

Research Article

Combining TOPSIS with Group Eigenvalue Method for Wine Evaluation Model

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Abstract: In recent years, with the continuous improvement of people's living standards, more and more people join the wine consumption. It is important for brand wine enterprises to evaluate the wine. On the one hand, they can price according to the different grades of wine, on the other hand they can also be looking for cheap and fine raw materials from wine evaluation model. Determining the quality of wine is generally by hiring a group of qualified member (expert) to evaluate the wine according to several evaluation indexes. Then, according to evaluation indexes values given by each expert, a multiple attribute group decision making model is obtained. The group eigenvalue method can get ideal expert of each evaluation index, thus it makes the whole process of evaluation is more objective. So this article will introduce a eigenvalue method to the wine evaluation model, put forward a group decision making method based on TOPSIS and the group eigenvalue method. First, the group eigenvalue method is used to calculate each evaluation index of ideal expert evaluation. Then, TOPSIS method is used to solve the multi-attribute evaluation model. Finally, an application example is given to illustrate the validity and practicability of the method.

Keywords: Group eigenvalue method, multi-attribute group decision making, TOPSIS, wine quality evaluation

INTRODUCTION

With the development of Chinese economy in recent years, more and more people began to try to wine. Wine industry shows blowout type development and wine demand is growing fast. 2013 "Chinese wine report" shows, at present, in Chinese wine consumption market, annual consumption scale of wine is more than 100 billion RMB. Consumption of red wine market capacity is about 1.8 billion liters per year and about 25% of which are imported wine. Chinese wine market attracts more and more international famous wine manufacturers to enter China. Customs data showed, Chinese imported red wine from about 60% of the European Union, of which about 35% from France. If the Chinese wine manufacturers want to win in the fierce market competition, the wine quality is especially important. The link of wine quality evaluate is a very important and because of the confusion which originates from the Chinese wine market and most consumers lack of professional knowledge about the wine. It is important for brand wine enterprises to evaluate the wine. On the one hand, they can price according to the different grades of wine, on the other hand they can also be looking for cheap and fine raw materials from wine evaluation model. For wine production enterprises, determining the quality of wine is generally by hiring a

group of qualified member (expert) to evaluate the wine according to several evaluation indexes. The most often of these evaluation indexes are: appearance analysis, aroma analysis, texture analysis and balance (overall) evaluation. Then the wine is grade classification according to the comprehensive analysis of the evaluation value.

Because of wine quality evaluation model is a decision model for evaluation of the multiple expert, so it belongs to 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 numerous areas (Behzadian *et al.*, 2012), such as supply chain management, business and marketing management, human resource management, energy management, water resources management. Group eigenvalue method proposed by Qiu (1997) can get a ideal expert in the treatment of group decision making problems. The method has been applied in many aspects (Luo *et al.*, 2008; Ying, 2011; Jia and Fan, 2012; Xiao and Sun, 2012).

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In this study, the group eigenvalue method is introduced to wine evaluation model. A new group decision method which combines TOPSIS with group eigenvalue method is put forward.

WINE QUALITY EVALUATION MODEL

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

$$D^k = (a_{ij}^k)_{m \times n} = \begin{matrix} & o_1 & o_2 & \dots & o_n \\ x_1 & a_{11}^k & a_{12}^k & \dots & a_{1n}^k \\ x_2 & a_{21}^k & a_{22}^k & \dots & a_{2n}^k \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_m & a_{m1}^k & a_{m2}^k & \dots & a_{mn}^k \end{matrix}$$

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

For the wine quality evaluation model $D^k = (a_{ij}^k)_{m \times n}, k = 1, 2, \dots, s$, in the following discussion, we will develop a new group decision method, which combines the TOPSIS and group eigenvalue method.

New method combining topsis with group eigenvalue method: In this section, we will give the calculation steps of the new method for the wine quality evaluation as follows:

Step 1: For the wine quality evaluation model $D^k = (a_{ij}^k)_{m \times n}, k = 1, 2, \dots, s$, we use group eigenvalue method to get the ideal score vector of o_j with respect x_1, x_2, \dots, x_m and the specific steps are:

- **Construct the new decision matrix:**

$$E(o_j) = \begin{matrix} & D_1 & D_2 & \dots & D_s \\ x_1(o_j) & a_{11}^1 & a_{21}^2 & \dots & a_{1s}^s \\ x_2(o_j) & a_{12}^1 & a_{22}^2 & \dots & a_{2s}^s \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_m(o_j) & a_{1m}^1 & a_{2m}^2 & \dots & a_{sm}^s \end{matrix}$$

- **Calculate the ideal expert's scoring vector for every o_j :** Set $X = E(o_j)$, then calculate the matrix $F = X^T X$, the Matlab software can help to obtain the largest eigenvalue ρ_{\max} of matrix F and then the corresponding eigenvector with respect to ρ_{\max} is X_j^* . At last, normalize the eigenvector to form the

indicators' weights vector which is also called "the ideal expert's scoring vector".

Step 2: Construct the new normal decision matrix $X = (x_{ij}) = (X_1^0, X_2^0, \dots, X_n^0)$:

where, $X_1^0 = \frac{X_1^*}{\|X_1^*\|}$.

Step 3: Calculate the positive and negative ideal solution: The positive ideal solution is defined as $x^* = (x_1^*, x_2^*, \dots, x_n^*)$, where $x_j^* = \max_j \{x_{ij}\}$

And the negative ideal solution is defined as $x^- = (x_1^-, x_2^-, \dots, x_n^-)$, where $r_j^- = \min_j \{x_{ij}\}$.

