Supplier selection and evaluation using Delphi technique and Analytic Network Process

Mohsen keramatpanah¹, mahmood shirazi², ali rajabzadeh³, amin keramatpanah⁴, emad ahmadipour⁵,

1. M.A student of Industrial management, Institute of management and planning, Tehran, Iran
2. Industrial management Assistant professor, Institute of management and planning, Tehran, Iran
3. Industrial management professor, Tarbiat modares university, Tehran, Iran
4. M.A student of Business management, Department of Management, Azad University, Gilan, Iran
5. M.A student of Financial management, Allameh Tabatabayee University, Tehran, Iran

* Corresponding author email : novin.zedyac@gmail.com

ABSTRACT: Now days the importance of supplier selection for organizations has been stressed. Many organization face with increasing competition and uncertainty environment, coming from changing needs of customer and cost structures. So, the main purpose of this research is to provide a good insight into the use of Analytic Network Process (ANP) procedures for appropriate supplier evaluation and selection. Therefore, we identified six criterias and seventeen sub-criterias for selecting supplier. These criterias and sub-criterias have been deriviated from literature reviews and verified and completed using DELPHI Techniques by experts. Then the sub-criterias were put into an questionnaire to acquire relationships and consequence of sub-criterias.Finally, the obtained relationship of sub-criterias applied as inner relation and outer lationship among sub criterias in and analytic Network to compare on a pairwise bassi to estimate their relative importance .To present the application of the proposed mode, a case as an example is proposed.

INTRODUCTION

Supplier selection and evaluation have presented as one of the most important topics in production management. During last decade, automobile manufacturing plants have changed their trend toward long term relationship with suppliers for sustainable management.

In fact, reputable manufacturing organizations spend more than half of their budget on purchasing raw material and this has made outsourcing under an increasingly focus of attentions.

Supplier selection and evaluation also plays a pivotal role in a business progress and development. Experts are in agreement that considering daily demand increase, highly-speed change in business environment, Uncertainties, existence of internal competitors, only, those suppliers who can afford and meet the manufacturing’s need are to enterprise participation with them.(Esmaeelian, 2006)

As supplier selection is a multi-criteria problem which entails both quantitave and qualitative factors, a number of models and techniques are introduced. In decision making texts we deal with two type of methods:

Hard techniques or methods

Soft techniques or methods

Hard operation research techniques includes linear programming, integer and Goal programming, Game theory, path Analysis, Non Linear programming and etc.

As we use tangible data and apply complex mathematical system, the technique is hard, in the other hand, techniques such as Topsis, Electre, AHP, ANP, DEMATEL, Drama Theory, ISM, SCA, are soft operation research and Decision making techniques which are less tangible and expert-based judgment values.(Azar and Rajabzadeh, 2010)

On the whole, it is essential to note that we apply soft Decision Making methods for non-constraint models and hard Decision Making methods for constraint-based models.(Azar,2003)

At the end, purpose of this paper is to select strategic supplier in non-constraint mode using Analytical Network Process as soft Decision Making technique and tool in Multi-Criteria supplier selection problems.
Literature review

Determining criteria is first phase in this research. Dickson was the first identifying different criterias, he sent questionnaire to 273 firms. He presented the most important criterias as: quality, performance history, warranty, delivery, technical capability, pricing (Elleram, 1990). Weber (1991) reviewed 74 papers studying supplier selection criterias, and found that pricing is the most important criterion for supplier selection and evaluation.

They also showed that supplier selection is a multicriteria decision making problem and the priority of criteria depends on each purchasing situation and their effects on each other.

Ro a presented, respectively, 60 and 51 criteria for supplier selection and evaluation. A comprehensive study of criterias for supplier selection and evaluation is presented by Ghodsypour (1998). Later, Weber and current, obtained on-time delivery, quality facilities, pricing, geographic location and technology as the most prominent factors in supplier evaluation and selection. Here, in this research we reviewed supplier selection literature and finally acquired six criterias & seventeen sub-criterias. As shown in super decision figure (1) which was deriviated from literature review and Delphi Technique.

