# Supplier Selection using MADM Method Under Uncertainty

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### Abstract

In existing literature, there are several studies on supplier selection process, which opine that the suppliers' information is usually incomplete and uncertain. Several methods have been proposed for solving this problem, one of which is the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method with interval data. There is no doubt that the TOPSIS with interval data method is a powerful technique in uncertain decision-making context. Despite its usefulness, it is logical that when data are imprecise, weight is imprecise too. To overcome this limit, the extended Shannon's Entropy method with interval data is used. The main findings of this study confirm the effectiveness of the hybrid proposed models.

**Keywords:** TOPSIS, Entropy, Uncertainty, Supplier Selection Problem

## Introduction

These days, the management of supply chain has attracted the attention of most companies since this ensures their survival in a competitive market condition and they can reach to customer satisfaction objects through applying this management system. Competition between companies is no longer meaningful. Instead, competition between supply chains has been evolved. For this reason, supplier selection problem plays a significant role as a strategic feature in company's success (Shahgholian *et al*., 2011). Supplier selection is the process by which suppliers are reviewed, evaluated, and chosen to become part of the company's supply chain. The overall objective of supplier selection process is to reduce purchase risk, maximise overall value to the purchaser, and build the closeness and long-term relationships between buyers and suppliers (Sanayei *et al*., 2010). Therefore, supplier selection process represents a complex problem and thus a Multi Attribute Decision Making (MADM) problem (Enyinda *et al*., 2010). On the other side of this coin, in many circumstances, the attributes, especially qualitative ones, could only be properly assessed using human judgement, which is subjective in nature and is inevitably associated with uncertainties caused due to the following two phenomena. 1. A human beings inability to provide complete judgements, or the lack of information, which is referred to as "ignorance" (incompleteness). 2. The vagueness of meanings about attributes and their assessments, which is referred to as "fuzziness" (vagueness) (Guo *et al*., 2009).

Generally uncertainty means lack of certainty. It is a state of having limited knowledge where it is impossible to exactly describe the existing state a future outcome, or more than one possible outcome (Nadeem *et al*., 2014). In existing literature, there are several studies on supplier selection process, which opine that suppliers' information is usually incomplete and uncertain (for instance, Sanayei *et al*., 2010; Izadikhah, 2012; Mukherjee & Kar, 2012; Lin, 2012). Nevertheless, source of uncertainty is classified into two categories. These are internal uncertainties that are specific to the supplying firm (i.e. suppliers don't have adequate capacity to produce the required amount, lack of correct and up to date information, lack of adequate financial resources, technology, commitment, and logistic capabilities, etc.). And those that come from the environment in which the firm exists (i.e. increase in the general price level of raw material and cultural barriers, etc.) (Nadeem *et al*., 2014). Whether the uncertainty in the supply chain can be reduced or eliminated effectively, to a great extent, relies on our description of the uncertainty in supply chain systems. There exist a lot of methods for quantitative description of supply chain uncertainty, generally involving: interval analysis, statistical method, fuzzy sets method, scenario analysis method, etc. (Xu *et al*., 2013). Therefore, in this paper an extended technique for order preference by similarity to ideal solution (TOPSIS) method with interval data is proposed to solve the supplier selection problem under uncertainty.

TOPSIS proposed by Yoon & Hwang, is one of the widely used techniques in MADM (Lin *et al*., 2008). MADM models are selector models that are used for evaluating, ranking, and selecting the most appropriate alternative from among several alternatives (Alinezhad & Amini, 2011). Moreover, TOPSIS can rank a finite number of feasible alternatives in order of preference according to the features of each attribute of every alternative and select a suitable alternative that conforms to the decision maker's ideal. The basic concept of TOPSIS technique is that the selected alternative will have the shortest Euclidean distance from the ideal solution and the farthest Euclidean distance from the anti-ideal solution (Lin *et al*., 2008). In the classical TOPSIS method, the rating of alternatives and the weights of criteria are presented by real values (Dymova *et al*., 2013). Jahanshahloo *et al*. (2006) extended the concept of TOPSIS to develop a methodology for solving MADM problems with interval data. That is the problem we will wish to address here.

