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Research Article

Fuzzy Multi-attribute Group Decision Making Method for Wine Evaluation Model

[1]Haiping Ren and [2]Lianwu Yang
[1]School of Software, Jiangxi University of Science and Technology, Nanchang 330013,
[2]School of Mathematics and Computer Science, Yichun University, Yichun 336000, P.R. China

Abstract: In recent years, with the fast increase of red wine consumption, the wine evaluation becomes more important for wine enterprises. Establishing the grade of wine needs many qualified members (experts) to evaluate the wine according to several evaluation indexes. Evaluation indexes are mainly quality indexes. Interval numbers are more suitable than numerical numbers to demonstrate these indexes. Then, the wine evaluation model is a fuzzy multiple attribute group decision making model. In this study, we will propose a fuzzy TOPSIS method for the wine evaluation model, in which the evaluation index values are expressed with interval numbers. The coefficient of variation method is used to determine the index weights. Finally, an application example is given to illustrate the validity and practicability of the method.

Keywords: Interval number, multi-attribute group decision making, TOPSIS, wine evaluation

INTRODUCTION

In recent years, more and more people began to drink wine with the development of economy and improvement of people's life. Wine industry shows blowout type development and wine demand is growing fast. To gain the sustainable development in the fierce market competition, more and more wine enterprises attach great importance to the wine quality evaluation. The wine quality evaluation is important for brand wine enterprises lies in that they can not only price wine according to the different grades of wine, but also can look for cheap and fine raw materials. For wine evaluation, the enterprise often hires a group of qualified member (expert) to evaluate the wine according to several evaluation indexes, which are appearance analysis, aroma analysis, texture analysis and balance (overall) evaluation. These evaluation indexes are quality indexes. In such case, interval numbers are more suitable than crisp numbers to demonstrate these evaluation indexes. Then wine quality evaluation model is a multi-attribute group decision making model. The TOPSIS method proposed by Hwang and Yoon (1981) is widely used in the treatment of multi-attribute decision making (Shih, 2008; Shih *et al*., 2007; Xu, 2013; Zhang and Zhang, 2013). It calculates the closeness to evaluate the alternatives. The closeness is the index which is not only close to the positive ideal point, but also far from negative ideal point. In recent years, TOPSIS has been successfully applied in many aspects such as investment project selection, business and marketing management, human resource management, water resources management and energy management (Behzadian *et al*., 2012). In multi-attribute decision making problems, the attribute weights is important for the decision result, then in this study we propose the coefficient of variation method to get the weights of wine evaluation indexes (attributes). Coefficient of variation method is an objective method, which can overcome the artificial and uncertainty of subjective weight (Men and Liang, 2005).

In this study, a fuzzy group decision making method is put forward for the wine evaluation.

WINE QUALITY EVALUATION MODEL

Consider a wine quality evaluation problem. Let $X = \{x_1, x_2, \ldots, x_m\}$ be the set of wine samples (alternatives) and $O = \{o_1, o_2, \ldots, o_n\}$ be the set of n evaluation indexes. $D = \{D_1, D_2, \ldots, D_s\}$ is the s of wine evaluation experts. Suppose the rating of wine sample x_i ($i = 1, 2, \ldots, m$) on evaluation index O_j ($j = 1, 2, \ldots, n$) given by decision maker D_k ($k = 1, 2, \ldots, s$) is interval number $\tilde{a}_{ij}^k = [a_{ij}^{kL}, a_{ij}^{kU}]$. Hence, the wine quality evaluation model is a multi-criteria group decision making problem can be concisely expressed in matrix format as follows:

Corresponding Author: Haiping Ren, School of Software, Jiangxi University of Science and Technology, Nanchang 330013, P.R. China
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$$\tilde{D}^k = (\tilde{a}_{ij}^k)_{m\times n} = \begin{array}{c} \\ x_1 \\ x_2 \\ \vdots \\ x_m \end{array} \begin{array}{c} \begin{array}{cccc} o_1 & o_2 & \cdots & o_n \end{array} \\ \begin{pmatrix} \tilde{a}_{11}^k & \tilde{a}_{12}^k & \cdots & \tilde{a}_{1n}^k \\ \tilde{a}_{21}^k & \tilde{a}_{22}^k & \cdots & \tilde{a}_{2n}^k \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{a}_{m1}^k & \tilde{a}_{m2}^k & \cdots & \tilde{a}_{mn}^k \end{pmatrix} \end{array}$$

where, $k = 1, 2, \ldots, s$. Suppose that $w = (w_1, w_2, \ldots, w_n)$ is the indexes weight vector, which satisfies $w_j \geq 0, \sum_{j=1}^{n} w_j = 1, j = 1,2,\ldots,n$.

For the wine quality evaluation model $\tilde{D}^k = (\tilde{a}_{ij}^k)_{m\times n}$, $k = 1,2,\cdots,s$, in the following discussion, we will develop a new group decision method foe the wine evaluation model.

