Abstract—In most industries the cost of raw materials and component parts constitutes the main cost of a product, such that in some cases it can account for up to 70%. In such circumstances decision making of purchasing management can play a key role in cost reduction. In today’s highly competitive environment, an effective supplier selection process is very important to the success of any manufacturing organization. Supplier selection is one of the most critical activities of purchasing management in supply chain. Supplier selection is a complex problem involving qualitative and quantitative multi-criteria. A trade-off between these tangible and intangible factors is essential in selecting the best supplier. The work incorporates AHP in choosing the best suppliers. The results suggest that AHP process makes it possible to introduce the optimum order quantities among the selected suppliers so that the Total Value of Purchasing (TVP) becomes maximum. In this work, an AHP-based supplier selection model is formulated and then applied to a real case study for a FMCG company in Kerala. The use of the proposed model indicates that it can be applied to improve and assist decision making to resolve the supplier selection problem in choosing the optimal supplier combination. The work represents the systematic identification of the important criteria for supplier selection process. In addition, the results exhibit the application of development of a multi-criteria decision model for evaluation and selection of suppliers with proposed AHP model, which by scoring the performance of suppliers is able to reduce the time taken to select a vendor.

Keywords--Analytic Hierarchy Process (AHP), supplier selection, Total Value of Purchasing (TVP).

I. INTRODUCTION

Procurement is the process in which the supplier sends products in response to customer order. There should be a structure of procurement, direct as well as indirect materials, and strategic as well as general materials. In each case, it is important to identify the critical mechanism for increasing supply chain profits. Eastern condiments, a private enterprise, has always been a front-runner in the FMCG segment of the Spice, an aromatic vegetable product used as a flavoring or condiment product, including Spice, is an aromatic vegetable product used as a flavouring or condiment, normally refers to the derivatives from certain herbs like Seeds, Leaves, Bark, roots etc. They are used mainly for enhancing taste to the food. The name spice is derived from the word species, which was applied to groups of exotic foodstuffs in the middle Ages. Spice term was formerly applied also to pungent or aromatic foods, to ingredients of incense or perfume and to embalming agents. Modern usage tends to limit the term to flavourings used in food or drinks, although many spices have additional commercial uses, e.g., as ingredients of medicines, perfumes, incense and soaps. The most crucial barrier for the domestic product manufacturers is inadequate supply of raw materials.

Therefore, nowadays these industries have a major problem regarding to the raw material procurement. To lie down a procedure for purchase and to evaluate suppliers rate and develop them so as to select suppliers on the basis of the ability to meet the quality requirements. The scope involves purchase of raw materials items such as dry chillies, coriander, turmeric, cumin, fenugreek, fennel, rice, fruits and vegetables, preservatives, salt outsourced etc, purchased at Ernakulam, Adimaly, Theni and other places and imported from other countries. A distribution of potential supplier’s evaluation and develops of existing suppliers. Main objective is to develop guidelines for strategic planning, based on the appropriate decisions made by adopting benefits, opportunities, costs, and risks (BOCR) [1] as the control criteria. Development of reliable and stable procurement decision needs long range planning; it is not wise to consider only short term planning which is mostly established on the basis of Cost. In long range or strategic planning we need to consider various criteria influencing the decision. Several desirable and undesirable indices should be taken into account for each decision. Many of the indices are definitive and some of them which are less important are probable. Definitively desirable indices are called benefits and definitively undesirable ones are called costs. On the other hand, probably desirable indices are called opportunities and probably undesirable ones are called risks.
There are many researches which have been used ANP as a proper Multi criteria decision making method. AHP/ANP methodology allows addressing both tangible and intangible assets and actions which effects uniformly [2]. The ANP has been applied for solving other economic problems. Piantanakulchai [3] applied ANP for prioritizing the potential highway alignments. ANP is also used as a novel approach to tackle the selected problem of how to make the decision on national missile defence program. Azis Iwan J [4] applied ANP for making decision on financial arrangement in Asia zone.

The purpose of the study by Ilker et al. [5] is to develop a multi criteria model of organic food marketing strategies, which are believed to improve the domestic market. The Analytic Network Process is utilized to construct such a model. Cevik [6] presented an integrated framework based on ANP and utilizing Delphi Technique to select an enterprise resource planning (ERP) system. There is also one example, which is making decision regarding the establishment of commercial ties with China [7]. They concluded that Preferred Normal Trade Relations (PNTR) is the best choice. ANP model is used for locating facilities strategically [8]. ANP model has been used for selection of the appropriate energy policy for Turkey [9], for product mix planning in semiconductor fabricator [10]. Majid Azizi [11][12][13] presented ANP for various decision making problems.

