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**ABSTRACT**

Supplier's Selection is one among the foremost essential activities of supply chain management. Supplier's Selection could be an advanced activity involving qualitative and quantitative multi-criteria. A trade-off between these tangible and intangible factors is essential in choosing the most effective Supplier. This paper explains the various methods for supplier selection and the use of AHP in selecting the most effective suppliers. The complete procedure of AHP is explained in this paper with some examples. The complete model development for the supplier selection is shown. The importance of AHP process in supplier selection is stressed. The use of MATLAB Software is shown to calculate the priority vector and thus find the solution of Example AHP Problem.

**KEYWORDS:** Analytic Hierarchy method (AHP), Supplier choice, Total worth of Purchasing (TVP).

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**INTRODUCTION**

The Issues of supplier selection have attracted the interest of researchers since the 1960's, and research studies in this area have increased, several authors have pointed out the importance of supplier selection by emphasizing the impact that decisions throughout the entire supply chain have, from procurement of raw material to delivery of finished products to final customers. In order to help decision makers or purchasers make sound decisions with respect to supplier selection, researchers have developed different criteria and decision methods and models dealing with different aspects of the supplier selection process. This paper throws light on supplier selection criteria and methods. Based on review, it would not be irrational to suggest that the supplier selection issues need further attention in order to harmonize the combination of qualitative and quantitative criteria to develop the best criteria and method for the selection of the best suppliers.

The Supplier Selection systems have been categorized in to a number of headlines, which are briefly furnished as under:

**PRE-QUALIFICATION METHOD OF SUPPLIERS**

Pre-qualification is the procedure of reducing the set of all suppliers to a smaller set of suitable suppliers. The different methods available in this category are:

A) **Categorical Methods** – Categorical methods are qualitative models fundamentally.

The existing or familiar suppliers are assessed on a set of criteria, based on historical data and the buyer's know-how. Subsequent on rating of all criteria, the buyer offers an overall rating. The categorical approach enables the structural evaluation process in a systematic and solid way which is the primary advantage of the approach.

B) **Analysis of Data Envelopment** - Data envelopment analysis system that classifies and splits suppliers between two groups – *Efficient* and *Inefficient*. Suppliers are judged based on two sets of criteria, namely *outputs* and *inputs*. Data envelopment analysis deems a supplier to have a qualified efficiency of 100 percent if he brings out a set of output parameters which is not brought out by other suppliers with a specified set of input factors.

C) **Cluster Analysis** – Cluster Analysis is a method derived from statistics. Cluster Analysis employs a sorting algorithm to cluster a number of items which are explained by a set of numerical aspect scores into a number of

clusters. It identifies the differences between items within a cluster. This categorization is applied to decrease a larger set of suppliers into smaller convenient subsets.

### **MATHEMATICAL PROGRAMMING MODELS**

Mathematical programming (MP) models often take for only the quantitative criteria. It allows the decision makers to think about different restrictions in choosing the best set of suppliers. Mathematical programming models are obviously ideal for solving the supplier choice difficulty since they can optimize results using single objective models and multiple objective models as well.

Mathematical programming in two kinds which are:-

**a) Multi Objective Models (MOM)** This category deals with optimization problems comprising two or more matching criteria.

**b) Goal Programming (GP) Models** – Goal Programming is an important tool which differs from most mathematical programming models. It provides the decision maker with adequate flexibility to set target levels on many criteria. It also obtains the best compromise solution that comes closely to each one of the specified targets.

### **MULTI-ATTRIBUTE DECISION MAKING TECHNIQUES (MADMT)**

This technique is implemented to resolve the problem coming across in supplier's selection. Generally a supplier selection problem includes more than one criterion and these criteria are often inconsistent with the other. Hence, this technique is an absolute solution in supplier's selection task, which includes:-

**a) Analytical Hierarchical Process** – This is a decision making methodology created for prioritizing alternatives. The main feature of this method is that it incorporates both qualitative and quantitative criteria. The hierarchy process usually comprised of three varied levels, which contains criteria goals and alternatives. Since Analytical Hierarchical Process employs a ratio scale for human decision, the alternatives weights reflect the importance of the criteria in achieving the aim of the hierarchy.

