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Supplier Ranking in Automobile Industry by Using TOPSIS Methods

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Abstract

Supplier selection has become an important concept for improving supply chain performance. The aim of this paper is to identify factors that facilitate and affects the supplier selection in the context of Indian automobile industry. An inductive approach based on grounded theory was chosen as the research methodology where data was collected from the well-known two wheeler automobile manufacturer of India. This paper represents the case study of an automobile industry. TOPSIS method is used for ranking the supplier in the basis of data provided by the industry. The result of this study gives the best possible solution of the supplier selection for the automobile industry.

Keywords: Automobile industry, Key performance indicator (KPI), TOPSIS, Supplier Selection.

Introduction

In order to maintain a competitive position in the global market, organizations 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 of this, selecting the right suppliers is a critical component of these new strategies. Several conflicting quantitative and qualitative factors or criteria like cost, quality, delivery etc. affect supplier selection problem. Therefore, it is a multi-criteria decision making problem that includes both quantitative and qualitative factors, some of which conflict to each other. Increases and varieties of customer demands, advances of recent technologies in communication and information systems, competition in global environment, decreases in governmental regulations, and increases in environmental consciousness have forced companies to focus on supply chain management. The “supply chain management” term has been used for almost 20 years and is defined as the integration of activities to procure materials, their transformation into intermediate goods and final products, and delivery to customers. In supply chains, coordination between a manufacturer and suppliers is typically a difficult and important link in the channel of distribution. Once a supplier becomes part of a well-managed and established supply chain, this relationship will have a lasting effect on the competitiveness of the entire supply chain. Because of this, supplier Selection problem has become one of the most important issues for establishing an effective supply chain system. Besides, selection of suppliers is a complicated process by the facts that numerous criteria must be considered in the decision making process. Research results indicate that supplier selection process is one of the most significant variables, which has a direct impact on the performance of an organization. As the organization becomes more and more dependent on their suppliers, the direct and indirect consequences of poor decision making will become more critical. The nature of this decision is usually complex and unstructured. On the other hand, supplier selection decision making problem involves trade-offs among multiple criteria that involve both quantitative and qualitative factors, which may also be conflicting. In this paper, we have identified some effective criteria which affect the process of supplier selection. Based on TOPSIS, we have calculated the weights for each criterion has been calculated and in putted those weights to the TOPSIS (Technique for Order Preference Similarity to Ideal Solution) method to rank suppliers.

Literature review

The objective of supplier selection is to identify suppliers with the highest potential for meeting a firm’s needs consistently. Weber et al. (1991)

