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An Integrated AHP-TOPSIS Approach in Supplier Selection: An Automotive Industry as a Case Study

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Abstract:
A multi-criteria problem is the one which is evaluated against qualitative and quantitative factors. A practical example of such problem is supplier selection. A supplier selection problem deals with both tangible and intangible factors to select the best suppliers. It becomes more complicated in presence of constraints such as capacity, cost, quality etc. in such circumstances, manager faces two problems: (1) who are the best suppliers (2) how much quantity should be purchased from each selected supplier. The work addressed in this paper describes an integration of Analytical Hierarchy Process (AHP), Technique For Order Preference By Similarity To Ideal Solution (TOPSIS) and linear programming to solve a multi-criteria supplier selection problem where both qualitative and quantitative factors are taken into account. While AHP qualitatively determine the weights assigned to different criteria, TOPSIS determines ranking of suppliers and linear programming mathematically determine the optimal order quantity from chosen suppliers by taking the output of TOPSIS as its input. A case study of an automobile company is presented and future scope is discussed.

Keywords: *Supplier selection, AHP, TOPSIS, Linear programming, automotive industry, MCDM.*

1. Introduction

Supplier selection process evaluates a number of suppliers against a set of common criteria to select suppliers who are capable of meeting business needs. This process is considered as a multi-criteria decision-making (MCDM) problem that deals with both qualitative and quantitative criteria to identify suppliers. Since a manufacture spends more than half of its total sales on purchased items, the selection process becomes most important activity in purchasing department. In automotive industry the selection process is even more critical as wrong selection of suppliers can cause the purchased cost to go upto 80% of total revenue. In the process of supplier selection, a buyer identifies, evaluates and contracts with suppliers. The selection process consists of following steps:

i. Identification of potential suppliers
ii. Collection of information from suppliers
iii. Issue of bids for the contract
iv. Evaluation of suppliers based on common objectives

There are two kinds of supplier selection problems

i. Supplier selection problem with no constraint: all suppliers can satisfy the buyer's requirements. In such problems, buyer needs to identify best supplier.
ii. Supplier selection with constraint: all suppliers face some limitations in terms of capacity, quality etc and hence no supplier can satisfy all requirements of buyer's. In such circumstances, the management needs to make two decisions: (1) selection of best suppliers (2) quantity to be purchased from each selected suppliers.

The most important task in supplier selection problem is to identify criteria for evaluation of suppliers. In this study, a very comprehensive application of Analytic Hierarchy Process (AHP) and TOPSIS for a case is presented to choose the best supplier along with the quantity to be ordered.

2. Literature Review

A lot of criteria have been discussed in the domain of supplier selection problem. The study conducted by Dickson (1966) identified 23 criteria to evaluate 170 buyers. Weber (1991) reviewed several papers on supplier selection and concluded that quality was the most important criteria which is followed by delivery and cost. Seven criteria such as price, quality, delivery, sales support, equipment, technology, order process and supplier company financial position were proposed by Patton (1996). The idea of including management as the criteria in supplier selection was presented by Ellram (2002). This paper considers seven criteria on which supplier selection has been done. Since supplier selection is a Multi Criteria Decisions Making Problem, there are several methods such as Artificial intelligence and expert systems, Mathematical programming, Traditional (conventional) Multiple Criteria Decision Making (MCDM) techniques, Multivariate statistical analysis etc. that helps to arrive at a unique solution. Some of these methods have been implemented in past. Every solution approach has its own limitation. The most popular approaches in MCMD are Analytical Hierarchical Process, Technique for Order Preference by Similarity to Ideal Solution, DEMATEL etc.

The advantage of incorporating intangibles in decision making process is the attribute of AHP. This method is very popular in manufacturing sector. In recent years many authors of manufacturing sectors have utilized AHP to solve decision making process. For example: Chan et al. (2000) employed the AHP technique in FMS design problem. The outcome of AHP model is to select the best FMS design among its alternatives that were evaluated on criteria like finance, building time, flexibility, risk factor and last but not the least productivity. Similarly, Liu et al. (1999) incorporated AHP based modeling technique to develop the computer aided process plans.

In TOPSIS according to (Wang & Elhag, 2006) the best alternative is the one that have the shortest distance from the positive ideal solution (PIS) and it maximizes the benefit criteria and minimizes the cost criteria while the worst alternative is the one having longest distance from the negative ideal solution (NIS). A literature review performed on TOPSIS methodology by Behzadian et al. (2012), suggested the integration of classical TOPSIS with other techniques would be able to deal practical and theoretical problems and such integration can enhance the overall performance. Many researchers have applied AHP-TOPSIS hybrid for different applications. In this paper, we have addressed Analytical Hierarchical Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) hybrid to arrive at a unique solution for an automobile industry.

