Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 97 (2014) 2195 – 2203
Procedia Engineering
www.elsevier.com/locate/procedia

12th GLOBAL CONGRESS ON MANUFACTURING AND MANAGEMENT, GCMM 2014

# A hybrid approach using AHP-TOPSIS for analyzing e- SCM performance

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**Abstract**

To sustain in this competitive environment, it is required for organizations to implement information technology (IT) based functions with their supply chain management (SCM) system. The objective of this research is to select a best alternative with an aim to improve electronic supply chain management (e- SCM) performance of Indian automobile industry located at Delhi region. To accomplish the aim, a hierarchy based model has been developed through considering eight criteria and five alternatives. The considered alternatives namely are: investment in web based technologies, investment in advanced manufacturing technologies, role of top management, role of supplier and supply chain integration. The developed model has been analyzed to select a best alternative using analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) as a hybrid approach. Analysis reveals that the alternative, 'investment in web based technologies' holds first rank among all considered alternatives and can play a vital role in improving the e-SCM performance of an organization. The outcomes of this research enable mangers to make better decisions during framing strategies in improving e-SCM performance of an organization effectively.


Selection and peer-review under responsibility of the Organizing Committee of GCMM 2014

*Keywords*: Information technology, Supply chain management, AHP, TOPSIS

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## 1. Introduction and background

In this present era, mostly organizations are trying to incorporate information technology (IT) to build their supply chain management (SCM) system more operative. IT creates a path to increase the flow of information, raw material in order to make more effective and operative SCM, which will facilitates in robust and resilient design of supply chain [1]. The term SCM can be defined as a network of interconnected business processes ranges from


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doi:10.1016/j.proeng.2014.12.463

supplier's to the end consumer. Stevens [2] says that effective and efficient SCM of an organization can manage better relationships with their partners to improve the supply chain performance.

The e- SCM has a capability to integrate their supply chain partners and improves production planning, scheduling and inventory management etc. IT integration helps in providing the efficient and timely business information among the supply chain stages [3]. It also provides an onward visibility from planning stage to the implementation stage. Therefore, most of the companies have implemented IT in their supply chain management system and all remaining are trying for implementation [4]. In existing studies many researchers suggested that e-SCM may play a crucial role in improving the supply chain performance of an organization [5-8].

Over the last years, various methods and several dimensions have been used for the measurement of supply chain performance. In this paper, for the evaluation of e-SCM performance, eight criteria and five alternatives have been identified and considered based on the literature review and discussion with field experts chosen from automobile industries located near around Delhi region of India. These criteria namely are: decrease customer response time [9-10], on time delivery [11], increase order information sharing [12], increase employee's skills [13], improve production efficiency [14], enhance transportation tool utilization [15], identify market innovative opportunities [16] and expand accessibility of information [17]. The five mutually exclusive alternatives namely: investment in web based technologies, investment in advanced manufacturing technologies, role of top management, role of supplier and supply chain integration have been considered, to know their impact on e- SCM performance under concern of considered eight criteria.

In last decade, an emerging competitiveness has been noticed in the Indian market for automobile sector. As a consequence of that automobile manufacturers are trying to incorporate IT based disputes with business functions to make their supply chain performance system more effective. Saad and Patel [18] reported a lack of research for supply chain performance system of Indian automobile industries. By keeping above theme in the mind, present research has been performed on automobile industries located at Delhi region of India. To pursue this research, a questionnaire has been framed and sends to the decision makers through e-mail, to collect their opinions about considered factors (criteria and alternatives) related to the e-SCM system. To know the internal consistency of the collected data, reliability analysis has been performed using SPSS (Statistical Package for the Social Sciences) software. Then, a hierarchy type model has been developed as shown in Fig. 1 and analyzed by applying a hybrid AHP-TOPSIS approach.

