Analytical Hierarchy Process Applied to Vendor Selection Problem: Small Scale, Medium Scale and Large Scale Industries

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Abstract

Vendor selection is an important process for an effective inventory management. This paper deals with a brief review of the literature regarding AHP technique and its relevancy to its application in vendor selection process. Vendor selection is a complicated process. This process needs evaluation of multiple criteria and various constraints associated with them.

This paper has been developed based upon the views of various experts. A well researched methodology has been adopted for the synthesis of priorities and the measurement of consistencies. A consistency ratio has also been calculated. Industries has been classifies into small scale, medium scale and large scale. Various criteria for vendor selection process as received from the expert have been identified. These criteria have been compared using average matrix, priority matrix and overall priority matrix.

After analysis of the results we found that for large scale industries, vendor reliability, product quality and vendor experience are the top three vendor selection problems that needs to be taken up on priority for effective vendor selection.

Keywords: Vendor Selection, Analytical Hierarchy Process

Introduction

This paper endeavors to investigate the problem of vendor selection using Analytical Hierarchy Process (AHP) in Small-scale industries (SS), Medium-scale industries (MS) and Large-scale industries (LS) under different criteria for the same. In India, industries having investment in plant and machinery less than rupees ten million are called small-scale industries (Singh et al, 2003). Similarly, industries having investments between ten million and one thousand million in plant and machinery are considered as medium scale industries (Karandikar, 1999), whereas for large scale industries, investments in plant and machinery is more than one thousand million has been considered as criteria (Singh et al, 2005). Decision criteria used for vendor selection can be different depending on the size of a buyer organisation. Large companies use a different set of criteria and a formal approach when selecting suppliers compared to small and medium sized enterprises (Pearson et. al., 1995).

AHP makes the selection process very transparent. It also reveals the relative merits of alternative solutions for a Multi Criteria Decision Making (MCDM) problem. (Drake, P.R., 1998). AHP approach is a subjective methodology (Cheng and Li, 2001); information and the priority weights of elements may be obtained from a decision-maker of the company using direct questioning or a questionnaire method. It is generally agreed in the literature that the following makes the supplier selection decision making process difficult and/or complicated (de Boer, 1998, Murlidharan et.al., 2001):

- Multiple criteria – both qualitative and quantitative
- Conflicts amongst criteria – conflicting objectives of the criteria
- Involvement of many alternatives – due to fierce competition
- Internal and external constraints imposed on the buying process

Objectives & Issues

In modern era of industrialization and globalization, every organization has to ensure that their product must meet the international standards and quality requirements to remain competent in this rapidly changing industrial environment. To achieve this, it is a necessary requirement that vendor from which the organization is getting the supply of raw material or any other kind of necessary inputs should be selected correctly. This multi criteria decision making problem is now a part of day to day affair of all the organizations. The main objective of the paper is to rate vendors (large scale, medium scale and small scale) with respect to various criteria. Here in this paper we are presenting an easy to understand approach for solving this problem. For this, a questionnaire based study has been adopted and views of experts from industry and academia have been taken.

Methodology

Problem of selection of vendor has been dealt with by using questionnaire based study. A structured questionnaire was framed and all the criteria are rated by the professional of various fields. The framework adopted for this study is as shown in figure1.

