EVALUATION AND SELECTION OF TRANSPORTATION SERVICE PROVIDER BY TOPSIS METHOD WITH ENTROPY WEIGHT

by

Xu WU[a], Cheng ZHANG[b*], and Luojun YANG[b]

[a] School of Science, East China Jiaotong University, Nanchang, China
[b] School of Transportation and Logistics, East China Jiaotong University, Nanchang, China

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In this paper, an improved technique for order of preference by similarity to ideal solution is proposed to select the optimal transportation service provider among several alternatives according to a multi-criterion method. An entropy method is embedded to determine the weights of different criteria and it is effective to avoid the subjectivity and arbitrary of choosing the weights. A case study demonstrates the proposed method is reasonable and valid for practical problems.

Key words: *entropy weight, ideal solution, multi-criteria decision-making, TOPSIS method*

Introduction

Numerous methods have been used to make a decision according to an analysis model. Several tools have been developed to solve multi-criteria decision-making (MCDM) problems effectively. Technique for order preference by similarity to ideal solution (TOPSIS), proposed by Hwang and Yoon [1], is a measure to find the optimal alternative from all the candidate alternatives according to some given criteria. The TOPSIS is an efficient and concise MCDM tool to deal with decision-making problems in a lot of different applications. In the classic TOPSIS method, the weights of all criteria are given by decision-makers and they usually depend on subjective knowledge and experiences of the experts. Due to subjective setting of weights, it may generate some different results on evaluating the candidate alternatives [1-3]. Tang and Fang [4] proposed an efficacy coefficient method to deal with rank reversal. The fuzzy theory was adopted to improve the TOPSIS method for some certain background [5, 6], and the TOPSIS method was applied to evaluate the Chinese high-tech industry successfully [7]. The problem in selection of transportation service provider is a typical MCDM problem and it has many factors to be considered in decision making.

Entropy is a basic quantity in information theory associated to any random variable, which can be interpreted as the average level of uncertainty inherent in the variable's possible outcomes. The concept of information entropy was introduced by Claude Shannon in 1948. The entropy weight method and application are available in [8]. In this paper, the entropy is employed to determine the weights of the criteria in the TOPSIS method.

[*] Corresponding author, e-mail: hpunyxy@163.com; zhangcheng001@126.com

An improved TOPSIS method

In this section, an improved decision-making approach will be presented. A flowchart for the novel approach is illustrated in fig. 1. For a given MCDM problem, it is supposed that there are m alternatives, which are represented mathematically as the set $A = [A_1, A_2,... A_m]$. The goal of the model is to find the optimal answer among the m alternatives. There are n criteria for evaluating the performance of each alternative. These criteria are expressed in terms of set $C = [C_1, C_2,..., C_n]$.

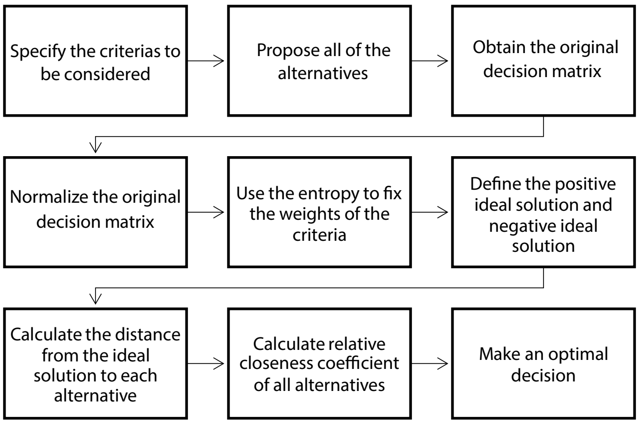

Figure 1. Flowchart of the improved TOPSIS

The original decision matrix of the model is given:

$$D = \begin{pmatrix} & C_1 & C_2 & \cdots & C_n \\ A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ A_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix}$$

The element x_{ij} is the rating of alternative A_i with respect to criteria C_j.

The proposed novel decision-making approach consists of nine steps:

Step 1. Specify the criteria to be considered: The selection of criteria plays an important role in the evaluation of the alternative. This means to determine the meaning of the $C = [C_1, C_2,..., C_n]$. It depends on the different characteristics of the specific problem.

Step 2. Propose all of the alternatives for the specific problem: This means to determine all of the alternatives $A = [A_1, A_2,... A_m]$.

Step 3. Obtain the original decision matrix D: A decision matrix D:

$$D = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \tag{1}$$

The element x_{ij} is the rating of alternative A_i with respect to criteria C_j.

Step 4. The decision matrix is normalized by the column vector normalization method. The normalized decision matrix is $R = \{r_{ij}\}$ and it can be calculated:

$$r_{ij}=\frac{x_{ij}}{\sum_{i=1}^{m}x_{ij}},\ i=1,\cdots,m,\ j=1,\cdots,n \tag{2}$$

where m and n are the numbers of alternatives and criteria, respectively.

