Evaluation and Selection of Strategic Suppliers using MBSC/GRA Combinational Model

Pooya Farahany
Graduate School of Management, Iran University of science and Technology, Tehran, Iran

ABSTRACT

Strategic planning in selection of suppliers has attracted growing interests in the recent years. The existing evaluation methods are based on performance records and most of them may not be objective. Therefore their analysis can not result in a precise, reliable outcome. In our study, we use two distinct approaches: Balanced Scorecard and Grey Relational Analysis which are used to create a precise, comprehensive model needed for selection of strategic suppliers. The former one which has been dealt with in many studies focus on an individual organization. Here in this study, taking the inter-organizational relations are into account, enhanced and performance evaluation criteria are identified and they are priorized using grey relation analysis and Shannon Entropy weighting method. For this purpose, a case study is provided which has been carried out on an active company in auto-making industry.

KEYWORDS: Grey Relational Analysis, Balanced Scorecard, Evaluation of Strategic Suppliers.

1. INTRODUCTION

Emergence of industrial era in which information and communications form the base of humans actions has put companies and organizations subject to new challenges. On the other hand, given the sensitive, determinant role which selection of strategic supplier plays on organizations’ profitability as well as their competitive position, it seems necessary to make efforts to develop and improve decision-making models which can make a precise and reliable evaluation of suppliers. The multi-purpose nature of such decisions which may involve certain qualitative and quantitative criteria- that sometimes they may be complicated has make utilization of multi-purpose decision-making inevitable. Given the fact that data and expertise comments are used for determining the relevant criteria and sub-criteria in organization, Gray Theory Systems (GTS) appear to be one of the efficient theories in dealing with such problems.

The main objective of this study, therefore, is to provide a proper model for evaluation and rating the strategic suppliers in order to help organizations evaluate and priorize their potential suppliers. We make effort to use “modified balanced scorecard” approach to devise a comprehensive, complete criteria for evaluation of suppliers using questionnaires and interviews with managers and experts of supply chain of component-making companies working with Iran Khodro in order to weight the criteria using Shannon Entropy – due to the incompleteness of data – and evaluate and priorize the potential suppliers using GTS.

2. A REVIEW ON LITERATURE

The researches which have been conducted on supplier selection fall into two categories:

The first category contains selection of criteria. It deals with finding the degree of importance of criteria and provision of a proper framework helping select a potential supplier. Dickson (1966) studied over 273 cases of organizations’ purchase directors, and suggested 23 criteria [1].Ellram (1990) offered a five-stage model for developing purchase department which help select a proper supplier, based on the organization’s strategies. He also studied the relations governing organizations and suppliers and made suggestions in relation to collective decision-making and finding inter-criteria relationships [2]. Mandal and Deshmukh (1994) suggested interpretive structural modeling for this purpose [3]. Barbarosoglu and Yazgac (1997) divided criteria and sub-criteria of Turkish manufacturing industries into three categories [4]. Weber et al., (2000) suggested Data Envelopment Analysis which takes “cost” as input and “profitability” as output [5]. Sarkis and Talluri (2002) divide selection criteria into two main groups: strategic performance and organizational factors [6]. Chan (2003) categorized the supplier and manufacturing organization into five levels: temporary, temporary operational, periodical, tactical and strategic. He accordingly put criteria in these levels [7]. Huang and Keskar (2007) identified criteria based on a model containing three parts: product, supplier, society [8].


3. MODIFIED BALANCED SCORECARD MODEL

Before the early 1990s, evaluation of organizations was made only through using financial criteria which indicated the past performance of a given organization but not efficient in evaluation of the future performance. The Balanced Scorecard (BSC) model was presented by Robert S. Kaplan and David P. Norton since 1992. It has been proposed to be a strategic approach and an organizational performance evaluation which can be used for strategy and policy implementation [14].

This model turned out to be an efficient model due to its ability to take into account the financial and non-financial criteria simultaneously. Of course this model had certain weak points, but it could be efficient subject to certain modifications. Modified balanced scorecard which is used in our study considers organizations from five perspectives. Indeed, it considers not only customer, internal business process, learning and growth and financial, but also it contains evaluation criteria and indices.

