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A Multiple Attribute Group Decision-making Model for Selecting the Best Supplier

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Abstract

In the current literature, supplier selection is an important Multi Attribute Group Decision Making (MAGDM) problem which heavily contributes to the overall supply chain performance. Several solutions for the above problem are proposed. In this paper, TOPSIS and Borda's function approach, which is one of these methods, is discussed. So that, in the present model, first TOPSIS is used to find the individual preference ordering. Then, Borda's function is used to find the collective preference orderings. Finally, a simple example is provided in order to demonstrate its applicability and effectiveness of the proposed method.

Keywords: MAGDM, Topsis, Borda's Function, Supplier Selection Problem

Introduction

Multi Attribute Decision Making (MADM) is an important component of modern decision science. The theory and methods of MADM have been extensively applied to the fields of engineering project, economy, management and military affairs, such as investment decision making, venture capital project evaluation, facility location, bidding, maintenance services, military system efficiency evaluation, development ranking of industrial sectors, comprehensive evaluation of economic performance, etc. Essentially, MADM is to select the most desirable alternative(s) from a given finite set of alternatives according to a collection of attributes by using a proper means. It mainly consists of two stages: 1. collect decision information. The decision information generally includes the attribute weights and the attribute values, especially, how to determine the attribute weights is an important research topic in MADM. 2. Aggregate the decision information through some proper approaches (Xu, 2015).

The increasing complexity of the socio-economic environment makes it less and less possible for a single expert or decision maker to consider all relevant aspects of a problem. Therefore, complex decision problems usually have to be conducted by integrating a group of expert's knowledge and experiences. Generally, the practice of Multiple Attribute Group Decision Making (MAGDM) is to invite internal experts, external experts, or their combination of related fields to evaluate each attribute of every alternative individually. In the MAGDM, the experts usually have diverging opinions, because they often come from different specialty fields and each expert has his/ her unique characteristics with regard to knowledge, skills, experience and personality. Thus, how to obtain the maximum degree of consensus or agreement from these experts for the given alternatives is an interesting and important research topic (Li & Sun, 2012). On the other side of this coin, supplier selection is a fundamental issue of supply chain area that heavily contributes to the overall supply chain performance, and also, it is a hard problem since supplier selection is typically a Multi Criteria Group Decision problem (Izadikhah, 2012). In this paper to solve this problem, TOPSIS and Borda's function approach is proposed.

TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) proposed by Yoon and Hwang is one

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of the widely used techniques in Multi Attribute Decision Making. 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, Lee, Chang & Ting, 2008). In addition, the Borda rule is an appropriate procedure in multi-person decision making when several alternatives are considered (Lapresta *et al*., 2008). It is based on a majority rule relation (Hwang & Yoon, 1981). In other words, the Borda technique assigns ranks to options based on the rational that the higher position of an option on the voters list, the higher the rank assigned. The voting position of an option is determined by adding the ranks for each option from every voter using the Borda vote aggregation function. The winner is an option that receives the highest score calculated such that all options are assigned a score starting with 0 for the last favourable solution, 1 for the second worst, 2 for the third worst, and so on. All scores are weighted by the number of voters, resulting in the Borda score for each option (Mysiak, 2010). Nevertheless, the TOPSIS and Borda's function approaches are the ordinal and cardinal approach. The ordinal (ranking) and cardinal (rating) approach allows committee members to individually evaluate each candidate and to find the collective preference ordering so that, TOPSIS can be used to find the individual preference ordering. Then Borda's function can be used to find the collective preference orderings (Hwang & Lin, 1987).

This paper aims to use a numerical example to illustrate the process of the proposed MAGDM method (TOPSIS and Borda's function approach) in supplier selection context.

