Evaluating Alternatives Using ARAS Method Integrated with Entropy Weight Method for Vendor Selection in Supply Chain Management

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Abstract: Vendor selection has been a vital issue for any manufacturing organization. It's always been a challenging task for decision-maker to find out the most suitable vendor for supply among the many numbers, which is based on different types of evaluation processes and criteria. Although numbers of multiple criteria decisions making (MCDM) methods are available for solving the MCDM problem, it's observed that in most of these methods the ranking results are very sensitive to the changes in the attribute weights. The aim of this paper is to describe the applications of Additive Ratio Assessment (ARAS) methods for solving the vendor selection problem, integrated with Entropy Weight Method, which is used to carry out the individual weights of the criteria. Further to understand the procedure of linking these two methods are explained with the help of an illustrative example, the ranking performance of mentioned methods is calculated and compared with each other. In the illustrative example, a manufacturing firm is looking to select the most suitable vendor for supply among the five-vendor based on four different criteria as Quality, Price/Cost, Delivery, and Service.

Index Terms - **Vendor Selection, ARAS, Entropy Weight Method, Supply Chain Management.**

I. INTRODUCTION

In today's highly competitive but also interrelated business environment, the effective selection of business partners is one among the foremost important issues, enterprises are handling. For the rationale, companies face a stiff competition which forces them to specialize in the improved quality, cost reduction activities, and improved time interval. Therefore, they have to be very efficient to satisfy the dynamic market requirements and to be hospitable change, low cost, top quality products and supplier satisfaction. Increases of customer demands, supply/demand chain, advances of recent technologies, especially evolution in information and communication technologies, competition during a global environment, and increases in environmental consciousness have forced enterprises to specialize in better supply chain management. Moreover, radical product and technology innovation demand manufacturer to show back to the suppliers and therefore the key partners so as to take care of their existing customer base. Nowadays quite ever, businesses are counting on strategic relations with their customers and suppliers so as to make value-added systems which will give them a competitive edge up the market. Most of the time vendors are being selected by companies supported three basic factors, their ability to satisfy some quality standards, their delivery schedule and therefore the price they provide. However, in modern management, one must take into consideration numerous other factors so as to succeed and establish a long-term relationship with its vendors and so as to think about vendor because the best intangible assets of the organization.

II. LITERATURE THEORIES

Entropy Weight Method

Decision makers choose from the alternatives in multi-criteria decision-making problems. Decision makers must be taken into consideration criteria which affect the alternatives when making this choice. There are many criteria that influence this decision in the selection process of any alternatives and each of these criteria in different severity levels are effective over alternatives. Analytic hierarchy process (AHP) and expert opinions as subjective evaluation methods are used to determine the weight of the criteria. Criteria are categorized according to expert's opinion that is difficult, since generalization cannot be made clearly and the objective assessment methods should be used in case of the deficiency of pairwise comparisons. Shannon is firstly introduced Information entropy in his paper of "A Mathematical Theory of Communications", which is a measure of uncertainty, then it has been broadly used in many areas such as engineering, management and so on (Wu et al., 2011). The entropy by Shannon, can be used to ascertain the disorder degree and its utility in system information. The smaller the entropy value is, the smaller the disorder degree of the system is. The index's weight is determined by the amount of information based on Entropy Weight Method, which is one of objective fixed weight methods (Li et al., 2011).

Entropy Weight Method includes following 5 steps (Deng et al., 2000; Shemshadi et al., 2011):

Step 1: Construction of a decision matrix (X). A set of alternatives $(A= \{A_i, i=1, 2, ..., n\})$ is to be compared to with respect to a set of criteria $(C= \{C_j, j=1, 2, ..., m\})$. Therefore, an n×m performance matrix (the decision matrix; X) can be obtained as:

$$X = \begin{bmatrix} x_{11} & x_{12} & ... & x_{1m} \\ x_{21} & x_{22} & ... & x_{2m} \\ . & . & ... & . \\ . & . & ... & . \\ . & . & ... & . \\ x_{n1} & x_{n2} & ... & x_{nm} \end{bmatrix}$$

where x_{ij} is a crisp value indicating the performance rating of each alternative A_i with regard to each criterion C_j.