**b) Analytic Network Process** – This process captures the outcome of the feedback and dependence in the clusters of elements, which is considered a comprehensive decision making system. Analytical hierarchical process serves a point of starting for analytic network process. It incorporates feedback and relationship among decision alternatives and attributes. Analytic Network Process is a coupling of two parts – One consists of a control network of criterion that controls the interactions. The second part is a network of power among clusters and elements.

**c) Total Cost of Ownership Models-**

This models basically includes quantification and summarization of several costs related with the choice of vendors. It adjusts or penalizes the unit price quoted by the supplier. This methodology based on philosophy, which looks beyond the purchase price to include different purchase-related costs.

**d) Technique for the Performance of the Order by match to Ideal Solution–**

This technique is to determine the ranking order of all suppliers and linguistic values. It uses to assess the weights and ratings of the factors. It is based on the idea that the optimal alternative has the shortest distance from the positive ideal solution and the extreme distance from the negative ideal solution.

**e) Multiple Attribute Utility Theory (MAUT)** – This theory is also considered a linear weighting technique, which enables purchasing professionals to formulate feasible sourcing strategies and is also suitable of handling multiple conflicting attributes. This is used for international supplier choice, where the environment is more complex and risky.

**f) Outranking Methods (OM)** – Outranking methods are helpful decision making tool to solve multi criteria problems. The method is partially compensatory and is competent of dealing with situations where imprecision is present.

### **ARTIFICIAL INTELLIGENCE (AI) METHODS**

Artificial Intelligence Methods are the system based on computer using historical data and experience. These systems deal with the complexity and uncertainty surrounded with the process of supplier selection.

Two of the models are:

**a) CBR (Case Based Reasoning) Systems** – This system falls in the category of the so called artificial intelligence (AI) approach. This system is a software-driven database which enables a decision maker with useful experience and information from similar and previous decision situations.

**b) Artificial Neural Network (ANN)** – This model saves money and time. The disadvantage of this model is that it demands specialized software and experts in its operation.

### **FUZZY LOGIC APPROACH**

In this approach, linguistic values are taken to assess the ratings and weights for various factors. The weights and ratings of the criteria in the problem are assessed by means of linguistic variables. One can easily construct a normalized unclear decision matrix once the decision makers' fuzzy ratings were pooled.

### **COMBINED APPROACHES OR HYBRID METHODS**

Some authors have joint decision models from many steps in the process of supplier selection. They developed a mathematical programming model and TCO. Some had incorporated AHP and LP (Linear Programming) to consider tangible and intangible factors in selecting the best suppliers. Some presented a successful model using MAUT and LP for solving the problem of supplier selection. Some has proposed a multi-criteria group approach using fuzzy TOPSIS to deal with uncertainty.

### **AHP (ANALYTIC HIERACHY PROCESS)**

Analytic Hierarchy Process is one of Multi Criteria decision making method which was developed by **Prof. Thomas L. Saaty**,[1]. It is a method to derive ratio scales from paired type comparisons. The inputs can be obtained from the actual measurement such as price, weight etc., or from the subjective opinion such as satisfaction feelings or preference. AHP allows some small inconsistency in judgment because of fact that human is not always consistent. The ratio scales are derived from principal Eigen vectors and consistency index is derived from the principal Eigen Value.

Having a comparison matrix, at your expense, now we would like to compute the priority vector, which is the normalized Eigen vector of matrix. We will use MATLAB to compute the Eigen values and the normalized Eigen Vector.

### **Supplier Selection with AHP technique**

Analytic Hierarchy method (AHP), since its invention, has been a tool at the hands of manufacturers and researchers, and it's one among the foremost and wide used multiple criteria decision-making tools (Omkarprasad, Kumar, 2006), [2]. Several outstanding works are printed to support AHP. They embody applications of AHP in different fields like designing, choosing best different, resource allocations, resolving conflict, improvement, etc., also as numerical extensions of AHP (Vargas, 1990). Among applications of AHP technique for the sector of choosing the best options, the subsequent publications are related to Supplier choice. Ghodsoupor and O'Brion (1998), [3] studied the conflicts between 2 tangible and intangible factors, supported AHP technique, i.e. qualitative and quantitative, in order to choose the most effective suppliers. They integrated AHP and applied mathematics to consider each tangible and intangible factor in selecting the most effective suppliers and place the optimum order quantities among them. During the AHP and LP the full worth of buying becomes most. This model can apply to Supplier choice with or without capability constraints.

