Volume : 2 | Issue : 6 | June 2013 • ISSN No 2277 - 8179

Research Paper

Supplier Selection Using AHP and Promethee-2

Engineering

KEYWORDS : Multi criteria decision making (MCDM), supplier selection, PROMETHEE-2

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ABSTRACT

Supplier selection is one of the most critical activities of purchasing management in supply chain. Supplier selection is a complex problem involving qualitative and quantities multi-criteria. A tradeoff between these tangible and in tangible factors is essential in selecting the best supplier. The work incorporates PROMETHEE-2 and AHP in choosing the best suppliers. the result suggest that AHP and PROMETHEE-2 process makes it possible to introduce the optimum order quantities among the selected supplier so that the total value of purchasing becomes maximum. In the present study an efficient multi criteria decision making (MCDM) approach has been proposed for quality evaluation and performance appraisal in supplier selection. Supplier selection is a multi criteria decision making (MCDM) problem influenced by multiple performance criteria/ attributes. These criteria attributes may be both qualitative as well as quantities. Qualitative criteria estimates are generally based on previous experience and expert opinion on a suitable conversion scale (11 point fuzzy scale).this conversion is based on human judgment; therefore, predicted result may not be accurate always because the method doesn't explore real data. In solution of MCDM problems there should be common trend is to convert quantitative criteria values in to an equivlant single performance index called multi attribute performance index (MPI). Benchmarking and selection of the best supplier can be made in accordance with the MPI values of all alternative. This study highlights application of PROMETHEE-2 and AHP adapted from MCDM for utilizing quantitative real performance estimate scores. Detail methodology of PROMETHEE-2 and AHP has been illustrated in this reporting through a case study.

I. INTRODUCTION

The decision to place a certain volume of business with a supplier should always be based on a reasonable set of criteria. The art of good purchasing and supply management is to make the reasoning behind this decision as sound as possible. Normally, the analysis of the supplier's ability to meet satisfactory quality, quantity, delivery, price /cost and service objectives governs this decision. some of the more important supplier attributes related to these prime criteria may include past history, facilities and technical strength, financial status, organization and management, reputation, systems, procedural compliance, communications, labor relations and location. The nature and amount of purchase will influence the weighting attached to each objective and hence the evidence needed to support.

Background

Many studies focused on figuring out evaluation criteria used for supplier selection. Dickson (1966) interviewed with industrial procurement managers and summarized 23criteria that were applied for supplier evaluation. The top three evaluation criteria are quality, delivery, and previous performance. The study of Lehmann and O'Shaughnessy (1982) presented five criteria of performance, economics, integrative, adaptive, and legalistic for evaluating suppliers. Caddick and Dale (1987) suggested using quality, effectiveness of production plan and control system, previous performance, purchased items, and price as supplier evaluation criteria. Patton (1996) proposed seven criteria for supplier evaluation, and they were price, quality, delivery, sales support, equipment and technology, procurement, and finances. Tagaras and Lee (1996) recommended adopting cost (including both direct and indirect costs), delivery, and incoming quality as supplier evaluation criteria. Choi and Hartley (1996) and Barbarosoglu and Yazgac (1997) considered that suppliers could be evaluated from quality of shipment, delivery, and cost. Maloni and Benton (1997) and Beamon (1998) evaluated the performance of supply chain management by cost. Su and Chang (2001) suggested quality, price, delivery, quantity, and service for supplier evaluation and selection.