In such environments classical MADM methods, which use crisp numbers to express the ratings and weights, do not provide adequate and affective decision-making (Stanujkic *et al*., 2012). It should be emphasized at this point that there is no doubt that the TOPSIS with interval data method is a powerful technique in uncertain decision-making context. However, it is logical that when data are imprecise, weight is imprecise too (Lotfi & Fallahnejad, 2010). Since, to overcome this limitation, the extended Shannon's Entropy method with interval data is used. The concept of Shannon's entropy has an important role in information theory and is used to refer to a general measure of uncertainty. So, in MADM the greater the value of the entropy corresponding to an special attribute, which implies the smaller attributes weight, the lesser the discriminate power of that attribute in decision making process (Lotfi & Fallahnejad, 2010). In continuation, this paper aims to use a numerical example to illustrate the process of the proposed MADM method (TOPSIS with interval data based on the extended Shannon's entropy with interval data) in supplier selection problem. So that, at first, the extended entropy method is used to determine the weights of criteria's, and then the extended TOPSIS method is used to rank the preference order of alternatives.

The paper is organised as follow. In the second section, the literature and in the third section, the proposed approach is discussed. Numerical example is provided in the next section. The paper is concluded in the fifth and the last section.

## Literature Review

In supplier selection process the suppliers' information and performances are usually incomplete and uncertain (Izadikhah, 2012). Under this situation, it becomes necessary to develop such decision-making models, which can easily handle the uncertain information (Chatterjee & Chatterjee, 2012). As noted earlier, several methods have been proposed for solving this problem. For instance, interval analysis, statistical methods, fuzzy sets method, scenario analysis method, etc. in this section, we will mention some of them (we assessed just those ones, which were based on TOPSIS approach). Jahanshahloo *et al*. (2009) proposed a new TOPSIS method with interval data. This new method can sort units by interval efficiency due of the nature of data. If the data are real numbers, this new method is the same as the current TOPSIS method. Yue (2011) extended TOPSIS for determining weights of decision makers with interval data. Amindoust *et al*. (2012) performed a taxonomy and review on supplier selection methods under uncertainty (particularly MADM methods). Andreica and Andreica (2012) used the TOPSIS and ELECTRE III method with interval data to select the best portfolio structure. Izadikhah (2012) extended TOPSIS method for group decision making with Atanassovs interval-valued intuitionistic fuzzy numbers, to solve the supplier selection problem under incomplete and uncertain information environment. In the research by Ju and Wang (2012), the DS (Dempster-Shafer theory)/ AHP (Analytic Hierarchy Process) method and extended TOPSIS method are incorporated to solve group Multi Criteria Decision making problems with incomplete information. Li *et al*. (2012) presented a new model for MCGDM by integrating fuzzy AHP with fuzzy TOPSIS based on interval-typed fuzzy numbers, to help group decision makers for well selection during refract ring treatment. Mehralian *et al*. (2012) developed a fuzzy TOPSIS model for supplier selection by considering risk factors. Momeni *et al*. (2012) applied a new integrated method to technology selection. Their proposed approach is based on fuzzy AHP (FAHP) and interval TOPSIS methods so that FAHP is used in determining the weights of the criteria and then ranking of technologies determined by interval TOPSIS method. Das *et al*. (2013) proposed an application of weighted fuzzy Multi Attribute Decision Making method based interval type-2

TOPSIS method on supplier selection in a risk oriented supply chain. Dymova *et al*. (2013) proposed a new approach to the solution of MADM problems with the use of TOPSIS method in the interval setting. This method called "direct interval extension of TOPSIS method", which is free of heuristic assumption and limitations of known methods concerned with the definition of positive and negative ideal solutions and using the Euclidean distance when intervals in a decision matrix intersect. Iranzadeh *et al*. (2013) selected and graded of suppliers by using fuzzy TOPSIS method. firstly, the important criteria in evaluation of items suppliers were collected by questionnaire and the main criteria were chose and their importance grade was specified by other questionnaire; consequently, the suppliers were graded in ten groups by using fuzzy TOPSIS. Jafarnejad and Salami (2013) used the grey TOPSIS and Delphi methods to select the most appropriate auto bumper suppliers of an assembling company in IRAN. Finally, Roghanian *et al*. (2014) used fuzzy TOPSIS model to evaluate and select suppliers, in uncertainty conditions.