Yahya and Kingsman (1990) used Saaty's (1980),[1] AHP technique to see priority in choosing suppliers. The authors applied merchandiser rating in provider choice and in deciding a way to apportion business as in crucial wherever scarce development effort is applied. This study is performed for a government sponsored entrepreneur development program in Asian country. The actual Umbrella theme of Malaysia's article of furniture business was applied as option to this technique. The choice of vendors in theme Company needs to be done not solely to confirm edges to the purchasers however additionally to develop the vendors. The multiple and conflicting objectives, both obtaining sensible quality article of furniture corporations improve their operations, imply that the criteria to use in choosing vendors may well be completely different than that for traditional commercial buying of products. Given the requirement to spot the strengths and weakness of vendors for the event functions of the theme, a merchandiser rating system is important and can't be avoided. Akarte (2001) used AHP to pick out the best casting suppliers from the cluster of evaluated suppliers. The analysis procedure took care of eighteen completely different criteria. These were segregated into four groups namely: development capability, producing capability, quality capability, and price and delivery. Out of eighteen completely different criteria, six were of objective and twelve were of subjective sorts. The analysis technique of this model relies on relative performance of every Supplier for subjective (qualitative) criteria that is obtained by quantifying the ratings expressed in quantitative terms. The Supplier United Nations agency has the utmost score is chosen.

Tam and Tummala (2001), [4] have used AHP in merchandiser choice of a telecommunication system, which could be an advanced, multi-person, multi-criteria decision drawback. The authors have found AHP to be terribly helpful in involving several manufacturers with completely different conflicting objectives to make a consensus call. The choice method, as a result, is systematic and reduces time to pick out the seller. Handfield, Walton and Sroufe (2002) studied Environmental criteria to provider assessment by re-modeling, buying in to a more strategic activity. The authors integrated the environmental problems to form purchasing managers introduce dimensions in to their selections, that each qualitative and quantitative factors complicate the matter. By applying AHP in environmental criteria to Supplier assessment, the authors were able to solve the above drawback. AHP technique could integrate environmental criteria within the sourcing decision method for Supplier choice.

In order to form an organization distinctive, Yu and Jing (2004) developed a brand new model to decide on the best Supplier combination for Tian Jin electrical Construction Company. Consistent with the previous analysis by tam-o'-shanter and Tummala (2001) [4], Yu and Jing (2004) pointed out, through analysis, that trust between suppliers and consumers is the best criterion for choosing best Supplier that reduces the value, by using AHP and applied mathematics (LP). The authors established trust for Tian Jin

In the Electric Construction Company's Through analysis, the authors came up with the fact that quality criteria will be a lot potent in Supplier choice than quantity, although alternative criteria such as: value, quality and delivery were used and trust was focused on as necessary criteria for provider choice. Liu and Hai (2005) [5] studied supplier choice by desegregation a cooperative buying program. The authors came up with a brand new approach, supported the employment of Saaty's (1980) AHP technique. The potential use of the AHP process for the advanced manufacturing process was done by F. Tahriri and M.R. Osman [6]. The involvement of trust factor was studied by S.Jing [7]. The criterions which need to be used in the supplier selection are studied by many authors. The evolution of the criterions to be used in the Supplier selection was studied by Zhang [8]. The application of environmental criterion in the supplier selection for AHP was studied by Handfield [9].

This system, known as selection AHP (VAHP), provides a less complicated technique than AHP, but does not lose the systematic approach of accounting the weights and sorting performance of suppliers. (VAPH) permits the buying manager to get non inferior purchasing choices and consistently analyze the inherent trade-offs among the relevant criteria.