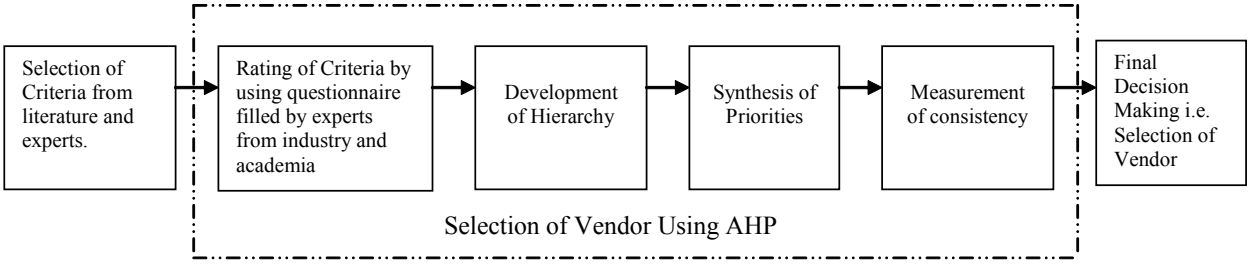

Figure 1: Framework of the study

Analytical Hierarchy Process: A Brief Review

The foundation of the Analytic Hierarchy Process (AHP) is a set of axioms that carefully delimits the scope of the problem environment (Saaty 1986). It is based on the well- defined mathematical structure of consistent matrices and their associated eigenvector's ability to generate true or approximate weights, Merkin, (1979); Saaty (1980, 1994). The AHP methodology compares criteria, or alternatives with respect to a criterion, in a natural, pair wise mode. To do so, the AHP uses a fundamental scale of absolute numbers that has been proven in practice and validated by physical and decision problem experiments. The fundamental scale has been shown to be a scale that captures individual preferences with respect to quantitative and qualitative attributes just as well or better than other scales (Saaty 1980, 1994). It converts individual preferences into ratio scale weights that can be combined into a linear additive weight for each alternative. The resultant can be used to compare and rank the alternatives and, hence, assist the decision maker in making a choice.

In this study, all the criteria have been rated from 1 to 9 versus all other criteria as well as versus small scale, medium scale and large scale industries, accordingly as stated in the Table 1 (Crowe et al., 1998; Saaty, 2000; Hafeez et al., 2002)

Table 1: Scale of Preference between Two Elements

S.No.	Preference weights/ level of importance	Definition	Explanation
1	1	Equally preferred	Two activities contribute equally to the objective
2	3	Moderately preferred	Experience and judgment slightly favour one activity over another
3	5	Strongly preferred	Experience and judgment strongly or essentially favour one activity over another
4	7	Very strongly preferred	An activity is strongly favoured over another and its dominance demonstrated in practice
5	9	Extremely preferred	The evidence favouring one activity over another is of the highest degree possible of affirmation
6	2,4,6,8	Intermediates values	Used to represent compromise between the preferences listed above
7	Recipro-cals	Reciprocals for inverse comparison	

Based on the ratings obtained through the questionnaire, matrices are formed and the priorities are synthesized using the methodology of AHP. Following are the steps used in this process:

- Synthesis of priorities for all the criteria and measurement of Consistency Ratio (CR).
- Prioritizing of small scale, medium scale and large scale industries as against all the criteria of vendor selection separately.
- Synthesis of overall priority matrix of small scale, medium scale and large scale industries.

Synthesis of Priorities and the Measurement of Consistency

The pair-wise comparisons of the criteria of vendor selection problem generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number of elements at each level. The number of elements at each level decides the order of every matrix of the next higher level. After all matrices are developed, eigenvectors or the relative weights (the degree of relative importance amongst the elements) and the maximum eigenvalue (λmax)

for each matrix are calculated. The λmax value is an important validating parameter in AHP. It is used for calculating the consistency ratio CR (Saaty, 2000) of the estimated vector in order to validate whether the pair-wise comparison matrix provides a completely consistent evaluation. The consistency ratio is calculated as per the following steps:

Step 1 Calculate the eigenvector or the relative weights and λmax for each matrix of order *n*

Step 2 Compute the consistency index for each matrix of order *n* by the formulae:

CI = (λmax -n)/ (n-1)

Step 3 The consistency ratio is then calculated using the formulae:

CR = CI/RI

where Random Consistency Index (RI) varies depending upon the order of matrix. Tables 2 shows the value of the Random Consistency Index (RI) for matrices of order 1 to 10 obtained by approximating random indices using a sample size of 500 (Saaty, 2000).