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 recent years, TOPSIS has been successfully adopted in various fields, e.g. location analysis, construction processes, human resource management, transportation, product design, manufacturing, water management, and quality control, and has demonstrated satisfactory results (Lin *et al*., 2008). TOPSIS has also been employed in Multi Attribute Group Decision Making environment. For instance, Chen (2000), Wanga and Leeb (2007), and Krohling and Campanharo (2011) extended the TOPSIS method for fuzzy environment. Saghafian and Hejazi (2005) and Lin *et al*., (2008), proposed a modified fuzzy TOPSIS method for group decision problem. Boran, Genç, Kurt and Akay (2009) combined TOPSIS method with intuitionistic fuzzy set to select appropriate supplier in-group decision-making environment. Ghaemi Nasab and Malkhalifeh (2010) extended TOPSIS for group decision making based on the type-2 fuzzy positive and negative ideal solutions. Yue (2011) developed TOPSIS method for determining weights of decision makers with interval numbers. Huang and Li (2012) proposed a new aggregation rule for the use of TOPSIS in-group decision context. Izadikhah (2012) used an 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. And Zhang (2014) presented an MAGDM model to the assessing project risks. In addition, in the literature, Borda approach and TOPSIS and Borda's function have been applied in various fields. For instance, Lapresta *et al*. (2008) used linguistic labels as inputs in the Borda count. Shahbandarzadeh and Haghighat (2010) used LINMAP for target market selection so that LINMAP technique is used separately for each level (strengths, weaknesses, opportunities and threats), and at last unified the results of each level by using of Borda method. Anisseh and Yusuff (2011) suggested a new method under the linguistic framework for heterogeneous group decision making. To accomplish this, an integrated fuzzy group decision-making method based on Borda count is proposed. Kim and Ye (n.d.) proposed a general fuzzy grey decision making method, which takes into consideration of the grey degree of the weight and the attribute value at the same time, for the MADM where attributes have the generalised super mixed-type values given by real number, interval value, linguistic value, and uncertain linguistic value. Then, four ranks are obtained by four methods of plan evaluation such as the evaluation by the relative approach degree of grey TOPSIS. Finally, the weighted Borda method is used to obtain final rank by using the results of four methods. Fu (2008) developed three extended TOPSIS models, the pre-model, post-model, and inter-model, associated with three approaches to aggregating group preferences (the pre-operation, post-operation, and inter-operation), which depend on Dempster's rule or its modifications, some social choice functions (i.e. Borda's function and some mean approaches). Gharakhlou *et al.* (2010) used TOPSIS, fuzzy and SAW techniques for making changes in the route network to facilitate rescue operations in urban disasters. Next, the results were combined by means of Borda method. Kim *et al.* (n.d.), proposed an interval weight determining method and three methods of grey interval relation decision making: the evaluation of plans by the relative approach degree of grey TOPSIS method, the evaluation by the relative approach degree of grey incidence and the evaluation by the relative approach degree of grey incidence using maximum entropy estimation. The final rank of plans has been obtained by weighted Borda method considering the above three ranking results.

It should be emphasized at this point that, according to Hojjati and Anvari (2014), decision makers are not limited just to one method of MADM in critical issues, because it is possible that various MADM methods attain different results. In order to get over this problem, aggregate method (Borda method) has been introduced. In addition, in the literature, many studies exist on using Borda's function. However, most of them are limited to combine the results of different MADM methods (i.e., Hojjati & Anvari, 2014; Hashemi & Zamani, 2015 etc.). However, but in this paper we used Borda's function for to unify the results of each DM (expert) where same method is used (TOPSIS).

This paper focused on the application of MAGDM models, particularly TOPSIS and Borda's function approach for solving the supplier selection problem. In the next section, the proposed method will be considered.