To select supplier, researcher have applied different techniques in single from or Integration form. For example, Ghodsypour and Obrien (1998) used integration of AHP & MP, Demirtas and Ustun (2009) used integration of ANP, MOP, MIP.

Since the calculation of qualitative elements in independent form is unreal in industrial area, and it is impossible to express a portion or a whole interdependencies and outerrelationships between Criterias and Sub-Criterias by AHP.

So, Saaty (2005) has brought analytic network process (ANP) into literature which considers AHP but differs by applying network structure and influences in his book “The analytic network process” with complete details.

A decision making problem in ANP technique is modeled through a network structure and the relationships between criterias during the modeling process, feedbacks between criterias clusters and interdependencies and outerrelationships in and out of criterias and sib-criterias are being considered. Considering this kind of structuring, ANP technique provides complex decision making problems to be analyzed and solved more accurately and realistically (Saen, 2007).

Following above, we face with different soft and hard or techniques which is basis of our research. In this paper, we suggest an Analytic network process.

MATERIALS AND METHODS

This paper is a practical and descriptive research following discussion, we first reviewed literature to verify and investigate about aspects of supplier selection criteria and sub-criteria theories. Then we used three different questionnaires, Relationship questionnaire, Delphi and ANP. Questionnaires were sent to thirteen exports of company who are experienced in heater and cooler industry. As this study is question-based and complete answers through decision making and soft operation research, the question are listed below:

What are the important criteria and sub-criterias of supplier selection?
What are the inner and outer relationship in sub-criterias?
What are the priority of sub-criterias and suppliers?

Data analysis tools

Delphi Technique

To extract the appropriate criterias and sub-criterias, Delphi questionnaire were used, we used Delphi to obtain opinion and idea of expert about criterias and sub-criterias (poloyi, 2012). In this study, we performed two stage of Delphi Technique which first was literature review-based items that completed by experts and at the second stage finalized and verified by them (table 1)

Analytic network Process modeling

Step 1- Modeling the network

In this step, we apply ANP to assess the criterias and subcriterias. The relevant elements are put in Criteria cluster and their Sub-Criterias are assigned in separate cluster with their Criteria name title, you see Network in figure (1).
Step 2. Formulating the interrelationships and dependencies among other Sub-criteria

As shown, figure (1) is a view of overall Network model which Sub-criterias Inneralrelationships and outer dependencies among them are formulated using experted-based deriviated relationships through questionnaire. Dependencies are shown by straight arrows among Sub-Criterias clusters and inneraltionships are presented as a looped arc within same clusters in figure (1).

Step 3. Performing paired comparison between the Criterias and Sub-Criterias

After setting the realationships between same and other Sub-Criterias, we obtained pairwise comparison matrix as unweighted supermatrix.

For criterias we performed pairwise comparisons with respect to our Goal, for example: with respect to goal (Supplier selection), which od a pais is more important, Quality or Service, Quality or Supplier experience, Quality or Technical & Engineering Capability and etc.

For sub-criterias, as we dealt with impacts of them, we performed pair wise comparison according to their inner and outer in fluencies, for example in term of inner we evaluated sub-criteria’s interdependencies this way. For quality sub-criterias with respect to process standardization, which one more affects PS, Quality Control tests or rejection rate decrease?

Step 4. Super matrix formation

The priority values obtained from pair wised comparison questionnaires are put as the column of the super matrix.

In term of inner and outer dependencies, super matrix gives the impact priority value of a factor on the left of the super matrix on a factor at the top of the super matrix. The result of these steps is an initial matrix named unweighted super matrix (Saaty, 2005).

Then to obtain weighted matrix, we multiply all the factors in the blocks of the initial super matrix (unweighted) by the priority values of corresponding cluster weight (Saaty, 2005). The weighted super matrix is columns add up to one which known as a stochastic matrix. Then the weighted super matrix is raised to large power to take first, second, third degree impacts. Take the powers of weighted super matrix until the differences between consecutive matrix factors are less than very small number (Saaty, 2005).

To attain the final values of sub-criterias in the limit matrix, normalize each block.

An Actual Case

To show the use of analytic network process in supplier selection, we provided a case in this research. The implementation of the network is presented as discussed.