The objective of this research is to design a method to rank the various procurement alternatives for Eucalyptus wood for a socially responsible paper making factory in India. Different from other researchers we propose a BOCR analysis in the multi criteria decision making approach. Cost is not only the control criteria for decision making. This paper applies AHP [14] and ANP [15] as the tools for selecting the best choice in the field of various procurement decisions. This paper is the result of an extensive study to select the optimal alternative for supplying the domestic product manufacturers is inadequate supply of raw materials.

II. THE ANALYTIC NETWORK PROCESS

An initial study identified the multi-criteria decision technique, known as the analytic hierarchy process (AHP), to be the most appropriate for solving complex decision-making problems [16]. AHP was first introduced by Saaty [17] and used in different decision-making process. The basic assumption of AHP is the condition of functional independence of the upper part, of the hierarchy, from all its lower parts, and from the criteria or items in each level.

Many decision-making problems cannot be structured hierarchically because they involve interaction of various factors, with high-level factors occasionally depending on low-level factors [17][15]. Saaty suggested the use of AHP to solve the problem of independence among alternatives or criteria, and the use of ANP to solve the problem of dependence among alternatives or criteria.

The ANP, also introduced by Saaty, is a generalization of the AHP [15]. Whereas AHP represents a framework with a uni-directional hierarchical AHP relationship, ANP allows for complex inter-relationships among decision levels and attributes. The ANP feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate, direct or indirect [18]. For instance, not only does the importance of the criteria determine the importance of the alternatives, as in a hierarchy, but also the importance of the alternatives may have impact on the importance of the criteria [15]. Therefore, a hierarchical structure with a linear top-bottom form is not suitable for a complex system. The ANP is a coupling of two parts. The first consist of a control hierarchy or network of criteria and sub-criteria that control the interactions in the system under study. The second is a network of influences among the elements and clusters. The network varies from criterion to criterion and a super-matrix of limiting influence is computed for each control criterion. Finally, each of these super matrices is weighted by the priority of its control criterion and the results are synthesized through addition for all the control criteria.

III. METHODOLOGY

The AHP approach is capable of handling interdependence among elements by obtaining the composite weights through the development of a “super matrix.” In order to utilize the AHP method, some principal points, such as: (1) think about the significant elements and decide what kind of logical groupings would best describe the problem; (2) build clusters and create the nodes within them; (3) examine and determine which element influences or is influenced by the others; (4) create the links between the parent node and its children nodes; and (5) make pair wise comparison judgments between elements and synthesize the overall priorities for the alternatives. In addition, an analytical procedure for the AHP, including: (1) model construction and problem structuring; (2) pair wise comparison matrices of interdependent component levels; (3) super matrix formation; and (4) selection of best alternatives. Hence, we have designed some steps for using the Series System model as follows.
In other words, the unweighted super matrix is raised to limiting powers to calculate the overall priorities, and thus the cumulative influence of each element on every other element with which it interacts is obtained. In this case, it is necessary to raise the unweighted super matrix to the power, where is an arbitrary large number. The unweighted super matrix

**Step 4:** Selection of best alternatives the overall priorities of alternatives may be obtained through using the limiting process method. Then, alternatives may be prioritized and the best. There are many researches which have been used AHP as a proper Multi criteria decision making method. AHP methodology allows addressing both tangible and intangible assets and actions which effects uniformly. The AHP has been applied for solving other economic problems. [13]

An article on AHP written by Dr. Thomas L. Saaty[19] triggered the impetus in conducting this study. The article contained the basic issues relating to Analytic Hierarchy Process & its application in multi-criteria decision analysis. Thomas L. Saaty is an American mathematician serving as University Professor at the University of Pittsburgh, where he teaches in the Joseph M. Katz Graduate School of Business. He is the inventor, architect, and primary theoretician of the Analytic Hierarchy Process, a decision-making framework used for large-scale, multiparty, multi-criteria decision analysis, its generalization to decisions with dependence and feedback. The book The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation, McGraw-Hill written in 1980 is a prominent contribution by Dr. Saaty.

### 2.1 An Illustration of Analytical Hierarchy Process

The various aspects of Analytical Hierarchy Process and its use in selection of a most optimum alternative from a set of alternatives are illustrated with the help of a simple example [14]:

For example, suppose we have two fruits Apple and Banana. I would like to ask Mr.XYZ, which fruit he likes better than the other and how much he likes it in comparison with the other. Let us make a relative scale to measure how much he likes the fruit on the left (Apple) compared to the fruit on the right (Banana).

