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Integration of Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for Supplier Selection

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Abstract: Supplier selection, the process of determining the suitable 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. In other words, supplier selection is a multi-criteria decision-making problem which includes both qualitative and quantitative factors. In order to choose the best suppliers, it is essential to make a trade-off between these tangible and intangible factors, some of which may conflict. This study aims to build decision support system to help problems solving prioritization improved management of government assets with AHP and TOPSIS methods. Integration of AHP and TOPSIS methods are used to perform weighting and ranking alternatives. Weights are obtained by comparison of the level of interest criteria carried out by experts ranked, while alternative methods produced are based on the calculation method in which the best alternative has the shortest distance from the positive ideal solution and the farthest from the negative ideal solution.

Keywords: Supplier Selection, Multi Criteria Decision Making (MCDM), Technique for Order Preferences by Similarity to the Ideal Solution (TOPSIS), Analytical Hierarchy Process (AHP)

I. INTRODUCTION

For many years, the traditional approach to supplier selection has been to select suppliers solely on the basis of price. However, as companies have learned that the sole emphasis on price as a single criterion for supplier selection is not efficient, they have turned into to a more comprehensive multi-criteria approach. Recently, these criteria have become increasingly complex as environmental, social, political, and customer satisfaction concerns have been added to the traditional factors of quality, delivery, cost, and service. The realization that a well-selected set of suppliers can make a strategic difference to an organization's ability to provide continuous improvement in customer satisfaction drives the search for new and better ways to evaluate and select suppliers. The use of multiple suppliers provides greater flexibility due to the diversification of the firm's total requirements and fosters competitiveness among alternative suppliers. Keeping in view the strategic importance of the supplier's role in the functioning of supply chains the researchers have developed number of criteria, methods and models for supplier selection. The relevant literature has been thoroughly reviewed and presented below.

In this paper presents a framework that integrates the analytical hierarchy process (AHP) and the technique for order preference by similarity to ideal solution (TOPSIS) to assist designers in identifying customer requirements and design characteristic and help achieve an effective evaluation of the final design solution. The proposed approach starts with applying the AHP method to evaluate the relative overall importance of customer requirements and design characteristics. The TOPSIS method is then used to perform competitive benchmarking. Finally, a search strategy is employed to set target values for design characteristics of the recommended design alternative.

II. LITERATURE REVIEW

The Analytic Hierarchy Process (AHP) methodology developed by Thomas L. Saaty is probably the best-known and most widely used model in decision-making. It is a powerful traditional decision-making tool in determining the priorities among different criteria, the advantage of the AHP technique is that it provides a systematic approach for consolidating information about alternatives using multiple-criteria. It is an objective weighing technique for setting the weighing scale for qualitative and quantitative data. AHP facilitates group decision making. AHP also allows for consistency checking. In other words, it allows the

decision makers to check the quality of the results in the comparison matrix. Consistency is concerned with the compatibility of a matrix of the ratios constructed from a principal right eigenvector with the matrix of judgments from which it is derived. The consistency ratio is calculated for the maximum eigenvalue and is required to be less than 0.1 for acceptable consistency.

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is used to solve problems using multi-criteria decision-making process. According to survey and research the recognized variables and effective criteria in supplier selection, with regards to this point that, considering all criteria has been extracted by expert judgment. Thereafter, we will evaluate and determine weight of each supplier and finally, by implementing (TOPSIS) method, the rank of each supplier is determined. TOPSIS has been a favorable technique for solving multi criteria problems. This is mainly for two reasons, 1.) Its concept is reasonable and easy to understand. And 2.) In comparison with other MCDM methods, like AHP, it requires less computational efforts, and therefore can be applied easily. TOPSIS is based on the concept that the optimal alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS).