Proposed Approach

Topsis Method

TOPSIS assumes that we have m alternatives (options) and n attributes/criteria and we have the score of each option with respect to each criterion. Let x_{ij} score of option i with respect to criterion j. we have a matrix $X = (x_{ij})_{m.n}$ matrix. Let J be the set of benefit attributes or criteria (more is better). Let J' be the set of negative attributes or criteria (less is better). The idea of Topsis can be expressed in a series of steps (Tayeb, Ahcene, Omar & Mouloud, 2007):

Step 1: Obtain performance data for n alternatives over k criteria. Raw measurements are usually standardised; converting raw measures x_{ij} into standardised measures s_{ij}. Construct normalised decision matrix. This step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. Normalize scores or data as follows:

$$r_{ij} = X_{ij} / \sqrt{\sum X_{ij}^2} \text{ for } i = 1, \ldots, m; j = 1, \ldots, n.$$

Step 2: Develop a set of importance weights wk, for each of the criteria. The basis for these weights can be anything, but usually, is ad hoc reflective of relative importance. Scale is not an issue if standardizing was accomplished in step 1. Construct the weighted normalised decision matrix. Assume we have a set of weights for each criteria wj for j = 1, …, n. multiplies each column of the normalised decision matrix by its associated weight. An element of the new matrix is:

$$V_{ij} = w_j r_{ij}$$

Step 3: Determine the ideal and negative ideal solutions.

Ideal solutions:

$$A^* = \{v_1^*, \ldots, v_n^*\}, \text{ where}$$

$$V_j^* = \{\max_i (v_{ij}) \text{ if } j \varepsilon J; \min_i (v_{ij}) \text{ if } j \varepsilon J'\}$$

Negative ideal solutions:

$$A' = \{v_1', \ldots, v_n'\}, \text{ where}$$

$$V_j^* = \{\min_i (v_{ij}) \text{ if } j \varepsilon J; \max_i (v_{ij}) \text{ if } j \varepsilon J'\}$$

Step 4: Calculate the separation measures for each alternative. The separation from the ideal alternative is:

$$S_i^* = [\sum_j (v_j^* - v_{ij})^2]^{\wedge 1/2} \quad i = 1, \ldots, m.$$

Similarly, the separation from the negative ideal alternative is:

$$S_i' = [\sum_j (v_j' - v_{ij})^2]^{\wedge 1/2} \quad i = 1, \ldots, m.$$

Step 5: calculate the relative closeness to the ideal solution C_i^*:

$C_i^* = S_i^{'} / S_i^* + S_i^{'} \quad 0<C_i^*<1$

Step 6: Rank order alternatives by maximizing the ratio in step 5. Select the option with C_i^* closest to 1.

Borda's Function

The method Borda function is the rank-order method. With m candidates in A, assign marks of m-1, m-2, …, 1, 0 to the first ranked, second ranked, … last ranked candidate for each individual, then determine the Borda score for each candidate as the sum of the individual marks for that candidate. Then the candidate with the highest Borda score is declared as the winner. The Borda score of a candidate x is equivalent to the sum of the number of individuals that have x preferred to y for all y϶A /{X}.

Borda's function:

Let

$F_B\,(X) = \sum_{y \in A} \#\,(i\text{: } X\ P_i\ Y)$

And the candidates are ranked in the order of the value of F_B (Hwang & Lin, 1987).

TOPSIS and Borda's function Approach

In this approach, TOPSIS can be used to find the individual preference ordering. Then Borda's function can be used to find the collective (social) preference orderings. With m candidates in A, scores of m-1, m-2, …, 1, 0 can be assigned to the first ranked, second ranked, …, last ranked candidate by each committee member. The Borda score (the sum of the committee members scores) can be determined for each candidate. Finally, the candidates are ranked according to their Borda scores (Hwang & Lin, 1987).

Numerical Example

In this section, a numerical example is used to illustrate the application of the proposed method. Assume that there are four committee members, who are experts (Experts; E1, E2, E3, and E4), seven alternatives (Suppliers; S_1, S_2, …, and S_7), and five criteria (C_1=quality, C_2=on-time delivery, C_3=service, C_4=responsiveness, and C_5=price and cost). As you see, the performance values for each expert are shown in table 1-4. In addition, several researchers have argued that the equal weight rule is often a highly accurate simplification of the decision making process (Birnbaum, 1998). Thus, W_j= (0.2, 0.2, 0.2, 0.2, and 0.2).

