A Supplier Selection Using a Group Decision Making Under Multiple Criteria by Considering Individual Criteria Set

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Abstract

Some authors implicitly claim that in the TOPSIS and Borda's function approach, each expert may or may not be using the same criteria. Meanwhile, in our reviews of the literature, not any reference was found that deals with supplier selection problem in the conditions each expert have own criteria set. So, the application of a Multiple Attribute Group Decision Making (MAGDM) model, particularly TOPSIS and Board's function approach for solving an supplier selection problem, while, each expert have own criteria set is the aim of this paper. Finally, a simple example is provided in order to demonstrate its feasibility and practicability of the proposed method.

Keywords: MAGDM, TOPSIS, Borda's Function, Individual Criteria Set, Supplier Selection Problem

Introduction

Due to the ever-increasing complexity of socioeconomic environment, it is very difficult for only one decision-maker (DM) to consider all the important aspects of a problem. Thus, most decisions in an organisation, whether public or private, are made by a group of people. This change of how to focus on the problem, i.e. the focus moves from that of one decision-maker to that of a group of people, introduces the important issue of how best to aggregate the decision-makers' preference structures. There are several possible ways to aggregate information when more than one individual participate in a decision process. The two most useful approaches to aggregating individual preferences are the aggregation of individual judgments and the aggregation of individual priorities (Alencar, Almeida, & Morais, 2010). In addition, supplier selection, the process of finding the right suppliers who are able to provide the buyer with the right quality products and/ or services at the right price, at the right time and in the right quantities, is one of the most critical activities for establishing an effective supply chain. On the other hand, it is a hard problem since supplier selection is typically a Multi Criteria (also often-called Attribute) Group Decision Making problem (Boran, Genç, Kurt, & Akay, 2009). The definition of MAGDM is described specifically as follow: multi DMs (Decision Makers) make judgements or evaluations by virtue of respective knowledge, experience and preference for a decision space (i.e., a finite set of alternatives) under multi attributes to rank all the alternatives or give evaluation information of each alternative, and then decision results from each DM are aggregated to form an overall ranking result for all the alternatives (Pang & Liang, 2012). In other words, the practice of 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, skill, experience and personality (Li & Sun, 2012). So, there is no reason to restricted experts to using the same criteria. Hwang and Lin (1987, p. 286) implicitly claim that (in TOPSIS and Borda's function approach), each expert may or may not be using the same criteria. Meanwhile, in their book and in our reviews of the literature, no any reference was found that deals with supplier selection problem in the conditions each expert have own criteria set.

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a multiple criteria method to identify the solution from a finite set of alternatives. The basic principle is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution (Iravani *et al*. 2009). 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 rationale that the higher the 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 favorable 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). Even so, the TOPSIS and Borda's function approach proposes, is the ordinal and cardinal approach. The ordinal (ranking) and cardinal (rating) approaches allow committee members (experts) to individually evaluate each candidate (alternative) 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 sets out to present a Multiple Attribute Group Decision Making (MAGDM) model, focusing on the situation where the experts have their criteria set.