This paper focuses on the application of a TOPSIS with interval data, introduced by Jahanshahloo *et al.* (2006) and the extended Shannon's entropy method with interval data, introduced by Lotfi and Fallahnejad (2010) for solving supplier selection problems in uncertain environment. according to Mohaghar *et al*. (2014), in order to find a solution to the problem, a variety of authors have tried to combine two or more techniques through shifting the solution in a specific stage to another technique or using results of one as input of another based on a logical idea. These innovative approaches can both cover the weaknesses of different techniques and pave the way to benefit from the advantages of all involved techniques simultaneously. Even so, it is the aim of this paper. In the next section, the proposed method will be considered.

## Proposed Approach

In many real life problems, the data of the decision-making processes cannot be measured precisely and there may be some other types of data, for instance interval data and fuzzy data. In other words, the decision maker would prefer to say his/her point of view in these forms rather than a real number because of the uncertainty and the lack of certain data, especially when data are known to lie within bounded variables, or when facing missing data, judgement data, etc. (Lotfi & Fallahnejad, 2010). So, suppose $A_1, A_2,\ldots,A_m$ are m possible alternatives among which decision makers have to choose, $C_1, C_2,\ldots, C_n$ are criteria with which alternative performance are measured, $x_{ij}$ is the rating of alternative $A_i$ with respect to criterion $C_j$ and is not known exactly and only we know $x_{ij} \in [x_{ij}^l, x_{ij}^u]$. A MADM problem with interval data can be concisely expressed in matrix format as shown in Table 1 (Jahanshahloo *et al*., 2006).

**Table 1: Criteria for Different Alternatives**

| - | $C_1$ | $C_2$ | … | $C_3$ |
|---|---|---|---|---|
| $A_1$ | $[x_{11}^l, x_{11}^u]$ | $[x_{12}^l, x_{12}^u]$ | … | $[x_{1n}^l, x_{1n}^u]$ |
| $A_2$ | $[x_{21}^l, x_{21}^u]$ | $[x_{22}^l, x_{22}^u]$ | … | $[x_{2n}^l, x_{2n}^u]$ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| $A_3$ | $[x_{m1}^l, x_{m1}^u]$ | $[x_{m2}^l, x_{m2}^u]$ | … | $[x_{mn}^l, x_{mn}^u]$ |

$w= [w_1, w_2\ldots w_n]$, where $w_j$ is the weight of criterion $C_j$.

### TOPSIS with Interval Data

In Jahanshahloo *et al*. (2006), an interval extension of original TOPSIS method was proposed. This approach may be described as follow:

1. Calculate the normalised decision matrix. The normalised value $\bar{n}_{ij}$ is calculated as:

$$\bar{n}_{ij}^l = x_{ij}^1 / \sqrt{\sum_{j=1} m (x_{ij}^l)^2 + (x_{ij}^u)^2}\ , j=1,\ldots,m,\ i=1,\ldots,n, \quad (1)$$

$$\bar{n}_{ij}^u = x_{ij}^u / \sqrt{\sum_{j=1} m (x_{ij}^l)^2 + (x_{ij}^u)^2}\ , j=1,\ldots, m,\ i=1,\ldots,n, \quad (2)$$

2. Calculate the weighted normalised interval decision matrix. The weighted normalised value $\bar{v}_{ij}$ is calculated as:

$$\bar{v}_{ij}^l = w_i \bar{n}_{ij}^l,\ j=1,\ldots, m,\ i=1,\ldots, n, \quad (3)$$

$$\bar{v}_{ij}^u = w_i \bar{n}_{ij}^u,\ j = 1,\ldots, m,\ i=1,\ldots, n, \quad (4)$$

Where $w_i$ is the weight of the $i_{th}$ attribute or criterion, and $\sum_{i=1} n = 1$.

