertex method is defined to calculate the distance between them as follows:

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]}$$

Table 1: Linguistic variables and corresponding triangular fuzzy numbers for the for the ratings

Linguistic variable	Triangular fuzzy number
Very Poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium Poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium Good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very Good (VG)	(9, 10, 10)

It is an effective and simple method to calculate the distance between two triangular fuzzy numbers (Chen, 2000).

Definition 3: Owing to the fuzziness of the employee performance evaluation problem, the ratings of qualitative criteria are considered as linguistic variables, which are a variable whose values are linguistic terms (Chen, 2001). In this study, the linguistic variables are express in triangular fuzzy numbers as Table 1.

Power customer credit evaluation model: Consider a power customer credit evaluation problem. Let $X = \{x_1, x_2,\dots, x_m\}$ be possible alternatives (evaluate employees) set and $O = \{o_1, o_2,\dots, o_n\}$ be the evaluation criteria set with which alternative evaluations are measured. Suppose the rating of alternative x_i $\{i = 1, 2,\dots, m)$ on criteria o_j $(j = 1, 2, \dots, n)$ given by decision maker is $\tilde{a}_{ij}$. And when $\tilde{a}_{ij}$ is linguistic variable, we use the Table 1 to describe it by triangular fuzzy number and note $\tilde{a}_{ij} = (a_{ij}^l, b_{ij}^m, c_{ij}^u)$. Hence, the power customer credit evaluation model is a multi-criteria problem can be expressed in matrix format as follows:

$$A = (\tilde{a}_{ij})_{m\times n} = \begin{array}{c} \\ x_1 \\ x_2 \\ \vdots \\ x_m \end{array} \begin{array}{c} \begin{array}{cccc} o_1 & o_2 & \cdots & o_n \end{array} \\ \begin{pmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \tilde{a}_{m2} & \cdots & \tilde{a}_{mn} \end{pmatrix} \end{array}$$

where, $k = 1, 2, \dots, s$ and $w = (w_1, w_2, \dots, w_n)$ is the criteria weight vector.

In general, criteria can be classified into two types: benefit attributes and cost attributes. In other words, the criteria set can be divided into two subsets: I_1 and I_2, where I_k $(k = 1, 2)$ is the subset of benefit criteria set and cost criteria set, respectively.

The normalization method mentioned above is to preserve the property that the range of a normalized triangular fuzzy number $\tilde{r}_{ij}$ belongs to the closed interval (0, 1). Hence, the fuzzy decision matrix $\tilde{D} = \left(\tilde{a}_{ij}\right)_{m\times n}$ are transformed into the normalized fuzzy decision matrix $\tilde{R} = \left(\tilde{r}_{ij}\right)_{m\times n}$, where $\tilde{r}_{ij} = \left(r_{ij}^l,\ r_{ij}^m,\ r_{ij}^u\right)$ obtained by the following formula (Xu, 2004):

$$\begin{cases} r_{ij}^l = \dfrac{a_{ij}^l}{c_{jmax}^l} \\ r_{ij}^m = \dfrac{a_{ij}^m}{c_{jmax}^m}, \quad i \in M,\ j \in I_1 \\ r_{ij}^u = \dfrac{a_{ij}^u}{c_{jmax}^u} \end{cases}$$

and

$$\begin{cases} r_{ij}^l = \dfrac{c_{jmin}^l}{a_{ij}^l} \\ r_{ij}^m = \dfrac{c_{jmin}^m}{a_{ij}^m}, \quad i \in M,\ j \in I_2 \\ r_{ij}^u = \dfrac{c_{jmin}^u}{a_{ij}^u} \end{cases}$$

where,

$$c_{j\max}^l = \max_i\{a_{ij}^l\}, c_{j\max}^m = \max_i\{a_{ij}^m\},\quad c_{j\max}^u = \max_i\{a_{ij}^u\},$$
$$c_{j\min}^l = \min_i\{a_{ij}^l\},\ c_{j\min}^m = \min_i\{a_{ij}^m\},\ c_{j\min}^u = \min_i\{a_{ij}^u\}$$

and $M = \{1, 2,\dots, m\}$

Relative ratio method for power customer credit evaluation: In this section, we will propose the calculation steps of relative ratio method for the power customer credit evaluation as follows:

Step 1: Calculate the normal performance decision matrix $\tilde{R} = \left(\tilde{r}_{ij}\right)_{m\times n}$.