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

Among numerous MCDA/MCDM methods developed to solve real-world decision problems, TOPSIS continues to work satisfactorily in diverse application areas. Hwang and Yoon originally proposed TOPSIS to help select the best alternative with a finite number of criteria. As a well-known classical MCDA/MCDM method, TOPSIS has received much interest from researchers and practitioners (Behzadian, Otaghsara, & Yazdani, 2012). TOPSIS has been employed in Group Multiple Attribute Decision Making environment. For instance; Wanga and Leeb (2007), Krohling and Campanharo (2011), extended the TOPSIS method for group decision making under fuzzy environment. Lin *et al*., (2008), proposed a modified fuzzy TOPSIS method for group decision problem. Ghaemi Nasab and Malkhalifeh (2010) extended TOPSIS for group decision making based on the type-2 fuzzy positive and negative ideal solutions. Huang and Li (2012) proposed a new aggregation rule for the use of TOPSIS in-group decision context. Zhang (2014) presented an MAGDM models to the assessing project risks. TOPSIS has also been employed in MAGDM environment for supplier selection problem. For instance, Sanayei *et al*. (2008) proposed an integrated approach of Multiple Attribute Utility Theory (MAUT) and linear programming (LP) method for rating and choosing the best supplier, in-group decision process. Boran *et al.* (2009) proposed TOPSIS method combined with intuitionistic fuzzy set to select appropriate supplier in-group decision-making environment. So that, intuitionistic fuzzy weighted averaging (IFWA) operator is utilised to aggregate individual opinions of decision makers for rating the importance of criteria and alternatives. Zhang, Zhang, Lai, & Lu (2009) proposed a new approach based on vague sets group decision to deal with the supplier selection problem in supply chain systems. The experimental results show that the proposed approach is reliable and reasonable. Sanayei *et al*. (2010) proposed a hierarchy MCDM (Multiple Criteria Decision Making) model based on fuzzy sets theory and VIKOR method to deal with supplier selection problem in-group decision environment. Shahgholian *et al.* (2011) used Multi Criteria Group Decision Making based on fuzzy sets approach for supplier selection problem. Zouggari and Benyoucef (2011) used fuzzy TOPSIS method to supplier selection problem in-group decision-making environment. Izadikhah (2012) used an extended TOPSIS method for group decision making with Atanassov's interval-valued intuitionistic fuzzy numbers to solve the supplier selection problem under incomplete and uncertain information environment. Kar (2014) proposed an approach for group decision support for the supplier selection problem by integrating fuzzy Analytic hierarchy Process (AHP) and fuzzy goal programming method. Memon *et al*. (2015) applied the combination of grey system theory and uncertainty theory that requires neither any probability distribution nor fuzzy membership function. Generally, the objective of this paper is to develop framework for reducing the purchasing risks associated with suppliers, in-group environment. In addition, in the literature, Borda approach and TOPSIS and Board's function has 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 was 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, their obtained four ranks 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 depends on Dempster's rule or its modifications, some social choice functions (i.e. Board's function and some mean approaches). Gharakhlou, Faraji Sabokbar, & Givehchi (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. In addition, Azadfallah (2015) focused on the application of MAGDM models, particularly TOPSIS and Bordas function approach for solving the supplier selection problem. So, in the present model, first TOPSIS is used to find the individual preference ordering (with same criteria set for each DMs). Then, Bordas function is used to find the collective preference orderings.

It should be stressed at this point that, according to Hojjati and Anvari (2014), decision makers are not limited just to one method of MADM in fatal issues, because it is possible that various MADM methods gain different results. To get over this problem, aggregate method (Borda method) has been introduced. And, in the literature, many studies exist on using Board's function. However, most of them are limited to combined the results of different MADM methods (i.e., Hojjati & Anvari, 2014; Hashemi & Zamani, 2015 etc.). But, in this paper, we used Bordas function for to unify the results of each DM (expert), where, same method is used (i.e. TOPSIS). Also, each experts have own criteria set.

In general, this paper focused on the application of MAGDM models, particularly TOPSIS and Board's function approach for solving the supplier selection problem, while each expert has his own criteria set. In the next section, the proposed method will be considered.

Proposed Approach

TOPSIS Methods

TOPSIS assumes that we have m alternatives (options) with n attributes/criteria and the score of each option with respect to each criterion. Let x_{ij} be 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 *et al*., 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. Normalise 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:

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

$V_j^* = \{\max (v_{ij}) \text{ if } j \in J;\ \min (v_{ij}) \text{ if } j \in J'\}$

Negative Ideal Solutions:

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

$V_j^* = \{\min (v_{ij}) \text{ if } j \in J;\ \max (v_{ij}) \text{ if } j \in J'\}$

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

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

Similarly, the separation from the negative ideal alternative is:

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

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 proposes 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, respectively; 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 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 yϵA /{X}.