3. Determine the positive ideal and negative ideal solution.

$$\overline{A}^{+}_{jj} = \{\overline{v}_1^{+},...,\overline{v}_n^{+}\} = \{(\max \overline{v}_{ij}^{u} / i \in I), (\min \overline{v}_{ij}^{l} / i \in J)\}, \quad (5)$$

$$\overline{A}^{-}_{jj} = \{\overline{v}_1^{-},...,\overline{v}_n^{-}\} = (\min \overline{v}_{ij}^{u} / i \in J)\}, \{(\max \overline{v}_{ij}^{l} / i \in I), \quad (6)$$

where $I$ is associated with benefit criteria, and $J$ is associated with cost criteria.

4. Calculate the separation measures, using the n-dimensional Euclidean distance. The separation of each alternative from the ideal solution is given as:

$$\overline{d}_j^{+} = \left\{\sum_{i} \in I(\overline{v}_{ij}^{l} - \overline{v}_i^{+})^2 + \sum_{i} \in I(\overline{v}_{ij}^{u} - \overline{v}_i^{+})^2\right\}^{1/2}, \quad j = 1,\ldots, m. \quad (7)$$

Similarly, the separation from the negative ideal solution can be calculated as:

$$\overline{d}_j^{-} = \left\{\sum_{i} \in I(\overline{v}_{ij}^{u} - \overline{v}_i^{-})^2 + \sum_{i} \in I(\overline{v}_{ij}^{l} - \overline{v}_i^{-})^2\right\}^{1/2}, \quad j = 1,\ldots, m. \quad (8)$$

5. Calculate the relative closeness to the ideal solution. The relative closeness of the alternative $A_j$ with respect to $\overline{A}^{+}$ is defined as:

$$\overline{R}_j = \overline{d}_j / (\overline{d}_j^{+} + \overline{d}_j^{-}), \; j = 1,\ldots, m. \quad (9)$$

Obviously, an alternative $A_j$ is closer to the $\overline{A}^{+}$ and farther from $\overline{A}^{-}$ as $\overline{R}$j approaches to 1.

6. Rank the preference order. Therefore, according to the closeness coefficient, we can determine the ranking order of all alternatives and select the best one from among a set of feasible alternatives.

## Entropy with Interval Data

In Lotfi and Fallahnejad, (2010), an extended Shannon's Entropy method was proposed. This approach may be described as follow:

1. The normalised values $P_{ij}^{l}$ and $P_{ij}^{u}$ are calculated as:

$$P_{ij}^{l} = x_{ij}^{l} / \sum_{j=1}^{m} x_{ij}^{u}, \; P_{ij}^{u} = x_{ij}^{u} / \sum_{j=1}^{m} x_{ij}^{u}, \quad j=1,\ldots, m, \; i = 1,\ldots, n. \quad (10)$$

2. Lower bound $h_i^{l}$ and upper bound $h_i^{u}$ of interval entropy can be obtained by:

$$h_i^{l} = \min \{- h0 \sum_{j=1}^{m} p_{ij}^{l}. \mathrm{Ln}\, p_{ij}^{l}, - h0 \sum_{j=1}^{m} p_{ij}^{u}. \mathrm{Ln}\, p_{ij}^{u}\}, \; i= 1,\ldots, n. \quad (11)$$

$$h_i^{u} = \max \{- h0 \sum_{j=1}^{m} p_{ij}^{l}. \mathrm{Ln}\, p_{ij}^{l}, - h0 \sum_{j=1}^{m} p_{ij}^{u}. \mathrm{Ln}\, p_{ij}^{u}\}, \; i= 1,\ldots, n. \quad (12)$$

where h0 is equal to (Ln m)-1, and $P_{ij}^{l}$. Ln $p_{ij}^{l}$ or $p_{ij}^{u}$. Ln $p_{ij}^{u}$ is defined as 0 if $P_{ij}^{l}= 0$ or $P_{ij}^{u}= 0$.

3. Set the lower and the upper bound of the interval of diversification $d_i^{l}$ and $d_i^{u}$ as the degree of diversification as follow:

$$d_i^{l} = 1- h_i^{u}, \; d_i^{u} = 1- h_i^{l}, \; i= 1,\ldots, n. \quad (13)$$

4. Set $w_i^{l} = d_i^{l} / \sum_{s=1}^{n} d_s^{u}$, $w_i^{u} = d_i^{u} / \sum_{s=1}^{n} d_s^{l}$, i=1,…, n, as the lower and upper bound of interval weight of attribute i.