From uncertainty perspective which deals with certain circumstances, focuses on a collection of criteria which evaluates the compatibility of supplier with supply chain stresses on integration with supply chain. In the relation, there are eight indices including strategic cooperation, conformity with supply chain strategy, number of shareholders, geographical distance from manufacturing and distribution centers, importation of raw materials, technological changes, bulk of importation of the given commodity and newly established companies.

4. GRAY THEORY

Analysis of gray relationship was first devised by Prof. Deng in 1982 [15]. The theory was originally developed for certain obscure problems with incomplete data. It uses the incomplete data to render desired outcome. Gray analysis forms a part of Gray Theory which is used for solving problems with complicated relations between factors and their variables. A gray system includes certain obscure information which is stated via numbers and gray variables. A gray number is referred to a number with no clear value, instead gives us a range containing the exact value. Such a number can be indicated in lower constraint only through $x \in [a, +\infty]$ and upper constraint only via $x \in [-\infty, a]$. Let $a$ is lower constraint and a upper one, the gray number is $x \in [a, a]$. The concept of a grey system is shown in Fig.1 [16]. Relationships between gray numbers have been defined in the Appendix of this study.

4.1 Grey Relational Analysis

The analysis of such a relationship is based on reference supply chain. The chain is taken as an ideal factor to which any item is closer takes higher rank. The main idea of this analysis, as a quantitative method, is based on the similarity of their curves. Much the similarity, higher the rank from among series relations and vice-versa [17], [18]. For appraisal of the similarity we can use grey relational grade. According to definition, Let $X_0 (k)$ be the reference sequence with $k$ entities, that is $X_0 (k) = \{x_0 (1), x_0 (2), \ldots , x_0 (n)\}$, where $k = 1, 2, \ldots , n$

Let $X_j (k)$ be the comparative sequence. Each $X_j$ contains an equivalent number of entities as $X_0$, that is $X_i (k) = \{x_i (1), x_i (2), \ldots , x_i (n)\}$, where $k = 1, 2, \ldots , n, i = 1, 2, \ldots , m$

The Grey relational coefficient between the comparative sequence $X_i$ and the reference sequence $X_0$ at the jth entity is defined as:

$$Y_{0i}(j) = \frac{(\Delta_{\text{min}} - \Delta_{\text{max}})}{(\Delta_{\text{min}}(j) + \Delta_{\text{max}})}$$
Where $\Delta_{oi}(j)$ is absolute value of the difference between $X_0$ and $X_i$ at the jth entity, that is:

$$\Delta_{oi}(j) = |x_o(j) - x_i(j)|$$  \hspace{1cm} (2)

Where

$$\Delta_{\text{max}} = \max_i \max_j \Delta_{oi}(j)$$

$$\Delta_{\text{min}} = \min_i \min_j \Delta_{oi}(j)$$  \hspace{1cm} (3)

Where Eq. (3) is the first and secondary maximum difference. The first maximum difference is selected in all $j$, and the secondary maximum difference is selected in all $i$. Similarly, Eq. (4) is called the first and secondary minimum difference.

$\zeta \in [0,1]$ is the distinguishing factor to control the resolution between $\Delta_{\text{max}}$ and $\Delta_{\text{min}}$; here 0.5 is taken. This coefficient aims at compaction or expanding the gray relational coefficient [19].

The Grey relational grade for the sequence of $X_i$ is given as:

$$\Gamma_{oi}(x_0, x_i) = \frac{1}{n} \sum_{j=0}^{n} \eta_{oi}(j)$$  \hspace{1cm} (5)

Where $n$ is the number of entities in a sequence.

5. STRATEGIC SELECTION OF SUPPLIER

In a general categorization, inputs of an organization fall into two groups:

- Necessary but non strategic inputs
- Strategic inputs

Based on the definition, strategic inputs are referred to as inputs with high values which can define an organization’s basic deserves and play a potential role in making varieties in that organization’s products. The necessary but not strategic inputs are referred to as certain type of inputs that make no distinct in buyer products. According to the categorization, we must analyze the suppliers in terms of being strategic or not before optimizing a purchase then form the below groups:

Group 1: those who provide necessary but not strategic inputs.
Group 2: those providing strategic inputs.