![Figure 2.1 Depiction of relative favouring between two things](image)

For instance he strongly favours banana to apple then he gives mark like shown: [21]
Now suppose he has three choices of fruits. Then the pair wise comparison goes as the following

Table 2.1 Number of Comparisons per number of Things

<table>
<thead>
<tr>
<th>Number of things</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of comparisons</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>10</td>
<td>15</td>
<td>21</td>
<td>n(n-1)/2</td>
</tr>
</tbody>
</table>

The scaling is not necessary 1 to 9 but for qualitative data such as preference, ranking and subjective opinions, it is suggested to use scale 1 to 9.

Now, if XYZ has 3 kinds of fruits to be compared and he made subjective judgment on which fruit he likes best, like the following

To fill the lower triangular matrix, we use the reciprocal values of the upper diagonal. If \( a_{ij} \) is the element of row \( i \) column \( j \) of the matrix, then the lower diagonal is filled using this formula: \( a_{ji} = 1 / a_{ij} \)

Thus now we have complete comparison matrix

Notice that all the elements in the comparison matrix are positive or \( a_{ij} > 0 \).

Having a comparison matrix, now we would like to compute priority vector, which is the normalized Eigen vector of the matrix. Nevertheless it is easy to compute because all we need to do is just to normalize each column of the matrix.

Suppose we have 3 x 3 reciprocal matrixes from paired Comparison

We can make a matrix from the 3 comparisons above. Because we have three comparisons, thus we have 3 by 3 matrix.

The diagonal elements of the matrix are always 1 and we only need to fill up the upper triangular matrix. How to fill up the upper triangular matrix is using the following rules:

If the judgment value is on the left side of 1, we put the actual judgment value.

If the judgment value is on the right side of 1, we put the reciprocal value. [21]

Comparing apple and banana, Mr.XYZ slightly favours banana, thus we put 1/3 in the row 1 column 2 of the matrix. Comparing Apple and Cherry, Mr.XYZ strongly likes apple, thus we put actual judgment 5 on the first row, last column of the matrix. Comparing banana and cherry, banana is dominant. Thus we put his actual judgment on the second row, last column of the matrix.

Then based on his preference values above, we have a reciprocal matrix as shown below:

Figure 2.2 Depiction of the relative favouring between two things by a person. Now suppose he has three choices of fruits. Then the pair wise comparison goes as the following

Figure 2.3 Depiction of relative favouring between three things

Kindly observe that the number of comparisons is a combination of the number of things to be compared. Since we have 3 objects (Apple, Banana and Cherry), we have 3 comparisons. Table below shows the number of comparisons.

Table 2.1 Number of Comparisons per number of Things

<table>
<thead>
<tr>
<th>Number of things</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of comparisons</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>6</td>
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<td>n(n-1)/2</td>
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To fill the lower triangular matrix, we use the reciprocal values of the upper diagonal. If \( a_{ij} \) is the element of row \( i \) column \( j \) of the matrix, then the lower diagonal is filled using this formula: \( a_{ji} = 1 / a_{ij} \)

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Notice that all the elements in the comparison matrix are positive or \( a_{ij} > 0 \).

Having a comparison matrix, now we would like to compute priority vector, which is the normalized Eigen vector of the matrix. Nevertheless it is easy to compute because all we need to do is just to normalize each column of the matrix.

Suppose we have 3 x 3 reciprocal matrixes from paired Comparison
We sum each column of the reciprocal matrix to get

\[
\begin{array}{c|c|c}
\text{Apple} & \text{Banana} & \text{Cherry} \\
\hline
\text{Apple} & 1 & \frac{1}{3} & 5 \\
\text{Banana} & 3 & 1 & 7 \\
\text{Cherry} & \frac{1}{5} & \frac{1}{7} & 1 \\
\end{array}
\]

Then we divide each element of the matrix with the sum of its column, we have normalized relative weight. The sum of each column is 1.

\[
\begin{array}{c|c|c|c}
\text{Apple} & \text{Banana} & \text{Cherry} & \text{Sum} \\
\hline
\text{Apple} & \frac{\frac{6}{21}}{21} & \frac{7}{21} & \frac{6}{13} \\
\text{Banana} & \frac{3}{21} & \frac{3}{13} & \frac{7}{13} \\
\text{Cherry} & \frac{1}{21} & \frac{1}{13} & 1 \\
\end{array}
\]

The normalized principal Eigen vector can be obtained by averaging across the rows

\[
W = \frac{1}{3} \left[ \frac{\frac{6}{21} + \frac{7}{21} + \frac{6}{13}}{21} \right] = \frac{0.2828}{0.6434} = \frac{0.0738}{0.2828}
\]

The normalized principal Eigen vector is also called priority vector. Since it is normalized, the sum of all elements in priority vector is 1. The priority vector shows the relative weights among the things that we compare. In our example above, Apple is 28.28%, Banana is 64.34% and Cherry is 7.38%. John’s most preferable fruit is Banana, followed by Apple and Cherry. In this case, we know more than their ranking.