**Theorem:** The inequality $w_i^{l} \le w_i^{u}$, i= 1,…, n is held.

**Numerical example:**
In this section, a numerical example is used to illustrate the application of the proposed method. Assume that there are seven alternative (suppliers; $S_1$, $S_2$, …, $S_7$) and four criteria ($C_1$=price and cost, $C_2$=quality, $C_3$=on-time delivery, and $C_4$=production facility and capacity). As you see, the performance values are shown in Table 2.

**Table 2: Interval Decision Matrix of 7 Alternatives**

| Criteria / Alternative | $C_1$* | | $C_2$ | | $C_3$ | | $C_4$** | |
|---|---|---|---|---|---|---|---|---|
| | $x_{1j}^{l}$ | $x_{1j}^{u}$ | $x_{2j}^{l}$ | $x_{2j}^{u}$ | $x_{3j}^{l}$ | $x_{3j}^{u}$ | $x_{4j}^{l}$ | $x_{4j}^{u}$ |
| $S_1$ | 8500 | 9000 | 95 | 96 | 27 | 28 | 1000 | 1000 |
| $S_2$ | 10500 | 10900 | 65 | 67 | 30 | 33 | 2000 | 2000 |
| $S_3$ | 11000 | 11500 | 77 | 80 | 25 | 27 | 4000 | 4000 |
| $S_4$ | 12500 | 12900 | 71 | 73 | 40 | 45 | 3000 | 3000 |
| $S_5$ | 11500 | 11700 | 60 | 63 | 35 | 39 | 2500 | 2500 |
| $S_6$ | 13000 | 13500 | 63 | 65 | 41 | 44 | 3500 | 3500 |
| $S_7$ | 12000 | 13000 | 58 | 60 | 23 | 26 | 1500 | 1500 |

*.cost-type criteria
**. As can be seen, the last criterion is in the crisp form.

First, we want to get a weight for each criterion by using the proposed approach (the extended Shannon's entropy method with interval data). So, in Table 3, the normalised rates, and in Table 4, entropy, degree of diversification and weight are presented.

**Table 3: Normalised Rates ($P_{ij}$)**

| Criteria / Alternative | $C_1$ | | $C_2$ | | $C_3$ | | $C_4$ | |
|---|---|---|---|---|---|---|---|---|
| | $x_{1j}^l$ | $x_{1j}^u$ | $x_{2j}^l$ | $x_{2j}^u$ | $x_{3j}^l$ | $x_{3j}^u$ | $x_{4j}^l$ | $x_{4j}^u$ |
| $S_1$ | .103 | .109 | .188 | .190 | .112 | .116 | .057 | .057 |
| $S_2$ | .127 | .132 | .129 | .133 | .124 | .136 | .114 | .114 |
| $S_3$ | .133 | .139 | .153 | .159 | .103 | .112 | .229 | .229 |
| $S_4$ | .152 | .156 | .141 | .145 | .165 | .186 | .171 | .171 |
| $S_5$ | .139 | .142 | .119 | .125 | .145 | .161 | .143 | .143 |
| $S_6$ | .158 | .164 | .125 | .129 | .169 | .182 | .200 | .200 |
| $S_7$ | .145 | .158 | .115 | .119 | .095 | .107 | .086 | .086 |

**Table 4: Entropy, Degree of Diversification and Weight**

| - | $C_1$ | | $C_2$ | | $C_3$ | | $C_4$ | |
|---|---|---|---|---|---|---|---|---|
| Entropy | .975 | .996 | .978 | .994 | .945 | .988 | .957 | .957 |
| degree of diversification | .004 | .025 | .006 | .022 | .012 | .055 | .043 | .043 |
| weight | .027 | .380 | .044 | .329 | .083 | .832 | .300 | .661 |

From the above results, it can be concluded that, the criteria weights is as follow:

$W_j$ = (.027, .380; .044, .329; .083, .832; .300, .661)

Next, when the TOPSIS method with interval data is applied, the following values are derived (Table 5-10).

