An Information Entropy Weighting Method Combined to TOPSIS Approach for Ranking Consulting Firms

Mohamed F. El-Santawy[1,]* and A. N. Ahmed[2]

[1]Department of Operation Research, Institute of Statistical Studies and Research (ISSR)
Cairo University, Egypt. *Corresponding author: lost_zola@yahoo.com
[2]Department of Mathematical Statistics, Institute of Statistical Studies and Research (ISSR), Cairo University, Egypt

Abstract: The purpose of this paper is to select and rank consulting firms by suggesting new multi-criteria decision making approach. The new technique employs an Information Entropy Weighting (IEW) method to allocate weights when no preference exists among criteria involved. The Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) technique is combined to the new weighting method to rank the consulting firm. A MCDM problem of consulting firms found in real-life international company is presented. The new approach so-called SDV-MOORA is employed to solve the MCDM problem.

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1. Introduction

A consulting firm is a firm of experts (consultants) providing professional advice to an organization or an individual for a fee. A consulting firm consists of consultants who are experts in their field. For some global consulting firms, their employees represent from many nationality. Usually, a consulting firm provides its service which is in core business discipline, from marketing to operations; but there are consulting firms which not only provide business service but politics as well [7].

The MCDM includes many solution techniques such as Simple Additive Weighting (SAW), Weighting Product (WP) [11], and Analytic Hierarchy Process (AHP) [12]. The problem of allocating the weights of criteria when no preference is an open research area. The Information Entropy method is very suitable for allocating weights among criteria because it gives more weight to more informative criteria. Many scholars tried to tackle this problem by applying the Information Entropy Weight (IEW) method [8,9].

In this paper, a real-life problem existed in multi-national company is presented. The company is wiling to introduce a new product to the Egyptian market; so it needs consultations concerning pricing strategy, marketing, and operations. The Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method, a branch of MCDM methods, is applied to rank the international consulting firms. An Information Entropy Weighting (IEW) method is introduced for the criteria of selection. This paper is structured as following:

Section 2 is made for the TOPSIS approach, section 3 is devoted to the Information Entropy Weight new method, the case study is illustrated in section 4, and finally in section 5 conclusion is presented.

2. TOPSIS

A MCDM problem can be concisely expressed in a matrix format, in which columns indicate criteria (attributes) considered in a given problem; and in which rows list the competing alternatives. Specifically, a MCDM problem with m alternatives ($A_1, A_2, ..., A_m$) that are evaluated by n criteria ($C_1, C_2, ..., C_n$) can be viewed as a geometric system with m points in n-dimensional space. An element x_{ij} of the matrix indicates the performance rating of the i^{th} alternative A_i, with respect to the j^{th} criterion C_j, as shown in Eq. (1):

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{bmatrix} \end{array} \quad (1)$$

Hwang and Yoon [11] introduced the TOPSIS method based on the idea that the best alternative should have the shortest distance from the positive ideal solution and farthest distance from the negative ideal solution. They assumed that if each criterion is monotonously increasing or decreasing, then it is easy to define an ideal solution. Such a solution comprises all the best achievable values of the criteria, while the worst solution is composed of all the worst criteria values achievable, the TOPSIS solution method consists of the following steps [1]:

Step 1: Normalizing the decision matrix

The normalization of the decision matrix is done using the following transformation, for each x_{ij}.

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = 1, \cdots, m; \quad j = 1, \cdots, n. \tag{2}$$

Step 2: Constructing the normalized weighted decision

The columns of the normalized decision matrix are multiplied by the associated weights as follows

$$v_{ij} = w_j . n_{ij}, \quad i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, n, \tag{3}$$

where w_j represents the weight of j^{th} criterion, and $\sum_{j=1}^{n} w_j = 1$

Step 3: Determining the positive and negative ideal solutions

The positive and negative ideal value sets are determined, respectively, as follows

$$A^+ = (v_1^+, v_2^+, \ldots, v_n^+) = \{(\max_j v_{ij} | j \in \Omega_b), (\min_j v_{ij} | j \in \Omega_c)\}, \tag{4}$$

$$A^- = (v_1^-, v_2^-, \ldots, v_n^-) = \{(\min_j v_{ij} | j \in \Omega_b), (\max_j v_{ij} | j \in \Omega_c)\}, \tag{5}$$

where Ω_b is the set of benefit criteria and Ω_c is the set of cost criteria.

Step 4: Measuring the distance from positive and negative ideal solutions

Two Euclidean distances for each alternative are calculated as follows:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}, \quad i = 1, 2, \ldots, m, \tag{6}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \quad i = 1, 2, \ldots, m, \tag{7}$$

where S_i^+ and S_i^- represents the distance of alternative A_i from the positive and negative ideal solutions, respectively.

Step 5: Calculating the relative closeness to the ideal solution

The relative closeness to the ideal solution is defined as follows

$$RC_i = \frac{S_i^-}{S_i^+ + S_i^-}, \quad i = 1, 2, \ldots, m, \quad 0 \leqslant RC_i \leqslant 1, \tag{8}$$

where RC_i represents the relative closeness.

Step 6: Ranking the alternatives

Alternatives must be ranked based on RC_i in which the highest score is the best alternative.

In the past decade, TOPSIS have been extended according to the requirements of different real-world decision making problems, it has been successfully applied in various optimization areas like supplier evaluation and selection [4], expatriate host country selection [5], robot selection [6], operating system selection [2], customer evaluation [3], facility location [10], and personnel training [9].