3. Research Methodology

The main objectives of this research were first of all to identify the major supplier selection criteria that must be considered by an automobile company. Based on the literature review of supplier selection criteria, major attribute of suppliers were identified and a questionnaire form was prepared. This form was then distributed to three experts and they were asked to rate the selection criteria as per importance in automobile sector. Once the priorities of criteria are identified from questionnaire, the next step is to develop the pair comparison matrix as per Satty's 9-point scale for the AHP-based supplier selection framework analysis. To determine the final weights of these criteria, AHP was used as a decision analysis tool and TOPSIS to rank suppliers. Highest ranking will be given to best supplier. To minimize the total cost and to identify quantity of item to be ordered from supplier, weighted rank of TOPSIS was delivered to linear programming model.

Following are the steps of methodology applied in the case study:

1. Define criteria

The efficiency measures for selection problem consists of seven factors, namely, Quality, Responsiveness, Delivery, Finance, Management, Technical Capability, and Facility.

2. Design the hierarchy

The hierarchy consists of the overall goal, criteria, sub-criteria (could have several levels), and the decision alternatives. Figure2 illustrates the proposed hierarchy.

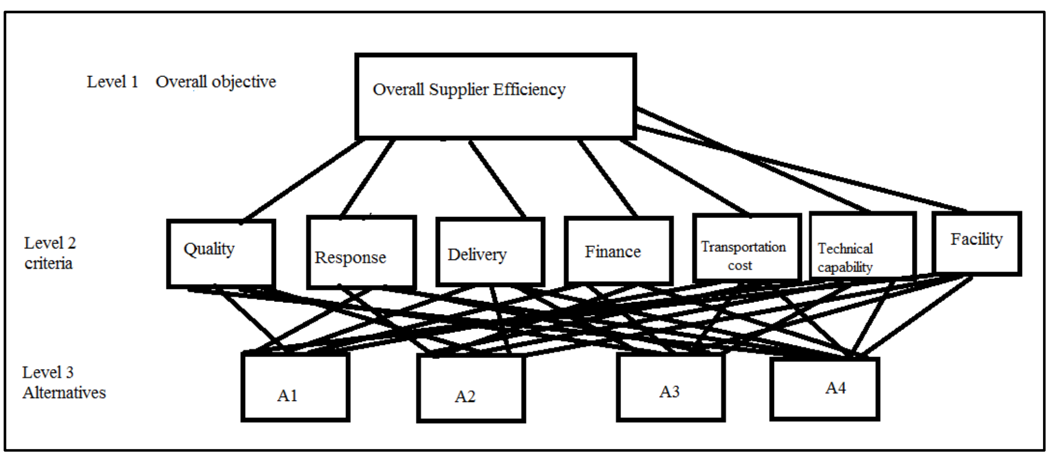

Figure 1: Hierarchy in case study

3. Perform the pairwise comparison and prioritization:
4. Check the consistency of the matrix

$Consistency\ index(CI) = (\lambda max - n)/(n - 1)$

Where λmax is the largest Eigen value of the considered matrix. The random index depends on number of criteria is shown below in Table 1

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	.58	.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 1: Random Index (RI) based on matrix size (n)

The recommended consistency ratio is less than or equal to ten percent.

1. Calculate the weights of the criteria
2. Establish a decision matrix for the ranking as per TOPSIS and normalize it.

A decision matrix is formed where column represent different alternatives and rows represent criteria or attribute.

3. Form weighted normalize decision matrix.

Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights.

4. Determine the positive ideal solution and the negative ideal solution.
5. Compute the distance between each alternative and positive and negative ideal solution.

10. Calculate the relative closeness of each alternative
11. Rank the alternatives based on relative closeness
12. Use Linear Programming to evaluate suppliers quantitatively
13. Convert the PGP model (Wang et.al. (2004)) into linear programming model as shown below:

Decision variable:
Qy Purchasing quantity from supplier *y*
y Supplier index,
Parameters:
Tj Customer demand for component *j*
TVP Total value of purchase
TCP Total cost of purchase
TTC Total transportation cost
Dy Unit purchasing cost of supplier *y*
Ry Production capacity of supplier *y*
Aj Total number of potential alternatives for component *j*
Wy TOPSIS weight for supplier y
Constraints:

$$Ry \geq Qy \quad (1)$$

$$Qy \geq 0 \quad (2)$$

$$\sum_{y=1}^{Aj} Qy = Tj \quad (3)$$

Objectives:
Priority 1: Maximize *TVP*

$$\sum_{y=1}^{Aj} WyQy = TVP \quad (4)$$

Priority 2: Minimize *TCP*

$$\sum_{y=1}^{Aj} Dy\ Wy = TCP \quad (5)$$

Priority 3: Minimize *TTC*

$$\sum_{y=1}^{Aj} TCy\ Qy \quad (6)$$

6. Find optimal solution.

Use excel solver tool to determine the optimal solution of the linear programming. The optimal solution will decide which supplier(s) will be chosen and how many items they need to supply.