Step 2: To ascertain objective weights by the entropy measure, the decision matrix in Eq. (1) needs to be normalized for each criterion C_j, *(j=1, 2, ..., m) as*

$$p_{ij} = \frac{x_{ij}}{\sum_{p=1}^{n} x_{pj}}, i = 1,2,\dots,n$$

The Normalized decision matrix is obtained as a result of the process.

$$P = \begin{bmatrix} p_{11} & p_{12} & \dots & p_{1n} \\ p_{21} & p_{22} & \dots & p_{2n} \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ p_{m1} & p_{m2} & \dots & p_{mn} \end{bmatrix}$$

Step 3: Calculate the entropy measure of every index using the following equation:

$$e_j = -k \sum_{i=1}^{n} p_{ij}.\ln p_{ij}$$

Where, $k = \frac{1}{\ln(n)}$ is a constant which guarantees $0 \le e_j \le 1$.

Step 4: The degree of divergence (d_j) of the average intrinsic information contained by each criterion C_j, *(j=1, 2, ..., m)* can be calculated as

$$d_j = 1 - e_j$$

the more d_j is, the more important the criterion jth is.

Step 5: The objective weight for each criterion C_j, *(j=1, 2, ..., m)* is thus given by

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$$

ARAS Method

A typical MCDM problem is concerned with the task of ranking a finite number of decision alternatives, each of which is explicitly described in terms of different decision criteria which are to be taken into account simultaneously. In this paper, ARAS method is applied for performance evaluation of vendor for any manufacturing firm. According to ARAS method, a utility function determining the complex relative efficiency of a feasible alternative is directly proportional to the relative effect of values and weights of the main criteria considered in a problem.

The procedure of solving problems by using ARAS methods, in cases when MCDM problem incudes beneficial criterion and non-beneficial criterion, can be precisely described by using the following steps.

Step 1: At first, the related decision/evaluation matrix is formulated. In any MCDM problem (discrete optimization problem), the relevant data is represented by the decision matrix showing preferences form feasible alternatives rated on n criteria (attributes).

$$X = \begin{bmatrix} x_{12} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}$$

where m is the number of alternatives, n is the number of criteria describing each alternative and x_{ij} is the value representing the performance of ith alternative with respect to jth criterion.

Step 2: Determine the optimal value of each criterion. Let x_{0j} be the optimal value of jth criterion. If the optimal value of jth criterion is known, then

$$x_{0j} = \max x_{ij} \text{ for beneficial criterion}$$
$$x_{0j} = \min x_{ij} \text{ for non-beneficial criterion}$$

Now, taking into account the optimal values of all the considered criteria, the original decision matrix is reformulated as follows:

$$X = \begin{bmatrix} x_{01} & x_{0j} & \dots & x_{0n} \\ . & . & \dots & . \\ x_{i1} & x_{ij} & \dots & x_{in} \\ . & . & \dots & . \\ . & . & \dots & . \\ x_{m1} & x_{mj} & \dots & x_{mn} \end{bmatrix}$$

Step 3: In this step, all the initial criteria values are normalized while employing the following equations.

For beneficial criteria, $r_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}}$

For non-beneficial criteria, $r_{ij}^{*} = \frac{1}{x_{ij}}, \ r_{ij} = \frac{r_{ij}^{*}}{\sum_{i=0}^{m} r_{ij}^{*}}$

Step 4: From the normalized decision matrix, the corresponding weighted normalized decision matrix is developed using the following equation:

$$v_{ij} = w_j * r_{ij}, \quad i = 1,2,3\dots,m$$

where w_j is the weight of jth criterion and r_{ij} is the normalized performance of ith alternative with respect to jth criterion.