III.   METHODOLOGY ADOPTED

A.   Analytic Hierarchy Process (AHP)
Analytic hierarchy process (AHP) was developed in the 1970s by Thomas Saaty is a highly outstanding management tool for complex multi-criteria decision problems. The approach can be used to help decision-makers for prioritizing alternatives and determining the optimal alternative using pair-wise comparison judgments. Weighting the criteria by multiple experts avoids the bias decision making and provides impartiality. In this paper, we have used the following steps of AHP (Saaty, 1980) to help us to measure the relative importance or the weighted values of several criteria.
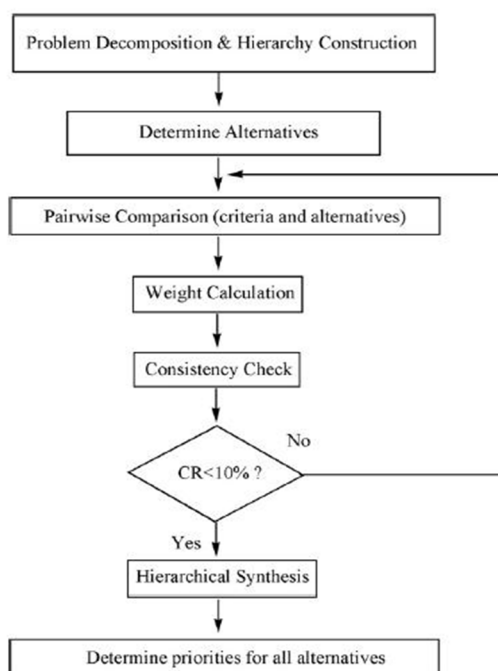

Fig. 1 AHP Flow Chart

In AHP, preferences between alternatives are determined by making pairwise comparisons. In a pairwise comparison, the decision maker examines two alternatives by considering one criterion and indicates a preference. These comparisons are made using a preference scale, which assigns numerical values to different levels of preference. The standard preference scale used for AHP is 1-9 scale which lies between "equal importance's" to "extreme importance" where sometimes different evaluation scales can be used such as 1 to 5. In the pairwise comparison matrix, the value 9 indicates that one factor is extremely more important than the other, and the value 1/9 indicates that one factor is extremely less important than the other, and the value 1 indicates equal importance. Therefore, if the importance of one factor with respect to a second is given, then the importance of the second factor with respect to the first is the reciprocal. Ratio scale and the use of verbal comparisons are used for weighting of quantifiable and non-quantifiable elements.

TABLE I
THE FUNDAMENTAL SCALE FOR PAIRWISE COMPARISONS

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
2,4,6 and 8 can be used to express intermediate value		

The steps to follow in using the:

1) Define the problem and determine the objective.
2) Structure the hierarchy from the top through the intermediate levels to the lowest level.
3) Construct a set of pair-wise comparison matrices for each of the lower levels. The numerical value for the element depends on Saaty Nine Point Scale shown in Table 1. There is n (n-1) / 2 judgments required to develop the set of matrices.
4) Having done all the pair-wise comparisons and entered the data, the consistency is determined using the Eigen value. Steps 3 and 5 are performed to have relative importance of each attribute for all levels and clusters in the hierarchy.
5) To do so, normalize the column of numbers by dividing each entry by the sum of all entries. Then sum each row of the normalized values and take the average. This provides Principal Vector [PV].
6) Find the consistency Index, CI, as follows:
7) $CI = (\Lambda_{max} - n)/(n-1)$ Where n is the matrix size

Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 2. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.

TABLE II
RANDOM INDEX TABLE

N	1	2	3	4	5
RCI	0	0	0.58	0.9	1.12
N	6	7	8	9	10
RCI	1.24	1.32	1.41	1.45	1.51

B. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

A Multi-Criteria Decision Making (MCDM) technique helps the decision makers (DMs) to evaluate the best alternatives. TOPSIS method is a most common technique of multi-Attribution Decision Making (MADM) models. "Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)" is a method of multi-criteria decision analysis and this method was introduced by Hwang and Yoon in 1981. TOPSIS logic is rational and understandable. It chooses the alternative which has the shortest geometric distance from the positive ideal solution and compares a set of alternatives by identifying weights for each criterion, normalizes the scores for each criterion and calculates the geometric distance between each alternative and the ideal alternative in order to give the best score for each criterion. TOPSIS method helps to choose the right suppliers with a various finite number of criteria.

1) *Step 1:* The structure of matrix

D =

	X_1	X_2	…	X_j
A_1	X_{11}	X_{12}	…	X_{1j}
A_2	X_{21}	X_{22}	…	X_{2j}
.	.	.	…	.
.	.	.	…	.
A_i	X_{i1}	X_{i2}	…	X_{ij}

2) *Step 2:* Calculate the Normalized the matrix D by using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{J} x_{ij}^2}}$$

3) *Step 3:* Construct the weighted normalized decision matrix by multiplying:

$$V_{ij} = w_{ij}.r_{ij}$$

4) *Step 4:* Determine the positive ideal solution and negative ideal solution

$$A^* = \{(max\ v_{ij}\,|\,j \in J), (min\ v_{ij}\,|j \in J')\}$$

$$A^- = \{(min\ v_{ij}\,|\,j \in J), (max\ v_{ij}\,|j \in J')\}$$

5) *Step 5:* Calculate the separation measure

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$$

6) *Step 6:* Calculate the relative closeness to the ideal Solution

$$C_i^* = S_i^- \Big/ S_i^* + S_i^- \ , 0 \le C_i^* \le 1$$

7) *Step 7:* Calculate the total score and select the alternative closest to 1.

