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Selection of Supply Chain Partner For Coke Energy Ltd. India using Combined AHP (analytical hierarchy process)-WSM (weighted sum model) Approach

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Abstract

A supply chain (SC) consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves. Supplier selection is one of the basic activities of Supply Chain Management (SCM). A best supplier for the firm is one who has implemented the concept of customer's satisfaction successfully in his firm. Therefore the evaluation of suppliers becomes a task of prime importance. Such a case may be treated as a case of multi criteria decision making for the solution of which two Multi Criteria Decision Making (MCDM) techniques may be used. In present paper the use of Analytical Hierarchy Process (AHP) and Weighted Sum Model (WSM) is shown with an example. Firstly, the weights of criteria are calculated by using AHP, and then by implementing WSM, assessment of suppliers has been done.

Keywords: Suppliers, Analytical Hierarchy Process (AHP), Weighted Sum Model (WSM).

Introduction

Supplier selection is becoming increasingly important as companies continue to develop more collaborative and long-term relationships with their suppliers. As discussed by Timmerman (1986), close working relationships with high performing suppliers are essential in modern production environments. The interaction between the organization and the suppliers should be two way so as to make the suppliers aware of their performance so that it would be helpful for them to cope up with the organization's need. When a supplier selection decision needs to be made, the organization should develop a set of evaluation criterions that can be used to evaluate the suppliers and to find out the potential suppliers by rating them. Traditionally, supplier evaluation models were based on financial measures with less emphasis on other tangible and intangible criteria. However, with the widespread use of manufacturing philosophies such as just-in-time (JIT) emphasis has shifted to the simultaneous consideration of multiple supplier attributes in the supplier evaluation process. Application of various attributes varies with situations and the organization should give proper weightings to each attribute as per the situation. Proper evaluation and rating of suppliers helps the organization not only in benchmarking the suppliers but it also helps the organization to reduce purchase risk, maximize overall value to the purchaser (Gupta and Gupta, 2012). A trade-off between these tangible and intangible factors is essential in selecting the best supplier (FarzadTahriri et.al, 2008). The work incorporates Weighted Sum Model (WSM) in choosing the best suppliers. The results suggest that WSM 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 WSM-based supplier selection model is formulated and then applied to a real case study for a small scale industry. Supplier selection criteria have been standardized using the principle of standard deviation. 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 WSM model, which by scoring the performance of suppliers is able to reduce the time taken to select a vendor.

Literature Review

Analytical Hierarchy Process (AHP) and Weighted Sum Model (WSM)

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, Ching-Torng&Huanget, 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).

Supplier Selection Criteria

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). Among applications of AHP method for the field of selecting the best alternative, the following publications are specified to supplier selection. Ghodsupour and O'Brion (1998) studied the conflicts between two tangible and intangible factors, based on AHP method, i.e. qualitative and quantitative, in order to choose the best suppliers. They integrated AHP and Linear Programming to consider both tangible and intangible factors in choosing the best suppliers and placed the optimum order quantities among them such that by using integrated AHP and LP the Total Value of Purchasing (TVP) becomes maximum. This model can apply to supplier selection with or without capacity constraints. Yahya and Kingsman (1999) used Saaty's (1980) AHP method to determine priority in selecting suppliers. The authors applied vendor rating in supplier selection and in deciding how to allocate business, as well as in determining where scarce development effort is applied. This study is performed for a government sponsored entrepreneur development program in Malaysia. The particular Umbrella Scheme of Malaysia's furniture industry was applied using this method. The selection of vendors in Scheme Company has to be done not only to ensure benefits to the purchasers but also to develop the vendors. The multiple and conflicting objectives, both getting good quality furniture companies improve their operations, imply that the criteria to use in selecting vendors might be different than that for normal commercial purchasing of goods. Given the need to identify the strengths and weakness of vendors for the development purposes of the scheme, a vendor rating system is essential and cannot be avoided. 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. The authors have found AHP to be very useful in involving several decision makers with different conflicting objectives to arrive at a consensus decision. The decision process, as a result, is systematic and reduces time to select the vendor. Handfield, 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

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above problem. AHP method may integrate environmental criteria in the sourcing decision process for supplier selection. In order to make a company unique, Yu and Jing (2004) developed a new decision model to choose the optimal supplier combination for Tian Jin Electric Construction Company. According to the previous research by Tam and Tummala (2001), Yu and Jing (2004) found out, through research, that trust between suppliers and buyers is the best criterion for selecting optimal supplier which reduces the cost, by using AHP and Linear Programming (LP). The authors established trust for Tian Jin Electric Construction Company. Through research, the authors came up with the fact that quality criteria can be more influential in supplier selection than quantity, although other criteria such as: cost, quality and delivery were used and trust was focused on as important criteria for supplier selection. Liu and Hai (2005) studied supplier selection by integrating a collaborative purchasing program. Based on the above literature review the following model has been proposed.