There have been many researches regarding to supplier evaluation criteria since Dickson (1966), and it is not easy to distinguish which criteria are major and how the priority of criteria should be from these reports. Based on Dickson's investigation result in 1966, Weberet al. (1991) examined 74 papers regarding to supplier evaluation and published between 1967 and 1990, and determined the corresponding frequencies of the 23 evaluation criteria mentioned on these papers. Price, delivery, quality, and service are the four of the most popular criteria for supplier evaluation. Beside the criteria that provide quantitative data, some other qualitative criteria are also important for supplier evaluation. In Ellram's research (1990) of supplier selection, not only quantitative criteria such as cost, quality, and delivery needed to be applied but also several qualitative criteria were recommended for evaluating suppliers' performance and potential. These qualitative criteria were compatibility of management, consistency of goal, and supplier's strategy. Some researchers were interested to figure out the evaluation criteria in different industries or operation. Qiu (1994) recommended quality, price, delivery, and quantity as the criteria for evaluating and selecting suppliers in order to achieve a world class manufacturer. Chen (1998) studied how the laptop companies in Taiwan managed suppliers and found that generally cost was the most important when Taiwanese companies evaluated suppliers' performance. As to the suppliers of key components, the top three evaluation criteria to supplier performance were quality, cost and on-time delivery. Huang (2000) chose the Taiwanese companies in the industries of automobile, motor, bicycle, and computer which may or may not join the Corporate Synergy Development (CSD) system. He found that quality was the most important for supplier selection in these industries. Regarding to another important supplier evaluation item, cost, it was weighed differently among these companies. The tier-2 companies (or "supplier companies") in the CSD system and the companies not joining the CSD system considered cost as very important criterion for supplier selection; in comparison, the tier-1 companies (or "customer companies") in the CSD system thought cost to be less important. Hu (2003) tried to find out the major criteria of supplier selection and evaluation in the high-technology industry in Taiwan. Chu (2004) investigated the differences of perspectives in supplier selection between high-tech and traditional industries and between multinational companies and outsourcing suppliers.

II. LITRATURE REVIEW

2.1 Supplier Ranking

Several supplier ranking approaches were studied or developed for supplier selection, and these approaches are introduced as below.

- Categorical method: According to the studies of Timmerman (1986) and Willis and Huston (1990), categorical method is to list the criteria of supplier evaluation first. When performing supplier evaluation, each supplier is ranked by specifying one of three levels (good, regular, or poor) to each of these criteria, and the one getting the most criteria with "good" ranking is the best supplier.
- Weighted point method: Willis and Huston (1990) explained this method in steps. First is to determine and list the criteria for supplier evaluation (which is like categorical method), and second is to assign weight or importance to each criterion. When

Volume : 2 | Issue : 6 | June 2013 • ISSN No 2277 - 8179

evaluating suppliers, surveyors score subjectively on each criterion, and a supplier's final score is the sum of each criterion's score multiplying its given weight. The higher final score the supplier gets, the better the supplier is considered.

- Vender profile analysis, VPA: In order to reduce human uncertainty when scoring on evaluation criteria for different suppliers, Thompson (1990) recommended vender profile analysis for supplier evaluation. VPA is modified from weighted point method and the major difference is that VPA requests to input a range of performance score on each evaluation criterion instead of a distinct value (score). Once getting all the ranges of all the criteria, Monte Carlo simulation is applied to estimate the average performance score of a supplier.
- Dimensional analysis, DA: Different evaluation criterion has different unit, which makes evaluation results of these criteria could not be summed up directly. Willis and Huston (1990) represented this method of dimensional analysis for performance comparison between two suppliers. One supplier 's score of one evaluation criterion is divided by another company's score of the same criterion, so that the effect of unit difference can be eliminated.
- Vender performance index, VPI: Willis et al. (1993) proposed another method, vender performance index, for supplier evaluation. Vender performance index is modification from dimensional analysis and has similar calculation. The major difference is to divide a supplier's performance score of one evaluation criterion by a standard score set by the supplier-evaluating company other than to divide by another supplier's score. Therefore, VPI is easier than DA for figuring out the best supplier because all suppliers' performances can be evaluated together by VPI but every time only two suppliers are compared by DA. Analytic hierarchy process, AHP: Besides evaluation criteria, it is also very important to specify the weight to each criterion for supplier selection, and AHP is one method for figuring out the weights. To establish a supplier evaluation equation, generally a set of evaluation criteria need to be determined first, then AHP is applied to define the weights for these criteria, and then suppliers are rated on each criterion with weight to get the final evaluation result. Narasimhan (1983) applied AHP to figure out the weights of evaluation criteria for supplier selection and supplier decision would depend on the sum of a supplier's score on each criterion multiplying weight. Yang et al. (2006) endeavored to construct an outsourcing evaluation system of light emitting diode (LED) industry in Taiwan. Five perspectives were derived from the four perspectives of balanced scorecard (BSC) to establish this evaluation system, and they were financial capability, customer service capability, process capability, learning and growth capability, and response capability. 35 evaluation indicators were also selected under the five perspectives to fit with the characteristics of LED industry. Then AHP was used to determine the weight of each indicator and each perspective.
- Cost-ratio method: Timmerman (1986) suggested quality, delivery, and service for supplier performance evaluation. Instead of using the three criteria directly, it is suggested to collect all the related cost data then to estimate the respective percentage of unit price for each evaluation criterion.
- Cost of quality method, COQ: Fish and Shambu (2001) applied the concept of COQ (Cost of Quality) to turn evaluation criteria, such as quality, delivery, and service, into indexes of cost, and then suggested using these cost indexes for evaluation of supply chain's performance.