FUZZY MULTI-ATTRIBUTE GROUP DECISION MAKING METHOD

In this section, we will give the calculation steps of the fuzzy decision making method for the wine quality evaluation model as follows:

Step 1: For the wine quality evaluation model, collect the evaluation index values of the fuzzy decision matrix $\tilde{D}^k = (\tilde{a}_{ij}^k)_{m\times n}$, $k = 1, 2, \ldots, s$ into one decision matrix $\tilde{D} = (\tilde{a}_{ij})_{m\times n}$, where:

$$\tilde{a}_{ij} = [a_{ij}^l, a_{ij}^u] = \frac{1}{s}(\tilde{a}_{ij}^1 + \tilde{a}_{ij}^2 + \cdots + \tilde{a}_{ij}^s)$$

Step 2: Normalize the decision making matrix: In general, evaluation indexes have two types: benefit indexes and cost indexes. We note I_1 and I_2 are the subset of benefit index set and cost index set, respectively.

The normalization method is to preserve the property that the range of a normalized interval number $\tilde{r}_{ij}^k$ belongs to the closed interval [0, 1]. We transform the fuzzy decision matrix $\tilde{D} = (\tilde{a}_{ij})_{m\times n}$ into the normalized fuzzy decision matrix $\tilde{R} = (\tilde{r}_{ij})_{m\times n}$, where $\tilde{r}_{ij} = [r_{ij}^l, r_{ij}^u]$ obtained by the following formulas (Xu, 2004):

$$\begin{cases} r_{ij}^l = a_{ij}^l \Big/ \sqrt{\sum_{i=1}^{m} (a_{ij}^u)^2} \\ r_{ij}^u = a_{ij}^u \Big/ \sqrt{\sum_{i=1}^{m} (a_{ij}^l)^2} \end{cases}, \quad i \in M,\ j \in I_1$$

and,

$$\begin{cases} r_{ij}^l = (1/a_{ij}^u) \Big/ \sqrt{\sum_{i=1}^{m} (1/a_{ij}^l)^2} \\ r_{ij}^u = (1/a_{ij}^l) \Big/ \sqrt{\sum_{i=1}^{m} (1/a_{ij}^u)^2} \end{cases}, \quad i \in M,\ j \in I_2$$

where, $M = \{1, 2, \ldots, m\}$

Step 3: Determine the positive and negative ideal solution:

The Positive Ideal Solution (PIS) is defined as $x^* = (x_1^*, x_2^*, \ldots, x_n^*)$, where, $x_j^* = [1,1]$

And the negative ideal solution (NIS) is defined as $x^- = (x_1^-, x_2^-, \ldots, x_n^-)$, where, $x_j^- = [0,0]$.

Step 4: Calculating the index weights as follows:

- Defuse $\tilde{R} = (\tilde{r}_{ij})_{m\times n}$ into a crisp number decision matrix $G = (g_{ij})_{m\times n}$ by the expectation method given as follows (Hu and Zhang, 2010):

$$g_{ij} = \frac{1}{2}(r_{ij}^l + r_{ij}^u)$$

- The indexes weights are calculated by coefficient of variation method as follows (Men and Liang, 2005):

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

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

Step 5: Calculate the distance measures of each alternative x_i with the PIS and NIS, as follows:

$$d(x_i, x^*) = \sqrt{\sum_{j=1}^{n} w_j^2 d^2(\tilde{r}_{ij}, r_j^*)},$$

$$d(x_i, x^-) = \sqrt{\sum_{j=1}^{n} w_j^2 d^2(r_{ij}, r_j^-)}$$

where, $d(\cdot,\cdot)$ is the distance measure defined as follows:

Table 1: Evaluation values of different experts

Sample	Index	Expert D_1	D_2	D_3
x_1	o_1	[10, 11]	[11, 12]	[9, 10]
	o_2	[18, 20]	[23, 24]	[24, 25]
	o_3	[24, 26]	[33, 35]	[34, 38]
	o_4	[8, 10]	[7, 9]	[8, 10]
x_2	o_1	[5, 8]	[8, 10]	[9, 12]
	o_2	[18, 21]	[22, 25]	[14, 18]
	o_3	[21, 24]	[25, 28]	[19, 23]
	o_4	[7, 10]	[8, 10]	[7, 9]
x_3	o_1	[8, 10]	[8, 10]	[9, 11]
	o_2	[17, 23]	[23, 25]	[25, 27]
	o_3	[33, 37]	[36, 38]	[37, 39]
	o_4	[9, 10]	[8, 10]	[8, 10]
x_4	o_1	[11, 12]	[10, 12]	[9, 11]
	o_2	[21, 23]	[22, 25]	[23, 25]
	o_3	[33, 35]	[38, 40]	[40, 43]
	o_4	[8, 9]	[9, 10]	[9, 10]