Step 4: Calculating the indexes weight vector by coefficient of variation method.

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

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

where,

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

and,

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

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

Step 5: Calculate the distance measure of alternative x_j with the positive and negative ideal solution, as:

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

and,

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

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

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

Step 7: Rank the alternatives: Ranking order of the alternatives x_i ($i = 1, 2, \dots, m$) can be generated according to the increasing order of the relative closeness C_i .

A PARACTICAL EXAMPLE

A wine industry wants to evaluate four wine samples they produced. The wine samples are noted by x_1, x_2, x_3, x_4 . They hire 6 experts D_1, D_2, \dots, 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 are shown in Table 1.

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

Step 1: Construct the new decision matrix $E(o_j)$ according to the Table 1:

$$E(o_1) = \begin{pmatrix} 10 & 12 & 10 & 7 & 10 & 12 \\ 5 & 8 & 11 & 8 & 14 & 19 \\ 8 & 8 & 11 & 9 & 14 & 10 \\ 13 & 12 & 11 & 12 & 14 & 14 \end{pmatrix}$$

$$E(o_2) = \begin{pmatrix} 18 & 24 & 24 & 18 & 24 & 22 \\ 18 & 25 & 12 & 17 & 26 & 26 \\ 17 & 25 & 27 & 22 & 30 & 22 \\ 23 & 25 & 25 & 22 & 21 & 25 \end{pmatrix}$$

$$E(o_3) = \begin{pmatrix} 24 & 33 & 37 & 29 & 28 & 26 \\ 21 & 25 & 19 & 21 & 29 & 19 \\ 37 & 38 & 38 & 35 & 37 & 38 \\ 35 & 38 & 43 & 33 & 26 & 40 \end{pmatrix}$$

$$E(o_4) = \begin{pmatrix} 8 & 9 & 10 & 8 & 8 & 7 \\ 7 & 8 & 7 & 8 & 8 & 7 \\ 9 & 10 & 10 & 9 & 10 & 10 \\ 9 & 10 & 10 & 9 & 8 & 10 \end{pmatrix}$$

Table 1: Evaluation values of different experts

Sample	Index	Expert					
		D_1	D_2	D_3	D_4	D_5	D_6
x_1	o_1	10	12	10	7	10	12
	o_2	18	24	24	18	24	22
	o_3	24	33	37	29	28	26
	o_4	8	9	10	8	8	7
x_2	o_1	5	8	11	8	14	9
	o_2	18	25	12	17	26	26
	o_3	21	25	19	21	29	19
	o_4	7	8	7	8	8	7
x_3	o_1	8	8	11	9	14	10
	o_2	17	25	27	22	30	22
	o_3	37	38	38	35	37	38
	o_4	9	10	10	9	10	10
x_4	o_1	13	12	11	12	14	14
	o_2	23	25	25	22	21	25
	o_3	35	38	43	33	26	40
	o_4	9	10	10	9	8	10

Step 2: Calculate the ideal expert's scoring vector X_j^* for every o_j .

Set $X = E(o_j)$, then calculate the matrix $F = X^T X$, the Matlab software can help to obtain the largest eigenvalue ρ_{\max} of matrix F and then the corresponding eigenvector with respect to ρ_{\max} is X_j^* . The ideal expert's scoring vector X_j^* for every o_j is given as follow:

$$X_1^* = (0.4571, 0.5134, 0.4538, 0.5671)^T$$

$$X_2^* = (0.4828, 0.4637, 0.5324, 0.5182)^T$$

$$X_3^* = (0.4663, 0.3489, 0.5833, 0.5663)^T$$

$$X_4^* = (0.4772, 0.4277, 0.5520, 0.5335)^T$$

Step 3: Set $X_1^0 = \frac{X_1^*}{\|X_1^*\|}$, then construct the new normal decision matrix:

$$X = (X_1^0, X_2^0, X_3^0, X_4^0) = \begin{pmatrix} 0.2295 & 0.2578 & 0.2279 & 0.2848 \\ 0.2148 & 0.2322 & 0.2666 & 0.2595 \\ 0.2373 & 0.1776 & 0.2969 & 0.2882 \\ 0.2397 & 0.2149 & 0.2773 & 0.2680 \end{pmatrix}$$

Step 4: Calculate the positive and negative ideal solution:

The positive ideal solution is:

$$x^+ = (0.2418, 0.2578, 0.2969, 0.2882)$$

The negative ideal solution is:

$$x^- = (0.2295, 0.1776, 0.2279, 0.2595)$$

Step 5: Calculate the indexes weight vector $w = (w_1, w_2, \dots, w_n)$ by coefficient of variation method. The weight vector is given as:

$$w = (0.0676, 0.4577, 0.3259, 0.1488)$$

Step 6: Calculate the distance measure $d(x_i, x^*)$ and $d(x_i, x^-)$ and give them as below:

$$d(x_1, x^+) = 0.0225, d(x_2, x^+) = 0.0159,$$

$$d(x_3, x^+) = 0.0367, d(x_4, x^+) = 0.0209$$

$$d(x_1, x^-) = 0.0369, d(x_2, x^-) = 0.0280,$$

$$d(x_3, x^-) = 0.0229, d(x_4, x^-) = 0.0235$$

Step 6: Calculate the relative closeness C_i .

$$C_1 = 0.3789, C_2 = 0.3623, C_3 = 0.6159, C_4 = 0.4699$$

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

$$x_3 > x_4 > x_1 > x_2$$

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. A new group decision method, which combines TOPSIS and group eigenvalue is put forward. The group eigenvalue method can get ideal expert of each evaluation index, thus it makes the whole process of evaluation is more objective. 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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