Step 1- modeling network of supplier selection

As first step we construct the supplier selection model like figure (1). Inner and outer relationship between sub-criterias are acquire by experts opinion.
**Step 2- pair-wise comparison between criterias & sub-criterias**

The company expert team then compared the criteria with respect to goal, sub-criterias with respect to origin criterias and sub-criterias with respect to specific in flouncing sub-criteria, as explained in research methodology. These comparison datas were entered to pair wise comparison matrix, to establish unweighted and weighted matrix. Then finally as explained in pervious parts, the limit matrix obtained by raising the weighted super matrix to high powers using MATLAB software (table2).

![ANP Network structure of model](image)

**Step3- Supplier Selection**

To select appropriate supplier, we used professor lin (lin,2011) method that follows equation(1):

\[ D_i = \sum_{j=1}^{J} w_j E_{ij} \]

which \( D_i \) is overall priority of ith supplier and \( W_j \)s limiting priority of jth Subcriterias obtained from limit matrix and \( E_{ij} \) is comparison value of suppliers with respect to specific subcriterias.
Table 2. Criteria & Sub-Criteria weights and rankings

<table>
<thead>
<tr>
<th>Limiting priority</th>
<th>Normalized priority</th>
<th>Rank in Sub-Criteria</th>
<th>Rank in Criteria</th>
<th>Sub-Criterias</th>
<th>Criteria</th>
<th>Weighting priority</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.128971</td>
<td>0.29577</td>
<td>3</td>
<td>3</td>
<td>Customer Satisfaction</td>
<td>Supplier Experience</td>
<td>0.023671</td>
<td>6</td>
</tr>
<tr>
<td>0.053267</td>
<td>0.12216</td>
<td>5</td>
<td>2</td>
<td>Certificates and Prizes</td>
<td>Reputation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.253815</td>
<td>0.58207</td>
<td>2</td>
<td>1</td>
<td>IT</td>
<td>Technology Equipments</td>
<td>Engineering Capability</td>
<td>0.068016</td>
</tr>
<tr>
<td>0.002982</td>
<td>0.71734</td>
<td>11</td>
<td>1</td>
<td>HSE</td>
<td>Management Capability</td>
<td>Management &amp; HR</td>
<td>0.050288</td>
</tr>
<tr>
<td>0.000822</td>
<td>0.19774</td>
<td>15</td>
<td>2</td>
<td>IT</td>
<td>Management Capability</td>
<td>Financial Strength</td>
<td>0.267864</td>
</tr>
<tr>
<td>0.000353</td>
<td>0.08492</td>
<td>17</td>
<td>3</td>
<td>HSE</td>
<td>Management Capability</td>
<td>Pricing</td>
<td>0.267864</td>
</tr>
<tr>
<td>0.001347</td>
<td>0.32403</td>
<td>13</td>
<td>1</td>
<td>Management &amp; HR</td>
<td>Financial Strength</td>
<td>Pricing</td>
<td>0.267864</td>
</tr>
<tr>
<td>0.002810</td>
<td>0.67597</td>
<td>12</td>
<td>2</td>
<td>Management Capability</td>
<td>Financial Strength</td>
<td>0.267864</td>
<td>2</td>
</tr>
<tr>
<td>0.125057</td>
<td>0.00293</td>
<td>4</td>
<td>2</td>
<td>Financial Strength</td>
<td>Financial Strength</td>
<td>0.267864</td>
<td>2</td>
</tr>
<tr>
<td>0.309719</td>
<td>0.71028</td>
<td>14</td>
<td>3</td>
<td>Market Share</td>
<td>Financial Strength</td>
<td>0.267864</td>
<td>2</td>
</tr>
<tr>
<td>0.001278</td>
<td>0.28679</td>
<td>16</td>
<td>3</td>
<td>Standardization</td>
<td>Financial Strength</td>
<td>0.267864</td>
<td>2</td>
</tr>
<tr>
<td>0.000592</td>
<td>0.01169</td>
<td>17</td>
<td>3</td>
<td>IT</td>
<td>Management Capability</td>
<td>Financial Strength</td>
<td>0.267864</td>
</tr>
<tr>
<td>0.012392</td>
<td>0.24476</td>
<td>6</td>
<td>1</td>
<td>Management &amp; HR</td>
<td>Financial Strength</td>
<td>0.267864</td>
<td>2</td>
</tr>
<tr>
<td>0.037645</td>
<td>0.74356</td>
<td>7</td>
<td>1</td>
<td>Rejection Rate</td>
<td>Financial Strength</td>
<td>0.267864</td>
<td>2</td>
</tr>
<tr>
<td>0.017819</td>
<td>0.25843</td>
<td>8</td>
<td>2</td>
<td>After-Sale Service</td>
<td>Financial Strength</td>
<td>0.267864</td>
<td>2</td>
</tr>
<tr>
<td>0.046625</td>
<td>0.67621</td>
<td>3</td>
<td>3</td>
<td>Skilled Personnel</td>
<td>Financial Strength</td>
<td>0.267864</td>
<td>2</td>
</tr>
<tr>
<td>0.004506</td>
<td>0.06535</td>
<td>10</td>
<td>1</td>
<td>On-Time Delivery</td>
<td>Financial Strength</td>
<td>0.267864</td>
<td>2</td>
</tr>
</tbody>
</table>