Step 2: Calculate the positive and negative ideal solution:
The positive ideal solution is defined as:

$$R^* = (r_1^*, r_2^*, \dots, r_n^*)$$

where, $r_j^* = [1, 1, 1]$.
And the negative ideal solution is defined as:

$$R^- = (r_1^-, r_2^-, \dots, r_n^-)$$

where, $r_j^- = [0, 0, 0]$.

Step 3: Calculating the criteria weight vector by the following step:

- The final performance decision $\tilde{R} = \left(\tilde{r}_{ij}\right)_{m\times n}$ is firstly defused into a crisp number decision matrix $G = (g_{ij})_{m\times n}$ by the centroid defuzzification method given as follows (Yager, 1981):

$$g_{ij} = \frac{1}{3}(r_{ij}^l + r_{ij}^m + r_{ij}^u)$$

- The coefficient of variation method proposed by Men and Liang (2005) and the calculation formula is:

$$w_j = \frac{\delta_j}{\sum_{j=1}^{n} \delta_j}, j = 1, 2, ..., n$$

where $\delta_j = \frac{s_j}{\bar{x}_j}$, $\bar{x}_j = \frac{1}{m}\sum_{i=1}^{m} x_{ij}$ and

$$s_j = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(x_{ij} - \bar{x}_j)^2}$$

Obviously,

$$w_j \geq 0, \sum_{j=1}^{n} w_j = 1, j = 1,2,..., n$$

Step 4: Calculate the distance measure of alternative x_i with the positive and negative ideal solution, as:

$$d(x_i, x^*) = \sqrt{\sum_{j=1}^{n} w_j d(\tilde{r}_{ij}, r_j^*)}$$

and

$$d(x_i, x^-) = \sqrt{\sum_{j=1}^{n} w_j d(r_{ij}, r_j^-)}$$

Step 5: Calculate the relative ratio of the alternative: Set:

$$d(x^-) = \max_{1\leq i\leq m}\{d(x_i, x^-),$$
$$d(x^+) = \min_{1\leq i\leq m}\{d(x_i, x^*)$$

The relative ratio of the i-th alternative employee defined as:

$$\xi_i = \frac{d(R_i, R^-)}{d(R^-)} - \frac{d(R_i, R^*)}{d(R^+)}, i = 1,2,..., m$$

Easy to prove that the relative ratio $\xi_i \leq 0$, which reflects the i-th object close to being the ideal alternative and away from negative ideal vector extent greater, indicating that the alternative i and the positive ideal vector objects relative distance is smaller, while the negative ideal vector larger relative distance.

Step 6: Rank the alternatives. Ranking order of the alternatives x_j (j = 1, 2, …, m) can be generated according to the increasing order of the relative ratio ξ_i.

A PRACTICAL EXAMPLE

To illustrate the effectiveness and the practicability of the proposed method, a power supply enterprise to evaluate electricity customer credit industry as an example (Liu, 2009). Has three to evaluation of the customer x_j (j = 1, 2, 3), 11 evaluation index $O = \{o_1, o_2, \ldots, o_{11}\}$, respectively commercial credit index: business enterprise image o_1, the legal representative of the character o_2, market prospects o_3, asset-liability ratio (%) o_4, profit (￥10000) o_5, to pay electricity ratio (%) o_6, return on net assets (%) o_7, total assets net interest rate (%) o_8; Security credit index o_9; Law credit index o_{10} and cooperative credit index o_{11}, the index o_4 for "as small as possible", other indicators are "bigger is better" type. Try to evaluate the three customer credit. The power industry customer credit indexes are shown in Table 2.