Step 5. Construct the weighted column $W = \{w_1, w_2,... w_n\}$. Now the concept of entropy in informatics is adopted to define the weights of these criteria.

Let:

$$E_j=-\frac{1}{\ln m}\sum_{i=1}^{m}r_{ij}\ln r_{ij},\ j=1,\cdots,n$$

and if $r_{ij} = 0$ then $r_{ij} \ln r_{ij} = 0$. Now let $H_j = 1 - E_j$ and the H_j is the importance of the j^{th} criterion. For example, if $r_{1j} = r_{2j} = ... = r_{mj} = 1/m$ hold, then $E_j = 1$, *i. e.* $H_j = 0$. The weight of the j^{th} criterion is defined:

$$w_j=\frac{H_j}{\sum_{j=1}^{n}H_j},\ j=1,\cdots,n \tag{3}$$

It means that if the value of the j^{th} criterion of these m alternatives are the same, obviously the j^{th} criterion is the least important and its weight is zero. This is in line with our common sense.

Then the weighted and normalized decision matrix is obtained:

$$Y=\{y_{ij}\},\ y_{ij}=r_{ij}w_j,\ i=1,\cdots,m,\ j=1,\cdots,n \tag{4}$$

Step 6. Define the positive ideal solution and negative ideal solution. Let the positive ideal solution be $y^* = (y_1^*, y_2^*,..., y_n^*)$ and the negative ideal solution be $y^0 = (y_1^0, y_2^0,..., y_n^0)$ which the y_j^* and y_j^0 are the j^{th} component of positive ideal solution and negative ideal solution, respectively. Then the positive ideal solution and the negative ideal solution are obtained via the definition:

$$y_j^*=\begin{cases}\max\limits_i y_{ij},\ \text{if } j \text{ is for profit cretiria}\\ \min\limits_i y_{ij},\ \text{if } j \text{ is for cost cretiria}\end{cases},\ j=1,...n \tag{5}$$

$$y_j^0=\begin{cases}\max\limits_i y_{ij},\ \text{if } j \text{ is for cost cretiria}\\ \min\limits_i y_{ij},\ \text{if } j \text{ is for profit cretiria}\end{cases},\ j=1,...n \tag{6}$$

Step 7. Calculate the distance from the ideal solution each alternative. The distances from a given alternative y_i to the positive and negative ideal solutions are defined as d_i^* and d_i^0, respectively. They are calculated:

$$d_i^*=\sqrt{\sum_{j=1}^{n}(y_{ij}-y_j^*)^2},\quad i=1,...,m \tag{7}$$

$$d_i^0=\sqrt{\sum_{j=1}^{n}(y_{ij}-y_j^0)^2},\quad i=1,...,m \tag{8}$$

Step 8. Calculate relative closeness coefficient of all alternatives:

$$C_i^1=\frac{d_i^*}{d_i^*+d_i^0},\quad i=1,...,m \tag{9}$$

The lower value of the C_i^1 means the i^{th} alternative is better because it is closer to the positive ideal solution:

$$C_i^2 = \frac{d_i^0}{d_i^* + d_i^0}, \quad 1,\ldots,m \tag{10}$$

The higher value of the C_i^2 means the i^{th} alternative is better because it is farther to the negative ideal solution.

The aforementioned are two relative closeness coefficient methods, both of which can be chosen for decision making.

Step 9. The all alternatives are ranked by relative closeness coefficient C_i^1 (C_i^2). The lowest (highest) value of the C_i^1 (C_i^2) suggests that the ith alternative is optimal.

The final goal of the MCDM is to provide decision makers an ordered list of alternatives. This is achieved by ranking the proposed alternatives according to their closeness coefficients. Because a lower closeness coefficient C_i^1 indicates a better alternative, the alternatives are ordered according to increased closeness coefficient values. It means that the alternative with the lowest closeness coefficient is optimal.

Case study

In order to evaluate and select a best transportation service provider, the improved TOPSIS method is employed to make this decision.

Assuming that a company plans to purchase transportation service and there are ten candidate transportation service providers in market. Now the improved TOPSIS method is applied to select the suitable one.

The ten candidate transportation service providers are represented as $A = [A_1, A_2,\ldots A_{10}]$ and the evaluation criteria are represented as $C_1 = [C_1, C_2, C_3, C_4]$. The C_1, C_2, C_3, and C_4 represent the transportation price, transportation capacity, delivery time, company reputation, respectively. The C_2 and C_4 are profit criteria and the C_1 and C_3 are cost criteria. By means of public bidding and market research, the original decision matrix is drawn:

$$D = \begin{pmatrix} 100 & 400 & 10 & 0.90 \\ 145 & 600 & 19 & 0.99 \\ 85 & 500 & 20 & 0.84 \\ 90 & 300 & 8 & 0.88 \\ 120 & 700 & 6 & 0.86 \\ 110 & 900 & 9 & 0.75 \\ 80 & 800 & 12 & 0.80 \\ 105 & 500 & 8 & 0.90 \\ 95 & 1000 & 23 & 0.95 \\ 115 & 1000 & 11 & 0.99 \end{pmatrix}$$

