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SUPPLIER EVALUATION AND EFFICIENT SUPPLIER SELECTION USING MCDM APPROACHES: A CONCEPTUAL REVIEW

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ABSTRACT

Supplier evaluation and efficient supplier selection is one of the most critical activities of an organization. It determines the existence of the organization in terms of finance, products and reputation and also select the efficient supplier to the industries and organizations. In the research paper, supplier evaluation and efficient supplier selection is targeted for an virtual industry and the conceptual research work for the purpose is being presented. For purpose of supplier evaluation and efficient supplier selections are four renowned Multi criteria decision making (MCDM) techniques, Analytical hierarchy process (AHP), Weighted product model (WPM) , Weighted sum model (WSM) and AHP software is being targeted by the researchers. As the result of completion of the research work, the comparison among three MCDM techniques is also targeted.

KEYWORDS: Supplier Evaluation, Multi Criteria Decision Making (MCDM), Analytical Hierarchy Process (AHP), Weighted Product Model (WPM), Weighted Sum Model (WSM), AHP Software

I. INTRODUCTION

Suppliers have always been an integral part of a company's management policy. Furthermore, when firms are allocating more resources to their core competencies and encouraging the outsourcing of non-core activities they have more reliance and dependence on suppliers. It is increasingly important that companies have strong relationship with their suppliers to stay ahead of competition. The establishment, development and maintenance of the relationship between exchange partners are crucial to achieving success. In the current international competitive environment; many manufacturers are focusing on supplier management as a means for achieving sustainable competitive advantage (Morgan and Hunt 1994).

Supplier management is defined as organizing the optimal flow of high-quality, value- for-money materials or components to manufacturing companies from a suitable set of innovative suppliers (Goffin et al., 1997). It is crucial for several reasons. Suppliers can have significant influence on a manufacturer's performance through their contribution to cost reduction, new product design and enabling the constant improvement of quality. Consequently, studies of supply chain management (SCM) are now increasingly concentrating on the relationships between organizations involved rather than the traditional physical flow of materials and products (Monczka et al., 1998).

Selecting a proper vendor to meet production demand is a common problem that most manufacturing enterprises have to face. Normally, manufacturers conduct a performance evaluation on each vendor before a new product comes into mass production. The selection process is based on their previous performance records, so the ranking determines which vendor will get this supply contract. However, a survey on current evaluation methods shows that they are all less objective and lack accurate data processing (Tsai et al, 2003).

According to Elanchezhian et al (2010), supplier performance has to be measured occasionally for the following reasons:

- To increase performance visibility
- To uncover and remove hidden waste and cost drivers in the supply chain
- To leverage the supply base
- To align customer and supplier business practices
- To mitigate risk
- To improve supplier performance

In the proposed research work, supplier evaluation is targeted by using multi criteria decision making techniques. One of the main advantages of using these techniques are that these are simply, easy to operate and provide reliable results. The techniques proposed by the candidate are Analytical Hierarchy Process (AHP), Weighted Sum Model (WSM) and Weighted Product Model (WPM).

Following are the objectives of the research:

- To investigate various criteria for supplier evaluation for a industry
- To determine priorities for existing suppliers for the concerning firm
- To establish a comprehensive AHP-WSM model for supplier evaluation
- Assist the suppliers to re-evaluate themselves
- Critical review of evaluation procedures followed by a company
- Comparison of WSM and WPM methods

The research paper is organized in different sections. After Introduction, a Literature review showing AHP, WSM, WPM and supplier evaluation criterion is presented, followed by proposed methodology, expected outcomes and conclusion.

II. LITERATURE REVIEW

1. Analytical Hierarchy Process (AHP), Weighted Sum Model (WSM), and Weighted Product Model (WPM)

ANALYTICAL HIERARCHY PROCESS (AHP)

Definition

*"**Analytical Hierarchy Process (AHP)** is an approach to decision making that involves structuring multiple choice criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternatives".*

Introduction

The Analytic Hierarchy Process (AHP) is due to Saaty (1980) and is often referred to, eponymously, as the Saaty method. It is popular and widely used, especially in military analysis,(though it is not, by any stretch of the imagination, restricted to military problems).

In fact, it can be employ from the choice of a school for a child (which Saaty did for his son), through to the planning of transportation systems. There is much more to the AHP than we have space for but I will concentrate it for my project aspects.