## 2. Research Methodology

### *2.1 AHP approach*

The AHP is a multi-criteria decision making approach that was developed by [19]. It is a theory of measurement for dealing with quantifiable and intangible criteria that has been applied to numerous areas, such as decision theory and conflict resolution [20]. The step by step procedure of AHP is given as:

(1) Make a pair-wise comparison matrix of criteria by using a scale 1 to 9 given by Saaty [19]. Value 1, from that scale, is used when both criteria have same priority. Assuming N criteria, the pairwise comparison of criterion $i$ with criterion $j$ gives a square matrix $A_{NXN}$ where $a_{ij}$ represents the relative importance of criterion $i$ over the criterion $j$. In the matrix, $a_{ij}=1$ when $i = j$ and $a_{ji}=1/a_{ij}$.

(2) Find the relative normalized weight ($W_j$) of each criterion by normalizing the geometric mean of rows in the comparison matrix.

$$GM_j = \left[\prod_{j=1}^{N} a_{ij}\right]^{1/N} \quad \text{and} \quad W_j = {GM_j}\Big/{\sum_{j=1}^{N} GM_j} \tag{1}$$

(3) Calculate matrix $A3$ and $A4$ such that

$A3 = A1 * A2$ and $A4 = A3 / A2$,

where $A2 = [W1, W2, \ldots, Wj]^T$ (2)

(4) Find out the maximum eigen value which is the average of matrix $A4$.

(5) Calculate the consistency index (C.I.)

$$\text{C.I.} = \frac{(\lambda max - N)}{(N-1)} \quad (3)$$

The lower value of C.I., indicates smaller deviation from the consistency.

(6) Determine the consistency ratio (C.R.)

C.R. = C.I. / R.I (4)

According to Saaty, the value C.R $\leq$ 0.1 has been acceptable to make consistency in pair-wise comparisons. Where, R.I is the random index and depends on the matrix size. For the matrix size 8, the value of R.I has been suggested 1.41by Saaty.

### *2.2 TOPSIS approach*

Hwang and Yoon [21] developed a multi-criteria decision making approach, called as TOPSIS. This approach has systematic and simple procedure which provides an ease in calculation. Basic concept of this approach is to select the alternatives on the basis of shortest geometric distance from the positive ideal solution and longest geometric distance from the negative ideal solution. The step by step procedure of TOPSIS is given as:

**Step- 1** Generate an evaluation matrix by considering of 'y' alternatives and 'z' criteria, with the intersection of each alternative and criteria given as $x_{ij}$, we therefore have a matrix$\left(x_{ij}\right)_{y \times z}$

$$D = \begin{matrix} & C_1 & C_2 & . & . & . & . & C_z \\ A_1 & x_{11} & x_{12} & . & . & . & . & x_{1z} \\ A_2 & x_{21} & x_{22} & . & . & . & . & x_{2z} \\ A_3 & x_{31} & x_{32} & . & . & . & . & x_{3z} \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ A_y & x_{y1} & x_{y2} & . & . & . & . & x_{yz} \end{matrix} \quad (5)$$

**Step- 2** Normalize the matrix $\left(x_{ij}\right)_{y \times z}$ to convert into the matrix $R = \left(n_{ij}\right)_{y \times z}$, using the normalization formula given as:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{y} x_{ij}^2}} \quad (6)$$

**Step- 3** Determine the weighted normalized decision matrix

$$D = (d_{ij})_{y \times z} = (w_j n_{ij})_{y \times z}, \; i = 1,2 \ldots., y$$

$$D = \begin{bmatrix} d_{11} & d_{12} & . & . & d_{1j} & . & . & d_{1z} \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ d_{i1} & d_{i2} & . & . & d_{ij} & . & . & d_{iz} \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ d_{y1} & d_{y2} & . & . & d_{yj} & . & . & d_{yz} \end{bmatrix} \quad (7)$$