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assessed 74 supplier selection papers from 1966 to 1991, and illustrated that nearly 63% of them were in a multi-criteria decision making situation. In the past, several methodologies have been proposed for supplier selection problem. Weber and Ellram (1993) developed the use of a multi-objective programming approach as a method for supplier selection in just in time (JIT) setting. Weber and Current (1993) used multi-objective linear programming for supplier selection to systematically analyze the trade-off between conflicting criteria. In this model, aggregate price, quality and late delivery are considered as goals. Ghodsypour and O'Brien (1998) proposed integration of an AHP and linear programming to consider both tangible and intangible factors in choosing the best suppliers and placing optimum order quantities among them. They also presented a mixed integer non-linear programming model to solve the multiple sourcing problems, with multiple criteria and with supplier's capacity. Chaudhry et al. (1991) have used integer goal programming to solve the problem of allocating order quantities among suppliers. Karpak and Kasuganti (1999) have used visual interactive goal programming for supplier selection process. Liu et al. (2000) used data envelopment analysis (DEA) to compare the performance evaluation of different supplier for best selection. Kumar et al. (2002) have used fuzzy mixed integer goal programming for supplier selection problem. Wang et al. (2006) used the advantages of AHP and preemptive goal programming to incorporate both quantitative and qualitative factor in supplier selection problem. Bhuttamd Huq (2002) have illustrated and compared the technique of total cost of ownership and AHP in supplier selection process. Chang et al. (2006) applied an AHP to determine the optimal supplier. His model evaluated the suppliers based on 14 criteria. Wadhwa and Ravindran (2007) proposed a supplier selection methodology that consists of 3 objectives, such as price, lead time and rejects. All of these objective functions are minimization. Vahdani et al. (2008) also presented a three step methodology based on balancing and ranking methods in supplier evaluation. Hong et al. (2005) formulated a mixed integer linear programming model for the suppliers' assessment. The model provides jointly, "optimal order quantity" and "optimal number of suppliers". Narasimhan et al. (2010) developed a multi objective programming model to indicate the best supplier and the optimal order quantity. Mendoza and Venture (2008) utilized a two-step method to solve supplier selection problem. At the first step, AHP was used to rank and decrease number of supplier. At the second step, the mixed integer nonlinear programming model was applied to determine the optimal order quantity. Jiang (2010) presented a weighted linear programming model for supplier evaluation. His proposed model is based on maximizing the suppliers' score. Chang (2006) introduced a new extent analysis approach for the synthetic extent values of the pair wise comparison for handling fuzzy AHP (FAHP). The proposed FAHP with extent analysis is simple and easy for implementation to prioritize decision variables as compared with the conventional AHP. Chen (2012) presented a multiple-criteria decision-making model based on fuzzy-set theory for supplier selection. Kahraman et al. (2009) used the fuzzy AHP for domestic supplier selection with only 3 criteria and 11 attributes and neglected the many important criteria which create the uncertainty in supplying the products, that is, the risk factors involved in global supplier selection. Chiou et al. (2005) used a fuzzy hierarchical analytic process to determine the weights of criteria from subjective judgments and a non-additive integral technique to evaluate the performance of sustainable development strategies for aquatic products processors. Beside these approaches, Amiri et al. (2008) presented a multivariate approach for solving supplier selection problem. His approach is based on principal component analysis that used information obtained from Eigenvector to combine different ratio measures defined by every input and output.

Case study

The industrial data is collected from one of top most automobile industry these plants together are capable of churning out 6 million bikes per year. The plants have a large sales and service network with over 3,000 dealerships and service points across India. The plants have a customer loyalty program since 2000, called the Passport Program. The company has a stated aim of achieving revenues of $10 billion and volumes of 10 million two-wheelers by 2016–17. This in conjunction with new countries where they can now market their two-wheelers following the disengagement from plants hopes to achieve 10 per cent of their revenues from international markets, and they expected to launch sales in Nigeria by end-2011 or early-2012

TOPSIS model

TOPSIS is Multi Criteria decision Making (MCDM) which is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. It is a method of compensatory aggregation that compares a set of alternatives by identifying

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weights for each criterion, normalizing scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. Step used in TOPSIS model explained follows

- **Step 1**
  Create an evaluation matrix consisting of m alternatives and n criteria, with the intersection of each alternative and criteria given as x_{ij}, we therefore have a matrix $(A_{ij})_{m\times n}$
- **Step 2**
  Normalize the condition
  $n_{ij}=\frac{a_{ij}}{\sqrt{\sum a_{ij}^2}}$
  Where i=1, 2, 3 ….n and j=1, 2…..m

- **Step 3**
  Calculate the effectiveness measure of every index

$E_j = K\sum_{i=1}^{10}(Pij \times \log_e Pij)$

Where $K = \frac{1}{\ln 10}$ and $P_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$, where i=1, 2, 3 ….n and j=1, 2…..m

- **Step 4**
  Obtained the normalized weight of every index

$W_j = \frac{d_j}{\sum d_j}$

Where $d_j = 1 - E_j$ J = 1,2 …..m

Calculate the weighted normalized decision matrix:-
$V = N \times W_{nm}$
Determine the ideal and negative ideal solution:-
$V_j^+ = (V_i^+ \dots\dots\dots.. V_n^+) = \left[\left(\frac{\max V_{ij}}{I'\in i}\right)\left(\frac{\min V_{ij}}{i\in I"}\right)\right]$
$V_j^- = (V_i^- \dots\dots\dots V_n^-) = \left[\left(\frac{\min V_{ij}}{i\in J}\right)\left(\frac{\max V_{ij}}{i\in J}\right)\right]$
where I' is associated with advantage criteria and I" is associatedwith cost criteria.