Totally eight methods introduced and explained above could be sorted out into three groups from their purposes. "Purpose" means what a supplier ranking method is used for. The three groups are:

- "Scoring", using to score suppliers: The first group includes categorical method, weighted point method, VPA, and COQ.
- "Supplier comparison", applying to compare suppliers' performances: DA and VPI belong to the second group.
- "Criterion weight determination", determining weights for supplier evaluation criteria: The third group includes AHP and cost-ratio method.

All of the supplier ranking methods are summarized in Table 2-1.

Table 2-1: Summary of supplier ranking methods

Method	Description	Purpose
Categorical method	List evaluation criteria and rank suppliers subjectively by three levels.	Scoring
Weighted point method	List evaluation criteria, assign weight to each criterion, and score subjectively on each criterion. A supplier's final score is the sum of each criterion's score multiplying its given weight.	Scoring
Vendor profile analysis (VPA)	Input a range of performance score on each evaluation criterion and apply Monte Carlo simulation to estimate the average performance score of a supplier.	Scoring
Dimensional analysis (DA)	Compare two suppliers from dividing one supplier's score by another company's score of the same criterion to eliminate the effect of unit difference.	Supplier comparison
Vender performance index (VPI)	Divide a supplier's performance score of one evaluation criterion by a standard score set for simultaneous comparison among suppliers.	Supplier comparison
Analytic hierarchy process (AHP)	Define the weights for evaluation criteria by AHP and rate suppliers on each criterion with weight to get the final evaluation result.	Criterion weight Determination
Cost-ratio method	Collect all the related cost data then to estimate the respective percentage of unit price for each evaluation criterion.	Criterion weight determination
Cost of quality method (COQ)	Turn evaluation criteria into indexes of cost for evaluation of supply chain's performance	Scoring

Even though the ultimate purpose of scoring suppliers is for supplier performance comparison, there is difference between the first and second groups of methods. When applying the first group of methods, the evaluation results of all the criteria are required to be scores without unit or with the same unit and they can be summed up directly to get a final score, which makes direct performance comparison among suppliers feasible. In some other situations, however, the evaluation results may be with different units so that these results

cannot directly be summed up to obtain a final score, and the second group of methods are applied to eliminate the effect of units and to make direct performance comparison between or among suppliers.

2.2 Supplier selection process

As to supplier selection process, Zhang (1996) recommended a process for component supplier selection as the following steps:

- Organize a cross-function team composed with departments of purchasing, marketing, production, and quality assurance in order for supplier selection.
- Interview with managers of a supplier company to understand how they manage, what they are concerned, and whether they are willing to cooperate with the customer company's requests (such as shipments of small-quantity components).
- Send cross-function team to survey the supplier company on site in order to check the supplier's quality assurance system, production management, technical capabilities, equipments, and finances.
- Have the supplier company to review design specification and

quality requirement of the customer company then to make a quotation accordingly.
- Review the supplier's quotation. Negotiate and work with the supplier to make quoted price reasonable.
- Help the supplier to produce components that meet specification and requirement once when quotation negotiation is done and purchasing price is confirmed.