**Step- 4** Find out the Positive and Negative ideal solutions

$$A^{+} = \{(\max_{i} d_{ij} \mid j \in J), (\min_{i} d_{ij} \mid j \in J') \; for \; i = 1,2, \ldots . y\}$$

$$= \{d_1^{+}, d_2^{+}, \ldots . d_j^{+}, \ldots . d_z^{+}\} \quad (8)$$

$$A^{-} = \{(\min_{i} d_{ij} \mid j \in J), (\max_{i} d_{ij} \mid j \in J') \; for \; i = 1,2, \ldots . y\}$$

$$= \{d_1^{-}, d_2^{-}, \ldots . d_j^{-}, \ldots . d_z^{-}\} \quad (9)$$

Where,

$J = \{j = 1,2, . . z | j \; associated \; with \; the \; benifit \; criteria\}$
$J' = \{j = 1,2, . . z | j \; associated \; with \; the \; cost \; criteria\}$

**Step- 5** Calculate the distance/separation from:

- Positive Ideal Separation

$$S_i^{+} = \sqrt{\sum_{j=1}^{z} (d_{ij} - d_j^{+})^2} \qquad i = 1,2, \ldots \ldots , y \quad (10)$$

- Negative Ideal Separation

$$S_i^{-} = \sqrt{\sum_{j=1}^{z} (d_{ij} - d_j^{-})^2} \qquad i = 1,2, \ldots \ldots , y \quad (11)$$

**Step- 6** Calculate the Relative closeness coefficient to the Ideal Solution

$$CC_i^{*} = \frac{S_i^{-}}{(S_i^{+} + S_i^{-})}, \quad 0 < CC_i^{*} < 1, \quad i = 1,2, \ldots \ldots , y \quad (12)$$

$CC_i^{*} = 1 \;\; if \;\; A_i = A^{+}$

$CC_i^{*} = 0 \;\; if \;\; A_i = A^{-}$

The rank of considered alternatives can be decide, according to the descending order of $CC_i^{*}$.

## 3. Numerical illustration

In this study, eight criteria and five alternatives have been considered based on the literature and expert's opinions, to formulate an e- SCM based performance measurement model as shown in Fig. 1. We have prepared a survey based questionnaire on Google doc and send to the various automobile industries located near around the Delhi region of India. Some personal meetings for discussion with the field experts were also held. After that, expert's views have been collected on the nine point Likert scale and then to check the internal consistence of collected data, reliability analysis has been done using SPSS 16 software, through calculating the cronbach's alpha coefficient, which comes as 0.781, under the recommended range: 0.7 < $\alpha$ < 0.95.

Then by using AHP approach, make a pair-wise comparison matrix and obtain the priority weights for criteria as shown in Table 1. To know the reliability of this matrix, some important consistency measures have been computed as: maximum eigen value = 8.8462, consistency index = 0.1208 and consistency ratio = 0.085. According to Saaty, if consistency ratio comes less than 0.1, then we can say that matrix is consistent. In this case value of C.R. comes 0.085; it means weighted evaluation matrix for criteria is consistent.

After calculating criteria weights, TOPSIS approach has been used for the assessment of alternatives. For that at first, developed a decision matrix for alternatives with respect to criteria and then by using Eq. 6, normalized decision matrix is determined as given in Table 2. Then, using Eq. 7, a weighted normalized decision matrix is calculated as given in Table 3.