- **Step 5**
  Calculate the separation measure & using the n – dimensional Euclidean distance. The separation of each alternative from the ideal solution

$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - V_j^+\right)^2}$

$d_i^- = \sqrt{\sum_{j=1}^{n}\left(V_{ij} - V_j^-\right)^2}$

Where i= 1, 2, 3 ----------10.

- **Step 6**
  Calculate the relative closeness and rank than

$S.L_i = \frac{d_i^-}{d_i^- + d_i^+}$

$S.L_i$ = 1if and only if the alternative solution has the worst condition; and

$S.L_i$ = 0if and only if the alternative solution has the best condition.

- **Step 7**

  Rank the alternatives according to $S.L_i$ (i= 1, 2, 3 ………..n)

Experimantal setup

We have collected the data of spark plug supplier there are the 10 supplier supply the spark plug we have collected the on the basis some parameters like cost/unit, % defective, % late delivery, distance from plants in KM. There are 10 supplier supply spark plug of the company data shown in table below

Production per year =7035106.8

Consumption rate R= 58625.89/ month

Average lead time= 25 days

Ordering rate C_o= 7035/ order

Caring cost C_c= 12 + 20% of per piece cost

Lot size = $\sqrt{\frac{2\times R\times c_o}{c_C}}$

Lot size = $\sqrt{\frac{2\times 586258.9\times 7035}{12+20\%}}$ =58625.89/ supplier

Table-1: list of Supplier details

S.No.	Supplier	Cost/Unit (Rs)	% Defective	% Late Delivery	Distance from company (K.M.)
01	S1	165	0.45	2.3	500
02	S2	152	0.97	2.6	900
03	S3	98	1.60	2.9	1100
04	S4	140	0.86	3.4	1600
05	S5	86	1.40	2.4	150
06	S6	74	0.90	1.8	300
07	S7	92	0.86	3.0	110

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08	S8	77	0.84	3.0	400
09	S9	80	1.24	2.0	90
10	S10	82	0.96	2.2	120