The Basic Principles of AHP

Saaty (1994) described the analytic hierarchy process (AHP) as a decision making approach based on the “innate human ability to make sound judgments about small problems” (page 21). Desirable characteristics of such an approach include simplicity, usefulness for both individuals and groups, accommodative of intuition, compromise, and consensus building, and without prejudice toward specialized skills or knowledge. Saaty suggested AHP as a process that requires structuring the decision problem to demonstrate key elements and relationships that elicits judgments reflecting feelings or emotions, and whose judgments can be represented by meaningful numbers having ratio properties. These numerical representatives can be used to generate weights or priorities that represent the relative importance of decision criteria. Finally, alternatives can be compared to some absolute standard (as was done in this case) or to each other such that the comparison results and the criteria priorities can be synthesized into single statistics, each representing an alternative that can be further analyzed for sensitivity to changes in judgments. The structure of AHP consists of a hierarchy of criteria and sub-criteria cascading from the decision objective or goal. By making pair-wise comparisons at each level of the hierarchy, participants can develop relative weights, called priorities, to differentiate the importance of the criteria. The scale recommended by Saaty (1994) is 1 through 9, with 1 meaning no difference in importance of one criterion in relation to the other and 9 meaning one criterion is extremely more important than the other, with increasing degrees of importance in between. Only half the comparisons need be made; the “reverse” comparisons simply use the reciprocal values in the matrix of comparisons that results. The essence of the AHP calculations involves solving an eigenvalue problem involving this reciprocal matrix of comparisons.

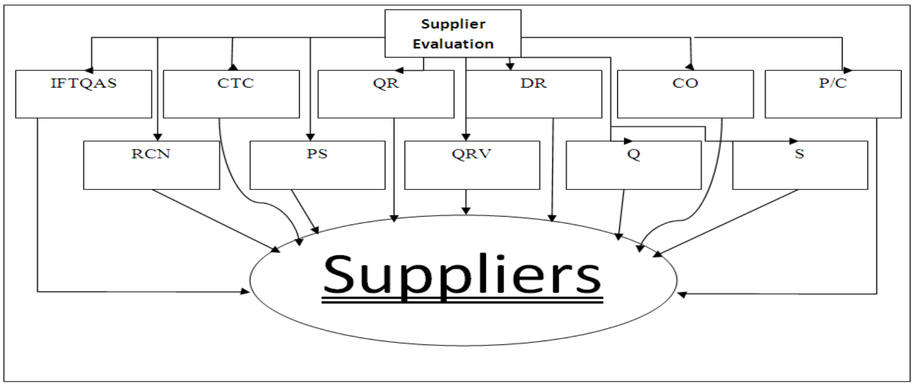

Figure 1: Hierarchical Model for Supplier Evaluation

Its essence is to construct a matrix expressing the relative values of a set of attributes which are formed by the judgments and each of these judgments is assigned a number on one common scale (adapted from Saaty) is given in Table-3.1

Table 3.1: The Saaty Rating Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favour one over the other.
5	Much more important	Experience and judgment strongly favour one over the other.
7	Very much more important	Experience and judgment very strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important.	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate Values	When compromise is needed

A basic, but very reasonable, assumption is that if attribute A is absolutely more important than attribute B and is rated at 9, then B must be absolutely less important than A and is valued at 1/9. These pair-wise comparisons are carried out for all factors to be considered, usually not more than 7, and the matrix is completed. The matrix is of a very particular form which neatly supports the mathematical calculations.

The next step is the calculation of a list of the relative weights, importance, or value, of the factors which are relevant to the problem in question (technically, this list is called an eigenvector). The final stage is to calculate a Consistency Ratio (CR) to measure how consistent the judgments have been relative to large samples of purely random judgments. If the CR is much in excess of 0.1 the judgments are untrustworthy because they are too close for comfort to randomness and the exercise is valueless or must be repeated. It is easy to make a minimum number of judgments after which the rest can be calculated to enforce a perhaps unrealistically perfect consistency.