In this proposal, the supplier selection criterion has been developed on the basis of literature review and a series of informal discussions with the academicians and industry personnel. The details of the criteria are given as follows (see Table 1):

S.No	Criteria	Reference
•	On-time delivery	FarzadTahriri *et.al,* (2008), C. Elanchezhian et al.,(2010)
•	Product quality	FarzadTahriri *et.al,* (2008), C. Elanchezhian et al.,(2010)
•	Price/cost	FarzadTahriri *et.al,* (2008), C. Elanchezhian et al.,(2010)
•	Facility and technology	FarzadTahriri *et.al,* (2008), C. Elanchezhian et al.,(2010)
•	Responsiveness to customer needs	FarzadTahriri *et.al,* (2008), C. Elanchezhian et al.,(2010)
•	Professionalism of salesperson	FarzadTahriri *et.al,* (2008), C. Elanchezhian et al.,(2010)
•	Quality of relationship with vendor	FarzadTahriri *et.al,* (2008), C. Elanchezhian et al.,(2010)
•	Performance History	FarzadTahriri *et.al,* (2008)
•		FarzadTahriri *et.al,* (2008)
•		FarzadTahriri *et.al,* (2008)
•		FarzadTahriri *et.al,* (2008)
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•		FarzadTahriri *et.al,* (2008)
•		FarzadTahriri *et.al,* (2008)
•		FarzadTahriri *et.al,* (2008)

Table 1: Criteria of Supply Chain Partner Selection

Research Methodology

The various stages involved in research methodology are as follows:

- Data collection
- Questionnaire design, and
- Establishment of scores of supply chain partners

The above mentioned stages were executed in the following manner:

- First of all a brief survey of supplier selection criteria was made with the help of available literature and a series of informal discussions with the industry personnel and academicians
- The list of criteria, prepared from the extensive literature survey and informal discussions, then circulated among various industry personnel and academicians for the purpose of generalization of the criteria. For this purpose, a five point Likert Scale was used and the standard deviation of the responses was calculated. After eliminating smaller values, modified list of criteria obtained. At the last, suggestions from the decision maker from the main firm were also taken for any modification or reduction in the criteria.
- Now, priorities of the criteria involved were calculated with the help of online CGI software. For this purpose, pair wise comparison between the criteria was made by the main firm personnel. For this purpose, saaty's scale was used.
- After getting the priorities of different criteria, values were assigned by the main firm personnel to different suppliers for different criteria (according to their performances).
- Finally, suppliers' values (assigned by main firm personnel) were multiplied by corresponding criteria values and their summation gave the final WSM score for

different suppliers. The supplier had chosen for which WSM score was the maximum.

Analytical Hierarchy Process (AHP)

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. An AHP hierarchy is a structured means of describing the problem at hand. It consists of an overall goal, a group of options or alternatives for reaching the goal, and a group of factors or criteria that relate the alternatives to the goal. In most cases the criteria are further broken down into sub criteria, sub-sub criteria, and so on, in as many levels as the problem requires (Fig. 1).The hierarchy can be visualized as a diagram like the one below, with the goal at the top, the alternatives at the bottom, and the criteria filling up the middle. In such diagrams, each box is called a node. The boxes descending from any node are called its children. The node from which a child node descends is called its parent. Applying these definitions to the diagram below, the five Criteria are children of the Goal, and the Goal is the parent of each of the five Criteria. Each Alternative is the child of each of the Criteria, and each Criterion is the parent of three Alternatives (T. L Saaty, 1990, 1994).

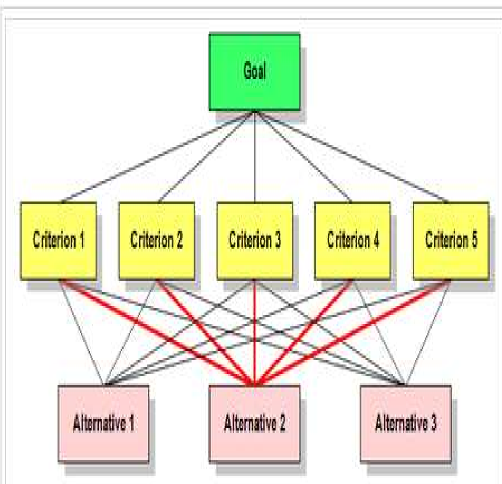

Figure 1: Hierarchical Structure for AHP (T. L Saaty, 1977 and 1994)