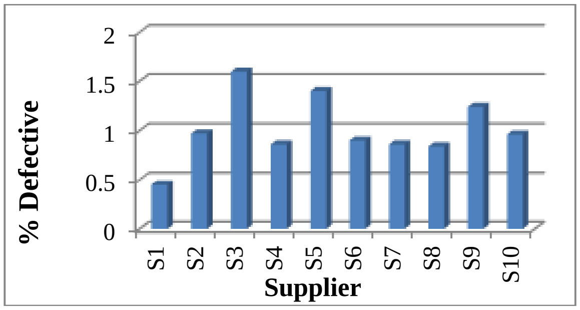

Figure-1: Relationship chart of %defective and suppliers

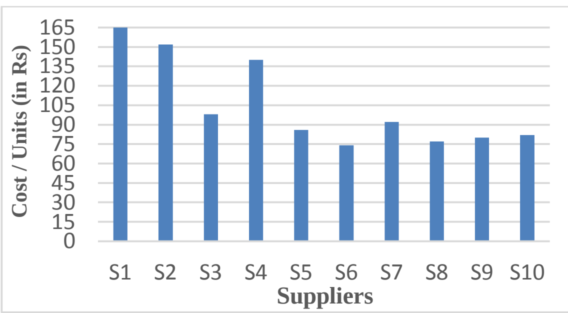

Figure-2: Relationship chart of Cost/Unit and suppliers

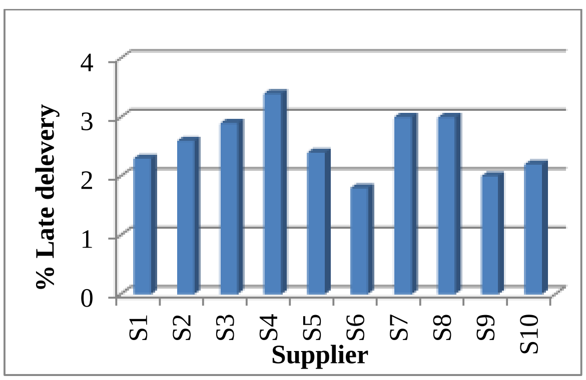

Figure-3: Relationship chart of % late delivery and suppliers

The above all data are different units like % of defective % late delivery Cost/unit So we will assign grade out of 10 suppliers for the % defective by interpolation methods Firstly we are assigning the grade of maximum and minimum % of defective shown in below.

Table-2: Grade of percentage defective

Percentage defective	0.45	1.60
Grade	5	9

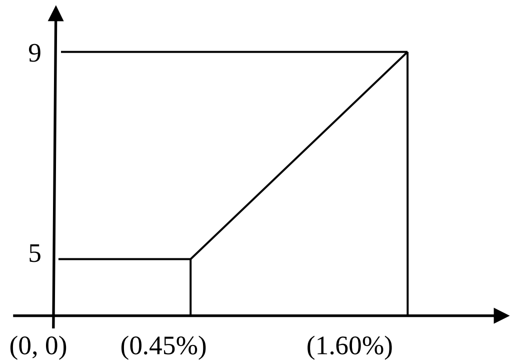

Figure-4: Grade of percentage defective

0.45% = 5

0.97% = 5+ $\frac{9-5}{(1.60-0.45)}$ × (0.97−0.45) = 6.80

1.60% = 9

0.86 = 5 + $\frac{9-5}{1.60-0.45}$ × (0.86-0.45) = 6.42

1.40 = 5+ $\frac{9-5}{(1.60-0.45)}$ × (1.40−0.45) = 8.30

0.9 = 5 + $\frac{9-5}{(1.60-0.45)}$ × (0.9−0.45) = 6.65

0.84 = 5 + $\frac{9-5}{(1.60-0.45)}$ × (0.84-0.45) = 6.36

1.24 = 5 + $\frac{9-5}{(1.60-0.45)}$ × (1.24-0.45) = 7.75

0.96 = 5 + $\frac{9-5}{(1.60-0.45)}$ × (0.96-0.45) = 6.77

We are assigning the grade of maximum and minimum % of late delivery shown in below

Table-3: Grade of percentage late delivery

Percentage late delivery	1.8	3.4
Grade	5	9

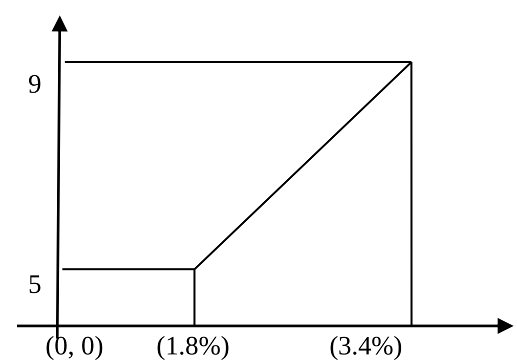

Figure-5: Grade of percentage late delivery

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$2.3 = 5 + \frac{9-5}{(3.4-1.8)} \times (2.3-1.8) = 6.6$