4. Case Study

NB Inc. is a hypothetical car manufacturer that deals with manufacturing and assembly of automobile parts. Only one component, i.e. chassis for the NB Inc. need to be purchased. There are only a limited number of potential suppliers having ISO 9000 certification. These potential alternative suppliers are presented as *A1, A2, A3 and A4.* Table 2 lists the supplier information for the chassis. The data is modified from a published example (Singh et al., 2012).

Constraint	**A1**	**A2**	**A3**	**A4**
Capacity	400	700	600	500
Unit Purchase Cost	.6	2.4	1.2	2.4
Defect Rate	1%	3%	2%	1%

Table 2: Supplier Information

When using the proposed methodology the first step is to prioritize the performance metrics by pairwise comparison with Saaty's 1–9 scales. The final pairwise matrix is shown in Figure3

	D1	D2	D3	D4	D5	D6	D7
Quality (D1)	1	5	1	4	9	8	9
Responsiveness (D2)	1/5	1	1/5	1/3	5	4	3
Delivery (D3)	1	5	1	4	9	8	9
Finance (D4)	1/4	3	1/4	1	5	4	3
Transportation cost (D5)	1/9	1/5	1/9	1/5	1	1/3	1/4
Technical capability (D6)	1/8	1/4	1/8	1/4	3	1	1/2
Facility (D7)	1/9	1/3	1/7	1/3	4	2	1

Figure 2: Pair-wise comparison matrix

After prioritizing the performance metrics, a final consistency checking is applied.
Priority vector (P) = [2.3368; 0.6667; 2.3368; 0.8750; 0.1667; 0.2500; 0.3750]
Eigen values (λ_i) = [7.8663; 7.2843; 7.8663; 8; 7.0284; 7.6284; 6.2528]
Max λ = 8; n=7
CI= 0.1667
RI= 1.32(From Table 1)
CR=0.13
Table 4 shows the final weight assigned to criteria.

Criteria	Weight
Quality	0.3338
Responsiveness	0.0952
Delivery	0.3338
Finance	0.125
Transportation cost	0.0238
Technical capability	0.0357
Facility	0.0535

Table 3: Final weights from AHP

The decision matrix Hij is shown in Figure 4

Attributes	Suppliers A1	A2	A3	A4
D1 (%)	95	94	96	90
D2 (%)	90	96	94	91
D3 (Day)	12	15	14	10
D4 (Grad)	5	3	6	3
D5 ($)	650	470	550	700
D6 (%)	46	52	38	40
D7 (Grad)	5	4	6	7

Figure 3: Decision matrix

Normalizing the decision matrix Hij into Sij such that

$$Sij = \frac{Hij}{(\sum Hij^2)^{\frac{1}{2}}} \quad (7)$$

ATTRIBUTES	SUPPLIERS 1	2	3	4
D1	0.51	0.5	0.51	0.48
D2	0.49	0.52	0.51	0.49
D3	0.47	0.48	0.54	0.39
D4	0.56	0.34	0.68	0.34
D5	0.54	0.39	0.46	0.58
D6	0.52	0.59	0.43	0.45
D7	0.45	0.36	0.53	0.62

Figure 4: Normalized matrix

Weighted normalized matrix *Vij* (Figure 6) is

$$Vij = Wij * Sij \quad (8)$$

ATTRIBUTES	SUPPLIERS A1	A2	A3	A4
D1	0.1702	0.1669	0.1702	0.1602
D2	0.0466	0.0495	0.0485	0.046
D3	0.1569	0.1602	0.1802	0.1302
D4	0.07	0.0425	0.085	0.0425
D5	0.0128	0.00928	0.0109	0.0138
D6	0.0186	0.211	0.0153	0.0161
D7	0.024	0.0192	0.0283	0.0332

Figure 5: Weighted normalized matrix

The positive ideal solution (PIS) and negative ideal solution (NIS) are V^+ and V^- respectively

V^+= {.1702, .0495, .1802, .085, .0138, .0211, and .0332}

V^- = {.1602, .0460, .1302, .0425, .009282, .0153, and .0192}

The separation measure E^+ and E^- is shown below in table 4

Separation measure	A1	A2	A3	A4
E^+	0.0008682	0.0024330	0.00006702	0.00444000
E^-	0.0016158	0.0009907	0.00449000	0.00121774

Table 4: Separation measure

Final ranking and relative weight of suppliers are as shown below in Table 5

Supplier	Relative closeness ($E^-/(E^++E^-)$)	Rank	Relative weight of suppliers
1	0.650	2	.3038
2	0.289	3	.135
3	0.985	1	.460
4	0.215	4	.100

Table 5: Rank of suppliers

The final rating for *A1*, *A2*, *A3* and *A4* are 2, 3, 1 and 4 respectively.

