

A Supplier Selection using an Extension of MCDM Models

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ABSTRACT

Supplier selection is a multiple criteria decision-making (MCDM) problem, which is affected by several conflicting factors. When alternatives are compared on several criteria and their weight aggregated, their ranks can change when alternatives are added or deleted. If a method does allow it to happen, the validity of the method could be questioned. However, some recent studies showed that rank reversals could also happen because people may reverse their preferences caused by some emotional feelings, like regret and rejoicing. Some experimental studies confirm that for most individuals regret has the greater impact. Therefore, the application of the new MCDM method based on regret in supplier selection problem is the aim of this paper. The result (in consistent to published studies: Wang, 2008) showed that the emotional feeling (regret) can greatly influenced in people preferences.

Keywords: MCDM, Supplier Selection Problem, Regret

INTRODUCTION

In order to maintain a competitive position in the global market, organisations have to follow strategies to achieve shorter lead times, reduced costs and higher quality. Therefore, suppliers play a key role in achieving corporate competitiveness, and as a result, selecting the right suppliers is a critical component of these new strategies (Jadidi *et al.*, 2010). Supplier selection is a multiple criteria decision-making (MCDM) problem, which is affected by several conflicting factors (Tahriri *et al.*, 2008). When alternatives are compared on several criteria and their weight aggregated, their ranks can change when alternatives are added or deleted (Saaty *et al.*, 2009).

Some recent studies showed that rank reversals could also happen because people may reverse their preferences due to some emotional feeling, like regret and rejoicing (Wang, 2007). Undoubtedly, emotions and feelings are indispensable factors in human's decision-making activities. Regret was defined as "the painful sensation of recognizing that what is compares unfavorably with what might have been". The converse experience of a favourable comparison between the two is called rejoicing. Some experimental studies confirm that for most individuals regret has the greater impact (Wang *et al.*, 2008).

This paper aims to used a numerical example to illustrate the process of the proposed new MCDM method in supplier selection context.

The paper is organized 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

Multi-criteria decision making approaches, propose dozens of methods for supplier selection problems including Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Data Envelopment Analysis (DEA), Fuzzy Set Theory (FST), Genetic Algorithm (GA), Mathematical Programming, Simple Multi Attribute Rating Technique (SMART), and their hybrids (Shahgholian *et al.*, 2011). Here, we will mention some of them.

Ghodsypour & Nezamirad (1998) used the integrating analytic hierarchy process and linear programming for supporting the decision in supplier selection problem. Next, an algorithm is developed for performing sensitivity analysis. Wang *et al.* (2004) integrated analytic hierarchy process (AHP) and preemptive goal programming (PGP)

based multi-criteria decision-making methodology, then developed to take into account both qualitative and quantitative factors in supplier selection. Wu (2007) developed an AHP simulation methodology to deal with SCM (supply chain management) problems. This is valuable in that it looks at the uncertainty in AHP and helps to reduce the uncertainty in AHP to some extent. In the paper by Tahriri *et al.* (2008), the different selection methods about supplier selection are discussed and the advantages and disadvantage of selection methods, especially the analytic hierarchy process (AHP) are illustrated and compared. Sarode and Khodke (2009) used the AHP in automotive industry, for supporting decision in supplier selection problem. Enyinda *et al.* (2010) developed the AHP-based supplier selection model and applied it to the generic pharmaceutical firm. Elanchezhian *et al.* (2010) used the multi-criteria decision-making (MCDM) technique (analytical network process (ANP) and technique for order performance by similarity to ideal solution (TOPSIS) method) to select the best vendor. Yaghoubi *et al.* (2011) used AHP and Grey system theory for supplier evaluation. The result shows that a proposed model is a suitable model for decision making and the outcomes of this model in the supplier evaluation process are reliable. Izadikhah (2011) used an extended technique for order preference by similarity to ideal solution (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. Eshlaghy and Kalantary (2011) proposed a model that modified the traditional TOPSIS technique (Neo-TOPSIS) and applied it to supplier selection problem. They discussed that two absolute (bad and good) candidates must be inserted in the decision maker (DM) matrix. These two absolute candidates are maximum and minimum standards of a decision maker. Neo-TOPSIS compares candidates (Suppliers) with these two standards, so distances between candidates become real. Razmi *et al.* (2011) developed a fuzzy multi-attribute decision making (FMADM) model, to deal with strategy selection problem in a supply chain. Shalini & Gupta (2012) proposed a hierarchy multiple criteria decision-making (MCDM) model based on fuzzy theory to deal with the supplier selection problems in the supply chain system. In addition, some MCDM methods based on Regret have been used in the past. So that, Kaliszewski & Michalowski (1998) showed that how a notion of decisional Regret, originating from extensions of the expected utility theory and can be incorporated into the MCDM modeling framework, and how non-regrettable decisions conforming to a DM's Regret attitude can be identified. Wang *et al.* (2007) focused on reference-dependent Regret model ((RDRM)