$2.6 = 5 + \frac{9-5}{(3.4-1.8)} \times (2.6-1.8) = 7$

$2.9 = 5 + \frac{9-5}{(3.4-1.8)} \times (2.9-1.8) = 7.75$

$3.4 = 5 + \frac{9-5}{(3.4-1.8)} \times (3.4-1.8) = 9$

$2.4 = 5 + \frac{9-5}{(3.4-1.8)} \times (2.4-1.8) = 6.5$

$3 = 5 + \frac{9-5}{(3.4-1.8)} \times (3-1.8) = 8.00$

$3 = 5 + \frac{9-5}{(3.4-1.8)} \times (3-1.8) = 8.00$

$2.0 = 5 + \frac{9-5}{(3.4-1.8)} \times (2.0-1.8) = 5.50$

$2.2 = 5 + \frac{9-5}{(3.4-1.8)} \times (2.2-1.8) = 6$

- **Step 1**

Create an evaluation matrix consisting of m alternatives and n criteria, with the intersection of each alternative and criteria given as (A_{ij}), we therefore have a matrix-$(A_{ij})_{m\times n}$

Table-4: Evaluation matrix table

S.No.	I/J	C_1	C_2	C_3	C_4
1.	S_1	165	5.00	6.60	500
2.	S_2	152	6.80	7.00	900
3.	S_3	98	9.00	7.75	1100
4.	S_4	140	6.42	9.00	1600
5.	S_5	86	8.30	6.50	150
6.	S_6	74	6.56	5.00	300
7.	S_7	92	6.42	8.00	110
8.	S_8	77	6.36	8.00	400
9.	S_9	80	7.75	5.50	90
10.	S_{10}	82	6.77	6.00	120
11.	$\sqrt{\sum_{i=1}^{m} a_{ij}^2}$	346.29	22.20	22.25	2266.52
12.	$\sum a_{ij}$	1046	69.38	69.35	5270

- **Step 2**

Normalize the condition

$$N_{ij} = \frac{a_{ij}}{\sqrt{\sum a_{ij}^2}}$$

Where i= 1, 2, 3 ….n and j= 1, 2…..m

Table-5: Normalize condition table

S.No.	I/J	C_1	C_2	C_3	C_4
01	S_1	0.47	0.22	0.29	0.22
02	S_2	0.44	0.30	0.31	0.39
03	S_3	0.28	0.40	0.35	0.48
04	S_4	0.40	0.29	0.40	0.70
05	S_5	0.24	0.37	0.29	0.06
06	S_6	0.21	0.29	0.22	0.13
07	S_7	0.26	0.29	0.36	0.04
08	S_8	0.22	0.28	0.36	0.18
09	S_9	0.23	0.35	0.24	0.03
10	S_{10}	0.24	0.30	0.27	0.05

- **Step 3**

To calculate the effectiveness measure of every index

$$P_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}}$$

Table-6: Effectiveness measure table

S.No.	I/J	C_1	C_2	C_3	C_4
1.	S1	0.16	0.07	0.09	0.09
2.	S2	0.14	0.09	0.10	0.17
3.	S3	0.09	0.13	0.11	0.20
4.	S4	0.13	0.09	0.12	0.30
5.	S5	0.08	0.12	0.09	0.02
6.	S6	0.07	0.09	0.07	0.06
7.	S7	0.08	0.09	0.11	0.02
8.	S8	0.07	0.09	0.11	0.08
9.	S9	0.07	0.11	0.07	0.02
10.	S10	0.07	0.09	0.08	0.02

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Where I = 1, 2, 3…….10 and J = 1, 2…..4

$E_j = -K\sum_{i=1}^{10}[(P_{ij} \times \log_e(P_{ij}))]$

Where $K = \frac{1}{\ln 10} = 0.4343$

$E_j = -K[P_{11} \times \log_e((P_{11})) + P_{21} \times \log_e(P_{21}) + P_{31} \times \log_e(P_{31}) \dots\dots + P_{101} \times \log_e(P_{101})]$