Then the original decision matrix is normalized by the column vector normalization method eq. (2) and the normalized decision matrix R is drawn:

$$R = \begin{pmatrix} 0.0952 & 0.0597 & 0.0806 & 0.1015 \\ 0.1429 & 0.0896 & 0.1452 & 0.1116 \\ 0,0810 & 0.0746 & 0.1613 & 0.0958 \\ 0.0857 & 0.0448 & 0.0645 & 0.0992 \\ 0.1143 & 0.1045 & 0.0484 & 0.0970 \\ 0.1048 & 0.1343 & 0.0726 & 0.0846 \\ 0.0762 & 0.1194 & 0.0968 & 0.0902 \\ 0.1000 & 0.0746 & 0.0645 & 0.1015 \\ 0.0905 & 0.1493 & 0.1774 & 0.1071 \\ 0.1095 & 0.1493 & 0.0887 & 0.1116 \end{pmatrix}$$

According to the entropy weight eq. (3), the weight of all criteria are obtained: $w_1 = 0.0953$, $w_2 = 0.3773$, $w_3 = 0.5072$, and $w_4 = 0.0202$.

Therefore, the weighted and normalized decision matrix Y is derived by the eq. (4):

$$Y = \begin{pmatrix} 0.0091 & 0.0225 & 0.0409 & 0.0021 \\ 0.0136 & 0.0338 & 0.0736 & 0.0023 \\ 0.0077 & 0.0282 & 0.0818 & 0.0019 \\ 0.0082 & 0.0169 & 0.0327 & 0.0020 \\ 0.0109 & 0.0394 & 0.0245 & 0.0020 \\ 0.0100 & 0.0507 & 0.0368 & 0.0017 \\ 0.0073 & 0.0451 & 0.0491 & 0.0018 \\ 0.0095 & 0.0282 & 0.0327 & 0.0021 \\ 0.0086 & 0.0563 & 0.0900 & 0.0022 \\ 0.0104 & 0.0563 & 0.0450 & 0.0023 \end{pmatrix}$$

Then the positive ideal solution and negative ideal solution are obtained by the eqs. (5) and (6):

$$y^* = (0.0073, 0.0563, 0.0245, 0.0023), \quad y^0 = (0.0136, 0.0169, 0.0900, 0.0017)$$

Now the distance can be drawn from each alternative to the positive and negative ideal solution by eqs. (7) and (8), respectively:

$$d^* = (d_1^*, d_2^*, ..., d_{10}^*) = (0.0376,\ 0.0544,\ 0.0638,\ 0.0403,\ 0.0173,\ 0.0138, 0.0270,\ 0.0294,\ 0.0655,\ 0.0207)$$

$$d^0 = (d_1^0, d_2^0, ..., d_{10}^0) = (0.0496,\ 0.0235,\ 0.0151,\ 0.0575,\ 0.0693,\ 0.0631,\ 0.0501,\ 0.0585,\ 0.0397,\ 0.0599)$$

At last, the relative closeness coefficient of all alternatives can be calculated by eqs. (9) and (10), respectively and we get the results:

$$C^1 = (C_1^1, C_2^1, ..., C_{10}^1) = (0.4310, 0.6980, 0.8084, 0.4118, 0.1997, 0.1793, 0.3504, 0.3345, 0.6222, 0.2568)$$

$$C^2 = (C_1^2, C_2^2, ..., C_{10}^2) = (0.5690, 0.3020, 0.1916, 0.5882, 0.8003, 0.8207, 0.6496, 0.6655, 0.3778, 0.7432)$$

According to the C^1, the ranking of these alternatives is drawn:

$$A_6 \succ A_5 \succ A_{10} \succ A_8 \succ A_7 \succ A_4 \succ A_1 \succ A_9 \succ A_2 \succ A_3$$

The same ranking result can be derived as aforementioned if the C^2 is used as the descending ranking basis.

Discussion and conclusion

By means of the previous results, the following conclusions are obtained directly.

- The sixth transportation service provider is the optimal one in our model while the third provider is the worst one.
- The reason is the delivery time holds the highest weight and the sixth transportation service provider has short delivery time, moderate price and transportation capacity.

At present, the improvement for TOPSIS method focuses on the setting of positive and negative ideal solutions and relative closeness coefficient, then the weights of the criteria need to be quantified rather than subjective decision. The improved TOPSIS method can be also applied to the MCDM problem and the specific application process is as described previously.

The improved TOPSIS method can be further developed, it avoids the arbitrarily and subjectivity on settling the weight of criteria by using the entropy method which is more realistic. Furthermore, it is more reasonable and effective.

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