–by Kujawski) for deterministic multi criteria decision-making. It was asserted that the RDRM model satisfies three properties. The first of these properties, referred to as the “independence of dominated alternatives”. It is shown that the adding or dropping a dominated alternative can change the ranking of the alternatives and violate the independence of dominated alternative property. Wang (2007) described two real-life cases to demonstrate the occurrence of rank reversal in ELECTRE II and III. Then reason behind the phenomenon is analyzed. Finally, this thesis (Master of Science) proposes a new MCDM method, which is based on Regret. Wang (2008) proposed to use a new MCDM approach based on a linguistic scale and pairwise comparison to measure a DM's anticipated Regret feelings. Finally, this thesis (PhD) has shown some key advantages over existing approach. Rai *et al.* (2013) focused on the application of a compromise ranking Method in the perspective of Regret theory as a multiple-criteria decision-making (MCDM) tool, for solving a material selection problem in a given manufacturing environment.

This paper focuses on the application of a new MCDM method based on Regret, introduced by Wang (2008), for solving a supplier selection problem.

In the next section, the proposed method will be considered.

PROPOSED APPROACH

The introduction of regret and rejoicing into the decision making process is based on two key assumptions: 1. people experience the sensations of regret and rejoicing which can influence their current decision making; 2. while making decisions people may try to anticipate and take into account feelings like regret and rejoicing. Therefore, building an MCDM model that incorporates these emotional effects not only provides for a better description of the human behaviour in decision making, but also offers the DMs the flexibility to trade off some economic benefits explicitly in order to gain a state of psychological satisfaction, for prescriptive purposes (Wang, 2007).

Assume that a DM wishes to consider his/her anticipated regret (R) and rejoicing (J) for a given MCDM problem which has m alternatives and n benefit criteria. The formula for computing the final priority of each alternative is defined as follow (Wang, 2008):

$$P_i^* = \frac{\prod_{k=1}^n (a_{ik}j_{ik} / r_{ik})^{w_k}}{\prod_{i=1}^m P_i} = \frac{\prod_{k=1}^n \mathbf{r}_{ik}^{w_k}}{\prod_{k=1}^n \mathbf{j}_{ik}^{w_k} / \prod_{k=1}^n \mathbf{a}_{ik}^{w_k} * \prod_{i=1}^m P_i} = P_i J_i / R_i =$$

Table 1: Proposed Scale for Measuring Pair Wise Regret Values

Linguistic expression	Numerical value
The feeling of regret when choosing alternative A_i over alternative A_j is not distinguishable	1
The feeling of regret when choosing alternative A_i over alternative A_j is noticeable	3
The feeling of regret when choosing alternative A_i over alternative A_j is strong	5
The feeling of regret when choosing alternative A_i over alternative A_j is very strong	7
The feeling of regret when choosing alternative A_i over alternative A_j is as strong as it can be	9
The intermediate values of 2, 4, 6, and 8 are used when the DM feels that the best answer lies between two successive linguistic choices from the above list of choices	2,4,6,8

For $i=1, 2, 3 \dots m$.

In the above formulas, a_{ik} is the performance value of alternative A_i in terms of criterion C_k , and r_{ik} and j_{ik} are the anticipated regret and rejoicing values associated with A_i in terms of criterion C_k (also, W_k is the weight of the k -th decision criterion).

In this model (multiplicity-based model), some points are noteworthy. First, rank reversals may happen with some additive models (such as the ELECTRE II and III models and the additive AHP models) when one considers benefit and cost criteria only (i.e. without the regret or rejoicing effects). While some previous studies had found that the multiplicative AHP are immune to these ranking problems. Thus, instead of addition the new model will be based on multiplication (Wang, 2007).

Second, in the proposed linguistic scale (Table 1) if r_{ij} takes a value between [1, 9] then r_{ji} will always have the value 1. This means that if there is a certain level of regret for choosing alternative A_i over alternative A_j in terms of criterion C_k , then there is no regret (i.e. the corresponding value is equal to 1) for choosing A_j over A_i under the same criterion.

In other words (Wang, 2008):

$$r_{ii} = 1, \text{ for any } i=1, 2, 3, \dots, m; \tag{2}$$

$$\text{If } r_{ij} > 1, \text{ then } r_{ji} = 1, \text{ for any } i, j = 1, 2, 3, \dots, m \tag{3}$$

Ref. Wang X., 2008, p. 37.