Hsu (2004) conducted empirical study to demonstrate a general supplier selection process of a global company as below:

- Request confirmation of a new supplier: A consensus to find a new supplier must be reached inside a company before starting supplier selection process.
- Preliminary review: Department of supply chain management performs preliminary review by a basic questionnaire and a supplier's company profile and business style review to figure out suppliers that meet basic requirements.
- Criteria confirmation for supplier selection: An internal conference is held after preliminary review to examine preliminary review results and to confirm the criteria of supplier selection which will be put on an advanced questionnaire. Generally supplier selection criteria are capabilities (finances, management, technology, manufacturing, resource availability, quality assurance and control system, risk management, and after-sales service), performance of customer service, product quality and reliability, price, and a supplier's location.
- Data collection and advanced questionnaire review: All suppliers are requested to reply the advanced questionnaire in time. Department of supply chain management follows up and reviews these replied questionnaires first. Then the suppliers passing questionnaire review are submitted for cross department review. Timing and team members for supplier on-site survey are determined if there is no objection to questionnaire review results.
- Supplier on-site survey: Survey team goes to visit the supplier, clarifies issues on the advanced questionnaire with the supplier, and examines whether the supplier is capable to meet the company's requirements.
- Survey result discussion: Each member of supplier survey team makes comments and scores from his/her professional viewpoint. The supplier which wins the most scores and gets the most members' positive comments will be submitted for superiors' review and approval.
- Notification of supplier selection result: When supplier decision is made, usually the department of supply chain management is responsible to inform the approved and disapproved suppliers. Requests for improvement are sent to the approved supplier and the supplier needs to reply with a corrective action plan.

Based on several studies and business practices, Hsu (2004) constructed a selection procedure, mainly for component supplier selection, described below:

- Quotation review: Examine a supplier's quotation to verify if the supplier is capable to meet the company's requirement.
- Supplier on-site survey: Conduct a survey in a supplier site to examine all the concerned capabilities, processes, system, and working situation.
- Scoring on supplier selection criteria: Rate suppliers according to their performances on order fulfillment, finances, cost, quality, organization and management, and other concerned criteria (such as working environment, certification, green policy, etc.).
- Supplier selection: Recommend to apply benchmarking, categorical method, weighted-point method, or cost-ratio method to choose proper suppliers.

III. PROPOSED MODEL

3.1 Weighing through the Analysis of Hierarchical Process (AHP)

An AHP is a scientific method for ranking alternative courses of action based on the decision maker's judgments concerning the importance of criteria. An AHP is a decision-making method for prioritizing alternatives when multiple criteria must be considered. AHP's have been applied to a wide variety of decision areas.

The AHP process begins by determining relative importance of the criteria in meeting the goals. Managerial judgments used to drive the AHP approach are expressed in terms of pair wise comparison of items on a given level of hierarchy with respect to their impact on the next higher level. Pair-wise comparison expresses the relative importance of one item versus another in meeting a goal or criterion. Each comparison represents an estimate of the ratio of the weights of the two criteria being compared.

Suppose that there are n criteria that need to be weighted for decision making, and then there are n (n-1) /2 judgments required. The comparison matrix for these n criteria can be expressed as:

$$A = \begin{bmatrix} a11 & a_{12} & -- & a_{1n} \\ a_{21} & a_{22} & -- & a_{2n} \\ -- & -- & -- & -- \\ a_{m1} & a_{m2} & -- & a_{mn} \end{bmatrix}$$

Where:
$a_{ij} = W_i / W_j$ and $a_{ij} = 1/ a_{ji}$ W_i = weight of the i^{th} criteria
Wj= weight of the j^{th} criteria
n
$\sum W_i = 1$
i=1
matrix A is reciprocal and has all positive elements. Let matrix be multiplied by W^T, W= (W_1, W_2. . . . . W_n), thereby yielding

$$(A - n \times I)W^T == 0 \qquad \text{---------- (6.1)}$$

Due to inconsistency property, the system of homogeneous linear equation above has only trivial solutions. In general, the precise value of a_{ij} are unknown and must be estimated. If A' is the estimation of A, and W' corresponds to A' then

$$A'W' = \lambda_{max} W' \qquad \text{----------}$$
(6.2)

Where λ_{max} is the largest Eigen value of A'. The value of W' can be obtained by solving the system of linear equations.