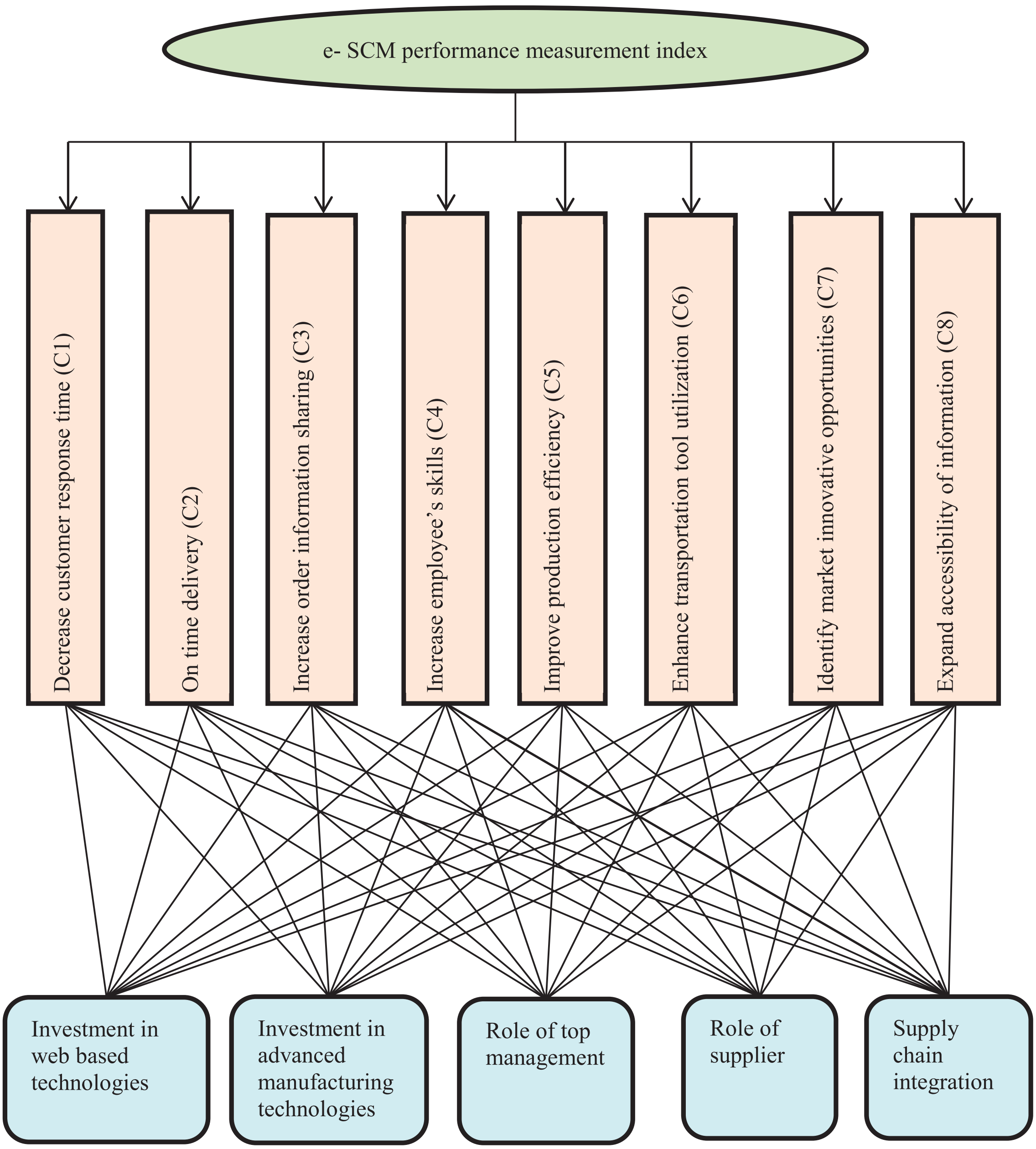


Fig. 1. Hierarchy based performance model

Table 1 Matrix for priority weights of criteria

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | Eigen value |
|---|---|---|---|---|---|---|---|---|---|
| C1 | 1 | 0.5 | 2 | 1 | 0.5 | 1 | 0.33 | 0.5 | 0.0866 |
| C2 | 2 | 1 | 3 | 2 | 0.33 | 3 | 1 | 2 | 0.1758 |
| C3 | 0.5 | 0.33 | 1 | 1 | 0.33 | 0.5 | 1 | 1 | 0.0754 |
| C4 | 1 | 0.5 | 1 | 1 | 0.5 | 1 | 3 | 2 | 0.1245 |
| C5 | 2 | 3 | 3 | 2 | 1 | 4 | 1 | 1 | 0.2203 |
| C6 | 1 | 0.33 | 2 | 1 | 0.25 | 1 | 1 | 0.5 | 0.0866 |
| C7 | 3 | 1 | 1 | 0.33 | 1 | 1 | 1 | 1 | 0.1182 |
| C8 | 2 | 0.5 | 1 | 0.5 | 1 | 2 | 1 | 1 | 0.1183 |