Third (consistency relation), suppose that the performance values of m alternatives in terms of the k -th benefit criterion are sorted in ascending order such that $a_{1k} \leq a_{2k} \leq a_{3k} \leq a_{4k} \leq \dots \leq a_{mk}$. By using the chosen performance value and the forgone performance value as reference points individually, the pairwise regret values $R(a_{ik}, a_{jk})$, for $i, j = 1, 2, 3 \dots m$ and $i \leq j$, should satisfy the following two conditions:

$$1) R(a_{ik}, a_{jk}) \leq R(a_{ik}, a_{(j+1)k}) \leq \dots \leq R(a_{ik}, a_{mk}). \tag{4}$$

For example: $R(a_{1k}, a_{2k}) \leq R(a_{1k}, a_{3k}) \leq R(a_{1k}, a_{4k}) \leq \dots \leq R(a_{1k}, a_{mk})$.

$$2) R(a_{1k}, a_{jk}) \geq R(a_{2k}, a_{jk}) \geq \dots \geq R(a_{(j-1)k}, a_{jk}). \tag{5}$$

For example: $R(a_{1k}, a_{mk}) \geq R(a_{2k}, a_{mk}) \geq R(a_{3k}, a_{mk}) \geq \dots \geq R(a_{(m-1)k}, a_{mk})$.

For each criterion, if the DM is consistent with his/her assessments, then his/her anticipated regret values should satisfy the above two relations. Otherwise, the DM needs to re-assess the inconsistent parts of his/her assessments.

Fourth(overall regret values), to be consistent with the above multiplicative formulas, r_{ik} is defined as the geometric mean of the regret contributions generated when alternative A_i is compared with each of the other alternatives under the decision criterion C_k , that is

$$r_{ik} = [\prod_{j=1}^m R(a_{ik}, a_{jk})]^{1/m-1} \tag{6}$$

NUMERICAL EXAMPLE

In this section, a numerical example is used to illustrate the application of the proposed method. In this example, there are four alternatives (Suppliers; $S_1, S_2 \dots S_4$) and three criteria (C_1 = shorter lead times, C_2 = reduced costs, and C_3 = higher quality). The performance values of the alternatives under these three criteria are shown in Table 2.

Table 2: Performance Values

-	C1	C2	C3
S1	18	5	16
S2	16	9	9
S3	9	11	14
S4	6	16	7

Several researchers have argued that the equal weight rule is often a highly accurate simplification of the decision making process (Birnbbaum, 1998). Thus, $W_j = [.333, .333, .333]$.

As noted earlier, assume that the DM only wants to consider his/her anticipated regret. In terms of the three decision criteria, the corresponding regret matrixes are as shown in Tables 3 through 5.

Table 3: Anticipated Regret for C₁

C ₁	S ₁	S ₂	S ₃	S ₄
S ₁	1	1	1	1
S ₂	3	1	1	1
S ₃	5	3	1	1
S ₄	7	5	2	1

Table 4: Anticipated Regret for C₂

C ₂	S ₁	S ₂	S ₃	S ₄
S ₁	1	9	9	9
S ₂	1	1	5	7
S ₃	1	1	1	3
S ₄	1	1	1	1

Table 5: Anticipated Regret for C₃

C ₃	S ₁	S ₂	S ₃	S ₄
S ₁	1	1	3	1
S ₂	5	1	3	1
S ₃	1	1	1	1
S ₄	5	1	3	1

Now, we need to examine the above regret values satisfying the two consistency relations described in Eq. 4, 5. For instance, in terms of the second criterion, the four alternatives performance values are 5, 9, 11, and 16. They are in ascending order because of $a_{12} \leq a_{22} \leq a_{32} \leq a_{42}$. In terms of the second criterion, it can be seen that:

- 1) $R(a_{12}, a_{22}) = 9 \leq R(a_{12}, a_{32}) = 9 \leq R(a_{12}, a_{42}) = 9$
 $R(a_{22}, a_{32}) = 5 \leq R(a_{22}, a_{42}) = 7$
- 2) $R(a_{12}, a_{42}) = 9 \geq R(a_{22}, a_{42}) = 7 \geq R(a_{32}, a_{42}) = 3$
 $R(a_{12}, a_{32}) = 9 \geq R(a_{22}, a_{32}) = 5$

This shows that these regret values satisfy the two consistency relations. Similarly, the pairwise regret values under the other criteria can also be examined. Next, by applying formula (Eq. 6) to the above regret matrixes, we can get (i.e. r_{12});

$$r_{12} = [\prod_{j=1}^4 r(a_{12}, a_{j2})]^{1/4-1} = [1*9*9*9]^{1/3} = 9$$

The new decision matrix with the r_{ik} values is as follow:

Table 6: r_{ik} values

rik	C1	C2	C3
A1	$\sqrt[3]{1} = 1$	$\sqrt[3]{729} = 9$	$\sqrt[3]{3} = 1.442$
A2	$\sqrt[3]{3} = 1.442$	$\sqrt[3]{35} = 3.271$	$\sqrt[3]{15} = 2.466$
A3	$\sqrt[3]{15} = 2.466$	$\sqrt[3]{3} = 1.442$	$\sqrt[3]{1} = 1$
A4	$\sqrt[3]{70} = 4.121$	$\sqrt[3]{1} = 1$	$\sqrt[3]{15} = 2.466$

Then, by applying formula (Eq. 1), we can get the final preference values of these alternatives.

$$P^*_1 = P_1/R_1 = \prod_{k=1}^3 a^{wk}_{1k} / \prod_{k=1}^3 r^{wk}_{1k} = \prod_{k=1}^3 (a_{ik} / r_{ik})^{wk} = (18/1)^{.333} * (5/9)^{.333} * (16/1.442)^{.333} = 4.789$$

Similarly, like above:

$$P^*_2 = 4.804$$

$$P^*_3 = 7.290$$

$$P^*_4 = 5.426$$

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

$$S_3 > S_4 > S_2 > S_1$$

Here, more studies have been done. In order to compare this result with the original (additive) and multiplicative (because, the new model will be based on multiplication) AHP results, we will use the same numerical example (Table 2).

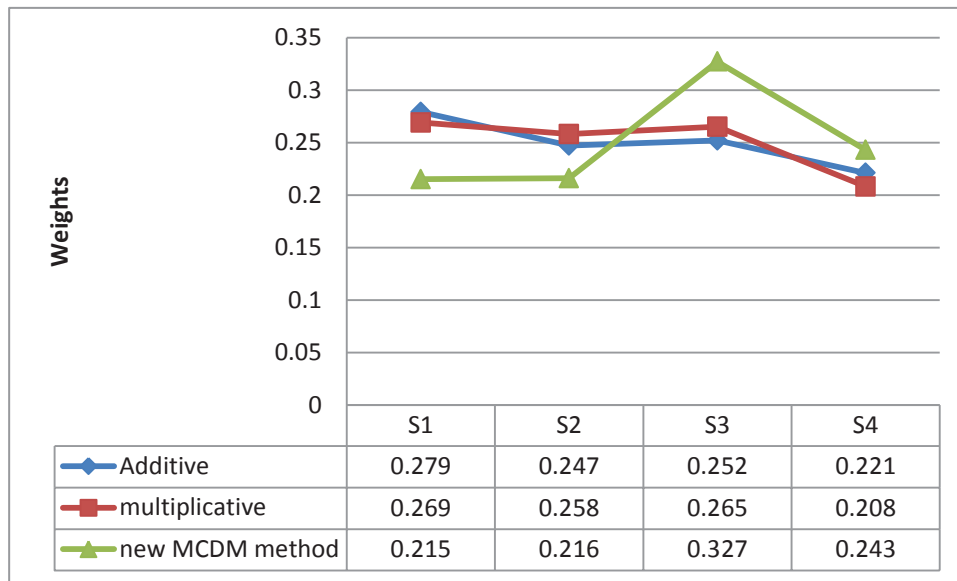
We assume that the reader is familiar with the original (additive) and multiplicative AHP model, and is not repeated here. The result is as follow (Table 7):

As seen in Table 7, the weights obtained by the additive and multiplicative AHP method are quite close to each other. However, this may not happen always.

Table7: AHP Results

method value	Additive	Additive Rank	Multiplicative	Normalized Multiplicative	Multiplicative Rank
P ₁	.279	S ₁ > S ₃ > S ₂ > S ₄ .279 .252 .247 .221	11.265	.269	S ₁ > S ₃ > S ₂ > S ₄ .269 .265 .258 .208
P ₂	.247		10.817	.258	
P ₃	.252		11.123	.265	
P ₄	.221		8.740	.208	

Figure 1: Comparison of Results



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

As seen in Fig. 1, in this illustrative example the differences between two models (original/ multiplicative AHP and new MCDM model based on Regret) are quite clear.

CONCLUDING REMARKS

According to Wang (2008), the emotional feeling (Regret) can greatly influence decision results. This means that inclusion of this emotional impact could greatly improve the decision making process. In this research, we focused our efforts on extending the MCDM method by involving Wang’s (2008) findings in decision-making process. Based on our demonstrated case in supplier selection context, comparative table (shown in Fig. 1) indicate that results obtained by new MCDM method based on Regret were significantly different from those obtained

using the additive and multiplicative AHP. While S1-S3-S2-S4 is, the supplier ranking obtained from application of traditional AHP, new MCDM method ranked S3 and S4 over S2 and S1. In other words, the new MCDM method significantly improves the quality of decisions by involvement of emotional feeling impact in multi criteria decision-making process. In the future researches, similar studies can be repeated for including other emotional feelings’ impact (rejoicing for instance) in multi criteria decision-making methods.

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