3.2 PROMETHEE Method:

Step:1 Normalize the decision matrix using the following equation:

$R_{ij} = [X_{ij} - \min(X_{ij})] / [\max(X_{ij}) - \min(X_{ij})]$
(i=1,2,3……, j=1,2,…..m) --------(6.3)
Where X_{ij} is the performance measure of i^{th} alternative with respect to j^{th} criteria.

Step:2 Calculate the evaluative difference of i^{th} alternative with respect to other alternative. This step involves the calculation of differences in criteria values between different alternative pair wise.

Step:3 Calculate preference function, P_j (i,i')

P_j (i,i')=0 if $R_{ij} <= R_{i'j}$
P_j (i,i')= ($R_{ij} - R_{i'j}$) if $R_{ij} > R_{i'j}$

Step:4 Tthe aggregate preference function taking in to account the criteria weight.

Aggregate preference function,
m m
$\prod(i,i') = [\sum W_j x P_j (i,i')] / \sum W_j$ ---------- (6.5)
j=1 j=1

Where W_j is the relative importance (weight) of j^{th} criteria

Step: 5 Determine the leaving and entering outranking flows as follow:

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Leaving or positive flow for i^{th} alternative

$$\phi^{+}(i) = 1/n\text{-}1 \sum_{i'=1}^{n} \prod(i,i') \quad (i \text{ is not equal to } i') \quad \text{---------- (6.6)}$$

Entering or negative flow for i^{th} alternative

$$\phi^{-}(i) = 1/n\text{-}1 \sum_{i'=1}^{n} \prod(i,i') \quad (i \text{ is not equal to } i') \quad \text{---------- (6.7)}$$

where n is the number of alternatives.

Here each alternative faces (n-1) other alternatives. The leaving flow express how much an alternative dominates the other alternative, while the entering flow denotes how much an alternative is dominated by other alternatives. Based on these outranking flows, the PROMETHEE-1 method provide a partial preorder of the alternatives, whereas the PROMETHEE-2 method give the complete preorder by using the net flow, though it losses much information of preference relations.

Calculate the net outranking flow for each alternative.

$$\phi(i) = \phi^{+}(i) - \phi^{-}(i) \quad \text{---------- (6.8)}$$

Determine the ranking of all the considered alternatives depending on the values of ϕ (i). the higher value of ϕ (i), the better is alternative. Thus the best alternative is the one having the highest ϕ (i) value.

IV. CASE STUDY RESULT

As a case study, the supplier selection problem in procuring silencer of vehicle in an automotive industry has been studied. The attributes for supplier selection are cost (Rs), insertion loss (db), volume (cc), and Weight (kg). The targeted values of each criterion correspond to the elements of reference data series for comparison. The target to minimize cost, achieve high insertion loss and less volume, less weight. For cost, volume and weight lower the better criteria (LB) and for insertion loss higher the better criteria (HB) have been selected.

The objective and subjective information regarding different supplier selection criteria are given in table 1.the objective values for these criteria are assigned from an 11-point scale , as given in table 2.the fuzzy judgements average (A), above average (AA), high (H), and very high (VH) shown in table1 are considered eqivlant to good, very good etc.