Table 2 Normalized decision matrix for alternatives with respect to criteria

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| A1 | 0.6964 | 0.4962 | 0.5507 | 0.4819 | 0.2933 | 0.6338 | 0.6154 | 0.5704 |
| A2 | 0.3095 | 0.4253 | 0.2065 | 0.5507 | 0.5133 | 0.3621 | 0.1538 | 0.1267 |
| A3 | 0.3869 | 0.2836 | 0.4819 | 0.5507 | 0.4399 | 0.4527 | 0.5385 | 0.5070 |
| A4 | 0.2321 | 0.4962 | 0.3442 | 0.2065 | 0.5133 | 0.3621 | 0.3077 | 0.3802 |
| A5 | 0.4643 | 0.4962 | 0.5507 | 0.3442 | 0.4399 | 0.3621 | 0.4615 | 0.5070 |

Table 3 Weighted normalized decision matrix

| Criteria weights | 0.0866 | 0.1758 | 0.0754 | 0.1245 | 0.2203 | 0.0866 | 0.1182 | 0.1183 |
|---|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
| A1 | 0.0604 | 0.0873 | 0.0415 | 0.0600 | 0.0646 | 0.0549 | 0.0728 | 0.0675 |
| A2 | 0.0268 | 0.0748 | 0.0156 | 0.0686 | 0.1131 | 0.0314 | 0.0182 | 0.0150 |
| A3 | 0.0335 | 0.0499 | 0.0364 | 0.0686 | 0.0969 | 0.0392 | 0.0637 | 0.0600 |
| A4 | 0.0201 | 0.0873 | 0.0260 | 0.0257 | 0.1131 | 0.0314 | 0.0364 | 0.0450 |
| A5 | 0.0402 | 0.0873 | 0.0415 | 0.0429 | 0.0969 | 0.0314 | 0.0546 | 0.0600 |

Using Eqs. 8 and 9 accordingly, the positive and negative ideal solution for criteria on behalf of alternatives are computed as follows:

For positive ideal solution

$$A^{+} = \{0.0604, 0.0873, 0.0415, 0.0686, 0.1131, 0.0549, 0.0728, 0.0675\}$$

For negative ideal solution

$$A^{-} = \{0.0201, 0.0499, 0.0156, 0.0257, 0.0646, 0.0314, 0.0182, 0.0150\}$$

According to the existing theory of TOPSIS approach, it is required to calculate the distance of alternatives from positive ideal solution and negative ideal solution. These distances are calculated by using Eqs. 10 and 11 and shown in Table 4 and 5 accordingly. Finally, by using Eq. 12, relative closeness coefficients of alternatives are calculated as given in Table 6.

Table 4 Separation from positive solution

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | $S_i^+$ |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.0023 | 0.0000 | 0.0000 | 0.0000 | 0.0492 |
| A2 | 0.0011 | 0.0002 | 0.0007 | 0.0000 | 0.0000 | 0.0006 | 0.0030 | 0.0028 | 0.0908 |
| A3 | 0.0007 | 0.0014 | 0.0000 | 0.0000 | 0.0003 | 0.0002 | 0.0001 | 0.0001 | 0.0528 |
| A4 | 0.0016 | 0.0000 | 0.0002 | 0.0018 | 0.0000 | 0.0006 | 0.0013 | 0.0005 | 0.0780 |
| A5 | 0.0004 | 0.0000 | 0.0000 | 0.0007 | 0.0003 | 0.0006 | 0.0003 | 0.0001 | 0.0476 |