In fact, the relative weight is a ratio scale that we can divide among them. For example, we can say that XYZ likes banana 2.27 (=64.34/28.28) times more than apple and he also like banana so much 8.72 (=64.34/7.38) times more than cherry [21]

IV. IMPLEMENTATION OF ANALYTICAL HIERARCHY PROCESS IN THE EVALUATION OF BIDS

3.1 Advertised Tender Enquiry For Procurement Of Goods

For the procurement of Goods having a value over Rs.25 Lakhs for the Government India Departments, Invitation for Bids is issued by them/procuring agency. Bidders have to submit their Quotations/Bids within a fixed date & time as mentioned in the Tender Enquiry Documents. The Quotations/Bids thus received are evaluated on the basis of certain criteria.

3.2 Criteria for Evaluation of Quotations

The criteria based on the basis of which bidders are to be evaluated are set by the Integrated Purchase Committee of the Health Ministry under the Chairmanship of Director General of Health Service with several Additional Secretaries & Directors as members. The various criteria against which the evaluations are to be made.

3.3 Preparation of the Questionnaire

A Questionnaire has to be handed out to the expert involved in the Bid evaluation to find out the priority that one criterion has over the other. The questionnaire has to be having choices so that the expert can easily tick on the preferred option. Although many scales can be used for quantifying Managerial Judgments, the scale given below is the standard used for AHP Analysis.

The Design of the Questionnaire is made in such a way that it initially provides the Respondent with information pertaining to the Purpose of the Questionnaire & the expected information from the Questionnaire. The Respondent is given information regarding the use of his response in the Questionnaire. A briefing is provided regarding how the questions are to be responded to. Then the serially numbered questions are provided with a request to the expert to tick on any of the nine options that he finds as the most suitable

The various options from 1 to 9 numerical values will have denominations as follows:
Using the relative weights of one criterion with respect to another as provided in the questionnaire, we obtain a complete comparison matrix depicting the relative weight of one criterion with respect to another as shown below.

<table>
<thead>
<tr>
<th>Numerical Value</th>
<th>Denomination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The two Criteria are equally favored</td>
</tr>
<tr>
<td>2</td>
<td>Intermediate Value between Numerical Values 1 &amp; 3</td>
</tr>
<tr>
<td>3</td>
<td>One Criterion is slightly favored over the other.</td>
</tr>
<tr>
<td>4</td>
<td>Intermediate Value between Numerical Values 3 &amp; 5</td>
</tr>
<tr>
<td>5</td>
<td>One Criterion is strongly favored over the other.</td>
</tr>
<tr>
<td>6</td>
<td>Intermediate Value between Numerical Values 5 &amp; 7</td>
</tr>
<tr>
<td>7</td>
<td>One Criterion is very strongly favored over the other.</td>
</tr>
<tr>
<td>8</td>
<td>Intermediate Value between Numerical Values 7 &amp; 9</td>
</tr>
<tr>
<td>9</td>
<td>One Criterion is extremely favored over the other.</td>
</tr>
</tbody>
</table>

The relative weight is a ratio scale that we can divide among them. For example, we can say that priority of Criterion A over Criterion B is (1.86=13/7) i.e. Criterion A 1.86 times more important than Criterion B.

Now, there were five Bidders who participated in the Tender for the procurement of spices and aromatics, viz. 1) M/s Loba agencies, 2) M/s Alpha spices (P) Ltd, 3) M/s Adimali spices trading company, 4) M/s Patel & co & 5) M/s A V Thomas & company Ltd. The Tender Documents submitted by them were evaluated on the Criterion. The bidders & their corresponding ‘Total percentage of Importance’ is, therefore, as follows:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Bidder</th>
<th>Total percentage of Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M/s Loba agencies</td>
<td>84%</td>
</tr>
<tr>
<td>2</td>
<td>M/s Alpha spices</td>
<td>84%</td>
</tr>
<tr>
<td>3</td>
<td>M/s Adimaly spices trading company</td>
<td>84%</td>
</tr>
<tr>
<td>4</td>
<td>M/s Patel &amp; co</td>
<td>83%</td>
</tr>
<tr>
<td>5</td>
<td>M/s A V Thomas &amp; company Ltd</td>
<td>56.5%</td>
</tr>
</tbody>
</table>