Table1: information for supplier selection alternatives

Supplier /criteria	Cost (Rs)	Insertion loss(db)	Volume (cc)	Weight (kg)
A	AA	VH	A	A
B	VH	H	VH	VH
C	AA	VH	AA	H
D	AA	H	AA	AA

At first, the information for various supplier selection alternatives with respect to different criteria, as shown in table1, are converted in to crisp scores using the 11-point scale as given in table 2. The transformed objective data, as given in table 3 , are then normalize using equations (1) or (2) given in table 4.

The criteria weights are calculated using AHP method, shown in table 5:

Table2: pair wise comparison matrix and computation

	Cost (Rs)	Inseration loss(db)	Volume (cc)	Weight (kg)	weights
Cost (Rs)	12/25	6/11	8/17	3/9	0.457
Inseration loss (db)	6/25	3/11	6/17	3/9	0.300
Volume (cc)	3/25	1/11	2/17	2/9	0.138
Weight (kg)	4/25	1/11	1/17	1/9	0.105

TOTAL=1.000

Table 3: 11- point fuzzy scale

Linguistic term	Crisp score
Exceptionally low	0.045
Extremely low	0.135
Very low	0.255
Low	0.335
Below average	0.410
Average	0.500
Above average	0.590
High	0.665
Very high	0.745
Extremely high	0.865
Exceptionally high	0.995

Table 7: objective data for supplier selection problem

Supplier /criteria	Cost (Rs)	Inseration loss (db)	Volume (cc)	Weight (Kg)
A	0.590	0.745	0.500	0.500
B	0.745	0.665	0.745	0.745
C	0.590	0.745	0.590	0.665
D	0.590	0.665	0.590	0.590

Table 8: Normalized decision matrix

Supplier /criteria	Cost (Rs)	Inseration loss (db)	Volume (cc)	Weight (Kg)
A	0	1	0	0
B	1	0	1	1
C	0	1	0.3673	0.6734
D	0	0	0.3673	0.6734

Now, the preference functions are calculated for all the pairs of alternative, using equation (3) and (4) and are given in table 9. Table 10 shows the aggregate preference function values for all the paired alternatives, as calculated using equation (5). The leaving and entering flows for different supplier are now computed using equation (6) and (7) respectively and are shown in table 11.

Table:9 preference functions for all the pairs of alternative

Suppliers pair/Criteria	Cost (Rs.)	Insertion loss (db)	Volume (cc)	Weight (Kg)
(A,B)	0	1	0	0
(A,C)	0	0	0	0
(A,D)	0	1	0	0
(B,A)	1	0	1	1
(B,C)	1	0	0.6327	0.3266
(B,D)	1	0	0.6327	0.6327
(C,A)	0	0	0.3627	0.6734
(C,B)	0	1	0	0
(C,D)	0	0	0	0.3061
(D,A)	0	0	0.3673	0.3673
(D,B)	0	0	0	0
(D,C)	0	0	0	0

Table 10: Aggregate preference function

Supplier	A	B	C	D
A	-	0.300	0	0.300
B	0.700	-	0.57859	0.61074
C	0.1214	0.300	-	0.03214
D	0.08926	0	0	-

Table 11: Leaving and Entering flows for different supplier

Supplier	Leaving Flow	Entering flow
A	0.200	0.30355
B	0.62978	0.2000
C	0.15118	0.19286
D	0.02975	0.31429

Table: 12 Net Outranking Flow values for different Supplier

Supplier	Net out Ranking Flow	Supplier Ranking
A	-0.10355	3
B	0.42978	1
C	-0.04168	2
D	-0.28458	4

V. CONCLUSION

Supplier selection decision has long term implication because selection of wrong supplier gives a huge loss to organization. It is therefore important to select the most appropriate supplier for a given industrial application. The problem of supplier selection is a strategic issue and has significant impact on the manufacturer's organizations. The presented study explores the use of PROMETHEE-1 and AHP method in solving a supplier selection problem and the results obtained can be valuable to the decision maker in framing the supplier selection strategies. The multi criteria decision making is a vital tool in solving the supplier selection problem. It allows the decision makers to rank the candidate alternative more efficiently and easily. The illustration of example gives the computational process of the AHP and PROMETHEE-2 method.

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