Once the hierarchy is built, the decision makers systematically evaluate its various elements, comparing them to one another in pairs. In making the comparisons, the decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations. For this purpose a pair wise comparison scale is used, which is shown in the Table.2 given below. After that AHP converts the evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. Priorities are numbers associated with the nodes of the hierarchy. The priority of the Goal is taken as 1.000. The priorities of the children of any Criterion can also vary but will always add up to 1.000, as will those of their own children, and so on down the hierarchy. If the priorities within every group of child nodes are equal then the priorities are called Default Priorities. The priority of an attribute with respect to the ultimate goal is called Global Priority. The priorities indicate the relative weights given to the items in a given group of nodes. Depending on the problem at hand, "weight" can refer to importance, or preference, or likelihood, or whatever factor is being considered by the participants. This capability distinguishes the AHP from other decision making techniques. In the final step of the process, numerical priorities are derived for each of the decision alternatives. Since these numbers represent the alternatives' relative ability to achieve the decision goal, they allow a straightforward consideration of the various courses of action.

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	**Definition**	**Explanation**
1	**Equal importance**	Two elements contribute equally to the objective
3	**Moderate importance**	Experience and judgment slightly favor one element over another
5	**Strong importance**	Experience and judgment strongly favor one element over another
7	**Very strong importance**	One element is favored very strongly over another; its dominance is demonstrated in practice
9	**Extreme importance**	The evidence favoring one element over another is of the highest possible order of affirmation

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Intensities of 2, 4, 6 and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc., can be used for elements that are very close in importance.

Table2: Pair Wise Comparison Scale (T. L Saaty, 1977, 1980 and P. Kumar, 2006)

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

- Define the problem and determine its goal,
- 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
- 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 (as discussed above). The pair wise comparisons capture a decision maker's perception of which element dominates the other.
- 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.
- 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.
- 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:

$CI = (\lambda - n)/(n-1)$ **(1)**

Where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 3, given below. Saaty (1980) suggests that the CR 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.

Weighted Sum Model (WSM)

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):

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

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 **(2)**. In single-dimensional cases, in which all the units are the same; the WSM can be used without difficulty (E.Triantaphyllou, *et. al.,* 1998).

Case Study

The research work is based on the selection of a potential supplier for a firm. In this research work, coke industry is targeted. The reason for targeting this industry is that it is very versatile industry and needs many suppliers for fulfilling its needs. The name of firm selected for the research work is Coke India Ltd., Indore (M.P). In the firm the analysis was made on four suppliers, which was purely the decision of the manager. Details of calculations involved are as follows:

- First of all criteria finalization was done by the candidate. For this purpose, the standard deviation for the list of criteria was determined (see Table 4). For the purpose of getting responses, a five point likert scale was used. The respondents were from industry and academics. A sample of fifty respondents was taken to make the distribution normal.

S.No	Criteria	Total Respondents	Total Rating	Average	Standard Deviation
•	On-time delivery	50	66	1.32	0.586932531
•	Product quality	50	186	3.72	1.370833204
•	Price/cost	50	177	3.54	1.763692786
•	Facility and technology	50	80	1.6	0.670059394
•	Responsiveness to customer needs	50	76	1.52	0.677329691
•	Professionalism of salesperson	50	88	1.76	0.37032804

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•	Quality of relationship with vendor	50	88	1.76	0.350509833
•	Performance History	50	83	1.66	0.823382769
•	Trust	50	160	3.2	1.309307341
•	Warranty	50	100	2	0.999795898
•	Discipline	50	95	1.9	0.418451958
•	Environmental performance	50	88	1.76	0.404061018
•	Management and organization	50	104	2.08	0.471212071
•	Technical capability	50	100	2	0.453557368
•	Capacity	50	99	1.98	0.443087498

Table 4: Details of Standard Deviations for criteria

- From the Table 4, it was observed that some criteria such as professionalism of the sales person, discipline etc., got very lesser values of standard deviations. As per advice of the main firm personnel, professors of the institute and some industry personnel, these criteria were then eliminated from the list of criteria. The modified list of criteria, thus, obtained is shown in Table 5.