Let $\tilde{a} = [a^L, a^U]$ and $\tilde{b} = [b^L, b^U]$ are two interval numbers, then the distance measure between them is defined as (Zhang and Fan, 2008):

$$d(\tilde{a},\tilde{b}) = \sqrt{(a^L - b^L)^2 + (a^U - b^U)^2}$$

Thus, we have:

$$d(\tilde{r}_{ij}, r_j^*) = \sqrt{(1 - r_{ij}^L)^2 + (1 - r_{ij}^U)^2}$$

and:

$$d(\tilde{r}_{ij}, r_j^*) = \sqrt{(r_{ij}^L - 0)^2 + (r_{ij}^U - 0)^2}$$

Step 6: Calculate the relative closeness coefficient of the alternative x_i:

$$C_i = \frac{d(x_i, x^-)}{d(x_i, x^-) + d(x_i, x^*)}, i = 1, 2, ..., m$$

Step 7: Rank the alternatives: Ranking order of the alternatives $x_i (i = 1, 2, \ldots, m)$ according to the relative closeness coefficient C_i. The bigger of C_i is, the better of the alternative (wine sample) x_i is.

A PARACTICAL EXAMPLE

A wine enterprise wants to evaluate four wine samples x_1, x_2, x_3, x_4, which are produced by themselves. They hire 6 experts D_1, D_2, …, D_6 to evaluate these wine samples. The evaluation indexes are appearance analysis (o_1), aroma analysis (o_2), texture analysis (o_3) and balance (overall) evaluation (o_4).The evaluation values given by experts are interval numbers and the specific evaluation values are shown in Table 1.

To sort the four wine samples using the proposed method, the specific calculation steps are given as follows:

Step 1: According to the Eq. (1) and (2), calculate the fuzzy decision matrix $\tilde{D} = (\tilde{a}_{ij})_{m\times n}$:

$$\tilde{D} = \begin{bmatrix} [10,11] & [7.3333,10] & [8.3333,10.3333] & [10,11.6667] \\ [21.6667,23] & [18,21.3333] & [21.6667,25] & [22,24.3333] \\ [30.3333,33] & [21.6667,25] & [35.3333,38] & [37,39.3333] \\ [7.6667,9.6667] & [7.3333,9.6667] & [8.3333,10] & [8.6667,9.6667] \end{bmatrix}$$

Step 2: The normal decision matrix $\tilde{R} = (\tilde{r}_{ij})_{m\times n}$ is calculated as:

$$\tilde{R} = \begin{bmatrix} [0.2336,0.2796] & [0.2055,0.3331] & [0.1747,0.2398] & [0.2055,0.2591] \\ [0.5061,0.5845] & [0.5044,0.7107] & [0.4542,0.5802] & [0.4520,0.5403] \\ [0.7086,0.8387] & [0.6071,0.8329] & [0.7407,0.8819] & [0.7602,0.8374] \\ [0.1791,0.2457] & [0.2055,0.3220] & [0.1747,0.2321] & [0.1781,0.2146] \end{bmatrix}$$

Step 3: The PIS and NIS are respectively given as:

$$x^* = (x_1^*, x_2^*, x_3^*, x_4^*) = ([1,1],[1,1],[1,1],[1,1])$$

$$x^- = (x_1^-, x_2^-, x_3^-, x_4^-) = ([0,0],[0,0],[0,0],[0,0])$$

Step 4: Calculate the index weight vector:

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

$$G = \begin{bmatrix} 0.2566 & 0.2693 & 0.2072 & 0.2323 \\ 0.5453 & 0.6076 & 0.5172 & 0.4962 \\ 0.7736 & 0.7200 & 0.8113 & 0.8168 \\ 0.2124 & 0.2638 & 0.2034 & 0.1964 \end{bmatrix}$$

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

$$w = (0.2432, 0.2078, 0.2764, 0.2726)^T$$

Step 5: Calculate the distance measures:

$$d(x_1, x^*) = 1.0782, d(x_2, x^*) = 0.6635,$$
$$d(x_3, x^*) = 0.3276, d(x_4, x^*) = 1.1102$$

and:

$$d(x_1, x^-) = 0.3439, d(x_2, x^-) = 0.7672,$$
$$d(x_3, x^-) = 1.1162, d(x_4, x^-) = 0.3120$$

Then we have $d(x^-) = 0.7225, d(x^*) = 0.6988$.

Step 6: The relative closeness coefficient of each wine sample obtained as follows:

$$C_1 = 0.2418, C_2 = 0.5362, C_3 = 0.7731$$

and,

$$C_4 = 0.2194$$

Step 7: Rank the alternatives: It is easy to see $C_3 > C_2$ $C_1 > C_4$, thus the wine quality evaluation result is:

$$x_3 > x_2 > x_1 > x_4$$

The wine sample x_3 is the best wine.

CONCLUSION

This study is focus on wine quality evaluation problem, which is a multi-attribute group decision making problem. Interval numbers are used to demonstrate the evaluation values given by experts. For the determination of indexes weights, we use coefficient of variance method, which is an objective method. Coefficient of variance method can use of number information itself reflects the index weight, thus overcomes the artificial and uncertainty of subjective weight. A group decision method for the wine evaluation model is put forward based on the concept of TOPSIS. An application example about wine quality evaluation is given to illustrate the validity and practicability of the method. The proposed method can also be extended to other aspect, such as investment project selection, employee performance evaluation.

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