It is essential to manage these two groups under different managerial systems. [20]

6. METHODOLOGY

In terms of its objective, our study is an applied one using library method for data collection. Evaluation was made using questionnaire and expertise comments. Having MBSC model and the subject’s literature, we defined 60 indices for evaluation of criteria. For defining the final criteria, questionnaire was used to give the views of managers and aliet for the supply chain of component makers working with Iran Khodro. Likert scale we used in the questionnaire which was 1 in value –as I completely disagree, and 5 as – I completely agree. 20 companies with A grade were chose to form statistical population from which 19 companies were selected using Morgan table. Then using the designated questionnaire distributed among directors of supply chain, relevant data were gained and put to analysis. At first, frequency of each selection was calculated based on directors and elite views. Then the importance degree was calculated for all 60 indices to determine the most important of them. In order to the calculation of importance degree, data collected from questionnaires were used, and for each one of the indices, their values were multiplied by their frequencies.

Considering that the index used in this questionnaire were Likert scale, having calculated importance degree, 70% of maximal mean desirability- that is, the index with 5 in value, were determined. All indices whose importance degree was 3.5 or more were chosen final indices for evaluation of strategic suppliers' performance. After collection of questionnaires for the purpose of finding the final indices, questionnaires were devised, in the next stage, for confirmation of the criteria. They were distributed among directors. These questionnaires included the criteria obtained from library studies and interviews. Then the supply managers were requested to give their views on modality of evaluation through each criterion. For the purpose of reliability, cronbach’s Alpha was used whose value was determined in both stages using SPSS software. The values turned out to be 0.725 and 0.723 which was desired statistically. Table 1. Indicates final criteria and their importance degree.
Table 1. Final criteria for evaluation of suppliers and their degree of importance

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Measures</th>
<th>Mean degree of importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial</td>
<td>Returned components cost</td>
<td>4.11</td>
</tr>
<tr>
<td></td>
<td>Competitive pricing</td>
<td>4.44</td>
</tr>
<tr>
<td></td>
<td>Debt ratio</td>
<td>3.61</td>
</tr>
<tr>
<td></td>
<td>Security margin in production ratio</td>
<td>4.22</td>
</tr>
<tr>
<td></td>
<td>Finished cost</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Possibility of the company's shares being admitted in stock exchange</td>
<td>3.94</td>
</tr>
<tr>
<td>Customer</td>
<td>Market share</td>
<td>4.89</td>
</tr>
<tr>
<td></td>
<td>Customer loyalty</td>
<td>4.22</td>
</tr>
<tr>
<td></td>
<td>On time delivery</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Price stability</td>
<td>4.78</td>
</tr>
<tr>
<td></td>
<td>Number of communication channels with customers</td>
<td>4.17</td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Number of customers dissatisfaction</td>
<td>4.56</td>
</tr>
<tr>
<td></td>
<td>Flexibility in supply</td>
<td>4.72</td>
</tr>
<tr>
<td>Growth</td>
<td>Employment, attraction, transfer of technology based on needs</td>
<td>4.89</td>
</tr>
<tr>
<td></td>
<td>Technology updating</td>
<td>4.28</td>
</tr>
<tr>
<td></td>
<td>Education</td>
<td>4.94</td>
</tr>
<tr>
<td></td>
<td>Personnel efficiency</td>
<td>3.94</td>
</tr>
<tr>
<td></td>
<td>Personnel satisfaction</td>
<td>4.67</td>
</tr>
<tr>
<td></td>
<td>Personnel maintenance</td>
<td>4.28</td>
</tr>
<tr>
<td></td>
<td>Learning organization</td>
<td>4.28</td>
</tr>
<tr>
<td>Internal Business Process</td>
<td>Period spent from request of customer to solving the problem</td>
<td>4.89</td>
</tr>
<tr>
<td></td>
<td>Coordination of processes with goals and strategies</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Structure of organization in terms of dimensions and sizes</td>
<td>4.06</td>
</tr>
<tr>
<td></td>
<td>Commitment to quality management and constant improvement of activities</td>
<td>4.89</td>
</tr>
<tr>
<td></td>
<td>Production capacity</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>After-sale services (including guarantee)</td>
<td>4.83</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Risk of strategic cooperation</td>
<td>4.11</td>
</tr>
<tr>
<td></td>
<td>Coordination of supply chain strategy</td>
<td>4.39</td>
</tr>
<tr>
<td></td>
<td>Number of shareholders</td>
<td>4.39</td>
</tr>
<tr>
<td></td>
<td>Small distance from manufacturing and distribution centers</td>
<td>4.33</td>
</tr>
<tr>
<td></td>
<td>Technological changes</td>
<td>4.72</td>
</tr>
<tr>
<td></td>
<td>Newly established companies</td>
<td>4.56</td>
</tr>
<tr>
<td></td>
<td>Importation of the relevant commodity</td>
<td>4.39</td>
</tr>
<tr>
<td></td>
<td>Importation of raw materials</td>
<td>4.33</td>
</tr>
</tbody>
</table>