As shown above for criterias, Quality (0.3966) and financial (0.267864) obtained higher weighting priority. For subcriteria, reputation (0.5820) in supplier experience cluster, technological equipments (0.7173) in engineering capability, skilled personnel (0.6759) in management and HR cluster, pricing (0.7102) in financial, Rejection rate (0.7435) in quality and on-time delivery (0.67621) in service cluster have the highest normalized weighting priorities.

Finally priority of suppliers acquired by applying equation (1) which is presented in table (3).
RESULTS AND DISCUSSION

The manufacturing companies and firms in currentdecadehave been facingstrategictransformation in their manufacturing and operational patterns. The manufacturing methods and patterns has been changed from mass production and manufacturing to mass customizedproduction. In mass customizedproduction as well as in advanced production paradigms, outsourcing is a necessary component of business processes. Generally, supplier selection and evaluation process is a complexproduction activity. The productivity and profit-making and customer satisfaction are completely proportional to the effective performance of supplier selection. Therefore, supplier selection is a pivotal decision-making for long-term life of the organization.

Different approaches are in use for supplier selection. This research is Multi-criteria supplier selection and evaluation model included six criterias (supplier experience, management and personal, technical and engineering capability, service quality, financial) and seventeen sub-criterias. Supplier selection and evaluation is therefore a key process for companies and firms as evaluating and choosing the appropriate suppliers can significantly increase competitive advantages. According to our goal selecting the best suppliers, normalized values limiting priorities of criteria and sub criterias were presented below:

As table (2) shows us that, the studied company focuses on pricing (0.3097) and reputation (0.26538) and customer-satisfaction (0.1289) and financial capability (0.1250) Sub-Criterias as prominent priorities.

It means that pricing terms, discount, long term relationship, ease of bargaining and market share and companies financial capability are key factors for supplier selection. On the other hand creating long-term relationships with evaluated and chosen suppliers has an important role in supply chain management. The other important Sub-Criterias were reject rate decrease (0.0376), on time delivery (0.0466), prizes and certification (0.0532).

On the whole As shown in table (3) using Professor Lin method, supplier B obtained the highest priority weight (0.4420), then supplier A (0.3555) and supplier C (0.2024) were in 2nd and 3rd ranks respectively.

Although many techniques such as AHP, linear programming, multi-objective programming and statistical method have been used to select and evaluate supplier, but this research applied analytic Network process considering its capabilities as an analysis tool. This tool focused on other aspects of problem such as element influences and impacts on each other. This paper serves a comprehensive Criteria and Sub-Criteria base for selecting the suppliers and provides a clear and complete factors and definitions as guidance to supply chain managers and researchers in developing, describing and improving a good supplier selection and evaluation framework.

Finally, The proposed model can be expected to manage effectively the relationships and feedbacks between elements and besides the ANP model can be used to help companies supervise suppliers in order to avoid qualitative decision makings in the future and to expand the joint relationships with their suppliers.

REFERENCES


Xia W, Wu Z. 2007. Supplier selection with multiple criteria in volume discount