**Table 5: Interval Normalised Decision Matrix ($\bar{n}_{ij}$)**

| Criteria / Alternative | $C_1$ | | $C_2$ | | $C_3$ | | $C_4$ | |
|---|---|---|---|---|---|---|---|---|
| | $x_{1j}^l$ | $x_{1j}^u$ | $x_{2j}^l$ | $x_{2j}^u$ | $x_{3j}^l$ | $x_{3j}^u$ | $x_{4j}^l$ | $x_{4j}^u$ |
| $S_1$ | .195 | .207 | .353 | .357 | .213 | .221 | .099 | .099 |
| $S_2$ | .241 | .251 | .242 | .249 | .237 | .260 | .199 | .199 |
| $S_3$ | .253 | .264 | .286 | .297 | .197 | .213 | .397 | .397 |
| $S_4$ | .287 | .297 | .264 | .271 | .316 | .355 | .298 | .298 |
| $S_5$ | .264 | .269 | .223 | .234 | .276 | .308 | .248 | .248 |
| $S_6$ | .299 | .310 | .234 | .242 | .324 | .347 | .347 | .347 |
| $S_7$ | .276 | .299 | .216 | .223 | .182 | .205 | .149 | .149 |

**Table 6: Interval Weighted Normalised Decision Matrix ($\bar{v}_{ij}$)***

| Criteria / Alternative | $C_1$ | | $C_2$ | | $C_3$ | | $C_4$ | |
|---|---|---|---|---|---|---|---|---|
| | $x_{1j}^l$ | $x_{1j}^u$ | $x_{2j}^l$ | $x_{2j}^u$ | $x_{3j}^l$ | $x_{3j}^u$ | $x_{4j}^l$ | $x_{4j}^u$ |
| $S_1$ | .005 | .079 | .016 | .117 | .018 | .184 | .030 | .066 |
| $S_2$ | .007 | .095 | .011 | .082 | .020 | .217 | .060 | .131 |
| $S_3$ | .007 | .100 | .013 | .098 | .016 | .177 | .119 | .262 |
| $S_4$ | .008 | .113 | .012 | .089 | .026 | .296 | .089 | .197 |
| $S_5$ | .007 | .102 | .010 | .077 | .023 | .256 | .074 | .164 |
| $S_6$ | .008 | .118 | .010 | .079 | .027 | .289 | .104 | .230 |
| $S_7$ | .007 | .114 | .009 | .073 | .015 | .171 | .045 | .098 |

* Based on table 3; $W_j$ = (.027, .380; .044, .329; .083, .832; .300, .661).

**Table 7: Positive and Negative Ideal Solution ( $\bar{A}$ )**

| - | $C_1$ | $C_2$ | $C_3$ | $C_4$ |
|---|---|---|---|---|
| $\bar{A}^+$ | .005 | .117 | .296 | .262 |
| $\bar{A}^-$ | .118 | .009 | .015 | .030 |

**Table 8: Distance of Each Alternative from the Positive Ideal Solution ( $\bar{d}_j^+$ )**

| $\bar{d}_1^+$ | $\bar{d}_2^+$ | $\bar{d}_3^+$ | $\bar{d}_4^+$ | $\bar{d}_5^+$ | $\bar{d}_6^+$ | $\bar{d}_7^+$ |
|---|---|---|---|---|---|---|
| .384 | .370 | .344 | .354 | .361 | .348 | .387 |

**Table 9: Distance of Each Alternative from Negative Ideal Solution ( $\bar{d}_j^-$ )**

| $\bar{d}_1^-$ | $\bar{d}_2^-$ | $\bar{d}_3^-$ | $\bar{d}_4^-$ | $\bar{d}_5^-$ | $\bar{d}_6^-$ | $\bar{d}_7^-$ |
|---|---|---|---|---|---|---|
| .233 | .262 | .317 | .354 | .305 | .363 | .213 |

**Table 10: Closeness Coefficient ( $\bar{R}_j$ )**

| $\bar{R}_1$ | $\bar{R}_2$ | $\bar{R}_3$ | $\bar{R}_4$ | $\bar{R}_5$ | $\bar{R}_6$ | $\bar{R}_7$ |
|---|---|---|---|---|---|---|
| .378 | .415 | .480 | .500 | .458 | .510 | .355 |

From the above results, it can be concluded that the ranking is as follow:

S6>S4>S3>S5>S2>S1>S7

Therefore, the best supplier is S6, since it is superior to all the other suppliers. Meanwhile, S7 have very bad performance.