As the AHP's true subtlety lies in the fact that it is a *Hierarchy* process. The first eigenvector has given the relative importance attached to requirements, but different options contribute to differing extents to the satisfaction of those requirements. Thus, subsequent matrices can be developed to satisfy the needs of the firm. (The matrices from this lower level in the hierarchy will each have their own eigenvectors and CRs.) The final step is to use standard matrix calculations to produce an overall vector giving the answer we seek, namely the relative merits of different firm's requirements.

Analytic Hierarchy Process (AHP), since its invention, has been a tool at the hands of decision makers and researchers, and it is one of the most widely used multiple criteria decision-making tools (Omkarprasad & Kumar, 2006). Many outstanding works have been published based on AHP. They include applications of AHP in different fields such as planning, selecting best alternative, resource allocations, resolving conflict, optimization, etc., as well as numerical extensions of AHP (Vargas, 1990). Akarte (2001) used AHP to select the best casting suppliers from the group of evaluated suppliers. The evaluation procedure took care of about 18 different criteria. These were segregated into four groups namely: product development capability, manufacturing capability, quality capability, and cost and delivery. Out of 18 different criteria, six were of objective and twelve were of subjective types. The evaluation method of this model is based on relative performance measure for each supplier for subjective (qualitative) criteria which is obtained by quantifying the ratings expressed in quantitative terms. The supplier who has the maximum score is selected. Tam and Tummala (2001) have used AHP in vendor selection of a telecommunication system, which is a complex, multi-person, multi-criteria decision problem.

Hand field, Walton and Sroufe (2002) studied Environmental criteria to supplier assessment by transforming purchasing in to a more strategic function. The authors integrated the environmental issues to make purchasing managers introduce dimensions in to their decisions, for which both qualitative and quantitative factors complicate the problem. By applying AHP in environmental criteria to supplier assessment, the authors were able to solve the above problem. AHP method may integrate environmental criteria in the sourcing decision process for supplier selection.

Supplier selection problem is a group Multiple Criteria Decision-Making (MCDM) out of which quantities criteria has been considered for supplier selection in the previous and existing decision models so far (Chen-Tung et al., 2006). In Multiple Criteria Decision-Making (MCDM), a problem is affected by several conflicting factors in supplying selection, for which a purchasing manager must analyze the trade off among the several criteria. MCDM techniques support the decision-makers (DMs) in evaluating a set of alternatives. Depending upon the purchasing situations, criteria have varying importance and there is a need to weigh them (Dulmin & Mininno, 2003). For Multiple Criteria Decision-Making (MCDM) problem of ABC steel manufacturing company a unique and suitable method is needed to facilitate the supplier selection and consequently provide the company with a proper and economical system for ordering raw materials. The analytic hierarchy process (AHP) has found widespread application in decision making problems, involving multiple criteria in systems of many levels (Liu & Hai, 2005). This method has the ability to structure complex, multi-person, multi attribute, and multi-period problem hierarchically (Yusuff, PohYee & Hashmi, 2001). The AHP can be very useful in involving several decision-makers with different conflicting objectives to arrive at a consensus decision (Tam & Tummala, 2001). The AHP method is identified to assist in decision making to resolve the supplier selection problem in choosing the optimal supplier combination (Yu & Jing, 2004).

The weighted sum model (or WSM) is the earliest and probably the most widely used method (Fishburn, 1967). The WSM method can be applied without difficulty in single-dimensional cases where all units of measurement are identical (for example, dollars, mileage, hours, etc.). Because of the additivity utility assumption, a conceptual violation occurs when the WSM is used to solve multidimensional problems in which the units are different (Triantaphyllou et. al., 1998).

The weighted product model (or WPM) is very similar to the WSM. The main difference is that instead of addition in the model there is multiplication. Each alternative is compared with the others by multiplying a number of ratios, one for each criterion. Each ratio is raised to the power equivalent to the relative weight of the corresponding criterion. In general, in order to compare the alternatives *AK* and *AL*, the following product (Bridgman, 1922 and Miller and Starr, 1969)

2. SUPPLIER EVALUATION CRITERIA

On the basis of literature review, following (please refer Table 1) are the criteria selected by the candidate for the purpose of supplier evaluation:

Table 1: Criteria for Supplier Evaluation

S. No	Criteria	Abbreviation	Reference
1.	Infrastructure Facilities , Technology & QA System	IFTQAS	Gupta and Gupta (2012); Elanchezhian et al. (2010)
2.	Conformance Test Certificate	CTC	Gupta and Gupta (2012)
3.	Quality Rating	QR	Gupta and Gupta (2012); Elanchezhian et al. (2010); Tsai et al. (2003)
4.	Delivery Rating	DR	Gupta and Gupta (2012); Elanchezhian et al. (2010); Tsai et al. (2003)

5.	Co-operation with organization	CO	Gupta and Gupta (2012)
6.	Price/cost	P/C	Elanchezhian et al. (2010); Tsai et al. (2003)
7.	Responsiveness to customer needs	RCN	Elanchezhian et al. (2010)
8.	Professionalism of salesperson	PS	Elanchezhian et al. (2010)
9.	Quality of relationship with vendor	QRV	Elanchezhian et al. (2010)
10.	Quantity	Q	Tsai et al. (2003)
11.	Services	S	Tsai et al. (2003)

III. PROPOSED RESEARCH METHODOLOGY

The proposed research methodology is consisting of the following stages:

- Literature survey
- Criteria finalization for supplier evaluation and Efficient supplier selections
- Questionnaire development for AHP,WSM and WPM
- Data collection
- Prioritization of candidates
- Comparative analysis of AHP, WSM and WPM methods

The detailed steps in the methodology are as follows:

- First of literature review will be done for identifying the supplier evaluation and Efficient supplier selection criteria (completed by the candidate);
- After identifying the major criteria in supplier evaluation and Efficient supplier selection, questionnaire development will be accomplished (accomplished by the candidate);
- After getting the questionnaires filled from the company personnel, next step is to get values of vendors for the methods of AHP, WSM and WPM. For the calculations of AHP, Expert Choice software will be used and for WSM and WPM methods manual calculations are proposed;
- In next step, comparative analysis of suppliers using hybrid AHP, AHP-WSM and AHP-WPM models will be accomplished;
- In the last step, the vendor will be declared as the best vendor for which, AHP, AHP-WSM and AHP-WPM score is maximum. If scores from both methods yield different values, some another analysis will be suggested to the firm. Hierarchical model for supplier evaluation is shown in Figure 1. Details of AHP, WSM and WPM are as follows:

1. ANALYTICAL HIERARCHY PROCESS

The Analytic Hierarchy Process (AHP) is a structured technique for helping people deal with complex decisions. Rather than prescribing a *correct* decision, the AHP helps people to determine one. Based on mathematics and human psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. The AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. It is used throughout the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education (Saaty, 1991).

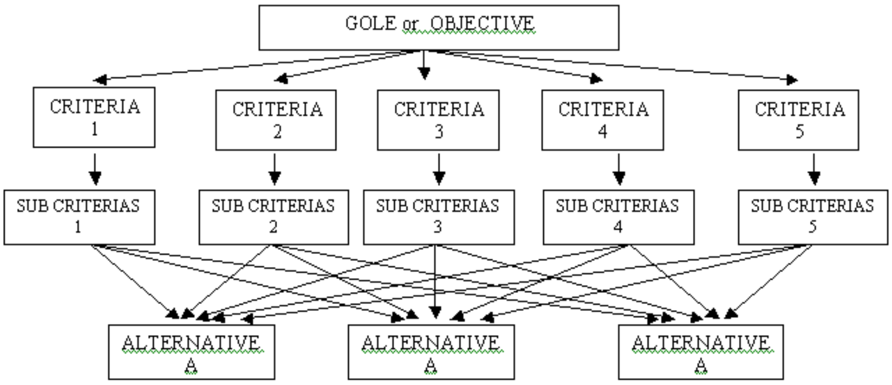

Figure 3.2: An AHP Model Hierarchy Structure

Saaty has defined the following steps for applying AHP (Kumar, 2006 and Saaty, 1980, 1977):

i. Define the problem and determine its goal,

ii. Structure the hierarchy with the decision maker's objective at the top with the intermediate levels capturing criteria on which subsequent levels depend and the bottom level containing the alternatives, and

iii. Construct the set of n× n pair wise comparison matrices for each to the lower levels with one matrix for each element in the level immediately above. The pair wise comparisons are made suing the relative measurement scale. The pair wise comparisons capture a decision maker's perception of which element dominates the other.

i. There are n× (n-1)/2 judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair wise comparison.

ii. The hierarchy synthesis function is used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

iii. After all the pair wise comparisons are completed; the consistency of the comparisons is assessed by using the Eigen value, **λ**, to calculate a consistency index, CI:

$$C.I. = (\lambda-n)/ (n-1 \quad (1)$$

Where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (C.R.).

$$C.R. = C.I. /R.I. \quad (2)$$

Where R.I. stands for Random Consistency Index, which with the appropriate value is given in Table 3 Saaty (1980) suggests that the C.R. is acceptable if it does not exceed 0.10. If the CR is greater than 0.10, the judgment matrix should be considered inconsistent. To obtain a consistent matrix, the judgments should be reviewed and repeated.