IV. IMPLEMENTATION WITH NUMERICAL EXAMPLE

In this section, to implement the methodology, we have solved simulated numerical example the management of a manufacturing company wants to choose their best suppliers based on proposed methodology.

A manufacturing firm wants to choose their best supplier for their hardware division. The evaluation is between ten suppliers, the evaluation objectives and choose the best of them. The evaluation group determines the value of each criterion which is based on the 10-pointer scale as shown in the table 1.

The selection criterions are Product Quality (PQ), Service Quality (SQ), Delivery Time (DT) and Price (Pr).

TABLE III
RATING OF FOUR CRITERIONS OF THE SUPPLIER

Selection Criteria → Rating ↓	PQ	SQ	DT	Pr	Abbreviation
4	Extremely Low				EL
5	Very Low				VL
6	Low				L
7	High				H
8	Very High				VH
9	Extremely High				EH

TABLE IV
CRITERION RELATIONSHIP MATRIX

	PQ	SQ	DT	Pr
PQ	1	3	7	5
SQ	1/3	1	5	3
DT	1/7	1/5	1	1/3
Pr	1/5	1/3	3	1

TABLE V
SHOWING SUPPLIERS AND THEIR ATTRIBUTES

Criteria → Alternatives ↓	PQ	SQ	DT	Pr
Supplier 1	EH	VL	L	VL
Supplier 2	VL	VL	H	VL
Supplier 3	EH	H	H	L
Supplier 4	H	EH	EH	EH
Supplier 5	VL	H	VL	EH
Supplier 6	EH	L	VL	H
Supplier 7	H	EH	EH	L
Supplier 8	H	EH	EH	H
Supplier 9	EH	VH	VL	L
Supplier 10	VL	VH	EH	VH

TABLE VI
DECISION MATRIX WITH CRITERION PARAMETRIC VALUES

Criteria → Alternatives ↓	PQ	SQ	DT	Pr
Supplier 1	9	5	6	5
Supplier 2	5	5	7	5
Supplier 3	9	7	7	6
Supplier 4	7	9	9	9
Supplier 5	5	7	5	9
Supplier 6	9	6	5	7
Supplier 7	7	9	9	6
Supplier 8	7	9	9	7
Supplier 9	9	8	5	6
Supplier 10	5	8	9	8
$\sum_{i=1}^{m} x_{ij}$	72	73	71	68
$\sqrt{\sum_{i=1}^{m} x_{ij}^2}$	23.37	21.7	23.09	21.95

Calculate the Normalized the matrix D by using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{J} x_{ij}^2}}$$

TABLE 7
NORMALIZED MATRIX

Criteria → Alternatives ↓	PQ	SQ	DT	Pr
Supplier 1	0.39	0.23	0.26	0.23
Supplier 2	0.21	0.23	0.30	0.23
Supplier 3	0.39	0.32	0.30	0.27
Supplier 4	0.30	0.41	0.39	0.41
Supplier 5	0.21	0.32	0.22	0.41
Supplier 6	0.39	0.28	0.22	0.32
Supplier 7	0.30	0.41	0.39	0.27
Supplier 8	0.30	0.41	0.39	0.32
Supplier 9	0.39	0.37	0.22	0.27
Supplier 10	0.21	0.37	0.39	0.36

Using AHP for weight calculation of each criterions.

A pair-wise comparison matrix developed as shown in Table V. In constructing the matrix, the question to be asked as each factor comparison is being made is "how much more strongly does this element (or activity) possess – or contribute to, dominate, influence, satisfy, or benefit – the property than does the element with which it is being compared?" (Saaty, 1990).