To sort the three power enterprise customer credit using the proposed method, the steps are given as follows:

Step 1: Give the decision matrix as:

$$A^T = \begin{bmatrix} [0,1,3] & [7,9,10] & [3,5,7] \\ [7,9,10] & [3,5,7] & [3,5,7] \\ [0,1,3] & [7,9,10] & [0,1,3] \\ [42.3,42.3,42.3] & [43.17,43.17,43.17] & [30.9,30.9,30.9] \\ [129.9,129.9,129.9] & [153,153,153] & [145.3,145.3,145.3] \\ [99.5,99.5,99.5] & [99.08,99.08,99.08] & [98.9,98.9,98.9] \\ [8.14,8.14,8.14] & [5.45,5.45,5.45] & [5.08,5.08,5.08] \\ [4.62,4.62,4.62] & [4.13,4.13,4.13] & [5.3,5.3,5.3] \\ [3,5,7] & [3,5,7] & [7,9,10] \\ [3,5,7] & [7,9,10] & [3,5,7] \\ [3,5,7] & [3,5,7] & [7,9,10] \end{bmatrix}$$

Step 2: The ideal solution and negative ideal solution are respectively given as:

$$R^* = (r_1^*, r_2^*, ..., r_{11}^*)$$
$$= ([1,1,1],[1,1,1],...,[1,1,1])$$

Table 2: The power enterprise customer credit index

	x_1	x_2	x_3
o_1	P	G	F
o_2	G	F	F
o_3	P	G	P
o_4	42.30	43.17	30.90
o_5	129.90	153	145.30
o_6	99.50	99.08	98.90
o_7	8.14	5.45	5.08
o_8	4.62	4.13	5.30
o_9	F	F	G
o_{10}	F	G	F
o_{11}	F	F	G

$$R^- = (r_1^-, r_2^-, ..., r_{11}^-) = ([0,0,0],[0,0,0],...,[0,0,0])$$

Step 3: Calculate the criteria vector:

- Calculate the crisp number decision matrix $G = (g_{ij})_{m\times n}$:

$$G = \begin{bmatrix} 1.3333 & 8.6667 & 1.3333 & 42.3 & 129.9 & 99.5 & 8.14 & 4.62 & 5 & 5 & 5 \\ 8.6667 & 5 & 8.6667 & 43.17 & 153 & 99.08 & 5.45 & 4.13 & 5 & 8.6667 & 5 \\ 5 & 5 & 1.3333 & 30.9 & 145.3 & 98.9 & 5.08 & 5.3 & 8.6667 & 5 & 8.6667 \end{bmatrix}$$

- Then the weight vector can be obtained by coefficient of variation method:

w = (0.1895, 0.0879, 0.2895, 0.0456, 0.0213, 0.0008, 0.0693, 0.0324, 0.0879, 0.0879, 0.0879)

Step 4: Calculate the distance measure:

$$d(x_1, x^*) = 0.6499, d(x_2, x^*) = 0.2585, d(x_3, x^*) = 0.5520$$

and

$$d(x_1, x^-) = 0.5701, d(x_2, x^-) = 0.8657, d(x_3, x^-) = 0.6559$$

Then we have $d(x^-) = 1.4994, d(x^*) = 0.4477$.

Step 5: The relative ratio of the *i*-th alternative defined as:

$$\xi_1 = -1.8555, \xi_2 = -0.0001, \xi_3 = -1.3776$$

Step 6: Obviously, $\xi_1 < \xi_3 < \xi_2$, then customer credit order is $x_1 < x_3 < x_2$ and this result coincides with Liu (2009).

CONCLUSION

This study is focus on power customer credit evaluation problems. The use of triangular fuzzy number multi-attribute decision-making model is established and a developed relative ratio method is proposed. In this study, the variation coefficient method is adopted to determine the weight of each evaluation index, the use of data information itself reflects the objective to determine the index weight, overcome the subjective weight in performance appraisal of artificial and uncertainty. In this study, the proposed method is simple, in line with the actual situation, the algorithm is easy to modular operation, which can rich the theory of power enterprise customer credit evaluation.

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