## METHODOLOGY

### Model Development

The objective of this work is to develop AHP technique for Supplier choice. The methodology of this work has been adopted from Yahya and Kingsman (1999), Tam and Tummala (2001) [4] and Yu and Jing (2004). So as to suits collecting quantitative and qualitative knowledge for AHP Supplier choice model that could be applied by the steel producing company, a six steps approach was performed to insure thriving implementation as follows:

Step one: Outline criteria for supplier choice

Step Two: outline sub criteria and sub sub-criteria for Supplier choice

Step three: Structure the class-conscious model

Step four: Place the order of criteria or sub criteria

Step five: Live Supplier performance

Step six: determine Supplier priority and choice

### Sensitivity analysis of result

Sensitivity analysis identifies the impact of changes within the priority of criteria on the suppliers' performance and order quantities. Once getting the initial resolution with the given weights of the attributes, sensitivity analyses were performed to explore the response of the general utility of alternatives and to changes within the relative importance (weight) of every attribute or criterion. The sensitivity analyses are necessary as a result of the importance of attributes or criteria, which needs different levels of trust, quality, cost, delivery, management and organization, financial and sourcing opportunities for the alternatives. A series of sensitivity analyses should be conducted.

**Example Solution to a Problem**

Based on the interview conducted with the three managers R(1), R(2) and R(3) the ratings out of the 10 is taken for criterion like Quality, Delivery etc and average rating is taken as the score for it.

The criteria are Cost, Quality, Delivery, Facility, Management and Organization and Financial.

The ratings of the pair wise criteria are done on the basis of the Information Shown below:

| Verbal judgment or preference   | Numerical rating |
|---|------------------|
| Extremely preferred   | 9                |
| Very strongly preferred   | 7                |
| Strongly preferred  | 5                |
| Moderately preferred  | 3                |
| Equally preferred   | 1                |
| Intermediate values between two adjacent judgments ( when compromise is needed) | 2, 4, 6, and 8   |

The Matlab Software Package is used to determine the normalized priority vector for all the matrixes. The Examples are given below:

|           | C    | Q    | D    | F    | M    | F |
|-----------|------|------|------|------|------|---|
| Cost      | 1    | 2    | 3    | 4    | 3    | 4 |
| Quality   | 1/2" | 1    | 5    | 3    | 6    | 5 |
| Delivery  | 1/3" | 1/5" | 1    | 2    | 7    | 4 |
| Facility  | 1/4" | 1/3" | 1/2" | 1    | 4    | 3 |
| MandA     | 1/3" | 1/6" | 1/7" | 1/4" | 1    | 2 |
| Financial | 1/4" | 1/5" | 1/4" | 1/3" | 1/2" | 1 |

Using Matlab the Highest Eigen value of the matrix is = 6.6593

The un-normalized Eigen Vector is  $d = 0.6558 \quad 0.6169 \quad 0.3316 \quad 0.2170 \quad 0.1065 \quad 0.0880$

The Normalized Eigen Vector is

$e = 0.3237 \quad 0.3045 \quad 0.1637 \quad 0.1071 \quad 0.0526 \quad 0.0434$

Thus the weights of Cost, Quality, Delivery, Facility, Management and Organization and Financial are 32%, 30%, 16.37%, 10.71%, 5.26 % and 4.34% respectively.

The process is repeated for all suppliers, SUPPLIER A, SUPPLIER B, SUPPLIER C and SUPPLIER D. The selection can be made by comparing the weights with respect to a particular criterion. The supplier with highest weight is chosen.

**CONCLUSIONS**

The issues of Supplier's choice have attracted the interest of researchers since 1960s, and plenty of researches during this space have evolved. Continuing the previous works in Supplier choice space, the work has got success in achieving its objectives.

The contribution was a development of a multi-criteria model for analysis and choice which is employed for Supplier choice in **JSW Steel Limited**. The use of AHP process is critical in the Supplier Choice process and the latest Software Packages like MATLAB can be used to solve for the weights and decide the relative importance of the criterion. The

supplier selection problem for multiple suppliers reduces to the Eigen value problem which can be solved using mathematical software tools like MATLAB. The priority vector is found as an Eigen vector which can be normalized to find the relative rates. The process is repeated at all levels and for all suppliers and local and global weights are found which can be used to decide the best supplier.

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