Step 5: In this stage, the optimality function value is determined.

$$S_i = \sum_{j=1}^{n} v_{ij}, \ i = 0,1,\ 2\ 3\ldots,\ m$$

where S_i is the value of optimality function for i^{th} alternative. The highest value of Si always signifies the best alternative, whereas, the lowest Si value identifies the least preferred alternative. Taking into account the computational process of ARAS method, it can be revealed that the optimality function S_i has a direct and proportional relationship with x_{ij} values and weights w_j of the considered criteria and their relative influence on the final result. The priorities of the alternatives can thus be determined based on S_i values. Consequently, it is convenient to evaluate and rank the decision alternatives using S_i values.

Step 6: The degree of alternative utility is determined by comparing with a variant, which is often taken as the ideally best value (S_0). The utility degree U_i of ith alternative can be calculated employing the following equation:

$$U_i = \frac{S_i}{S_0}, \qquad i = 1, 2, \ldots, m$$

It is quite obvious that the calculated values of U_i lie in the interval of [0, 1] and can be ordered in an increasing sequence to provide a complete ranking of the considered alternatives. The complex relative efficiency of the feasible alternatives can also be determined according to the utility function values.

III. ILLUSTRATIVE EXAMPLE

An Original Equipment Manufacturing (OEM) company wants to choose their best vendor for supply. In selection of a vendor various criterions are to taken into account, among the number of vendors. In this case of computation procedure and applicability of the proposed method, considering five suppliers and four criterions based on which most suitable supplier required to identified. The four criterions are Price/Cost, Service, Quality and Delivery, among which Price/Cost is non-beneficial and the attributes pertaining to other criteria are beneficial, which is shown in Table 1.

Table 1. Decision Matrix for Alternatives

	Quality	Price/Cost	Delivery	Service
Vendor 1	7	6	9	9
Vendor 2	7	7	7	9
Vendor 3	9	8	7	9
Vendor 4	5	4	9	7
Vendor 5	5	3	7	7

Implementation of Weight Entropy Method for Weight Calculation

Table 2. Normalized Decision Matrix with Criterion Weight

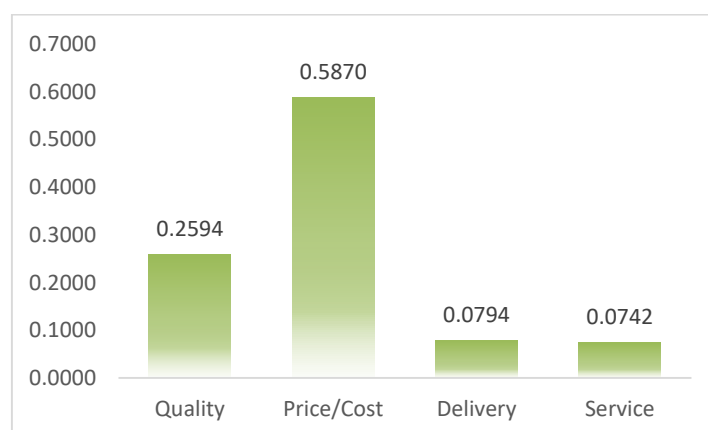|	C1	C2	C3	C4
Vendor 1	0.2121	0.2143	0.2308	0.2195
Vendor 2	0.2121	0.2500	0.1795	0.2195
Vendor 3	0.2727	0.2857	0.1795	0.2195
Vendor 4	0.1515	0.1429	0.2308	0.1707
Vendor 5	0.1515	0.1071	0.1795	0.1707
	-1.5840	-1.5519	-1.6017	-1.6022
k	0.6213	0.6213	0.6213	0.6213
e$_j$	0.9842	0.9643	0.9952	0.9955
d$_i$	0.0158	0.0357	0.0048	0.0045
w$_i$	0.2594	0.5870	0.0794	0.0742

Figure 1. Criterion Weightage

Implementation of ARAS for Vendor Ranking

ARAS method requires the decision matrix shown in Table 3. Before normalizing the decision matrix, the optimal performance ratings for each criterion are determined as the maximum values of beneficial criteria and minimum values of non-beneficial criteria. Optimal performance ratings (OPR) for each criterion are placed as V0 (Bold) in Table 3, Table 4 and Table 5.