Table 5 Separation from negative solution

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | $S_i^-$ |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.0016 | 0.0014 | 0.0007 | 0.0012 | 0.0000 | 0.0006 | 0.0030 | 0.0028 | 0.1056 |
| A2 | 0.0000 | 0.0006 | 0.0000 | 0.0018 | 0.0023 | 0.0000 | 0.0000 | 0.0000 | 0.0697 |
| A3 | 0.0002 | 0.0000 | 0.0004 | 0.0018 | 0.0010 | 0.0001 | 0.0021 | 0.0020 | 0.0874 |
| A4 | 0.0000 | 0.0014 | 0.0001 | 0.0000 | 0.0023 | 0.0000 | 0.0003 | 0.0009 | 0.0713 |
| A5 | 0.0004 | 0.0014 | 0.0007 | 0.0003 | 0.0010 | 0.0000 | 0.0013 | 0.0020 | 0.0846 |

Table 6 Final ranking of alternatives

| Alternative | Closeness coefficient ($CC_i^*$) | Rank |
|---|---|---|
| A1 | 0.6822 | 1 |
| A2 | 0.4342 | 5 |
| A3 | 0.6234 | 3 |
| A4 | 0.4777 | 4 |
| A5 | 0.6399 | 2 |

## 4. Results

On the basis of closeness coefficient, ranking of alternatives may be decided decided. From Table 6, it is noticed that the alternative ‘A1’ obtained first rank with the closeness coefficient (0.6822) and alternative ‘A2’ achieve last/lower rank with the closeness coefficient (0.4342) among the all considered alternatives. The comparative view of closeness coefficient of alternatives is shown in Fig. 2.

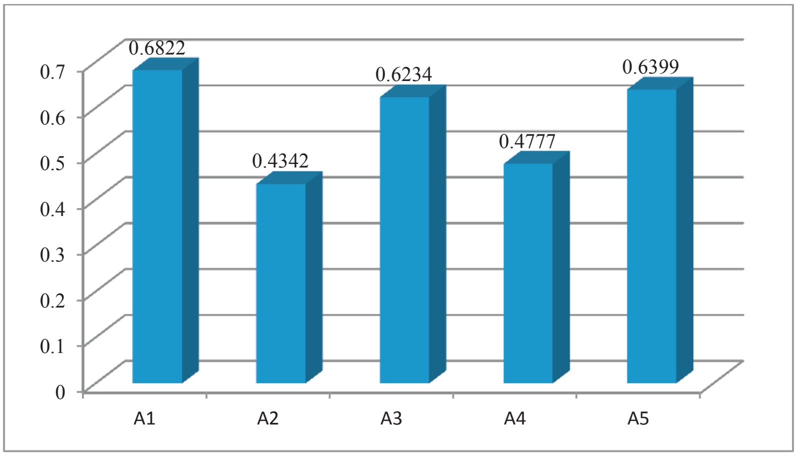


Fig. 2. Closeness coefficients of alternatives

## 5. Discussion and conclusions

The proposed hierarchy model shown in Fig. 1, contains eight criteria namely as: decrease customer response time (C1), on time delivery (C2), increase order information sharing (C3), Increase employee's skills (C4), improve production efficiency (C5), enhance transportation tool utilization (C6), identify market innovative opportunities (C7), and expand accessibility of information (C8) and five alternatives as: investment in web based technologies (A1), investment in advanced manufacturing technologies (A2), role of top management (A3), role of supplier (A4) and supply chain integration (A5) and is analyzed by using a hybrid AHP-TOPSIS approach. Firstly, priority weights for criteria are calculated using AHP technique, as given in Table 1, and then prioritize the alternatives using TOPSIS approach.