Table 2: Average random index (RI) based on Matrix Size (Saaty, 2000)

S. No.	Size of Matrix (n)	Random Consistency Index (RI)
1	1	0
2	2	0
3	3	0.52
4	4	0.89
5	5	1.11
6	6	1.25
7	7	1.35
8	8	1.40
9	9	1.45
10	10	1.49

The acceptable CR range varies according to the size of matrix i.e. 0.05 for a 3 by 3 matrix, 0.08 for a 4 by 4 matrix and 0.1 for all larger matrices, n>= 5 (Saaty, 2000, Cheng and Li, 2001). If the value of CR is equal to, or less than that value, it implies that the evaluation within the matrix is acceptable or indicates a good level of consistency in the comparative judgments represented in that matrix. In contrast, if CR is more than the acceptable value, inconsistency of judgments within that matrix has occurred and the evaluation process should therefore be reviewed, reconsidered and improved. An acceptable consistency ratio helps to ensure decision-maker reliability in determining the priorities of a set of criteria.

Prioritizing of Small Scale, Medium Scale and Large Scale Industries

The pair wise comparison of all criteria separately for each type of industries is executed in this step. For each criterion, a priority matrix is obtained for small scale, medium scale and large-scale industries by following the same procedure as stated in previous step 3.2.1.

Synthesis of Overall Priority Matrix

After the synthesis of priority matrices for the criteria of vendor selection as well as for the type of industry in 3.2.1 and 3.2.2 for every criteria, an overall priority matrix is synthesized. This priority matrix is obtained by multiplying the priority matrix obtained for each criterion for various types of industry with the priority matrix obtained by the comparison of criteria itself. The matrix thus synthesized will give the overall priority matrix for small-scale, medium-scale and large-scale industries using the criteria of vendor selection as criteria for the selection of type of industry.

Vendor Selection Using AHP

Evaluation and selection of vendors is a typical multiple criteria decision making (MCDM) problem involving multiple criteria that can be both qualitative and quantitative (Sonmez, M., 2006). Vendor Selection problem involves tangible and intangible criteria. These criteria may vary depending on the type of product being considered and include many judgmental factors (Sarkis, Alluri, 2002), (Jayaraman, Srivastava, Benton, 1999). The various criteria that are important for vendor selection, as evident in literature and from discussions with experts, are price, transportation cost, quality, quality certification, lead time, buffer stock needed, goodwill and reliability of the

vendor, experience of the vendor in the same field etc as shown in figure 2. (Weber et al, 1991; Bajaj et al, 2005). The problem is how to select vendors who can perform optimally on the desired criteria. AHP (Analytical Hierarchy Process) is one of the most extensively used MCDM methods because of ease with which it handles the multi criteria. The criteria based on which the vendor selection problem has been solved in this paper have been tabulated in Table 3 with their used abbreviations.