6.1 Suggested Algorithm
The suggested algorithm for evaluation of companies under study:

1. Decision-making matrix is form as follows. We name it matrix B.

\[
\begin{bmatrix}
X_1 & X_2 & \ldots & X_n \\
\mathbf{A}_1 & \otimes X_{11} & \otimes X_{12} & \ldots & \otimes X_{1n} \\
\mathbf{A}_2 & \otimes X_{21} & \otimes X_{22} & \ldots & \otimes X_{2n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
\mathbf{A}_m & \otimes X_{m1} & \otimes X_{m2} & \ldots & \otimes X_{mn}
\end{bmatrix}
\]

2. using Shannon Entropy, \( W_j \) (weight of each index) value was extracted from the above table and weight vector is as follows:

\[ W = [W_1, W_2, W_3, \ldots, W_n] \]

3. In this step, decision-making matrix was normalized based on the method below and the obtained matrix is name as Matrix R.
If the expectancy is larger-the-better (e.g., the benefit), then it can be expressed by

\[
R = \begin{bmatrix}
\otimes r_{11} & \otimes r_{12} & \ldots & \otimes r_{1n} \\
\otimes r_{21} & \otimes r_{22} & \ldots & \otimes r_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\otimes r_{m1} & \otimes r_{m2} & \ldots & \otimes r_{mn}
\end{bmatrix}
\]

If the expectancy is smaller-the-better (e.g., the cost and defects), then it can be expressed by

\[
r_{ij} = \frac{x_{ij}}{\bar{x}_j^{\text{max}}} \frac{\bar{x}_j}{x_{ij}^{\text{max}}}
\]

\[
X_j^{\text{max}} = \max_{1 \leq i \leq m} \{ \bar{x}_{ij} \}
\]

\[
X_j^{\text{min}} = \min_{1 \leq i \leq m} \{ \bar{x}_{ij} \}
\]

The above-mentioned normalizing method causes the normalized grey numbers to fall within \([0, 1]\).

4. Weight of each criterion is multiplied by the matching column to obtain balanced normal matrix, Rw.

5. In this step, reference sequence definition (positive ideal response) \(A^*\) is defined as follows:

\[
A^* = [r_{01}, r_{02}, \ldots, r_{0n}]
\]

Having created grey relations for all performance values in \([0, 1]\) index, if for every j index in i item, \(X_{ij}\) value equated 1 or any other values close to 1, it meant that the performance of i is better than others in j index [19]. Therefore, if all performance values are 1 for a given item, this would be preferred as the best item.

6. In this step, distance between desired item (base series) and other comparison items are calculated. So the matrix of distances of (H) indices was obtained which includes \(m\) lines and \(n\) columns.

\[
H = [\Delta_{ij}]
\]

7. Calculation of Grey relational coefficient between the comparative sequence \(X_i\) and the reference sequence \(X_0\) at the jth entity.