From Table 1, it is noticed that the criteria 'improvement in production efficiency' and 'on time delivery' achieved higher priority weights 0.2203 and 0.1758, respectively, which gives an indication about their importance for effective e-SCM of an organization. Further, alternatives are analyzed on the behalf of criteria weights to calculate the closeness coefficients as summarized in Table 6. From this table noticed that alternative 'investment in web based technologies' grips first rank with the highest closeness coefficient (0.6822). Based on closeness coefficient, ranking of considered alternatives is decided as follows: A1 > A5 > A3 > A4 > A2. Hence, it concludes that proper investment in web based technologies and higher level of supply chain integration is required to improve the e-SCM performance of an organization.

## References

[1]. J.V. Pereira, The new supply chain's frontier: Information management, International Journal of Information Management 29 (2009) 372-379.

[2]. G.C. Stevens, Integrating the supply chain, International Journal of Physical Distribution and Materials Management 23 (1989) 102-117.

[3]. D.H. Pearcy, L.C. Giunipero, Using e-procurement applications to achieve integration, Supply Chain Management: An International Journal 13 (2008) 26-34.

[4]. Z. Zhang, M.K.O. Lee, P. Huang, L. Zhang, X. Huang, A framework of ERP systems implementation success in China: An empirical study. International Journal of Production Economics 98 (2005) 56-80.

[5]. R. Kathuria, M. Anandarajan, M. Igbaria, Linking IT applications with manufacturing strategy: An intelligent decision support system approach, Decision Sciences 30 (1999), 959-992.

[6]. G.S. Kearns, A.L. Lederer, A resource-based view of strategic IT alignment: How knowledge sharing creates competitive advantage, Decision Sciences 34 (2003), 1-29.

[7]. B. Dehning, V.J. Richardson, R.W. Zmud, The value relevance of announcements of transformational information technology investments, MIS Quarterly 27 (2003) 637-656.

[8]. S.F. Wamba, L.A. Lefebvre, Y. Bendavid, E. Lefebvre, Exploring the impact of RFID technology and the EPC network on mobile B2B e-Commerce: A case study in the retail industry, International Journal of Production Economics 112(2008), 614-629.
[9]. B.M. Beamon, Measuring supply chain performance, International Journal of Operations and Production Management 19 (1999) 27-29.
[10]. Y.E. Chan, IT value: the great divide between qualitative and quantitative and individual and organizational measures, Journal of Management Information Systems 16 (2000) 225-261.
[11]. C. Morgan, Structure, speed and salience: performance measurement in the supply chain, Business Process Management Journal 10 (2004) 522-536.
[12]. P.C. Brewer, T.W. Speh, Using the balanced scorecard to measure supply chain performance, Journal of Business Logistics 21 (2000) 75-94.
[13]. D.A. Ellingson, J.R. Wambsganss, Modifying the approach to planning and evaluation in governmental entities: a balanced scorecard approach, Journal of Public Budgeting Accounting and Financial Management 13 (2001) 103-120.
[14]. A. Gunasekaran, C. Patel, E. Tirtiroglu, Performance measures and metrics in a supply chain environment, International Journal of Operations and Production Management 21 (2001) 71-87.
[15]. L. Lapide, What about measuring supply chain performance? In achieving supply chain excellence through technology, AMR Research 2 (2000) 287-297.
[16]. A.S. Maiga, F.A. Jacobs, Balanced scorecard, activity-based costing and company performance: an empirical analysis, Journal of Managerial Issues 15 (2003) 283–304.
[17]. R.S. Kaplan, D.P. Norton, Measuring the strategic readiness of intangible assets, Harvard Business Review 82 (2004) 52-63.
[18]. M. Saad, B. Patel, An investigation of supply chain performance measurement in Indian automotive sector, Benchmarking: An International Journal, 13 (2006) 36-53.
[19]. T.L. Saaty, The Analytic Hierarchy Process, McGraw-Hill, New York, 1980.
[20]. L.G. Vargas, An overview of the analytical hierarchy process and its applications, European Journal of Operational Research 48 (1990) 2-8.
[21]. C.L. Hwang, K. Yoon, Multiple Attribute Decision Making: Methods and Applications, Springer-Verlag, New York, 1981.