In the process of group decision making, each committee member (expert) provides the performance values, the alternatives with respect to each attribute (having common criteria for committee members). For expert 1:

Table 1: Performance Value for E1*

Criteria / Alternative	C_1	C_2	C_3	C_4	C_5^-
S_1	7	7	1	1	103
S_2	9	7	5	5	130
S_3	5	9	1	5	121
S_4	3	1	3	3	109
S_5	9	5	9	3	115
S_6	1	3	7	7	117
S_7	7	1	5	7	125

*note, that all attributes (criteria) except C5 are the benefit criteria (in the all tables).

For expert 2:

Table 2: Performance Value for E2*

Criteria / Alternative	C_1	C_2	C_3	C_4	C_5^-
S_1	1	7	7	7	101
S_2	1	1	5	5	132
S_3	9	5	9	3	123
S_4	5	3	5	5	108
S_5	3	3	5	9	115
S_6	3	9	3	1	119
S_7	3	9	5	5	121

For expert 3:

Table 3: Performance Value for E3*

Criteria / Alternative	C_1	C_2	C_3	C_4	C_5^-
S_1	9	1	7	9	105
S_2	7	7	1	5	130
S_3	1	7	5	1	122
S_4	9	3	9	1	111
S_5	3	9	1	3	115

Criteria / *Alternative*	C_1	C_2	C_3	C_4	C_5^-
S_6	1	5	9	1	116
S_7	3	1	3	7	123

For expert 4:

Table 4: Performance value for E4*

Criteria / *Alternative*	C_1	C_2	C_3	C_4	C_5^-
S_1	1	9	1	3	106
S_2	3	5	7	9	131
S_3	3	5	9	3	123
S_4	3	7	5	1	107
S_5	5	3	1	5	118
S_6	3	9	1	1	117
S_7	1	3	5	9	119

In this section, we have used TOPSIS to find the individual preference ordering. i.e., for E1:

1. Calculate the normalised decision matrix

For instance, for R_{11}:

$R_{11}= 7/\sqrt{7^2+9^2+5^2+3^2+9^2+1^2+7^2}=0.408$

$$R_{ij} = \begin{vmatrix} .408 & .477 & .072 & .077 & .331 \\ .524 & .477 & .362 & .387 & .418 \\ .291 & .614 & .072 & .387 & .389 \\ .175 & .068 & .217 & .232 & .351 \\ .524 & .341 & .651 & .232 & .370 \\ .058 & .205 & .507 & .542 & .376 \\ .408 & .068 & .362 & .542 & .402 \end{vmatrix}$$

2. Calculated the weighted decision matrix (as noted earlier, W_j= 0.2, 0.2, 0.2, 0.2, and 0.2). For instance, for V_{11}:

$V_{11}=0.408*0.2 = 0.082$

$$V_{ij} = \begin{vmatrix} .082 & .095 & .014 & .015 & .066 \\ .105 & .095 & .072 & .077 & .084 \\ .058 & .123 & .014 & .077 & .078 \\ .035 & .014 & .043 & .046 & .070 \\ .105 & .068 & .130 & .046 & .074 \\ .012 & .041 & .101 & .108 & .075 \\ .082 & .014 & .072 & .108 & .080 \end{vmatrix}$$

3. Determine the ideal and negative ideal solutions

A* = {v1*… vn*}; where, Vj* = {max (vij) if j ε J; min (vij) if j ε J'};

For instance, for v1*:

= max (0.082, 0.105, 0.058, 0.035, 0.105, 0.012, 0.082) =0.105

A* = (.105 .123 .130 .108 .066)

A^- = {$v1^-$ … vn^-}; where, Vj^- = {min (vij) if j ε J; max (vij) if j ε J^-}

For instance, for $v1^-$:

= min (0.082, 0.105, 0.058, 0.035, 0.105, 0.012, 0.082) =0.012

A^- = (.012 .014 .014 .015 .084)

4. Calculated the separation measures

$Si^* = [\Sigma_{j=1}^{7} (vj^* – vij) 2]^{\wedge 1/2}$, i = 1, 2, 3, 4, 5.