Table 3: Average Random Consistency Index (Saaty, 1980)

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency Index (R.I.)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The AHP uses relative values instead of actual ones. Thus, it can be used in single- or multi-dimensional decision making problems (Saaty, 1977), and hence is used in the following problem.

2. WEIGHTED SUM MODEL

The weighted sum model (or WSM) is probably the most commonly used approach, especially in single dimensional problems. If there are *M* alternatives and *N* criteria then, the best alternative is the one that satisfies (in the maximization case) the following expression (P.C. Fishburn, 1967):

$$A_{WSM}^{*} = \max_{i} \sum_{j-1}^{N} q_{ij} w_j, \text{ for i= 1, 2, 3… M.} \quad (3)$$

where *AWSM** is the WSM score of the best alternative, *N* is the number of decision criteria, *aij* is the actual value of the *i-th* alternative in terms of the *j-th* criterion, and *Wj* is the weight of importance of the *j*-th criterion. The assumption that governs this model is the additive utility assumption. That is, the total value of each alternative is equal to the sum of products given as (3). In single-dimensional cases, in which all the units are the same; the WSM can be used without difficulty.

3. WEIGHTED PRODUCT MODEL

The weighted product model (or WPM) is very similar to the WSM. The main difference is that instead of addition in the model there is multiplication. Each alternative is compared with the others by multiplying a number of ratios, one for each criterion. Each ratio is raised to the power equivalent to the relative weight of the corresponding criterion. In general, in order to compare the alternatives A_K and A_L, the following product (Bridgman, 1922 and Miller and Starr, 1969) has to be calculated:

$$R(A_K / A_L) = \prod_{j=1}^{N} (a_{Kj} / a_{Lj} \text{"})^{wj} \quad (4)$$

Where, *N* is the number of criteria, *aij* is the actual value of the *i-th* alternative in terms of the *j-th* criterion, and *Wj* is the weight of importance of the *j-th* criterion.

If the term $R\ (A_K / A_L)$ is greater than to one, then alternative *AK* is more desirable than alternative *AL* (in the maximization case). The best alternative is the one that is better than or at least equal to all the other alternatives. The WPM is sometimes called ***dimensionless analysis*** because its structure eliminates any units of measure.

IV. CONCLUSIONS

Evaluating a supplier and efficient supplier selections has always become a difficult task for a firm as it may involve many criteria of opposite nature. Many times cost determines the supplier. However, now a days, this trend is shifting towards other parameters also. In many firms, emphasis on quality, on time delivery and professionalism are also considered as determining criteria. Selection of criteria and number of criterion may vary from industry to industry and even from person to person. In this research selection of criteria was done on the basis of literature survey which may be modified as the result of discussions with the industry personnel. In present research work, all the necessary attempts were made for investigating criteria for supplier selection and originality of the work, yet extensive research may be done in this field.

There are some limitations of the research work also. Sometimes, it becomes very difficult for a supplier to give numerical values to the criteria. A supplier selection criterion is a qualitative term and for the purpose of calculations it must be quantifiable. In order to quantify the criteria we assign the numerical values to the criteria. At this point human behavior interferes. Many a times, due to fuzziness of our mind we cannot assign the numerical values to the qualitative terms. In order to quantify the qualitative data, different versions of AHP are being provided by the researchers but they are all in their early stages and are seeking further modifications. Therefore, a strong base should be investigated for assigning such numerical values. Other two methods (namely WSM and WPM) are also suffering from the same problem. However, both the three methods employed in the research work are very popular and universally adopted. In this manner, the combined AHP-WSM model and combined AHP- WPM model and AHP Model and Software seems to give desirable results.

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