8. Calculation of Grey relational grade for the sequence of \(X_i\).

9. Finally for the purpose of prioritizing the indices, for \(P, q \in I = \{1, 2, \ldots, m\}\) if \(P(\Gamma_p \leq \Gamma_q) < 0.5\), then it can be said that p desirability of higher than q.

### 7. CASE STUDY

One of the component maker companies working with Iran Khodro was chosen for case study. 8 companies were selected for rating. According to the suggested algorithm, evaluation weight of decision-making indices were calculated first using Shannon Entropy. These calculations were made in Matlab software and the results are indicated in Table 2.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Symbol</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returned components cost</td>
<td>X1</td>
<td>0.138954</td>
</tr>
<tr>
<td>Competitive pricing</td>
<td>X2</td>
<td>0.011456</td>
</tr>
<tr>
<td>Debt ratio</td>
<td>X3</td>
<td>0.054311</td>
</tr>
<tr>
<td>Security margin in production ratio</td>
<td>X4</td>
<td>0.020962</td>
</tr>
<tr>
<td>Finished cost</td>
<td>X5</td>
<td>0.005564</td>
</tr>
<tr>
<td>Possibility of the company’s shares being admitted in stock exchange</td>
<td>X6</td>
<td>0.043022</td>
</tr>
<tr>
<td>Market share</td>
<td>X7</td>
<td>0.120884</td>
</tr>
<tr>
<td>Customer loyalty</td>
<td>X8</td>
<td>0.014156</td>
</tr>
<tr>
<td>On time delivery</td>
<td>X9</td>
<td>0.025094</td>
</tr>
<tr>
<td>Price stability</td>
<td>X10</td>
<td>0.027598</td>
</tr>
<tr>
<td>Number of communication channels with customers</td>
<td>X11</td>
<td>0.020962</td>
</tr>
<tr>
<td>Quality</td>
<td>X12</td>
<td>0.025094</td>
</tr>
<tr>
<td>Number of customers dissatisfaction</td>
<td>X13</td>
<td>0.009877</td>
</tr>
</tbody>
</table>
Flexibility in supply X14 0.028463
Employment, attraction, transfer of technology based on needs X15 0.006953
Technology updating X16 0.005564
Education X17 0.014156
Personnel efficiency X18 0.013779
Personnel satisfaction X19 0.011456
Personnel maintenance X20 0.009877
Learning organization X21 0.005564
Period spent from request of customer to solving the problem X22 0.025094
Coordination of processes with goals and strategies X23 0.028463
Structure of organization in terms of dimensions and sizes X24 0.016025
Commitment to quality management and constant improvement of activities X25 0.025094
Production capacity X26 0.025094
After-sale services (including guarantee) X27 0.030219
Risk of strategic cooperation X28 0.005564
Coordination of supply chain strategy X29 0.013779
Number of shareholders X30 0.067717
Small distance from manufacturing and distribution centers X31 0.054211
Technological changes X32 0.013779
Newly established companies X33 0.036141
Importation of the relevant commodity X34 0.005564
Importation of raw materials X35 0.009877

Farahany, 2013

<table>
<thead>
<tr>
<th>Index</th>
<th>Very Weak</th>
<th>Weak</th>
<th>Average</th>
<th>Good</th>
<th>Very good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grey numbers</td>
<td>[0,1]</td>
<td>[1,4]</td>
<td>[4,6]</td>
<td>[6,9]</td>
<td>[9,10]</td>
</tr>
</tbody>
</table>

Returned components costs (X1), market share (X7) and number of shareholders (X30) were known to have the highest weight of importance respectively. For the purpose of evaluating the judgments by respondents an turning the verbal variables in questionnaire into grey numerical indices as can be seen following, they can be used.

Table 3. Verbal expressions and distant numbers of matching grey

Table 4. Grey relational coefficient

Table 5. Values of grey relational grade

Table 6. Ranking of strategic suppliers

Therefore, having considered the rating of suppliers according to Table 6, it can be seen that the Supplier 3 (A3), Supplier 6 (A6) and Supplier 8 (A8) rank first to three and Supplier 1 (A1) ranks lower.

\[
A_3 \gg A_6 \gg A_8 \gg A_5 \gg A_4 \gg A_7 \gg A_2 \gg A_1
\]
Considering the importance of financial perspective for most of the companies, the reduction of relative importance of this factor to 0% which means no involvement in decision making process is analyzed here in this section. As can be seen in Fig. 2, the rating of suppliers 1 and 2 do not change when this factor is eliminated. In fact, the said suppliers are not sensitive to weight changes. As to the suppliers 3 and 4, when the factor was eliminated, their positions changed slightly such that the supplier 3 was reduced from priority 1 to priority 2 and the supplier 4 was hiked from priority 5 to priority 4.