Borda's Function:

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

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 Board'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 feasibility and practability of the proposed MAGDM method. Assume that there are five committee members, who are experts (E_1, E_2… and E_5), six alternatives (suppliers; S_1, S_2… S_6), and five criteria sets for 5 experts (so that, each experts have own criteria set). For E_1; C_1=shorter lead times, C_2=reduced cost, and C_3=higher quality. For E_2; C1=quality, C2=on-time delivery, C3=service, and C4=responsiveness. For E3; C_1=quality, C_2=on-time delivery, C_3=service, C_4=responsiveness, and C_5=ordering cost. For E_4; C_1=performance of supplier, C_2=geographical location, C_3=financial position, C_4=quality, C_5=responsiveness, C_6=management and organisation, and C_7=logistic cost. For E_5; C_1=quality, C_2=reputation, C_3=packing ability, C_4=geographical location, and C_5=logistic cost. As you see, the performance values for each expert are shown in Table 1-5. Moreover, several researchers have argued that the equal weight rule is often a highly accurate simplification of the decision making process (Birnbaum, 1998). So, for E1: Wj=(.333, .333, and .333), E2: Wj=(.250, .250, .250, and .250), E3: Wj=(.200, .200, .200, .200. and .200), E4: Wj=(.143, .143, .143, .143, .143, .143, and .143), E5: Wj=(.200, .200, .200, .200, and .200).

In the process of group decision making, each committee members (experts) provides the performance values the alternatives for each attribute (table 1-5). For expert 1:

Table 1: Performance Value for E1

Criteria / Alternative	C_1	C_2	C_3
S_1	7	3	9
S_2	1	9	5
S_3	3	5	1
S_4	9	1	1
S_5	9	3	1
S_6	5	5	7

For expert 2:

Table 2: Performance Value for E2

Criteria / Alternative	C_1	C_2	C_3	C_4
S_1	5	7	5	7
S_2	7	5	7	3
S_3	5	3	3	1
S_4	3	9	5	1
S_5	1	9	5	1
S_6	1	3	5	5

For expert 3:

Table 3: Performance Value for E3

Criteria / Alternative	C_1	C_2	C_3	C_4	C_5^{-*}
S_1	1	3	1	9	112
S_2	3	5	7	9	117
S_3	9	7	5	9	121
S_4	5	3	9	1	112
S_5	9	9	5	7	121
S_6	3	7	5	9	109

*.cost-type criteria

For expert 4:

Table 4: Performance Value for E4

Criteria / Alternative	C_1	C_2	C_3	C_4	C_5	C_6	C_7^{-*}
S_1	1	3	7	5	3	7	111
S_2	3	5	1	9	1	5	118
S_3	3	9	1	7	5	5	123
S_4	3	9	7	3	5	7	115
S_5	5	9	3	7	5	5	122
S_6	3	3	1	9	9	3	106

*.cost-type criteria

For expert 5:

Table 5: Performance Value for E5

Criteria / Alternative	C_1	C_2	C_3	C_4	C_5^{-*}
S_1	7	9	5	9	112
S_2	1	9	3	5	115
S_3	3	1	5	1	120
S_4	5	1	9	9	113
S_5	5	7	7	7	123
S_6	3	3	1	3	111

*.cost-type criteria

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

1. Calculate the normalised decision matrix (based on Table 1)

$$R_{ij}=\begin{vmatrix} .446 & .245 & .716 \\ .064 & .735 & .398 \\ .191 & .408 & .080 \\ .574 & .082 & .080 \\ .574 & .245 & .080 \\ .319 & .408 & .557 \end{vmatrix}$$

2. Calculated the weighted decision matrix (as noted earlier; W_j= (.333, .333, .333).

$$V_{ij}=\begin{vmatrix} .149 & .082 & .238 \\ .021 & .245 & .132 \\ .064 & .136 & .026 \\ .191 & .027 & .026 \\ .191 & .082 & .026 \\ .106 & .136 & .185 \end{vmatrix}$$

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'};

   A* = (.191 .245 .238)

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

   A^- = (.021 .027 .026)

4. Calculated the separation measures

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

   S_1 =.169, S_2=.200, S_3=.270, S_4=.304, S_5=.267, and S_6=.148

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

   S_1 =.253, S_2=.242, S_3=.117, S_4=.170, S_5=.178, and S_6=.210

5. Calculated the relative closeness to the ideal solution

   $C_1^* = S1^- / S1^* + S1^-$ = 0.253 / (0.253+0.169) =0.600

   C_2^* = 0.547

   C_3^* = 0.302

   C_4^* = 0.359

   C_5^* = 0.400

   C_6^* = 0.587

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

S1 > S6 > S2 > S5 > S4 > S3

It is apparent that supplier 1 (S1), receives the highest score and thus better than the others perform. On the contrary, supplier 3 (S3), is the worst. Similarly, for E_2:

$C_1* = 0.744$, $C_2* = 0.584$, $C_3* = 0.313$, $C_4* = 0.370$, $C_5* = 0.318$, $C_6* = 0.385$

For E_3:

$C_1* = 0.319$, $C_2* = 0.545$, $C_3* = 0.718$, $C_4* = 0.493$, $C_5* = 0.728$, $C_6* = 0.529$

For E_4:

$C_1* = 0.454$, $C_2* = 0.338$, $C_3* = 0.454$, $C_4* = 0.611$, $C_5* = 0.592$, $C_6* = 0.494$

For E_5:

$C_1* = 0.769$, $C_2* = 0.450$, $C_3* = 0.282$, $C_4* = 0.601$, $C_5* = 0.725$, $C_6* = 0.230$

A comparison of the test results is given in Table 6 and Fig. 1.

Table 6: Comparison Results (for Five Experts)

Expert \ Rank	Results
E_1	S1 > S6 > S2 > S5 > S4 > S3
E_2	S1 > S2 > S6 > S4 > S5 > S3
E_3	S5 > S3 > S2 > S6 > S4 > S1
E_4	S4 > S5 > S6 > S1 ≈ S3 > S2
E_5	S1 > S5 > S4 > S2 > S3 > S6

Now, to aggregate the preference ordering into a consensus ordering, the Borda method is used. So, 5, 4,…, 1, 0 scores are assigned to the first rank, second rank, …, last rank. i.e., for S_1, respectively:

S1=5+5+0+1.5+5=16.5

Similarly, S2=12

S_3=6.5

S_4=12

S_5=16

S_6=12

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

S1 > S5 > S2 ≈ S4 ≈ S6 > S3

Thus, the best alternative is supplier 1 (S_1), since it is superior to all the other alternatives. Meanwhile, supplier 3 (S_3) have bad performance.

In the end, it seems that this conclusion caused by applying mathematical model and combing views of all members is more likely to be accepted by the group members.

CONCLUDING REMARKS

Some authors implicitly claim that in the TOPSIS and Borda's function approach, each expert may or may not be using the same criteria. Since in this paper, we focused on the proposed model (TOPSIS and Board's function approach) for solving the supplier selection problem; while,

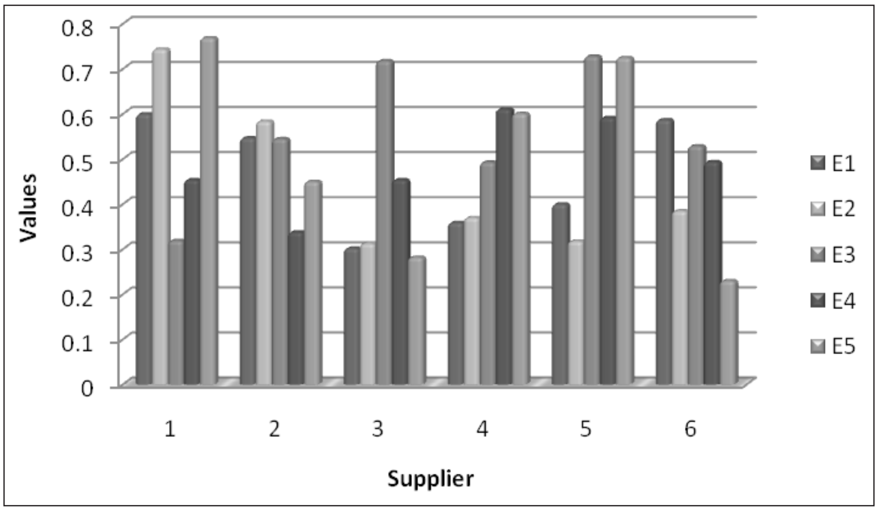

Fig. 1. Comparison Results (for Five Experts)

each expert have his own criteria set. The result implicitly shows the proposed MAGDM model is an effective approach in dealing with this kind of decision problem. Since each expert has his/ her unique characteristic with regard to knowledge, skills, experience and personality, therefore, to raise your chances for finding a right 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 models.

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