For instance, for S_1:

$S_1= \sqrt{}\ (0.082 – 0.105)^2+ (0.095-0.123)^2 + … + (0.066-0.066)^2 = 0.153$

S_1 =.153, S_2=.073, S_3=.129, S_4=.168, S_5=.083, S_6=.128, and S_7=.126

$Si^- = [\Sigma_{j=1}^{7} (vj^- - vij) 2]^{\wedge 1/2}$, i = 1… m.

For instance, for S_1:

$S_1= \sqrt{}\ (0.082-0.012)^2 + (0.095-0.014)^2+ … + (0.066-0.084)^2 = 0.109$

S_1 =.109, S_2 =.150, S_3=.134, S_4=.050, S_5=.162, S_6=.130, and S_7=.130

5. Calculated the relative closeness to the ideal solution

$C_1^* = S1^-/ S1^* + S1^- = 0.109 / (0.109+0.153) = 0.417$

C_2^* = 0.672
C_3^* = 0.509
C_4^* = 0.230
C_5^* = 0.661
C_6^* = 0.505
C_7^* = 0.507

6. Rank the preference order. According to the descending Order of Ci*, the preference order is (for E_1):

S2 > S5 > S3 ≈ S7 > S6 > S1 > S4

Similarly, for E_2:

$C_1^* = 0.461$, $C_2^* = 0.244$, $C_3^* = 0.634$, $C_4^* = 0.431$, $C_5^* = 0.466$, $C_6^* = 0.386$, $C_7^* = 0.488$

For E_3:

$C_1^* = 0.617$, $C_2^* = 0.507$, $C_3^* = 0.358$, $C_4^* = 0.502$, $C_5^* = 0.424$, $C_6^* = 0.403$, $C_7^* = 0.387$

For E_4:

$C_1^* = 0.309$, $C_2^* = 0.664$, $C_3^* = 0.551$, $C_4^* = 0.402$, $C_5^* = 0.436$, $C_6^* = 0.341$, $C_7^* = 0.479$

A comparison of the test results is given in Table 5.

Table 5: Comparison Results (for Four Experts)

Rank / *Expert*	*Results*
E_1	S2 > S5 > S3 ≈ S7 > S6 > S1 > S4
E_2	S3 > S7 > S5 > S1 > S4 > S6 > S2
E_3	S1 > S2 > S4 > S5 > S6 > S7 > S3
E_4	S2 > S3 > S7 > S5 > S4 > S6 > S1

Now, to aggregate the preference ordering into a consensus ordering, the Borda method is used. So, can more assurance to the results by applying a mathematical model. Therefore, 6, 5, …, 1, 0 scores are assigned to the first rank, second rank, …, and last rank. i.e., for S_1:

S1=1+3+6+0=10

Similarly, S2=17

$S_3 = 14.5$
$S_4 = 8$
$S_5 = 15$
$S_6 = 6$
$S_7 = 13.5$

From the above results, it can be easily derived that, the implied ranking is as follow:

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

Therefore, the best alternative is S_2, since it is superior to all the other alternatives. Meanwhile, S_6 have very bad performance.

Concluding Remarks

In the current literature, supplier selection is typically a Multi Attribute Group Decision problem (MAGDM). Since, how to obtain the maximum degree of consensus or agreement from these experts for the given alternatives is an interesting and important topic, in this paper to solve this problem, TOPSIS and Borda's function approach is proposed, and can provide more assurance to the results by applying a mathematical model. Moreover, the result implicitly shows the MAGDM (i.e., TOPSIS and Borda's function approach) is an effective approach in dealing with this kind of decision problem. Hence, to increase your chance of finding an appropriate supplier for your companies, we suggest using the proposed models in this paper. In addition, further research can apply this proposed approach to other managerial issue or compares with another MAGDM method.

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