S.No	Criteria	Total Respondents	Total Rating	Average	Standard Deviation
•	On-time delivery	50	66	1.32	0.586932531
•	Product quality	50	186	3.72	1.370833204
•	Price/cost	50	177	3.54	1.763692786
•	Facility and technology	50	80	1.6	0.670059394
•	Responsiveness to customer needs	50	76	1.52	0.677329691
•	Performance History	50	83	1.66	0.823382769
•	Trust	50	160	3.2	1.309307341
•	Warranty	50	100	2	0.999795898

Table 5: Modified List of Criteria

- Now priorities of the criteria with respect to the goal were calculated. For this purpose pair wise comparison of the criteria were made by the decision maker and the candidate. For the purpose of pair wise comparison, help of standard deviation data was also taken. Pair wise comparison was made by using saaty's pair wise comparison scale. Details of pair wise comparisons are given in Appendix 1. The values obtained as result of pair wise comparison when arranged in pair wise comparison matrix, the following pair wise comparison obtained (refer Table 6):

FROM / TO	On Time Delivery	Product Quality	Price/ Cost	Facility And Technology	Responsiveness Of Customer Needs	Performance History	Trust	Warranty
On-time delivery	1	1	2	5	4	6	2	9
Product quality	1	1	2	1	2	1	1	5
Price/cost	½	½	1	3	1	1/2	1	3
Facility and technology	1/5	1	1/3	1	1/3	1	2	2

Responsiveness to customer needs	¼	½	1	3	1	3	1/2	3
Performance History	1/6	1	2	1	1/3	1	1/3	2
Trust	½	1	1	½	2	3	1	5
Warranty	1/9	1/5	1/3	1/2	1/3	1/2	1/5	1

Table 6: Pair wise Comparison Matrix

- Next step was to calculate the priorities of different criteria. For this purpose, help of online CGI Software was taken by the candidate. Online CGI software is very fast and efficient software to solve AHP problem up to nine parameters. Besides, it can perform fuzzy AHP calculations and sensitivity analysis. It is available on www.cgi-ahpcalculations.com. The details of priorities obtained are mentioned in Table 7. CGI software also calculates the values for consistency index which finally yields consistency ratio. The value of consistency ratio is also supplemented along with the values of priorities of criteria in Table 7 (also refer Figure 2 for graphical details).

S.NO	CRITERIA	LOCAL PRIORITY	GLOBAL PRIORITY
•	On-time delivery	0.289489	0.289489
•	Product quality	0.150334	0.150334
•	Price/cost	0.108806	0.108806
•	Facility and technology	0.0874715	0.0874715
•	Responsiveness to customer needs	0.115892	0.115892
•	Performance History	0.081465	0.081465
•	Trust	0.135365	0.135365
•	Warranty	0.0311773	0.0311773
CR= 0.098< 0.10			

Table 7: Values of Priorities of Criteria from CGI Software

- In the next step, WSM score for different candidates was calculated. For this purpose , systematically designed questionnaire were circulated to the decision makers of the firm and after getting their collective judgments, judgment data matrix was formed (Table 8). After formation of judgment data matrix WSM scores were calculated. Experts from the main firm were requested to fill the entries against each data from 1 to 10, where 1 for the least valuable and 10 for the most valuable supplier for the given criteria.
- From the data obtained from judgment data matrix supplier II was suggested as the best supplier for the firm as this supplier scored the maximum WSM score of 7.029. After the supplier IV, supplier I and supplier III were suggested as the suppliers for the firm. This suggestion was purely made on the basis of WSM score obtained by the suppliers. Figure 3 shows these details graphically.
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Criteria/ Suppliers	On Time Delivery	Product Quality	Price/ Cost	Facility And Technology	Responsiveness Of Customer Needs	Performance History	Trust	Warranty	WSM SCORE
Weights	0.289	0.150	0.108	0.087	0.115	0.081	0.135	0.031	Σ = 1.00

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I	7	4	7	6	3	8	5	4	**5.171**
II	8	6	7	6	4	8	9	9	**7.092**
III	2	5	9	5	4	7	8	9	**5.121**
IV	5	8	9	6	3	2	7	8	**5.893**

Table 8: Judgment Data Matrix

Conclusion

In 21st century, India has emerged as a fast developing country. Today, all most all the industries of the country are electricity based. For this reason it becomes very essential to have keen interest in the development of these industries and fulfilling their needs. It is an established fact that supply chain partners play very important role in the development of any industry. In present research work, a strong emphasis has been made in selecting a potential supplier for the firm. From this research work it is suggested to the main firm to choose the supplier governed by the analysis.

Discussions

Choosing a supplier 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 – 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 and a series of informal discussions with the industry personnel. Sometimes the industry personnel become unable to give the right definition of the criteria he is using. In such cases, research may go in wrong direction.

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.

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.

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