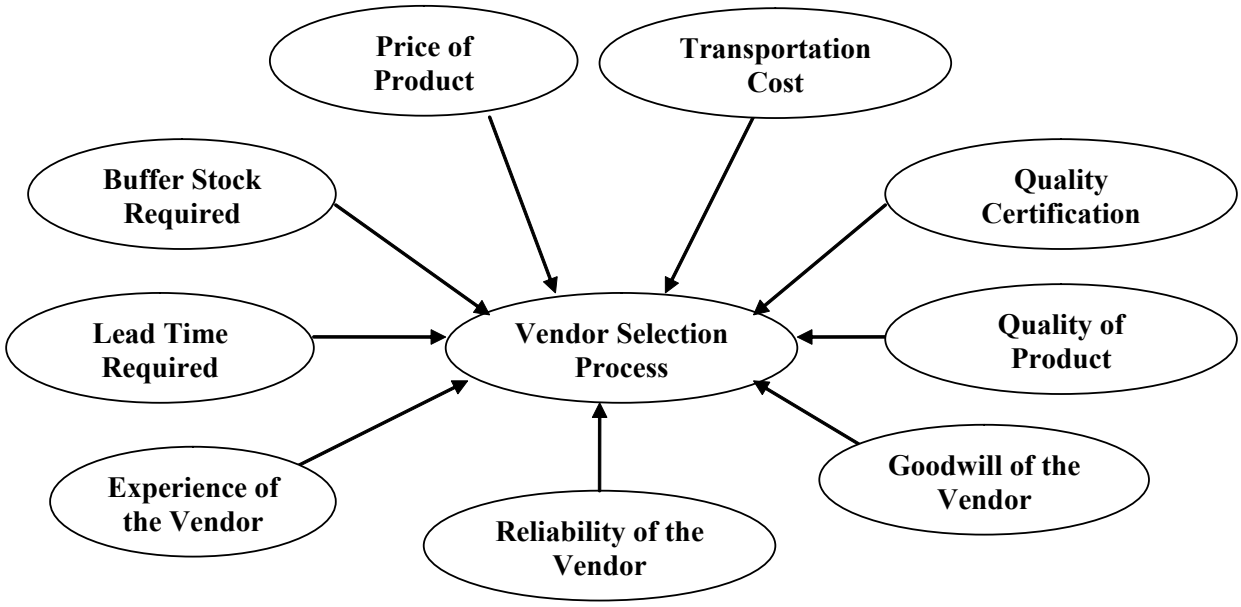

Figure 2.Criteria for Vendor Selection Process

Table 3.Criteria and Abbreviations Used

S.No.	Criteria	Abbreviation Used
1	Price of product	PP
2	Transportation ease and cost	TC
3	Quality certification of the vendor (ISO, ISI certification)	QC
4	Quality of product (based on rejection rate)	QP
5	Goodwill of the vendor	GW
6	Reliability of the vendor	RV
7	Experience of the vendor in the same field	EV
8	Lead time	LT
9	Buffer stock of Inventory required	BS

After the ratings have been obtained through the questionnaire, the average matrix for these ratings has been shown in table 4.

Table 4.The Average Matrix for the Criteria of Vendor Selection

Criteria	PP	TC	QC	QP	GW	RV	EV	LT	BS
PP	1	8	0.2	0.125	3	0.143	0.5	2	2
TC	0.125	1	0.143	0.125	0.2	0.143	0.2	0.333	0.333
QC	5	7	1	0.2	0.333	0.333	0.25	0.5	0.25
QP	8	8	5	1	1	1	1	3	3
GW	0.333	5	3	1	1	0.5	1	0.167	0.2
RV	7	7	3	1	2	1	2	3	3
EV	2	5	4	1	1	0.5	1	2	3
LT	0.5	3	5	0.333	6	0.333	0.5	1	1
BS	0.5	3	4	0.333	5	0.333	0.333	1	1

The maximum value of eigen vector for the above matrix, $\lambda_{max} = 12.63$

Consistency index, C.I. = (λmax -n)/ (n-1) = 0.45

Random Index for the matrix of order 9, R.I. = 1.45

Consistency Ratio, C.R. = C.I./ R.I. = 0.3, which is greater than 0.1.

The responses being taken over from a wide range of experts from various fields, the consistency ratio is found to be greater than the desired value.

The pair-wise comparison of all the criteria of vendor selection problem generates a priority matrix as given in the table 5.

Table 5. The Priority Matrix for the Criteria of Vendor Selection

S.No.	Criteria	Priorities	Rank
1	**PP**	**0.089**	**VI**
2	**TC**	**0.020**	**IX**
3	**QC**	**0.070**	**VIII**
4	**QP**	**0.196**	**II**
5	**GW**	**0.086**	**VII**
6	**RV**	**0.203**	**I**
7	**EV**	**0.136**	**III**
8	**LT**	**0.106**	**IV**
9	**BS**	**0.093**	**V**

The above table 5 shows that Reliability of the Vendor (RV), Quality of the Product (QP) and the Experience of the Vendor in the same field (EV) are top three in the vendor selection problem.