Table 3. Decision Matrix

	Quality	Price	Delivery	Service
OPR (V0)	**9**	**3**	**9**	**9**
Vendor 1	7	6	9	9
Vendor 2	7	7	7	9
Vendor 3	9	8	7	9
Vendor 4	5	4	9	7
Vendor 5	5	3	7	7
Criteria Type	Max	Min	Max	Max

Normalization and Weight Normalization
The decision matrix is normalized by using equation mentioned in step 2, step 3 and step 4, in ARAS method and values shown in Table 4. Then normalized decision matrix is weighted by considering criteria weights derived from EWM and values shown in Table 5.

Table 4. Normalized Decision Matrix

	Quality	Price	Delivery	Service
V0	**0.2143**	**0.2467**	**0.1875**	**0.1800**
Vendor 1	0.1667	0.1233	0.1875	0.1800
Vendor 2	0.1667	0.1057	0.1458	0.1800
Vendor 3	0.2143	0.0925	0.1458	0.1800
Vendor 4	0.1190	0.1850	0.1875	0.1400
Vendor 5	0.1190	0.2467	0.1458	0.1400
Weight(w_j)	0.2594	0.5870	0.0794	0.0742

Weight Normalization

Table 5. Weighted normalized decision matrix

	Quality	Price	Delivery	Service
V0	**0.0556**	**0.1448**	**0.0149**	**0.0134**
Vendor 1	0.0432	0.0724	0.0149	0.0134
Vendor 2	0.0432	0.0621	0.0116	0.0134
Vendor 3	0.0556	0.0543	0.0116	0.0134
Vendor 4	0.0309	0.1086	0.0149	0.0104
Vendor 5	0.0309	0.1448	0.0116	0.0104

IV. RESULTS AND DISCUSSION

The optimality function (S_i) and the utility degree (U_i) of each alternative is calculated using equation mentioned in step 5 and step 6, in ARAS method. S_i and U_i values and the ranking of the alternatives are presented in Table 6.

Table 6. S_i, U_i values and Ranking

Vendor	S_i	U_i	Rank
V0	0.2286	1.0000	
Vendor 1	0.1439	0.6293	3
Vendor 2	0.1302	0.5696	5
Vendor 3	0.1348	0.5897	4
Vendor 4	0.1648	0.7206	2
Vendor 5	0.1977	0.8645	1

Based on the four criteria of sustainability, a total of five suppliers in a manufacturing firm were considered, where it was concluded that the Vendor 5 is the best solution or we can say most suitable vendor for further business with manufacturing firm,

which has been confirmed by comparison with other vendor based on optimality function (Si) and the utility degree (Ui) shown in Table 6 and comparison shown in Fig 2.
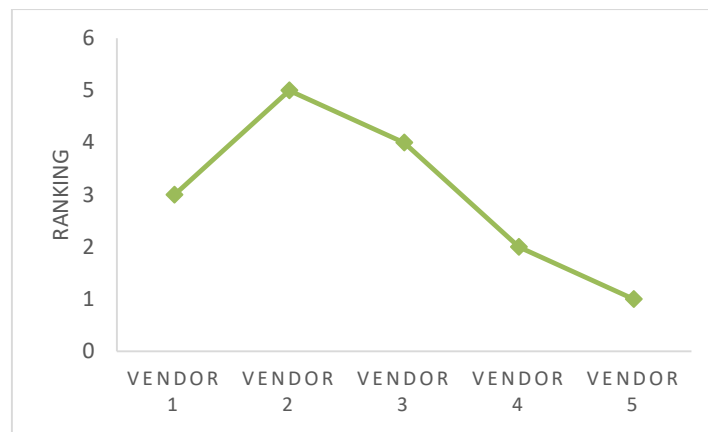

Figure 2. Rank Comparison of Vendors

Vendor selection is a very important process and activity for any manufacturing firm, it can be said that vendor selection is one activity in which huge brain storming and trial are carried out. This MCDM problem help the selector to take most suitable decision regarding the vendor selection process, Hence the vendor selection procedure and, above all, the selection of an adequate method is significant, especially from the aspect of the final result. In this paper, an illustrative example was successfully conducted aimed at indicating that multi-criteria decision making can be successfully applied for the vendor selection.

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