3. Information Entropy Weight Method

The weight of the criterion reflects its importance in MCDM. In this paper, an objective weight is applied; named Information Entropy Weight (IEW) based on the information entropy of raw data [13]. Range standardization was done to transform different scales and units among various criteria into common measurable units in order to compare their weights.

$$x'_{ij} = \frac{x_{ij} - \min_{1 \le j \le n} x_{ij}}{\max_{1 \le j \le n} x_{ij} - \min_{1 \le j \le n} x_{ij}} \tag{9}$$

$D' = (x')_{m \times n}$ is the matrix after range standardization; max x_{ij}, min x_{ij} are the maximum and the minimum values of the criterion (j) respectively, all values in D' are $(0 \le x'_{ij} \le 1)$.

So, according to the normalized matrix $D' = (x')_{m \times n}$ the information entropy is calculated as shown in the following steps, first in order to avoid the insignificance of ln f_{ij} in Eq. (11) f_{ij} is stipulated as shown in Eq. (10):

$$f_{ij} = \frac{1 + x'_{ij}}{\sum_{i=1}^{m} \left(1 + x'_{ij}\right)} \tag{10}$$

$$H_j = -\left(\sum_{i=1}^{m} f_{ij} \ln f_{ij}\right) \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n \tag{11}$$

After calculating the variation degree (H_j), the deviation degree of the criterion (j) noted by (G_j) is computed as in Eq. (12)

$$G_j = 1 - H_j \quad j = 1, 2, \ldots, n \tag{12}$$

It is obvious that (G_j) is greater if the value of (H_j) is smaller, consequently if the (G_j) is higher, the information entropy (H_j) is lower, which indicates that the more the information criterion (j) provides, the greater weight given to the criterion (j). The weight (W_j) of the criterion (j) is defined as:

$$w_j = \frac{G_j}{\sum_{j=1}^{n} G_j} = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j} \tag{13}$$

where $j = 1, 2, \ldots, n$.

4. Project Selection Problem

A multi-national manufacturing company must select a consulting firm to help determine the price for its new product. After preliminary screening, five alternative consulting firms are short-listed. A committee is formed to conduct the evaluation and selection of the four alternative consulting firms. The committee set four criteria to be compared; three benefit criteria, the company size (C_1), potential profit (C_2), and expected growth (C_3). One cost criterion, the cost of the consulting (C_4) is also considered. All criteria considered are quantitative type. Table 1 shows the four criteria, their relevant weights assigned by the committee, and their computation units.

Table 1: Criteria and their computation units

Criterion Index	Criterion Description	Computation Units
C_1	Company Size	No. of employees
C_2	Potential Profit	L.E.(Millions)
C_3	Expected Growth	Percentage
C_4	Cost	L.E.(Thousands)

The management presented the data included in the decision matrix found in Table 2 showing the five firms, and their performance ratings with respect to all criteria.

Table 2: Decision matrix

	C_1	C_2	C_3	C_4
Firm1	1635	56	14%	235
Firm2	2564	89	21%	243
Firm3	1587	48	18%	198
Firm4	1296	75	15%	263
Firm5	963	68	30%	217

In the above example, there is no preference among the criteria, no weights specified for them subjective by the decision maker, so the proposed method will be applied for allocating weights. Table 3 illustrates the range standardization done to decision matrix as in Eq.(9).

Table 3: Range standardized decision matrix

Index	C_1	C_2	C_3	C_4
Firm1	0.419	0.195	0	0.569
Firm2	1	1	0.437	0.692
Firm3	0.39	0	0.25	0
Firm4	0.208	0.658	0.062	1
Firm5	0	0.487	1	0.292

Table 4 shows the values of the variation degree (H_j), the deviation degree (G_j), and the weight assigned to each criterion (W_j) based on information entropy as in Eqs. (11,12, and 13).

Table 4: Weights assigned to criteria

	H_j	G_j	W_j
C_1	1.58224226	-0.582242	0.25071
C_2	1.58087619	-0.580876	0.25013
C_3	1.57601449	-0.576014	0.24803
C_4	1.58319906	-0.583199	0.25113

After determining A^+ and A^- (the positive and negative ideal solutions) as shown in Eqs. (4 and 5) S^+ and S^- (the separation distances from both ideal solutions) are computed for each alternative as in Eqs. (6 and 7). Then finally the relative closeness index for each alternative is computed as shown in Eq. (8). The higher the RC value the more preferable the alternative is. Table 5 combines the separation distances, the Relative Closeness (RC) score for each alternative, and their final ranks.

Table 5: Ranking lists and scores

	S^+	S^-	RC	Rank
Firm1	0.12054	0.04824	0.28585	5
Firm2	0.0535	0.13115	0.71028	**1**
Firm3	0.11347	0.05623	0.33137	3
Firm4	0.12318	0.04945	0.28648	4
Firm5	0.11163	0.09541	0.46084	2

As shown in Table 5, the second firm should be selected because of its highest RC.

5. Conclusion

In this paper, a new objective method of determining weights based on information entropy is illustrated. This new method is incorporated to TOPSIS method. The new method was employed to solve a consulting firm selection problem. The MCDM problem incorporates many financial aspects to be optimized. The MCDM should be reformulated and solved if any parameter or alternative is added or deleted because of its sensitivity to any changes.

Corresponding Author:
Mohamed Fathi El-Santawy
E-mail: lost_zola@yahoo.com

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