Table-7: Effectiveness of every index

E_1	E_2	E_3	E_4
0.86	0.97	0.96	0.82

Defining the divergence through

$D_j = 1 - E_j$

Table-8: Divergence of every index

D_1	D_2	D_3	D_4
0.14	0.03	0.04	0.18

The more the D_j the more important the condition J_{th}. Now obtaining the normalized weight to every index

$W_j = \frac{D_j}{\sum D_j}$

Table-9: Weight of every index

W_{D1}	W_{D2}	W_{D3}	W_{D4}
0.36	0.07	0.10	0.46

- **Step 4**

Calculated the weighted normalized decision matrix:-

$V = N \times W_n$

$$\begin{array}{c} \\ S1\\S2\\S3\\S4\\S5\\S6\\S7\\S8\\S9\\S10 \end{array}\begin{array}{cccc} C1 & C2 & C3 & C4 \\ \end{array}\begin{bmatrix} 0.47 & 0.22 & 0.29 & 0.22 \\ 0.44 & 0.30 & 0.31 & 0.39 \\ 0.28 & 0.40 & 0.35 & 0.48 \\ 0.40 & 0.29 & 0.40 & 0.70 \\ 0.24 & 0.37 & 0.29 & 0.06 \\ 0.21 & 0.29 & 0.22 & 0.13 \\ 0.26 & 0.29 & 0.36 & 0.04 \\ 0.22 & 0.28 & 0.36 & 0.18 \\ 0.23 & 0.35 & 0.24 & 0.03 \\ 0.24 & 0.30 & 0.27 & 0.05 \end{bmatrix} \times \begin{bmatrix} 0.36 & 0 & 0 & 0 \\ 0 & 0.07 & 0 & 0 \\ 0 & 0 & 0.10 & 0 \\ 0 & 0 & 0 & 0.46 \end{bmatrix}$$

$C1 \quad C2 \quad C3 \quad C4$

$$V = \begin{array}{c} S1\\S2\\S3\\S4\\S5\\S6\\S7\\S8\\S9\\S10 \end{array}\begin{bmatrix} 0.71 & 0.01 & 0.03 & 0.10 \\ 0.16 & 0.02 & 0.03 & 0.18 \\ 0.10 & 0.02 & 0.03 & 0.22 \\ 0.14 & 0.02 & 0.04 & 0.32 \\ 0.08 & 0.02 & 0.02 & 0.02 \\ 0.07 & 0.02 & 0.02 & 0.06 \\ 0.09 & 0.02 & 0.03 & 0.01 \\ 0.08 & 0.01 & 0.04 & 0.08 \\ 0.08 & 0.02 & 0.02 & 0.01 \\ 0.08 & 0.21 & 0.03 & 0.02 \end{bmatrix}$$

Determine the ideal and negative ideal solution:-

$$V_j^+ = (V_i^+ \dots\dots V_n^+) = \left[\left(\frac{\max V_{ij}}{I' \in i}\right)\left(\frac{\min V_{ij}}{i \in I''}\right)\right]$$

$$V_j^- = (V_i^- \dots\dots V_n^-) = \left[\left(\frac{\min V_{ij}}{i \in J}\right)\left(\frac{\max V_{ij}}{i \in J}\right)\right]$$

Where I' is associated with advantage criteria and I" is associated with cost criteria.

$V_j^+ =$	Max V_{i1}	Max V_{i2}	Max V_{i3}	Max V_{i4}
	0.17	0.21	0.04	0.32

$V_j^- =$	Max V_{i1}	Max V_{i2}	Max V_{i3}	Max V_{i4}
	0.17	0.21	0.04	0.32

- **Step 5**

Calculate the separation measure & using the n-dimensional Euclidean distance the separation of each alternative from the ideal solution.

$$d_i^+ = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^+)^2}$$

Table-10: Positive Ideal Solution

S.No.	(+) Euclidean Distance	Value
1.	d_1^+	0.13
2.	d_2^+	0.19
3.	d_3^+	0.21
4.	d_4^+	0.10
5.	d_5^+	0.01
6.	d_6^+	0.16
7.	d_7^+	0.02