Here, more studies have been done. According to Eshlaghy and Radfar (2006), changing the weight in decision-making process has a great influence in ranking results. Since, in order to compare the new result based on equal weight rule (1/n) with the proposed approach (the extended Shannon's entropy method with interval data) results (Table 10), we use the same numerical example (Table 2). With no intension to describe the whole procedure, we shall only point to the final results. Results are as shown in Table 11.

**Table 11: Closeness Coefficient ( $\bar{R}_j$ ) [Based on Equal Weight Rules, 1/n=1/8=0.125]**

| $\bar{R}_1$ | $\bar{R}_2$ | $\bar{R}_3$ | $\bar{R}_4$ | $\bar{R}_5$ | $\bar{R}_6$ | $\bar{R}_7$ |
|---|---|---|---|---|---|---|
| .361 | .359 | .629 | .609 | .470 | .627 | .157 |

From the above results, it can be concluded that, the ranking is as follow:

S3>S6>S4>S5>S1>S2>S7

Therefore, the best supplier is S3, since it is superior to all the other suppliers. Meanwhile, S7 have very bad performance.

A comparison of the test results is given in Table 12 and Fig. 1.

**Table 12: Comparison of Results**

| Model | Priority |
|---|---|
| TOPSIS with interval data based on the extended Shannon's entropy with interval data's weight (Proposed method) | S6 > S4 > S3 > S5 > S2> S1 > S7 .510 .500 .480 .458 .415 .378 .355 |
| TOPSIS with interval data based on the equal weight rules (1/n=1/8=0.125) | S3 > S6 > S4 > S5 > S1> S2 > S7 .629 .627 .609 .470 .361 .359 .157 |

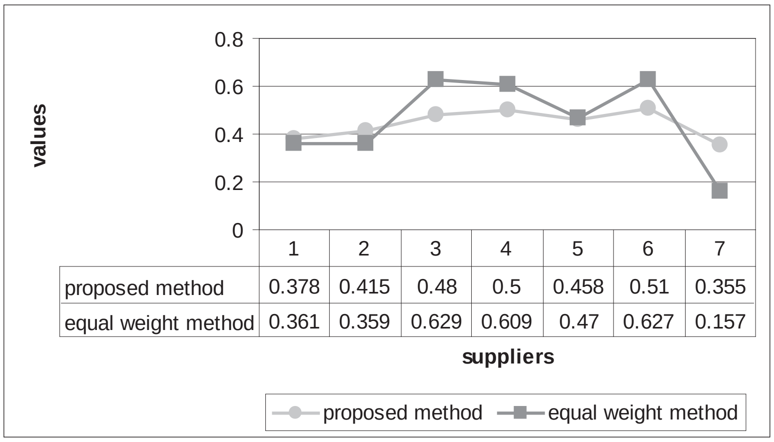


**Fig. 1. Comparison of Results**

As seen in Table 12 and Fig. 1, in this illustrative example the differences between two models (proposed and equal weighted method) are quite clear. This means that inclusion of this interval weight of attributes impact could greatly improve the decision making process. Therefore, findings in this paper confirm the effectiveness of proposed method.

## Concluding Remarks

There are several studies on supplier selection process which opine that suppliers' information is usually incomplete and uncertain. Several methods have been proposed for solving this problem too. In this paper, we proposed a hybrid approach based on TOPSIS with interval data and the extended Shannon's Entropy with interval data method, for supplier selection problems in uncertain environment. This approach can both cover the weaknesses of different techniques and pave the way to benefit from the advantages of involved techniques simultaneously. The findings in this paper confirm the effectiveness of proposed method. Moreover, further research can apply this proposed approach to other managerial issues or compared with another MADM methods under uncertainty environment.

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