TABLE VIII
PAIRWISE COMPARISON MATRIX

	PQ	SQ	DT	Pr
PQ	1	3	7	5
SQ	1/3	1	5	3
DT	1/7	1/5	1	1/3
Pr	1/5	1/3	3	1

TABLE IX
NORMALIZED MATRIX WITH PRINCIPAL VECTOR OR WEIGHT

	PQ	SQ	DT	Pr	Sum	PV
PQ	0.60	0.66	0.44	0.54	2.23	0.56
SQ	0.20	0.22	0.31	0.32	1.05	0.26
DT	0.09	0.04	0.06	0.04	0.23	0.06
Pr	0.12	0.07	0.19	0.11	0.49	0.12

A. Test of consistency

Let the pair-wise comparison matrix be denoted M1 and principal vector be denoted M2.

Then define M3 = M1*M2; and M4 =M3/M2. λmax = average of the elements of M4.

Consistency index (CI) = (λmax - N) / (N - 1)

Consistency Ratio (CR) = CI/RCI corresponding to N.

Where RCI = Random Consistency Index and N = Numbers of elements.

M1 =

1.00	3.00	7.00	5.00	2.00
0.33	1.00	5.00	3.00	2.00
0.14	0.20	1.00	0.33	2.00
0.20	0.33	3.00	1.00	2.00

M2 =

0.56
0.26
0.06
0.12

M3 =

2.36
1.10
0.23
0.49

M4 =

4.23
4.20
4.01
4.03

Consistency index (CI)   = (λmax - N) / (N - 1)
                          = (4.23-4) / (4-1)
                          = 0.08
Consistency Ratio (CR)   = CI/RCI (Reference Table 2)
                          =0.02/0.90
                          =0.085 < 0.10

The consistency Rate calculated was 0.085 that is less than 0.1, indicating sufficient consistency. The calculated weights are satisfactory.

Construct the weighted normalized decision matrix by multiplying:

$$V_{ij} = w_{ij}.r_{ij}$$

TABLE X
WEIGHTED NORMALIZED MATRIX

Selection Criteria → Alternatives ↓	PQ	SQ	DT	Pr
Supplier 1	0.21	0.06	0.01	0.03
Supplier 2	0.12	0.06	0.02	0.03
Supplier 3	0.21	0.08	0.02	0.03
Supplier 4	0.17	0.11	0.02	0.05
Supplier 5	0.12	0.08	0.01	0.05
Supplier 6	0.21	0.07	0.01	0.04
Supplier 7	0.17	0.11	0.02	0.03
Supplier 8	0.17	0.11	0.02	0.04
Supplier 9	0.21	0.10	0.01	0.03
Supplier 10	0.12	0.10	0.02	0.04

Determine the positive ideal solution and negative ideal solution

$$S^* = \{(max\ v_{ij}|j \in J),(min\ v_{ij}|j \in J')\}$$

$$S^- = \{(min\ v_{ij}|j \in J),(max\ v_{ij}|j \in J')\}$$

Table XI
Positive and Negative Ideal Solution

	PQ	SQ	DT	Pr
S^*	0.10	0.14	0.15	0.10
S-	0.15	0.11	0.11	0.15

Calculate the separation measure

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^*\right)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}$$

Calculate the relative closeness to the ideal Solution

$$C_i^* = \frac{S_i^-}{S_i^* + S_i^-}, \ 0 \le C_i^* \le 1$$

Table XII
Separation measure, relative closeness coefficient and ranking

Suppliers	S_i^*	S_i^-	C_i^*	Rank
Supplier 1	0.00	0.01	0.79	4
Supplier 2	0.01	0.00	0.05	10
Supplier 3	0.00	0.01	0.94	2
Supplier 4	0.00	0.00	0.68	7
Supplier 5	0.01	0.00	0.06	9
Supplier 6	0.00	0.01	0.86	3
Supplier 7	0.00	0.01	0.73	5
Supplier 8	0.00	0.00	0.72	6
Supplier 9	0.00	0.01	0.98	1
Supplier 10	0.01	0.00	0.15	8

V. RESULT & DISUCSSION

In this paper the proposed method, which integrates AHP and TOPSIS, for selecting the best supplier. AHP is used to determine the weights of the criteria, while TOPSIS is employed to determine the priorities of the alternatives. The results show that supplier 9 is the best supplier among the 10 other supplier. According to the result calculated the ranking is done for all 10 suppliers. This method is simple to understand and permit the pursuit of best alternative criterion in a simple mathematical calculation.

Due to this, decision making for selection of suitable supplier is of special importance. Acquired results from numerical example determine that the model could be used for decision making optimization is supplier selection.

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