The globalization of market after the economic reforms have led to drastic changes in the approach of small, medium and large scale organizations for formulating their strategies and priorities for investments and developing competencies. In such a dynamic environment, organizations that are able to continually build new strategic assets faster and cheaper than those of competitors will create long-term competitive advantage (Singh et al, 2005). So, in this environment, vendor selection is an important MCDM problem to be taken care of. So, we are here prioritizing the type of industry best suitable for this MCDM problem. As done in the case of synthesizing a priority matrix for the criteria of vendor selection, the priority matrices for these criteria have been obtained for SMEs and Large scale organizations.

Table 6. The Priority Matrices for the Criteria of Vendor Selection for Small Scale, Medium Scale and Large Scale Organizations

PP					TC					QC				
Scale	**SS**	**MS**	**LS**	**Priority Matrix**	**Scale**	**SS**	**MS**	**LS**	**Priority Matrix**	**Scale**	**SS**	**MS**	**LS**	**Priority Matrix**
SS	1	3	4	0.608	**SS**	1	0.333	0.2	0.104	**SS**	1	0.2	0.143	0.111
MS	0.333	1	3	0.274	**MS**	3	1	0.25	0.231	**MS**	5	1	0.2	0.444
LS	0.25	0.333	1	0.121	**LS**	5	4	1	0.665	**LS**	7	5	1	0.444
QP					**GW**					**RV**				
Scale	**SS**	**MS**	**LS**	**Priority Matrix**	**Scale**	**SS**	**MS**	**LS**	**Priority Matrix**	**Scale**	**SS**	**MS**	**LS**	**Priority Matrix**
SS	1	0.2	0.143	0.072	**SS**	1	0.167	0.2	0.084	**SS**	1	0.167	0.167	0.076
MS	5	1	0.2	0.232	**MS**	6	1	0.25	0.288	**MS**	6	1	0.25	0.277
LS	7	5	1	0.696	**LS**	5	4	1	0.627	**LS**	6	4	1	0.647
EV					**LT**					**BS**				
Scale	**SS**	**MS**	**LS**	**Priority Matrix**	**Scale**	**SS**	**MS**	**LS**	**Priority Matrix**	**Scale**	**SS**	**MS**	**LS**	**Priority Matrix**
SS	1	0.143	0.143	0.067	**SS**	1	5	7	0.696	**SS**	1	5	5	0.571
MS	7	1	0.2	0.270	**MS**	0.2	1	5	0.232	**MS**	0.2	1	4	0.184
LS	7	4	1	0.663	**LS**	0.143	0.2	1	0.072	**LS**	0.2	0.25	1	0.094

	PP	**TC**	**QC**	**QP**	**GW**	**RV**	**EV**	**LT**	**BS**
SS	0.608	0.104	0.111	0.072	0.084	0.076	0.067	0.696	0.571
MS	0.274	0.231	0.444	0.232	0.288	0.277	0.270	0.232	0.184
LS	0.121	0.665	0.444	0.696	0.627	0.647	0.663	0.072	0.094

From the priority matrices for the criteria of TC, QP, GW, RV and EV, we obtain that large scale organization are best suitable, priority matrices for Qc medium scale and large scale both are equally good whereas for the criteria of PP, LT, BS, small scale organizations are preferable.

Table7: Overall Priority Matrix

S.No.	**Type of Industry**	**Priorities**	**Rank**
1	**SS**	**0.236**	**III**
2	**MS**	**0.265**	**II**
3	**LS**	**0.483**	**I**

The overall priority matrix suggests that large scale industries are the best suitable alternative.

Findings

Here we found, through our analysis of MCDM problem of vendor selection, that Reliability of the Vendor (RV), Quality of the Product (QP) and the Experience of the Vendor in the same field (EV) are top three in the vendor selection problem (as shown in Table 5) and Large Scale (LS) organizations are found the best alternative as compared to Small Scale (SS) and Medium Scale (MS) organizations (as shown in Table 7).

Conclusion

The expert views as obtained through a questionnaire and then quantifying the obtained subjective views, using Analytical Hierarchy Process helped to conclude the above findings. It suggests that while large scale industries are the best alternative solution for the vendor selection problem, reliability of the vendor, product quality and the vendor experience are the top three problems in the vendor selection problem.

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