Since A3 has the maximum rating, it is chosen as the main supplier. However A3 only has a production capacity of 600 units, which cannot satisfy the demand, the decision process continues on to LP. The decision variables for LP are as follows

Supplier index *Y*=1, 2, 3, 4.

Q1, Q2, Q3 and Q4 are Purchasing Quantity of suppliers 1, 2, 3 and 4 respectively.

Tj= 1000

Capacity Constraint:

$$R1 = 400 \geq Q1 \quad (9)$$

$$R2 = 700 \geq Q2 \quad (10)$$

$$R3 = 600 \geq Q3 \quad (11)$$

$$R4 = 500 \geq Q4 \quad (12)$$

Demand constraint

$$Q1 + Q2 + Q3 + Q4 = 1000 \quad (13)$$

Quality constraint

$$1000 * 0.2 \geq Q1 * 0.01 + Q2 * 0.03 + Q3 * 0.02 + Q4 * 0.01 \quad (14)$$

Non negativity constraint

$$R1, R2, R3, R4 \geq 0 \quad (15)$$

$$Q1, Q2, Q3, Q4 \geq 0 \quad (16)$$

Priority 1 Max TVP

$$Q1 * 0.3038 + Q2 * .135 + Q3 * .460 + Q4 * 0.1 = TVP \quad (17)$$

Priority 2 Min TCP

$Q1 * 0.6 + Q2 * 2.4 + Q3 * 1.2 + Q4 * 2.4 = TCP$ (18)

Priority 3 Min TTC

$Q1 * 650 + Q2 * 470 + Q3 * 550 + Q4 * 700 = TTC$ (19)

A commercially available optimization software, excel solver is used to facilitate the linear programming optimization process. Optimal solution can be decided: supplier A2, A3 and A4 are chosen with 200, 600and 200 quantities respectively. Figure 6 & 7 shows the formulation and result respectively.

	q1	q2	q3	q4	lhs		rhs	
priority 1	0.3038	0.135	0.46	0.1	397.52			
	0.6	2.4	1.2	2.4	1680			
	650	470	550	700	564000			
capcity const 1	1				0	≤	400	400
capacity const 2		1			200	≤	700	500
capacity const 3			1		600	≤	600	0
capacity const 4				1	200	≤	500	300
quality constraint	0.01	0.03	0.02	0.01	20	≤	20	0
demand const	1	1	1	1	1000	≤	1000	0
c2	1	1	1	1	1000	≥	1000	0
solution values	0	200	600	200				

Figure 6: LP in Excel Solver

Target Cell (Min)

Cell	Name	Original Value	Final Value
$M$7	lhs TTP	0	564000

Adjustable Cells

Cell	Name	Original Value	Final Value
$H$17	solution values q1	0	0
$I$17	solution values q2	0	200
$J$17	solution values q3	0	600
$K$17	solution values q4	0	200

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$M$8	capcity const 1 lhs	0	$M$8<=$O$8	Not Binding	400
$M$9	capacity const 2 lhs	200	$M$9<=$O$9	Not Binding	500
$M$10	capacity const 3 lhs	600	$M$10<=$O$10	Binding	0
$M$11	capacity const 4 lhs	200	$M$11<=$O$11	Not Binding	300
$M$12	quality constraint lhs	20	$M$12<=$O$12	Binding	0
$M$13	demand const lhs	1000	$M$13<=$O$13	Binding	0
$M$14	c2 lhs	1000	$M$14>=$O$14	Binding	0
$M$5	priority 1 lhs	397.52	$M$5=397.52	Not Binding	0
$M$6	lhs	1680	$M$6=1680	Not Binding	0

Figure 7: Final solution

5. Conclusion and Future Scope

The case study presented above shows following outcomes:

- The consistency ratio is 0.13.
- In an integrated approach of AHP-TOPSIS, AHP determines the weight of criteria while TOPSIS is used to find final ranking of suppliers.
- The mathematical result from prioritized linear programming indicates that there can be three different solutions depending on priority selection. However the final result satisfies all three prioritized objective functions.
- The method does not consider some important costs such as service cost, inventory costs and ordering cost.
- The proposed method can be expanded to include sub criteria's for final selection of suppliers. Also, it can use goal programming to identify deviations from goals. One can use fuzzy set theory due to vagueness and insufficient data in primary design stage.

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