V. CONCLUSION

The Price Bid of the Bidder with the highest ‘Total Percentage of Importance’ has to be opened as it will be the most optimum Supplier. But in this case, as three of the five bidders have got equal scores in the ‘Total Percentage of Importance’ i.e. 84%, the price bids of M/s Prakash Pulverising Mills, M/s Kilpest India Ltd. & M/s Rako Agrochem (P) Ltd. have to be opened. On the Opening of the Price Bids, the following prices in the increasing order were found to be quoted:-

The optimum Bidder quoting the lowest purchase is M/s Loba agencies, the most eligible bidder, for the placement of the Purchase Order. The second most optimum bidders are M/s Alpha spices (P) Ltd & M/s Adimali spices trading company (P) Ltd. If, in case, the most optimum bidder viz. is M/s Loba agencies is not able to supply due to Force Majeure conditions, the Purchase Order can be issued to any of the second most optimum bidders viz. M/s Alpha spices (P) Ltd & M/s Adimali spices trading company (P) Ltd. or the quantities can be split in 50:50 basis & purchase orders can be issued to them. This method of selection of the optimum bidder helps in setting of the priorities as to whether the Quantity, Distance, or any other criterion should be given preference over another criterion based on the requirement of the procurement.
Hence in the interest of the exchequer, with the application of the Arithmetical Hierarchy Process as a decision making tool, we are able to determine the most eligible Bidder. AHP organizes the Evaluation Criteria in the hierarchical Order and facilitates the selection of the most suitable alternative. It uses a sound mathematical basis to express human judgments. Moreover, the Managerial judgments are used to drive the AHP approach and these judgments are expressed in terms of pair-wise comparisons of the evaluation criteria involved. The pair-wise comparison expresses the relative importance of one criterion with respect to another. Each of the pair-wise comparisons represents an estimate of the ratio of the weights of each criteria being compared. This ratio scale for expressing human judgments has been applied to a variety of decision making problems in other fields and it has been validated in situations where standard measures already exist. As AHP utilizes a ratio scale for human judgments, the weights reflect the relative importance in achieving the ultimate goal. The AHP helps in relative ranking the bidders after the techno-commercial evaluation which was not possible in the existing system. The effective implementation of an AHP approach in the Public Procurement helps in quantifying managerial judgments using mathematical techniques. The Bidder evaluation & selection based on the AHP Model helps the Procurement agency to pinpoint the most competent firm under intense competition with other bidders.

When a procurement agency is confronted with choosing the best bidder to deliver a good or service, the decision can often be very complex. The Bidder Evaluation problems are multi-objective problems which have many qualitative and quantitative concerns. This project has presented the AHP as a decision analysis tool in bidder evaluation problems. This project proposes a comprehensive AHP model to select the best supplier for a procurement agency. The basic difference between the existing vendor evaluation & the AHP vendor evaluation is that the according to the requirement of the procurement, the vendors are evaluated giving appropriate weightage to one criterion over another. The AHP models a decision making framework using a hierarchical relationship among the various evaluation criteria. It ensures the incorporation of both qualitative & quantitative factors when assessing the bids. We concluded that M/s Loba agencies is the most optimum bidder to whom the Purchase Order can be placed & that in case M/s Loba agencies is not being able to supply due to Force Majeure conditions, purchase orders can be placed on M/s albha spices (P) Ltd & M/s adimali spices trading company (P) Ltd. for supplying 50% of the quantity each.

Implementation of an AHP based approach in the Vendor Evaluation of various government departments can help in providing tangible values to rate each vendor appropriately based on the priority of each criterion as designated the department during a specific procurement process.

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Bidder</th>
<th>Quantity in Kilograms</th>
<th>Unit Price/Kg in Rs.</th>
<th>Total Price in Rs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M/s Loba agencies</td>
<td>50,000</td>
<td>196</td>
<td>9800000</td>
</tr>
<tr>
<td>2</td>
<td>M/s albha spices (P) Ltd Or M/s adimali spices trading company</td>
<td>50,000</td>
<td>200</td>
<td>10000000</td>
</tr>
</tbody>
</table>

REFERENCES


[13] Majid Azizi; A decision making model for compatible management of forester local cooperatives in the north of Iran; ISAHP 2009 Symposium, July 29-August 1, 2009, Pittsburgh, Pennsylvania, USA