8.	d_8^+	0.02
9.	d_9^+	0.01
10.	d_{10}^+	0.20

$$d_i^- = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^-\right)^2}$$

Table-11: Negative Ideal Solution

S.No.	(-) Euclidean Distance	Value
1.	d_1^-	0.29
2.	d_2^-	0.24
3.	d_3^-	0.22
4.	d_4^-	0.19
5.	d_5^-	0.36
6.	d_6^-	0.34
7.	d_7^-	0.37
8.	d_8^-	0.32
9.	d_9^-	0.37
10.	d_{10}^-	0.31

- **Step 6**

Calculating the relative closeness and rank them.

$S.L_i = \frac{d_i^-}{d_i^- + d_i^+}$

Where i= 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Table-12: Supplier ranking calculation

S.No.	Relative Closeness
1.	$S_1 = \frac{0.29}{0.29+0.13} = 0.7100$
2.	$S_2 = \frac{0.24}{0.24+0.19} = 0.5580$
3.	$S_3 = \frac{0.22}{0.22+0.21} = 0.5116$
4.	$S_4 = \frac{0.19}{0.19+0.10} = 0.6551$
5.	$S_5 = \frac{0.36}{0.36+0.01} = 0.9729$
6.	$S_6 = \frac{0.34}{0.34+0.16} = 0.6800$
7.	$S_7 = \frac{0.37}{0.37+0.02} = 0.9487$
8.	$S_8 = \frac{0.32}{0.32+0.02} = 0.9411$
9.	$S_9 = \frac{0.37}{0.37+0.01} = 0.9736$
10.	$S_{10} = \frac{0.31}{0.31+0.20} = 0.6070$

- **Step 7**

Rank of supplier according to their performance:

Table-13: Supplier Ranking

S.No	Rank	Suppliers
1.	1	S9
2.	2	S5
3.	3	S7
4.	4	S8
5.	5	S1
6.	6	S6
7.	7	S4
8.	8	S10
9.	9	S2
10.	10	S3

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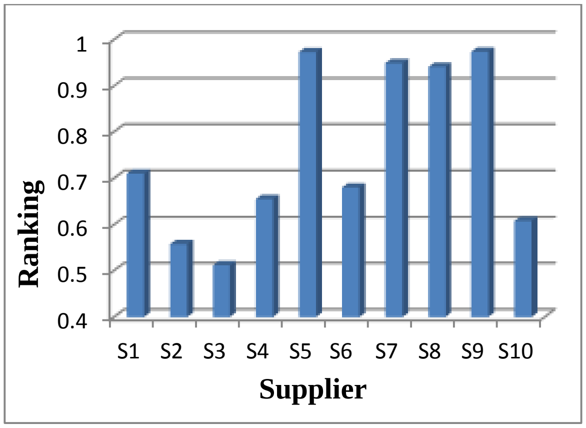

Figure-6: Column chart of Supplier Ranking

Conclusion

This study presented a structured methodology for supplier selection and evaluation in a supply chain, to help organization establish a systematic approach for selecting and evaluating potential suppliers in a supply chain. The main results and contributions of this study is addressed as follows:

A case study on supplier selection and evaluation for an Indian automobile industry: based on the proposed supplier selection and evaluation methodology, the key performance factors for an Indian automobile industry are analysed through the thorough literature study to establish the framework of evaluation criteria and indicators for selecting suppliers. Subsequently, the 10 automobile suppliers of a single company are selected using the data provided by the industry. Based on the evaluation and calculation processes for five key performance indicators, ranking of the ten selected suppliers was done by using the TOPSIS. The results in this study can help enterprises facilitate the selection and evaluation of suitable suppliers during supply chain planning and design. The results of such selection and evaluation can include increasing product development capability and quality, reducing development cycle time and cost, and ultimately increasing product marketability.

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