However, suppliers 5 and 6 were sensitive to weight change tremendously and elimination of the finance factor resulted in enhancement of supplier 5 from priority 4 to priority 1. It was due to excluding competitive pricing and finished cost. Such changes resulted in reduction of supplier 6 from priority 2 to priority 6. Weight change also enhanced supplier 7 from priority 6 to priority 5. Supplier 8 remained insensitive to these changes.

Therefore, if the financial problems are not important in selection of suppliers, supplier 5 can be chosen as a strategic supplier.

**Fig.2.** Comparison of suppliers' classification after omission the financial view in comparison to prior status

### 8. CONCLUSION

Given the sensitive, determinant role which selection of strategic supplier plays on organizations' profitability as well as their competitive position, it seems necessary to make efforts to develop and improve decision-making models which can make a precise and reliable evaluation of suppliers. The innovative effect of this study was to devise a supporting system for decision making through integration of grey relational analysis technique in modified balanced scorecard which led to improvement of quality of decision making and degree of importance of the final results. Given the flexibility of balanced scorecard model, in addition to the four perspectives, a further perspective we also added for evaluation of compatibility of supplier with supply chain. Consequently the scorecard comprising of five perspective was devised. Such a framework can be of importance in that it can enhance the quality of decision making as to the resource provision and also the efficiency of supply chain and reduction of the risk of supplier selection.

### REFERENCES


APPENDIX

Grey inter-numerical relations:
Definition 1: let the following two grey numbers are known:

\[ \boxplus_1 \in [a, b] \, , \, a < b \]
\[ \boxplus_2 \in [c, d] \, , \, c < d \]

So we have:

\[ \boxplus_1 + \boxplus_2 = [a + c, b + d] \]
\[ - \boxtimes = [-b, -a] \]
\[ \boxplus_1 - \boxplus_2 = \boxplus_1 + (- \boxtimes) : [a - d, b - c] \]
Definition 2: let K is a positive integer, its multiplication by the grey collection shall yield:

\[ k \otimes = [K \cdot a, k \cdot b], \quad k \in \mathbb{R}^+ \]

Definition 3: other adding and dividing rules for real numbers also apply to grey range collections.

Definition 4: the length of grey number \( \otimes_1 \) which is represented by \( L(\otimes_1) \) is as follows:

\[ L(\otimes_1) = [b - a] \]

Definition 5: the possibility that grey collection \( \otimes_1 \) may be smaller than \( \otimes_2 \) is defined as follows:

\[ P(\otimes_1 \leq \otimes_2) = \frac{\max(0, L^* - \max(0, b - c))}{L^*} \]

Four relations are supposed between the positions of grey numbers \( \otimes_1 \) and \( \otimes_2 \):

A. Let \( a = b \) and \( b = d \), then the two grey numbers are equal and we can write:

\[ \otimes_1 = \otimes_2 \]

\[ P(\otimes_1 \leq \otimes_2) = 0.5 \]

B. If \( c > b \), then we have

\[ \otimes_1 = \otimes_2 \]

\[ P(\otimes_1 \leq \otimes_2) = 1 \]

C. If \( d < a \) then we have

\[ \otimes_1 < \otimes_2 \]

\[ P(\otimes_1 \leq \otimes_2) = 0 \]

D. If there is a common part between two grey numbers, then if \( P(\otimes_1 \leq \otimes_2) < 0.5 \) it can be said \( \otimes_2 \) is smaller than \( \otimes_1 \). If \( P(\otimes_1 \leq \otimes_2) > 0.5 \) then \( \otimes_2 \) is larger than \( \otimes_1 \).